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Crossing the divide: A bioarchaeological approach to religious lifeways and deathways in medieval Santarém, Portugal.

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By

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Professor Sabrina C. Agarwal, Chair
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Abstract

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This project employs multiple methods to explore how shifting periods of autonomy during the Portuguese Middle Ages (c. 500-1500 AD) impacted the social and biological fabric of everyday life and post-mortem bodily integrity in religiously distinct communities. The archaeological materials from Santarém, Portugal offer an opportunity to facilitate a comparative approach, as many of the excavated cemetery sites within the municipality are a palimpsest, and contain members of distinct religious and temporal communities. This dissertation prioritizes two cemetery sites: Avenida 5 de Outubro (S.Av5Out; n = 164 burials) and Largo Cândido dos Reis (S.LCR; n = 622 burials) which contain the human skeletal remains of Islamic (c. 8th – 12th centuries, C.E.) and Christian (c. 12th – 16th centuries, C.E.) city residents. This project examines how religious identity might explain some of the variation within and between medieval communities through an investigation of both lived experience (lifeways) and death, dying, and burial treatment (deathways). Lifeways are examined through three major axes: 1) oral health and disease, 2) growth and development, and 3) cortical bone maintenance and loss. The data overall suggest minor differences between Islamic and Christian sub-samples, though Christians exhibited reduced stature, increased odds of some indicators of non-specific stress (porotic hyperostosis and periostosis), and dental pathological lesions. Deathways are similarly examined along three major axes: 1) *post-hoc* archaeothanatology, 2) macrotaphonomic indicators (preservation, erosion, weathering), and 3) microtaphonomy (histotaphonomy). Islamic and Christian burials were found to be highly different in terms of construction, with Islamic graves significantly narrower and shallower than their Christian counterparts. Islamic skeletons were also less represented, and significantly less preserved than their Christian counterparts, regardless of age and/or sex. The results of this dissertation are part of an emerging pattern that the Christian conquests (canonically termed "Reconquista") may well have been drastic in their restructuring and urbanizing of the Iberian Peninsula, for both the living and the dead. By examining both lifeways and deathways, this approach and accompanying results demonstrate synthesizing both bioarchaeological assessments of livelihood and funerary taphonomic assessments of deadlihood can reveal more textured understanding of past communities and how the living and the dead become intertwined in urban spaces.

This dissertation is dedicated to:

The Portuguese community, who have shown me nothing but warmth, compassion, and hospitality over these many years.

And most of all, to Dave and Lisa Trombley, for all their unwavering love and support, and for making a child's dream come true.

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Glossary of Arabic terms

al-Akhir – Judgement Day.

al-Andalus – Islamic cultural domain of the Iberian peninsula, typically cited as having lasted from 711 AD – 1492 AD.

al-Qiyamah – Day of Resurrection.

barzakh – literally “barrier, partition, obstacle, separation” that ontologically refers to the interspace between living and the resurrection (*Qiyamah*).

dafan – interment/burial.

darih – square-like tomb with straight walls with the absence of a *lahd.*

dhimmi – literally “protected person,” referring to non-Muslims in Muslim-controlled territories who were granted unique statuses in relation to beliefs, practices, and taxes. The use here refers to the older usage of *dhimmis* as non-Muslim communities within *al-Andalus* who were granted their status on principle of being people of the book (see *kitabi*) – i.e., Christian and Jewish communities.

fiqh – Islamic jurisprudence as interpreted scholastically or pragmatically, mutable and open to some degree of interpretation in order to enact legal proceedings (see also *shari'a*)

ghusl – Ritual washing and purification of one's body before and after prescribed activities (e.g. prayers, intercourse). Here it is used to describe the ritual washing of the body after death. Often considered a major ablution compared to *wudu*.

hadith – compilation of traditions (most typically oral or scriptural) passed from the Prophet Muhammad and his companions (see also *sunnah*).

hajj – one of the Five Pillars of Islam, the pilgrimage to Mecca that every Muslim should undertake once in their life.

hijra – the journey made by the Prophet Muhammed from Mecca to Medina in order to escape persecution in 622 C.E./A.D., marking the beginning of the Islamic calendar.

janâ'iz – stretcher or biers used to transport the body to the grave.

Janazah/salat al-janazah – Islamic funerary prayer and congregation that accompanies the interment of an individual.

kafan – shroud/veil used to cover the corpse prior to interment. Often prescribed to be me made of “Yemeni Cotton.”

kitabi/kitabiyya – "People of the Book," individuals whose religious belief system is of Abrahamic tradition.[1]

kitab al-Jana'iz – the Book of Funerals/Funerary Rites, detailing the prescriptions of interment.

lahd – a niche placed near the bottom of a grave, often oriented closest to the *qibla*.

maqbara (s.)/*maqabir* (pl.) – Islamic cemetery.

mayyit – the dead body

miswak/miswaak/siwak/sewak – the twig of the *Salvadora persica* tree, frayed to create a form of dentifrice. It is occasionally referenced in *hadith* where it is advocated as a means of maintaining important physical (i.e. oral) and possibly spiritual cleanliness preceding and following important ritual events and daily routines.

muhtasib – individual who carried out physical supervision and inspections of civil programs and public works such as trade, marketplaces, and supply-lines, often within accordance of *Shari'a*.

salah/salaah/salat/namaz – one of the Five Pillars of Islam, the act of temporally-prescribed prayer towards Mecca five times a day and which includes the ritual movements of standing, bowing, prostrating, and sitting/kneeling.

shaqq/shiqq/šaqq – burial space, often consisting of a rectangular trench.

Shari'a – Islamic jurisprudence as interpreted in a divine manner, considering both the Qur'ān and *hadith* as immutable authorities (see also *fiqh*).

sunnah/sunna – body of literature concerning prescriptions of practices that comprise Islamic customary traditions.

sûq – Marketplace containing various vendors and workshops.

qadi – Islamic judge who facilitates judicial rulings according to *Shari'a* and whose jurisdiction also includes supervision of civil and public works.

qibla – the direction of Mecca.

wudu – the procedure for self-cleaning and purification using water as a means of both ritual and physical cleansing and purity, often done prior to prayer (*sala*). Often considered a minor ablution compared to *ghusl*.

[1] In the case of medieval Santarém, note that *kitabi* also denotes a unilateral marital policy, whereby Muslims (typically males) are permitted to marry *kitabi* of Christian or Jewish faith, though Christian males are forbidden from marrying Muslim women (see Canon Law 68 of the Fourth Lateran Council of 1215; Lopes de Barros 2005: 6; see also Apud Fernandéz y González, Estado Social y Político, doc. XII, p. 307-308).

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Chapter 1: Introduction

Research Objectives

The objective of this dissertation is to contribute to the scholarship on the implementation of biocultural approaches (Dressler 2005; Goodman & Leatherman 1998) to the study of human skeletal remains. Specifically, this dissertation seeks to untangle the ways in which social and religious identities during the Portuguese Middle Ages (c. 500 – 1500 C.E.) impacted the human skeletal system both during life and after death. Analysis of human skeletal remains from archaeological sites is frequently cleaved along sub-disciplinary lines, where remains *in situ* and the extended mortuary context (e.g. burial, furnishings) are preferentially emphasized by funerary archaeologists interested in reconstructing aspects of mortuary customs, identity, social status (Parker Pearson 2000), and the osteological remains are preferentially emphasized by bioarchaeologists and osteologists intent on reconstructing aspects of skeletal health, pathology, diet, and activity patterns (Larsen 2002). The result is often a differential emphasis on aspects of mortal remains with the divide centering on, somewhat ironically, death itself. The funerary archaeologist is interested in the ways in which death and accompanying bodily disposal reflects social rites of the society of interest — termed "deathways" (Parker Pearson 2000), while the bioarchaeologists being interested in the livelihood of past communities — here termed "lifeways." Such emphasis is accompanied by differing theoretical frameworks and methodologies, occasionally furthering sub-disciplinary cleavage.

Undoubtedly, not all anthropological research on human skeletal remains falls so squarely along these divides — to suggest so would be a disservice to countless scholars who have integrated frameworks and methodologies across the life/death divide (Cradic 2017; Duday 2006; Knüsel et al. 2016; Robb et al. 2001; Sofaer 2006b). This dissertation follows this thread of scholarship, and focuses on both the "lifeways" and "deathways" from a medieval skeletal assemblage in central Portugal. Like many other sites in Iberia (Ruiz Taboada 2015), Santarém, Portugal is marked by the presence of distinct religious communities who interred their dead in relatively similar cemetery spaces. In the case of Santarém, both Muslim and Christian burials have been found throughout the city and in some cases, sharing the same cemetery spaces, despite being separated by distinct temporal phases of politico-religious occupation and management of the city. By integrating funerary and bioarchaeological methodologies and frameworks, this dissertation seeks to transcend the burier:buried divide, and elucidate the ways in which biosocial factors in past communities become entangled in both life *and* death as evidenced by human skeletal remains.

This integration begins with a series of analyses on lifeways and lived experience within the framework of historical bioarchaeology. The history and historiography of medieval Iberia is complicated, and often confers vehement debates about the role of religious faith communities in facilitating tolerance or violence (Clarke 2012; Fernandez-Morera 2016; Glick 1995; 2005; Kennedy 1996; Menocal 2002; Nirenberg 1998; Ray 2005; Real 2015). For example, while some (Menocal 2002) suggest that Muslim administrators encouraged tolerance for religious minorities under the *Dhimmi* (literally, "protected") system, others argue that these very systems were colonial agendas masking behind linguistic façades that facilitated marginalization (Fernandez-Morera 2016). Conversely, the "Reconquista" beginning in the 12th century C.E. and ending in the 15th century with the fall of Granada in 1492 C.E. was long touted as a beneficial restructuring of the peninsula in the name of Christianity. Yet, numerous scholars have questioned the role that respective 20th century political/dictatorial regimes in Spain (*España* *franquista*) and Portugal (*Estado Novo*) invented the concept altogether (Ballard 1996; Vakil 2003). A bioarchaeological investigation of lifeways has the means of transcending some of these historiographical debates by examining the remains of everyday people of the past (Larsen 2002). Joana Sofaer (Sofaer 2006b, 77) asserted that "We literally embody our history, and because our history is created through our relations with others we embody the history of our relations with them, thereby tapping into their histories too." Megan Perry (2007) eloquently demonstrated how bioarchaeology is not, in fact, a mere handmaiden to history but can be operationalized to help critically assess textual evidence and historiography. More recent scholarship has fully (re)crystalized "historical bioarchaeology" (Novak et al. 2020, 3) as an endeavor that "does not necessarily privilege human tissues (bones or teeth), but positions these findings *in relation to* other processes and things…allowing a move away from the old trope of testing the historical record with truths written in bone." In the case of the Middle Ages specifically, this is especially important as medieval bodies and their residues can provide a bottom-up, textured picture of everyday life, especially for those omitted from textual sources (Robb et al. 2018).

In these sections, I inquire: how might religious identity, at least reflected in burial treatment, explain some of the variation in disease prevalence, craft behaviors, hygienic regimens, or physical activity, and growth and development? How might these indicators of lifeways additionally pattern by age and sex? How might ethnohistorical documents, previous studies, and "vital data" (Novak et al. 2020) work (or fail to work) in concert with one another? What might such data and syntheses suggest about historical framings such as the Reconquista? These questions are tackled using bioarchaeological analyses of dental remains (Bonfiglioli et al. 2004; Buikstra et al. 1994; Klaus et al. 2010), various indicators of growth and development (Blom et al. 2005; Buikstra et al. 1994; Cares Henriquez et al. 2018; 2020; Goodman et al. 1990) and quantitative assessments of cortical bone (Brickley et al. 2005; Cho et al. 2003; Gilmour et al. 2021; Ives et al. 2004).

Stemming from this integration is a further research objective: to interrogate the current role of taphonomy and its funerary potential in bioarchaeological research. Taphonomy is frequently treated as part of routine reporting in bioarchaeological analyses and distinguishing pathology from 'pseudopathologies' at best, or criticized for its archaeological coopting from its paleontological origins at worst (Lyman 2010). Seldom is taphonomy framed as a worthwhile means of anthropological inquiry. Of particular concern is the relationship between taphonomy and demography in skeletal samples. The impact of taphonomic filters on demography is often mentioned in passing, and in rare cases, confronted directly (Waldron 1987; 1994; 2007). This dissertation seeks to tackle taphonomic complications to skeletal samples head-on, and inquire: what is the relationship between funerary treatment, taphonomy, and demography? How might the skeletal remains available for bioarchaeological study be mediated through taphonomic filters? How might such filters affect resulting paleodemographic assessments, or even the resultant interpretations of community-level analyses? These questions are crucial for understanding not only post-mortem processes, but how taphonomic understandings can become intertwined with health, funerary, and religious customs. Urbanization is a major theme considered throughout this dissertation, both for it's affect on the lived experience of the Santarém community (densification, agriculture, public hygienic buildings, water/sanitation, etc.) and the death experience of those interred within the city (post-mortem damage, landscaping, superimposition of religious architecture, etc.).

This dissertation investigates these questions by examining human skeletal remains in a funerary taphonomy framework (Knüsel et al. 2016). Funerary taphonomy underscores the relationship between funerary customs, burial environment, and osteological remains, and seeks to put taphonomic filters at the forefront of archaeological research, not as an afterthought or routine checklist. In doing so, taphonomic filters are integrated alongside funerary and mortuary customs, archaeothanatology, and detailed analyses of human skeletal remains to produce a synthesis of osteological, funerary, and taphonomic data. In this approach, taphonomy is reframed in a biocultural manner, to encompass both natural *and* cultural factors that affect human remains — something numerous archaeologists have long heuristically separated (Lyman 2010, 10). Additionally, the theoretical and methodological developments of funerary taphonomy necessitate a protracted funerary sequence, emphasizing stages such as pre-interment, interment, and post-interment phases (Andrews et al. 2006; Bello et al. 2006; Cradic 2017; Duday 2006; Forbes 2008; Nilsson 1998). This helps to situate taphonomy beyond the life:death, burier:buried dichotomies mentioned above, and extend the universe of taphonomic considerations even before burial, while maintaining attentiveness to cultural and funerary rites that may influence such taphonomic trajectories after interment.

Materials

This study focuses on the skeletal remains recovered through municipal and private excavations at the sites of Largo Cândido dos Reis (S.LCR) and Avenida 5 de Outubro (S.Av5Out) in Santarém, central Portugal. Ceramic and funerary typology placed these cemeteries within the larger Islamic occupation of Iberia in the Middle Ages (711 – 1492 CE), and Portugal more specifically (711 – 1147 CE), however, a key goal of this study was to refine these chronologies and situate them in a regional context using 14C dating (see Chapter 4). Both of these sites were excavated in response to urban development (Liberato 2012; Matias 2008a; Matias 2008b), and as such represent a salvage excavation sub-sample of what are certainly much larger necropoles. Both necropoles contained burials from various religious and political communities, as evidenced by their burial typologies, which is unsurprising given the history of superimposition among various communities and polities over the course of nearly two millennia. This study in particular focuses on the later medieval transition from the Islamic control of *Xantarin* (c. 8^{th} – 12^{th} centuries) to the later Christian medieval (c. 12^{th} – 16^{th} centuries) repurposing to *Sanctaren*.

Part of this restructuring process resulted in Christian burials being constructed adjacent (and in some cases, directly bisecting) previous Islamic burials, such that we have “distinct cultures within the same space” (Matias 2008b). As such, the presence of distinct religious communities with differing funerary treatments in the same geological and geographical space offers an opportunity to furnish a comparative religious approach, and examine how religious identity (at least in death) may correspond to patterns observed both lifeways and deathways.

Methodology

This study is organized into a series of sub-studies that vary in methodology, materials, and aim. Principally, the methodological approaches employed in this dissertation vary along two major axes, in their respective relation to lifeways and deathways: 1) bioarchaeological assessments of skeletal/dental health and disease and 2) funerary taphonomy.

Lifeways: Bioarchaeological Assessments of Skeletal/Dental Health and Disease

Thanks to their hypermineralized structure, dental remains often preserve exceptionally well in archaeological and paleontological settings (Hilson 1996). Bioarchaeologically, analysis of dental remains, especially for dental pathological lesions such as carious lesions and periodontitis can help elucidate aspects of diet and subsistence (Cohen et al. 1984; 2007; Driscoll et al. 2000; Powell 1985; Rose et al. 1991; Temple 2006; Temple et al. 2007; Temple 2007; Turner 1979; Walker et al. 1990), colonial encounters (Klaus et al. 2010; Larsen et al. 1994; Reeves 2000), sex and gender differences (Avery et al. 2019; Fields et al. 2009; Lukacs 1996; 2008; 2011; Lukacs et al. 2006; Trombley et al. 2019; Walter et al. 2016; Watson et al. 2010), and even heterogenous frailty (DeWitte et al. 2010). This study examines relationships between dental pathological lesions and religious identity as inferred by funerary treatment. While there have been a number of excellent studies examining funerary variation in dental pathological lesions (Redfern et al. 2015; Tornberg 2016), many studies focus on social status differences as inferred by funerary typology. Instead, this study compares religious identity in dental pathological lesions in order to construct a preliminary understanding of disease prevalence, possible dietary differences between religious communities, and sex/gendered differences within those respective communities.

In addition to dental pathological lesions, this study also examined dental remains (as well as other osteological remains) for information on stress during growth and development. Principally, linear enamel hypoplasia – defects resulting from non-specific perturbations during the formation of enamel – were examined here macroscopically (Buikstra et al. 1994; Goodman et al. 1990), both for their presence, and in cases of minimal dental wear, were measured for later entry into regression formulae to gain approximate age-at-formation (Cares Henriquez et al. 2018; 2020; Reid et al. 2000; Reid et al. 2006). These data were supplemented with additional skeletal indicators of non-specific stress: cribra orbitalia, porotic hyperostosis, periostosis, and terminal adult stature, all of which can be employed in a contextual and composite manner to better elucidate perturbations during growth and development (Blom et al. 2005; Bogin 1999; Bogin et al. 2007; Cole et al. 2019; Eveleth et al. 1990; Klaus et al. 2009; Rivera et al. 2017; Walker et al. 2009), in this case within and between religious funerary groups.

Finally, a comparative approach within and between religious funerary groups was carried out on quantitative analyses of cortical bone indices. Sufficient cortical bone quality and quantity are crucial for overall bone health and biomechanical resistance, as well as reducing likelihood of osteopenia, osteoporosis, and fractures (Center 2010; Holzer et al. 2009; Zebaze et al. 2015). Bioarchaeological assessments of cortical bone typically focus on childhood health, pathology, or age-related bone loss via quantification of cortical bone (Agarwal et al. 1996; Agarwal 2012; Beauchesne and Agarwal 2014; 2017; Brickley et al. 2005; Gilmour et al. 2021; 2022; Glencross et al. 2011; Mays 1996). This study examines two envelopes/skeletal locations for cortical bone quantity: metacarpals (via metacarpal radiogrammetry) and ribs (via cross-sectional area of histological thin-sections). Metacarpals have a long history in clinical diagnosis and screening for bone loss (Barnett et al. 1960; Garn 1970; Virtama et al. 1969), and began seeing bioarchaeological implementation at the turn of the 21st century (Brickley et al. 2003; 2005; Ives et al. 2004; Mays 1996). These data are supplemented with cortical bone quantity of ribs, which employ similar techniques of cortical bone quantification via indices (Agnew et al. 2012). Together, these help to bolster a better proxy of cortical bone quantity throughout the skeleton.

Deathways: Funerary Taphonomy, Decomposition, and Preservation

There are numerous techniques of documenting taphonomic influences on skeletal material, given the myriad of pathways bones can follow after burial. This dissertation employs standard macro-taphonomic assessments alongside more recent developments in histological analysis (histotaphonomy) to comprehensively examine how funerary differences in burial treatment within the same cemetery may pattern with preservation outcomes at microscopic and macroscopic scales.

A crucial first step of funerary taphonomy is characterizing burial/tomb architecture, typology, and dimensions. Careful note-taking within the field, as well as drawings and measurements of tombs themselves can help to elucidate decompositional differences, burial containers, necrodynamics, and other taphonomic susceptibilities or buffers. In addition to burial typology and metrics, careful field excavation of burials can furnish an archaeothanatological approach which employs a meticulous anatomical approach to understanding burials and taphonomy *in situ*. Originally developed by Duday (Duday et al. 1987; Duday 2006; 2009), archaeothanatology, or *archéologie de terrain* or *l'archéologie de la mort* focuses on meticulous excavation and documentation procedures for burials, focusing on how labile (relatively weak, easy to decompose) and persistent (stronger, slower to decompose) joints help build a chronological sequence of decomposition. The project lead in the excavation of Largo Cândido dos Reis (A. Matias) was a student of Duday's, and ensured careful documentation of bodily position, tomb dimensions, and architectural features (Matias 2008a; Matias 2008b) to furnish a post-hoc archaeothanatological approach (Harris et al. 2012).

One of the principal methodologies employed in taphonomic analysis both during and following excavation, is the semi-quantification of osseous material present. Put simply: 1) are the bones we expect to be present actually present, and 2) if so, how much of that bone is preserved? The first question stems from canonical zooarchaeological techniques developed for estimating the minimum number of individuals (MNI), whereby the number of bones observed are calculated as a function of the theoretical number of bones present (i.e., 206 for the average adult), indexed as the Bone Representation Index (BRI) (Bello et al. 2006). This can then be used to calculate well-represented bones (WRB) as those being present in >50% of expected cases, and well-represented skeletons (WRS) as skeletons with >50% of their bones represented. The second question helps to quantify the *amount* of bone preserved in the case of their presence. Following the work of Dutour (1989) among others (Bello et al. 2006), the anatomical preservation/conservation index (ACI or API) helps to zone different areas of the skeleton for calculation of preservation, based on quantitative thresholds (e.g., <25%, 25-50%, 50-75%, >75%). Similarly to WRB and WRS, well-preserved bones (WPB) are those with at least 50% of their element present, and well-preserved skeletons (WPS) are those with at least >50% of their bones well-preserved. Together, all of these numeric indices are used in concert to elucidate patterns in bone presence and preservation, especially between distinct funerary groups.

In addition to the presence of osseous material, macroscopic visual assessments of erosion and weathering are important for characterizing local burial environments and their effects on bone. Erosion assessments employ ordinal scores in order to aggregate the amount of surface damage due to roots and acids (Brickley et al. 2004), whereas weathering often corresponds to bleaching, surface exposure, cracking, and periosteal flaking (Behrensmeyer et al. 1985; Buikstra et al. 1994).

While erosion is informative of exogenous materials (e.g., roots) coming into contact with osseous remains, other intrusive organisms are also worth documenting when present. Typically, micromammals and rodents are prioritized in taphonomic analysis, for their capacity to leave distinctive gnaw-marks upon bone (Buikstra et al. 1994). Comparatively much less emphasis is placed on invertebrates within graves, likely due to their inability to preserve outside of exceptional conditions. Nevertheless, some invertebrate species, such as snails and shelled slugs such as *Testacella sp*. can be seen archaeologically via the presence of their shell remains. The field of archaeomalacology is still relatively young and specialized, and the presence of malacofaunal remains in burial contexts specifically is seldom documented archaeologically outside of seemingly intentional deposition as a funerary item such as marine *Spondylus* shells (Carter 2011; Helmke et al. 2015; Paulsen 1974). However, given terrestrial gastropod's well-documented feeding behaviors as partial-detritovores (Speiser 2001), and occupation of ecological niches (Kerney et al. 1979; Pilsbry 1939), the presence of malacofaunal remains can help elucidate microburial environments and taphonomic factors even further.

Finally, this dissertation employs a relatively newer means of taphonomic assessment by analyzing thin-sections of rib samples from a subset of Islamic and Christian burials. While histological assessments of taphonomy are certainly not novel, and in fact have a long history (Wedl 1864), their systematic use in bioarchaeological and funerary taphonomic frameworks is still relatively recent (Bell 1990; Turner-Walker & U Syversen 2002). Termed histotaphonomy, these assessments aim to semi-quantify the degree of bacterial, fungal, and cyanobacterial attack found within the microstructure of bone, alongside documenting the presence of cracking, weathering, or staining among other variables (Bell 2012; Booth 2016; 2017; Brönnimann et al. 2018; Goren et al. 2021; Hemer et al. 2021). While the origins of bacterial attack are still heavily debated, their relative presence can potentially elucidate decompositional histories (e.g., rapid vs. delayed burial), microburial environments, and the employment of clothing, shrouds, or vestments that may not survive archaeologically.

Organization of the study

This dissertation is arranged in a manner where many of the chapters are organized as sub-studies.

Chapter 2 outlines the theoretical basis for this dissertation, considering both lifeways and deathways from a bioarchaeological perspective. This chapter seeks to tether traditional bioarchaeological means of reconstructing the livelihoods of people of the past with funerary taphonomy's consideration for reconstructing deadlihood.

While Chapter 2 provides the theoretical foundations for this work, Chapter 3 provides additional context for the area and materials of this study. Chapter 3 begins by covering archaeological (and bioarchaeological) approaches to religion, before focusing on religion within medieval Iberia from both an anthropological and historical perspective. Following the pioneering perspective by Barceló (1993), archaeology (and bioarchaeology by extension) still has much to offer historical approaches to medieval Iberia, given the region's complicated and sometimes vehement historiography. Finally, Chapter 3 outlines the study area of Portugal, and Santarém specifically, before discussing the sites and materials utilized in this dissertation.

Chapters 4 through 10 comprise the methodology, analyses, results, discussion/interpretations of the various sub-studies carried out in this dissertation. Chapter 4 considers results from the first systematic radiocarbon (^{14}C) dating of Islamic burials throughout the city. These results are important not only for aiding our chronological understanding of the Islamic period, but also in characterizing funerary customs through time and elucidating key aspects of urbanization of the city during the Middle Ages. This comprises the first article in order to help contextualize subsequent studies and analyses.

Chapters 5 through 7 detail the reconstruction of 'lifeways' based on traditional bioarchaeological assessments. Chapter 5 examines oral health in a comparative framework by systematically analyzing the patterning in dental pathological lesions: calculus, caries, periodontitis, periapical inflammation, dental wear, enamel chipping, and enamel notching. Chapter 6 details assessments of growth and development via the patterning of non-specific indicators of stress, such as cribra orbitalia, porotic hyperostosis, periostosis, linear enamel hypoplasias, as well as terminal adult stature. Chapter 7 details the quantitative analysis of cortical bone as indexed by two differing tissue envelopes: the second metacarpal and mid-thoracic rib cross-sections.

Chapters 8 through 10 detail the reconstruction of 'deathways' based on funerary taphonomy and mortuary archaeology. Chapter 8 focuses on archaeothanatological reconstruction of possible burial containers, specifically shrouds, as based on the historical and decompositional evidence. Chapter 9 examines macrotaphonomic indicators observed in the Largo Cândido dos Reis sample, such as bone representation and preservation indices, erosion, weathering, and invertebrate presence. These results are contextualized alongside tomb typologies and burial metrics. Chapter 10 details the analyses and results from a comparative histotaphonomic study, focusing on preservation and bioerosion at the microscopic level.

Finally, chapter 11 forms the synthesis and conclusion of this dissertation and attempts to outline how both lifeways and deathways can shed differential light on processes of urbanization, representativeness, paleodemography, and heritage management.

Chapter 2: A bioarchaeology of lifeways and deathways

"*The most fundamental thing about life is that it does not begin here or end there, but is always going on.*"

— Timothy Ingold, 1995: 57

Post-processual critiques in the 1970s and 1980s helped to highlight the important role of the living community in funerary rites, but many critiques inadvertently decentered the dead. Sofaer (2006c, 18) showcases the ways in which processual archaeologists articulated "three bodies" – the living body as an ethnographic referent, the funerary body as an indication of social identity, and the bioarchaeological body as an object of scientific study material. Many post-processual critiques helped to address the first two 'bodies' but failed to (re)incorporate the third as a corpus of study. The inception of bioarchaeology in the 1980s helped to showcase the importance of the dead, and the wealth of information that human skeletal remains possess, particularly within ecological and human-adaptability frameworks (Buikstra et al. 1980; Larsen 1983; 1984; Goodman et al. 1988). Buikstra's early and seminal work (1977) advocated for a multi-methodological framework to integrate human skeletal remains with ecological datasets. Early bioarchaeologists made an important departure from previous physical anthropology on human skeletal remains by framing their research in testable hypotheses rather than descriptive reporting (Larsen 1997). While bioarchaeology certainly developed from the empiricist, positivist, and scientific tenets of processual archaeology, it sought to problematize human skeletal remains beyond objects of description (for a review, see Armelagos, 2003). In doing so, bioarchaeology has helped to re-center the dead, at least, human skeletal remains, as a worthwhile body of inquiry.

Bioarchaeology of lifeways

This section starts by examining the origins of biocultural approaches in biological anthropology and bioarchaeology, with a specific focus on health and stress. I then turn to bioarchaeological and biocultural approaches beyond health and stress, to such topics as social identity.

Origins of Biocultural Anthropology

While anthropologists and biologists alike have engaged with understanding the role of social conditions of health and variation for arguably over a century (Boas 1912; Douglass 1950), the implementation of formalized biocultural approaches to such intersections did not crystalize until fairly recently. Scotch's pioneering *Sociocultural Factors in the Epidemiology of Zulu Hypertension* (1963) was one of the foundational studies that suggested a link between Zulu hypertension levels with a changing social milieu. Where the majority of proximate biological data (primary data collected to quantify outcomes) was viewed in evolutionary contexts with ultimate causes often linked to ecology, Scotch (1963) differed by linking hypertension instead with rapid shifting social environments among the Zulu as they confronted an increasingly Westernized society. In a similar classic study, Henry and Cassel (1969) examined the effects of age on hypertension. While most scholars at the time had argued that increased hypertension with age was merely a byproduct of biological senescence, Henry and Cassel (1969) instead discovered that increased hypertension only correlated with age in certain Western populations. The discrepancies between age-related hypertension levels in various populations led the researchers to conclude that a universal biological explanation for variation could not hold up (Henry et al. 1969). Rather, the researchers suggested that elevated hypertension was more likely due to psychosocial stress placed on older populations because of rapid generational changes in technology, social relations, healthcare, and other lurking variables that may leave the elderly feeling vulnerable and isolated in contemporary Western contexts. Together, these studies as well as others helped to foster the beginning of a formalized biocultural approach by implementing interdisciplinary approaches straddling epidemiology, anthropology, human biology, and sociology to explain human biological variation and health.

Despite these groundbreaking studies, issues began to emerge in biocultural theorizing and application. Dressler (1995) presented a seminal yet critical review of the state of biocultural research in anthropology. For him, the main issue was methodology. While the gathering of proximate biological data remained similar across studies (e.g. measuring hypertension, adiposity, hormonal levels), the interpretation of ultimate causal factors ranged dramatically depending on the researchers and their respective disciplines. Most apparent was that researchers were grappling with how to make sense of their data under the idea of combining "the biological" and "the cultural" – concepts that generations before were viewed as disparate and even mutually exclusive. Researchers were plagued by questions such as: how can one weigh the relative impact of social or economic variables against biological or ecological ones (Alan H Goodman & Thomas Leatherman 1998)? At one point are observations of hypertension or cortisol impacted by family structure rather than ecological environment? Are these mutually exclusive to begin with, or can local family structure still be subsumed under or nested within a larger ecological context?

These questions became further compounded by issues of scale. Where pioneers in biocultural anthropology (e.g. Dressler, 1995; Singer, 1989) often advocated for ethnography and intensive immersion in smaller societies, epidemiologists on the other hand often conducted biocultural studies at far larger scales. As such, the issue of a generalized biocultural approach came into question, as social factors influencing health and variation in one context may not be translatable to others (Dressler, 1995). While such criticisms helped to underscore a more particularlistic approach with more attention paid to local context, they came with the cost of potentially creating a more fractured and increasingly specialized field of research.

A major point of contention during this period was the debates between Wiley (1992; 1993) and Singer (1989; 1992) that brought the issue of Biology vs. Cultural to the fore of biocultural approaches. Medical anthropology – originally conceived as a biocultural sub-discipline – saw a similar rift as its greater parent discipline, factioning into biocultural medical anthropology and critical medical anthropology. Critical medical anthropologist Merrill Singer (1989) lead by first criticizing medical ecology – an interdisciplinary approach subsumed under biocultural medical anthropology aimed at examining the ability for populations to adapt to their given environments through the lens of health. Drawing heavily on traditional ecological models and the evolutionary concept of adaptation, medical ecology sought to synthesize biological methodology with social-cultural interpretations (Singer, 1989). Singer criticizes that in doing so however, medical ecologists conflated social and economic inequalities with ecology and the environment, ultimately naturalizing suffering (1989, 226). In a concrete example, Singer cites medical ecologist Marshall Newman, who linked areas of malnutrition geographically to tropical climate, suggesting that inhabitants in such climates "represent the worst lags in man's adaptation to his nutritional environment" (1962, 26). David Landy criticized Newman by arguing that climate was not the sole factor responsible for maladaptation, but rather exacerbated preexisting inequalities and differential access to quality foods (1977). Examples such as these lead Singer (1989) to dismiss medical ecology's concept of adaptation as a useful concept in contemporary health issues, for its failure to take into account social conditions of health and disease. Further, he finds issues with medical ecology's biocultural approach for its failure to consider 'culture' whatsoever, let alone define it.

In response to the criticisms brought about by Singer (1989), biocultural medical anthropologist Wiley (1992) defended adaptation and biocultural modelling as useful concepts, despite medical ecology's limited and narrow use of them. Wiley (1992) began by carefully highlighting the differences between critical and biocultural medical anthropology, the former being political, activist, and phenomenological, and the latter being data-driven, cause-effect based, and evolutionary (1992, 217-218). Further, Wiley criticizes Singer's conception of adaptation and bioculturalism as a straw man, by citing outdated research (such as Newton's above) and by assuming adaptation to be "the perfect fit" (1992, 219). Wiley goes further to showcase Singer's misunderstanding of basic evolutionary knowledge, by highlighting his superficial reading of Gould and Lewontin's classic critique (1979) of the adaptationist program. Gould and Lewontin (1979) criticized biologists who overemphasized adaptation, yet they do not do away with the concept altogether, as Singer implies (1989, 226). Rather, they introduced a new, complementary concept of constraint, which was neglected by Singer. Wiley also highlights how "environment" in biocultural research includes socio-economic barriers, contrary to Singer's suggestion (1989). In this light, biological markers are used as "indicators" signaling larger ecological, economic, and social processes (1992, 225). Next, Wiley highlights the definitional differences of health between biocultural and critical medical anthropology, the former conceptualizing health as an ability to cope to demands and stressors, while the latter defines health according to identity, class, and power differentials (1992, 223). Finally, concerning the origins of disease, Wiley states that biocultural anthropologists are more focused on the process of coping and adapting (or failing to) to stressors (i.e. the how?), whereas medical anthropologists are more interested in unmasking power relations in resource distributions (i.e. the why?).

While the debate continued, the above excerpts hopefully showcase just how divided an anthropology of health came to be. The chasm between anthropological subfields continued to widen, and medical anthropology along with biocultural approaches fractured despite their original intentions to traverse such boundaries. Dichotomies of Biology vs. Culture resurfaced and became reified in such debates, leaving biocultural and critical approaches seemingly exclusive to one another. The question then, is whether a biocultural approach is still viable, and if so, can it incorporate both criticisms dialectically into a new synthesis? Can biocultural approaches examine social arenas of power and inequality while still being biologically grounded? I argue yes – that these approaches need not be mutually exclusive as Wiley and Singer have made them out to be. I suggest that a political economic perspective of human biology may better bridge this gap.

Goodman and Leatherman's seminal volume, *Building a New Biocultural Synthesis: Political-Economic Perspectives on Human Biology* (1998) explicitly sought to refine biocultural approaches while simultaneously bridging the rift caused by debates such as those discussed above. This volume became the foundation for various theoretical and methodological propositions for understanding the biological impact of human-political interactions, namely poverty. As stated in the title, this volume employed an explicit political economic perspective. Political economy began as a sub-field of world systems theory, which analyzed the interrelations and connectedness of capitalist relations. Few anthropologists showed interest with such approaches until the 1950s, when they "did not…appropriate all of classical political economy" but instead "appropriated Marx" (Roseberry, 1988:162). Leacock's early work on gender and power relations among Montagnais-Naskapi (e.g. 1954) was crucial in establishing an ethnographic approach to political economy, and by 1978, anthropological political economy crystalized with the publication of a special issue on political economy in *American Ethnologist*.

As a generalized approach and following the style of Leacock above, political economy in anthropology came to examine power relations and inequality as it was often manifested through labor control (Roseberry, 1998, 79). This is where Marx, or more specifically "visceral" Marxism – coined by Firth to depict American anthropologists who employ Marx to illuminate power relations and inequality as immoral byproducts of capitalist production (Firth, 1972, 29) – entered the theoretical discussion. Anthropological political economy comprised of comparisons between "delineated" classes, oftentimes heuristically simplified as the two-class system of bourgeois and proletariat coined by Marx (Roseberry, 1998, 84).

At first glance, it may seem that political economy may have little to do with human biology. Yet, in their opening chapter Goodman and Leatherman argue that unlike genetically deterministic or evolutionary models which have characterized the majority of biological anthropology, a political economic perspective on human biology examines "how sociocultural and political economic processes affect human biologies, and then how compromised biologies further threaten the social fabric" (1998, 5). In this light, Goodman and Leatherman fused political economic approaches in anthropology to the human adaptability paradigm, formally accredited to Baker (1984). Baker and his students refined theoretical and methodological approaches to human-environment interactions and adaptation by expanding the definition of environment to include socio-cultural contexts. Their classic study on Samoan-American immigrants (Baker et al. 1986) explained heightened levels of cardiovascular disease as a product of socio-environmental alteration, much similar to those studies of Henry and Cassel (1969) and Scotch (1963) discussed above. The human adaptability paradigm provided a theoretical and methodological means for assessing the biological impacts of political economic forces on human beings. Crucially however, Goodman and Leatherman (1998) go further than their human adaptability predecessors, arguing that knowing how limited access to resources affects health is only half of the equation, the rest lies in measuring the severity and investigating the sources of inequality (1998). This is where the political economic perspective of anthropology takes hold in their analysis to create a new synthesis. The authors plead to move beyond linking proximate biological markers with ultimate social phenomena, and rather ask *why* the ultimate stressors are happening in the first place. Clearly, the agenda of this new synthesis harkens to tenets put forth by *both* Wiley (1992) and Singer (1989), which years prior had been posed as mutually exclusive. Uniquely, this political economic perspective on human biology sought to retain adaptation and biological markers in the body, but also address the shortcomings of Wiley's (1992, 224) position that biological anthropology should avoid investigations of power differentials. In doing so, they helped to generate a more holistic and nuanced biocultural approach in the middle ground of what once was a chasm between scientific biological data and humanistic social theory. This synthesis eventually came to be synonymous with a "biology of poverty" (Goodman et al 1988, Leatherman and Goodman 1997; Thomas, 1998).

Goodman's chapter within this volume best exemplified the implementation of a political economic perspective to bioarchaeological skeletal samples. Analyzing various non-specific stress indicators in human skeletal remains from Dickson mound, Illinois as well as the Nubian kingdoms in the Nile River valley, Goodman argued that biocultural stress went beyond local ecological factors and more than likely are associated with inequality and political autonomy (Goodman 1998). Carefully contextualizing the patterns of stress indicators with burial tradition, grave goods, and broader archaeological knowledge of social and political hierarchies in these respective samples, Goodman ultimately argued that stress was more than likely synergistically linked to inequality as well as ecology. In essence, this was one of the early bioarchaeological studies to depart from traditional ecological-adaptation interpretations and instead consider social inequality, despite still analyzing "prehistoric" communities. Goodman (2013) later advocated for biological anthropologists to be at the forefront of reframing human biology in a tiered framework whereby 1) disease status and stress ("cultural-biologicals") are conceptualized as the intersection of genes, environment, and the body ("nature cultures"), followed by 2) how such "cultural biologicals" can then be understood in tandem with larger site-specific structures, ideas, and ideology, and 3) further situated in global, political-economic contexts. Goodman's first level linguistically reframes (via hyphenation) the interconnectedness within the "dance" between genes, body, and culture, whereas the second level scales up the larger context but maintains a "terroir" approach to human biologies (Goodman 2013). Arguably no greater example can be seen in the third level than by the 2020 SARS-COV2 pandemic, where the global political-economic potential was realized internationally, but with specific variations in patterning at national, local levels (levels 1-2). Illness and health are never devoid of cultural, political, nor economic inputs.

Stress and Skeletal 'Health'

Examinations of stress and skeletal health are arguably the largest and most routine means of elucidating lifeways of past people's through bioarchaeological analysis. Measures of stress indicators have a long history in human biology (Bogin 1995; 1999; 2001; 2006; Bogin et al. 1997; 2003; 2007; Dressler 2005; Ellison 2005; Ellison et al. 2007; Gluckman et al. 2006; Gluckman et al. 2004; Mcdade et al. 2008; Sapolsky 2004; Schell 1995; 1997; Schell et al. 2007; Tanner 1981; Tanner et al. 2014;) and bioarchaeology (Porter et al. 1987; Mays 1998a; Larsen 2001; King et al. 2005; Steckel 2005; Buzon 2006; Temple 2008; Klaus et al. 2009; Amoroso et al. 2014; Klaus 2014; Temple et al. 2014a). Biocultural stress is traditionally defined as environmental perturbations in the normal metabolic and/or physiological development of an individual (Huss-Ashmore et al. 1982). While many studies have demonstrated tremendous variation in growth, development, and health patterns throughout the world (Beall 1987; 1995; 1999; 2001), severe stress in any individual can pass certain thresholds to become physiologically embodied as lesions. Despite variation in human biology and the variety of stressors that individuals encounter, the human body responds in a fairly stereotypical fashion (Selye 1936; 1950; 1973). However, the implications of stress on health is debated and not all understood. Hans Selye's early work (1936; 1950) was one of the first to grapple with how to define and conceptualize stress and stress responses. He argued for two major considerations: 1) the temporality of stress, and 2) its non-specificity. Firstly, Selye (1973) suggested that a short-lived stress disruption and response resulted in little threat, whereas long-term or chronic stress could have severe health consequences. Sustained exposure to a stressor essentially pushes the body past a threshold to create an observable stress indicator or defect within the body. Secondly, Selye argued that because humans can have the same physiological response to many differing stressors, stress response and indicators must be seen as "nonspecific" (Selye 1973).

The non-specificity has helped to address the complex systems in which stress operates, and has become a useful heuristic device in bioarchaeology as specific stressors are difficult to identify in the past.

Selye's former point on the temporality of stress sparked tremendous research examining the timing and duration of stress. How long must stress be present before a biological substrate is affected? When are humans most susceptible to stress, and when are they buffered? These deceptively simple questions have been thoroughly debated, and patterns are beginning to emerge showing potential answers. Two perspectives that contribute to this venue of research are discussed below: The Developmental Origins of Health and Disease (Barker et al. 1989; Barker 2001; 2012) and Cumulative Adversity models (Merton 1968; Hatch 2005). The former model posits that gestation and uterine development is the most critical and sensitive period for stress, which can have long term health consequences as well as intergenerational ones. The latter suggests that enduring socio-economic conditions may further impact adult health throughout life. By exploring these two models, a complicated picture emerges of empirical and grounded biocultural research that may well inform investigations of health in the bioarchaeological record.

A wealth of studies helped provide the foundation for a tremendous amount of research and scholarship on the linkages between gestational stress and adult morbidity and mortality (Bogin 1995; 1997; Barker 2001; Cooper et al. 2001; Valeggia et al. 2001; Worthman et al. 2004; 2005; Ellison 2005; Kuzawa 2005; 2008; Bogin et al. 2007; Ellison et al. 2007; Schell et al. 2007; Armelagos et al. 2009; Kuzawa et al. 2009). This Developmental Origins of Health and Disease hypothesis (DOHaD), also known as the Barker hypothesis thanks to Barker's pioneering and extensive research, broadly states that "alterations in growth have permanent maladaptive consequences that place people at risk for disease later in life" (Bogin et al. 2007, 633). This mechanism by which this takes place is thought to be epigenetic, particularly methylation (Weaver et al. 2004; 2005; Waterland et al. 2007; Kuzawa et al. 2009; Hochberg et al. 2011). Methylation is the process of a methyl group attaching to a nucleotide (usually cytosine) of DNA (Jablonka et al. 2005). This can alter gene expression without directly modifying or altering the DNA sequence itself. Crucially, epigenetic changes can manifest through environmental input, and can operate within life cycles as well as across generations (Kuzawa 2008, 340).

Numerous intergenerational studies have demonstrated increased morbidity and mortality among offspring of stressed mothers despite being born into an affluent social environment (Emanuel 1986; 1993; Martorell 1995; Skjaerven et al. 1997; Price et al. 2000; Drake et al. 2004; Stein et al. 2004; Drooger et al. 2005; Agnihotri et al. 2008). A well cited example is the Dutch study conducted by Drooger and colleagues (2005) in The Netherlands. The researchers found that infants born to ethnic minority women were at a higher risk for low birth weight and early mortality than ethnic Dutch. This was surprising, as the Netherlands is one of the top providers of general and prenatal health care in the world. As Bogin et al. state, "Despite improved health care for the current generation of women in The Netherlands, the intergenerational influences of the past environments are not overcome" (2007, 636). Over forty years of controlled feeding studies on monkeys have found similar results, whereby small-birthed mothers gave birth to small-birthed females (Price et al. 2000). Even when nutritional intake of small-birth daughters was improved, it "took four generations to overcome the initial deficits of the great-grandmother generation" (Price et al. 2000; Bogin et al. 2007, 636). Ramakrishnan et al. conducted a meta-analysis of fourteen studies in Guatemala, finding that each 100g increase in maternal birthweight predicted a 10-20g increase in birthweight of the offspring, ultimately strengthening the intergenerational link between maternal and offspring birthweight (1999).

Epigenetic research has revealed that methyl groups can be inherited, helping to explain how adversity and stress transcends generations (Drake et al. 2004; Jablonka et al. 2005; Kuzawa 2008; Kuzawa et al. 2009). Altogether, these studies demonstrate how stress is certainly impactful during pregnancy, gestation, and early life. Further, they show how stress and adversity become embodied through multiple generations, what's been termed "imprinting" (Bogin et al. 2007), "intergenerational inertia" (Kuzawa 2008), "biological memory" (Thayer et al. 2011), and "nested lives" (Gowland 2015). This has facilitated a theoretical shift in biomedical research to view the mother as no longer a "buffer" for the fetus, but rather as a potential "vector," often placing greater scrutiny and censorship on the nine-month pregnancy period. However, Richardson and coauthors (2014; Richardson 2021) caution that the pregnancy period is less likely to explain uterine stress as the mother's *own* gestation. In other words, under a DOHaD model, a mother's own gestational, uterine, and postpartum environment is more likely to affect their children's uterine environment and health than the environment experienced when pregnant (Kuzawa 2008; Barker 2012; Chung et al. 2014; Richardson et al. 2014; Sletner et al. 2014). Recent studies by Gravlee (2009) and Kuzawa and Sweet (2009) have shown how race, even though it is a social construct, can have real physical effects on modern African American communities, becoming embodied as health inequalities such as hypertension. Both groups of researchers interpret the long history of racial subjugation in the United States as a persistent phenomenon creating a suite of health issues cascading into contemporary descendent groups, much like the Dutch Famine study (Drooger et al. 2005). In this light, the damage is seen as already done by adolescence, colloquially characterizing DOHaD as the "damaged goods" hypothesis (Armelagos et al. 2009, 270).

While DOHaD has demonstrated on multiple grounds the importance of early life, other studies are beginning to highlight the dynamic unfolding of health across the life course (O'Rand 1996; Alwin et al. 2005; Hatch 2005; Armelagos et al. 2009; Braveman et al. 2009; Agarwal et al. 2011; Gowland 2015; Agarwal 2016). These studies often conceptualize health in terms of the "life course" or "cumulative adversity" – the aggregation of experiences over a life time that affect health trajectories. Cumulative adversity/advantage (CA) was originally coined by sociologist Robert Merton (1968), who used the term to explain how famous scientists often receive more credit than those who are less famous, even when their research is similar. Merton synonymized cumulative adversity with the Matthew effect, taken from the Gospel of Matthew (Matthew 25:29, King James Version), which is akin to the cliché, 'the rich get richer, the poor get poorer.' The concept became quickly adopted in social epidemiological approaches and life course approaches (Hatch 2005). Life course approaches arose as interdisciplinary investigations of how events affect life cycle trajectories within individuals and between generations (Bengtson et al. 1993; Kuh et al. 1997; Ben-Schlomo et al. 2002; Elder Jr et al. 2003; Mayer 2009). These studies also tend to connect more sociological and anthropological insight with epidemiology. Hatch details that cumulative adversity operates at three processes: 1) adversity is persistent, 2) adversity is compromised by "chains of contingencies," and 3) adversity can be layered and "cascading" (2005, 131). The first point of persistence ties directly with the Selyean concept of stress above, and provides a means by which stress can aggregate and accumulate over one's life. The latter two levels tie with the intergenerational effects of stress –"those factors, conditions, exposures and environments experienced by one generation that relate to the health, growth and development of the next generation" (Emanuel 1986, 27). By tying cumulative adversity with life course approaches, a synthetic and interdisciplinary approach emerges that is able to note the effects of gestational stress but also acknowledge the health impact of cumulative stress of daily life. One rather evocative way to conceptualize this is to see humans not as human "beings" but rather as human "*becomings*" – perpetually in a state of flux and making (Ingold et al. 2013). Altogether, this details how important and sensitive the entire life course is, especially as it relates to health trajectories. As such, a cumulative adversity/advantage model has become synonymous with a "wear and tear" hypothesis (Armelagos et al. 2009, 270).

The longitudinal nature of observing life course and cumulative adversity approaches are rendered problematic in bioarchaeological analyses. Bioarchaeology often deals with cross-sectional samples (Wood et al. 1992), and has no way to institute longitudinal or matched-pairs studies to the ability of modern ones. However, some bioarchaeologists are at the forefront of reframing the human skeleton as a rich temporal dataset, drawing explicitly from life course literature (Sofaer 2006a; Sofaer 2006c; Armelagos et al. 2009; Agarwal et al. 2011; Gowland 2015; Agarwal 2016) and cumulative adversity approaches (Amoroso et al. 2014).

Over 20 years ago, Goodman and colleagues noted the benefits of studying skeletal tissues as it relates to stress (Goodman et al. 1988). While soft tissues are hierarchically affected earlier than skeletal tissues, they also tend to heal and remodel faster (McCance 1960; McCance et al. 1962). This means that stress must be present longer and often be more severe in order to affect skeletal substrates due to their slower remodeling rates (Garn et al. 1965; Garn 1970). In this sense, the severe and persistent presence of stress is more likely to be found in skeletal tissues. The skeleton's plastic and receptive nature allows it to record and embody persistent social environments as seen in Klaus' research (Klaus et al. 2009), much to the same effect as the modern studies conducted by Gravlee (2009) and Kuzawa and Sweet (2009) discussed above. In this sense, there is much overlap between studies of stress in modern humans and bioarchaeological samples – the difference is largely methodological. Whereas modern studies examine chronic disease, hypertension and birthweight (Table 1), bioarchaeological studies often examine infectious disease and defects embedded within the skeleton (Table 2). These 'stress indicators' as they are commonly referred to in bioarchaeology are admittedly not as specific as factors analyzed in modern studies, harkening back to Selyean stress (Selye 1936; 1950; 1973). However, analyzing combinations of multiple stress indicators can help yield precision, strengthen interpretations of systemic stress, and rule out possibilities of anomalous stress during growth, such as a fever (Humphrey 1998; Humphrey et al. 2000). Further, it gives bioarchaeologists the methodology to implement a life course perspective. As Agarwal notes "…the simultaneous study of multiple skeletal indicators allows the study of stress at longitudinally different points across the life cycle even within the limits of cross-sectional skeletal data" (2016, 133). In order then to implement life course approaches in bioarchaeological samples, skeletal tissues correlating with different ontogenetic processes must be analyzed in concert. Thanks in large part to biomedical research over the last century, human osteological tissues are becoming better understood, especially as they relate to different chronological stages of ontogenesis (Garn et al. 1965; Garn 1970; Frost 1990; 2000; 2001; 2003; Turner 1992; Parfitt 1993; O. Pearson et al. 2004; Ruff et al. 2006).

While Armelagos and colleagues (2009) were right to point out the difficulty in teasing apart the Developmental Origins of Health and Disease (DOHaD) models from Cumulative Adversity (CA) ones in bioarchaeological samples, a life course approach that incorporates multiple skeletal elements may be a first step in addressing such issues. Implementing multiple analyses of pan-skeletal stress can help to seriate stress events and elucidate whether stress was present in only childhood, only adulthood, or throughout the life course (Agarwal et al. 2011; Agarwal 2016; Gowland 2015). Life course approaches in bioarchaeology further help to address bioarchaeology's largest theoretical issue: the osteological paradox (Wood et al. 1992). Wood and colleagues published their seminal review (1992) in order to critically investigate bioarchaeological interpretations and the relationship between skeletal lesions and health. They outlined three conceptual pitfalls that problematize bioarchaeological interpretations: 1) demographic nonstationarity, 2) selective mortality, and 3) hidden heterogeneity. Demographic nonstationarity refers to the fact that populations are rarely, if ever, in stasis. Bioarchaeologists often assume the populations from which the skeletal samples derive from are relatively stable, and as such age-at-death distributions are often assumed to be reflective of mortality. Yet, if a population is nonstationary, which almost all are, age-at-death is more an effect of fertility than mortality. The second conceptual issue that Wood and colleagues discuss is selective mortality. This refers to the fact that skeletal remains reflect those who died at a given age, not all of those who were at risk of dying. As they put, "the only 20-year olds we observe in a skeletal sample are those who died at age 20" – those who survived past 20 years of age immediately enter a new age cohort (Wood et al. 1992, 344). Bioarchaeological samples then are inherently biased towards those who died at a given age, problematizing population estimates. Finally, the third and final issue they raise refers to the differential predispositions individuals have to diseases and death – what they term hidden heterogeneity. In essence, the authors argue that risk of exposure varies between individuals, and that it is near impossible to reconstruct exposure in antiquity. Because skeletal tissues are hierarchically affected later than soft tissues, a sudden onset of disease or vector may result in a rapid death which leaves no skeletal lesions. Conversely, the presence of lesions may paradoxically indicate better health, as they endured the stressful event long enough to produce lesions. All these issues culminate into the osteological paradox, and seriously complicate bioarchaeological interpretations of aggregate or population health. Further, it calls into question how bioarchaeologists should define health, and whether age-at-death is the best variable to measure health in skeletal samples.

Temple and Goodman (2014a) recently added to this discussion by further criticizing bioarchaeological definitions of health. In concert with Wood and colleagues, Temple and Goodman (2014a) question whether skeletal lesions and stress indicators actually impact survivorship. For example, if an individual has signs of developmental stress (e.g. LEH) but survived well into older age, they can only be considered 'stressed' during growth, but not necessarily as an adult. Further, they highlight how comparing sub-groups in terms of "healthy" and "unhealthy" or "stressed" and "not stressed" based on the presence of stress indicators results in typological categorization – something bioarchaeologists usually try to avoid (Temple et al. 2014a, 188–189). Finally, they follow McIlvane and Reitsema (2013) to argue that health is more than just the absence of skeletal lesions, but includes personal, mental, and social aspects (Temple et al. 2014a). Ultimately, the authors suggest that interpretations of stress indicators should adhere to a vocabulary of 'mortality' and 'survivorship', and not necessarily 'health' as it encompasses far more than the skeleton.

While life-course approaches cannot remedy the entirety of these issues, its theoretical basis paired with recent developments in statistical techniques can help to address issues of longevity and the cross-sectional nature of skeletal samples. Boldsen (2007b) was one of the first to directly address the osteological paradox, particularly selective mortality and frailty. Employing transitional analysis, a Bayesian method of age-estimation (Boldsen et al. 2002), he was able to seriate ages beyond 50+ which is otherwise is difficult using traditional aging methods. This allowed for a more fine-grained comparison of linear enamel hypoplasias (LEH) and their effect on longevity, mortality, and survivorship. Using statistical techniques such as risk and survival analyses in a medieval Danish population, he was able to demonstrate that frailty was not constant throughout the life course, but varied with age and sex. In males particularly, he found that adults with LEH had a 2.28 times higher death rate than their counterparts who did not have LEH. Ultimately, he concluded that "the risk of dying can only be understood in a lifelong perspective" (Boldsen 2007b, 64), supporting a lifecourse framework.

Numerous studies have also directly engaged with the osteological paradox by testing stress indicators with frailty, longevity, and mortality. DeWitte and her various colleagues have conducted a number of studies examining frailty and mortality in medieval English cemeteries (DeWitte et al. 2008; 2011; 2012; 2013; DeWitte 2010; 2014). Similar to Boldsen, DeWitte has employed survival and hazards analyses from epidemiology, particularly making use of Kaplan-Meier, Gompertz, and Gompertz-Makeham models. In a comparison of monastic and non-monastic cemeteries, DeWitte et al. (2013) found that those buried in monastic cemeteries were at a reduced risk of death and mortality, and lived longer than their non-monastic counterparts. They interpreted these findings with historical and archaeological context to suggest that monasticism likely resulted in relatively good hygiene, better standards of living, and better nutrition than their counterparts in the general community. In an analysis of the Black Plague (AD 1347-1351), DeWitte and Wood (2008) found that contrary to conventional thought, the Black Death did "not kill indiscriminately," but actually targeted certain frail individuals, though not as much as standard or expected mortality. In other words, the "frailer" individuals were more likely to die in the Black Death, but not as severely as those who were stressed under normal (i.e. not affected by the Black Death) conditions. Altogether, DeWitte's research as well as other's (Wilson 2014a) can help to address the osteological paradox by tying epidemiological and statistical methodologies which can be further bolstered by life course approaches (Agarwal et al. 2011; Gowland 2015; Agarwal 2016). Further, DeWitte and colleagues have shown interesting and contextual findings regarding frailty, risk of death, and age under differing social, religious, economic, and epidemic conditions. DeWitte and Wood's (2008) analysis of the Black Death is reminiscent of much of medical anthropology's similar findings that epidemics do not equally affect all members of a community, but rather severely impact socially and economically marginalized groups (Farmer 1999; Briggs et al. 2004). In this sense, bioarchaeologists may be able to move beyond "frailty" and consider how this term may be predicated on social, economic, and political marginalization, allowing entrance back into political economic theory and assessments of structural violence. Altogether, a bioarchaeology of the life course can provide a theoretical foundation with a complex methodology to better address more complicated intersections of health, history, and social milieu.

As biocultural approaches cemented themselves in bioarchaeology's theoretical foundations by the turn of the 21st century, bioarchaeology also expanded beyond routine osteological examinations of health, stress, and demography, what Klaus identifies as the transition from the "second wave" to "third wave" of bioarchaeology (2020, 186). In doing so, social approaches in bioarchaeology reached a "theoretical awakening" (Klaus 2020, 188) and have subsequently blossomed (Agarwal et al. 2011; Martin et al. 2014), and the field reconsidered how human remains could embody other social aspects of identity and personhood.

Social Bioarchaeology: Identity and Personhood

Socially informed bioarchaeological approaches to identity have been present since the field's inception (Buikstra 1977), but crystalized with the germinal volume by Knudson and Stojanowski (Knudson & Stojanowski 2009). Given its "nebulous nature," they loosely define identity as "peoples' perceptions of themselves and how they relate to larger social phenomena that characterize their existence" (Knudson & Stojanowski 2009, 1). Much of the anthropological history on identity studies began with conceptualizations surrounding ethnicity, largely deriving from Barth's foundational volume (Barth 1969a). Barth, among others (Banks 1996; Barth 1969b; Cohen 1974) was careful to underscore the variable, fluctuating nature of ethnicity, and how it could be coopted, manipulated, or maintained. It became preferable to 'tribe,' a term anthropology had long used and which often evoked immutability and homogeneity (Banks 1996). In doing so, these social theorists also set apart their articulation of ethnicity as distinct from psychological (De Vos 1975) and sociobiological (van den Berghe 1978) articulations championed by contemporaries. Ethnicity was adopted relatively quickly within social anthropology, and while archaeologists were slower to adopt its usage, numerous archaeologists near the turn of the century began implementing ethnicity as well as identity in a socially situated and multi-method framework (Pyszczyk 1989; Aldenderfer 1993; Brumfiel 1994; Jones 1997; Ponting 2002). As Insoll asserts: "For the issue is really whether one can actually have an archaeology that is *not* concerned with identity" (Insoll 2007, 1).

Bioarchaeologists were quick to follow, in large part due to the body's potential for visual and representational constructions of personal and social identities (Fisher et al. 2003; Joyce 2005). Additionally, bioarchaeology offers the unique possibility of seeing life-long formations and maintenance of identity play out throughout the life course and over the *longue durée*, becoming physically and chemically recorded within the human skeleton (Buikstra et al. 2009; Larsen 1997; Larsen 2002). The heterochronic nature of the human skeleton positions it as a unique palimpsest of varying life events embodied in differing tissues, envelopes, and matrices (Agarwal 2016; Agarwal et al. 2011). One of the richer bioarchaeological insights into identity formation concerns bodily modifications. For instance, cranial modifications — the manipulation of the cranium during growth and development while cranial growth is still ongoing and plastic — results in a life-long visual and physical identifier of social identity, and has been observed throughout numerous archaeological communities (Blom 2005; Geller 2006; Tiesler 2012; Tiesler 2014; Tiesler et al. 2018; Torres-Rouff 2002). Similarly, dental modifications, such as ablation (removal), inlays, and etching can reflect various aspect of social identity such as status, important life-cycle events, ethnicity, or death and grieving (Alt et al. 1998; Stojanowski et al. 2014; Burnett et al. 2017; Palefsky 2019; Temple et al. 2011; Temple 2018; Williams et al. 2006). These modifications leave indelible, visual signatures within the body, imbued with social meanings. Even forms of modifications that affect soft tissues, such as piercings and labrets, can similarly signal aspects of "embodied personhood" (Torres-Rouff 2003; 2012, 155).

What those social meanings meant to the people who practiced them is undoubtedly the challenge, and not always possible to discern. Bioarchaeologists for example have done well to examine how aspects of sex, gender, and age (Agarwal 2012; Agarwal et al. 2017; Geller 2008; Gowland 2006; Grauer et al. 1999; Sofaer 2006a; 2006c; Walker et al. 1998) comprise important aspects of identity in the past. However, such partitioning is not always straightforward, and many times identity can be collapsed into a singular axis such as sex, age, or gender rather than the confluence of multiple axes (Meskell 2001; 2002). Kimberlé Crenshaw, a Black feminist legal scholar, authored a foundational article (Crenshaw 1989) which coined the concept of “intersectionality”. Crenshaw championed a Black feminist approach in order to illuminate that violence against Black women in the United States was not a gender problem *or* a race problem (separated), nor even a gender *and* a race problem (additive), but one where the “intersectional experience is greater than the sum of racism and sexism” (1989, 140). Despite its legal and contemporary origins, adoption of the term has exploded throughout the social sciences, and much of the recent bioarchaeological scholarship engaging with identity has focused on intersectionality as a key departure from more cleaved conceptions (DeWitte et al. 2020; Maass 2022; Mant et al. 2021; Yaussy 2022). A key theoretical principle to social bioarchaeology (and arguably, to human adaptability paradigms discussed above), is the concept of embodiment (Schrader et al. 2020). This perspective stems from a transition of viewing the body/culture in light of object/subject polemics to “animating” the body as something far more than “simply a vehicle to transport the self” (Schrader et al. 2020, 15), and as a result, are inherently biocultural. While anthropological fascination with the body began in 1970s (Blacking 1977; Favazza 1987; Foucault 1973; 1977; 1982; Jackson 1981; Scheper-Hughes et al. 1987) embodiment became introduced into archaeology during post-processual critiques and fully legitimized after 1990 (Joyce 2005, 141; Meskell et al. 2003).

Bioarchaeology undoubtedly has contributed immensely in its capacity to reveal biocultural aspects of livelihood, suffering, and identities in past communities. Life course approaches in addition to embodiment and other social theoretical frameworks have aided bioarchaeologists to better theorize, and personalize, past communities from human remains. However, ironically, despite studying ‘death assemblages’, bioarchaeologists have generally struggled, theoretically and methodologically, to reveal aspects of death and dying.

Recentering the Dead, Death, and Dying

Despite the wealth of knowledge produced by bioarchaeologists, death and the act of dying still remain elusive and under-theorized for archaeologists and bioarchaeologists alike. Nilsson Stutz aptly identified that “burial archaeology does not equal the archaeology of death” (2016, 14). Rather, burial archaeology has focused on inhumations as windows into ‘the living’ who deposited the dead rather than focusing on death and dying. Conversely, bioarchaeological and osteological analysis, though they may be on remains of the dead, does not inherently furnish a death-informed approach. As Robb eloquently states "We have not had an ‘archaeology of dying’ or even an ‘archaeology of death’; we have an archaeology of already dead persons” (2013, 442). Building on Kellehear (2007), Robb underscores the distinction between death, a biological transition, from dying, a social act. This distinction helps to provide a pluralistic means — termed “deathways” — (see Parker Pearson, 1999) of investigating the process and negotiation that accompanies death and dying, and helping to tackle the tendency to treat the living as vibrant and the dead as inert. Indeed, Kellehear’s conception of both biological and social death harkens to Hertz’s pioneering 1907 article which distinguished the dead body as a source of organic matter from the dead body as a social being that required transition into a new form of existence (Hertz 1960a). In particular, this helps to showcase that cemeteries and graves are but one fragment of the larger process that encompasses mortuary practices (Hodder 1982b; Parker Pearson 1993, 226–227). Harris and Robb advocate for the importance of an ontological framing in order to understand how communities in the past engaged with death, dying, and funerary treatment (Harris et al. 2013). Failure to take an ontologically-relative position risks the superimposition of living/active : dead/inert dichotomies *a priori*, and obfuscates the protracted relationship between dying and funerary treatment.

The inherent transdisciplinary nature of burial archaeology is both "its blessing and its curse" (Nilsson Stutz 2016, 14), as the breadth of potential theoretical and methodological approaches to archaeological burials is vast, and consequently, a serious challenge for any one scholar to fully master. Joyce (2005, 151), building from Meskell (2016), critiques the polarized treatment of the body in anthropology: "as is generally the case in archaeology, the body is mainly approached as an 'objectified entity in physical/biological anthropological studies' *or,* as the dead body of mortuary studies, as an index of social organization, or as a focus of symbolism" (emphasis mine). Sub-disciplinary differences can be seen in archaeology's development out of culture history, and processual/post-processual approaches to burials, while bioarchaeology is born out of (at least, in part) the natural sciences. Klaus cheekily and correctly stated: "As bioarchaeologists, it seems that we may reside in the space between: we are somewhere in the slash in 'science/theory'" (Klaus 2020, 188). Even *within* the natural sciences, the 'severing' of the living body from the dead one is born out of the disciplinary distinction between osteology and taphonomy, with the former largely based in the New Physical Anthropology (Washburn 1951), and taphonomy deriving predominately from paleontology (Efremov 1940) and site formation processes. Understanding the historiography of taphonomy and its (bio)archaeological implementation is crucial to aid in furthering a more nuanced mortuary framework. Indeed, as Nilsson Stutz advocates, "a successful archaeology of death and burial must include literacy in all of these fields" (Nilsson Stutz 2016, 15). In the following section, I consider how a bioarchaeological approach to deathways can be operationalized.

Bioarchaeology of Deathways

Death studies, at least in the United States, did not crystalize until Mitford's classic study, *The American way of Death* (1963). Leveling criticisms against the American funeral industry for being extortive and capitalistic, Mitford's study not only framed death in America as peculiar, odd, and nonsensical, thus providing an anthropological foundation to avoid othering, but also brought discussions of death outside of the macabre and the taboo. This set the stage for death studies, in a variety of disciplines, to proceed and blossom without fear of social or academic backlash.

Much of the origins of religious funerary archaeology can be traced, in part, to the germinal works of both Hertz (1960b) and Van Gennep (1960). The works of both Hertz (1960) and Van Gennep (1960) were fundamental to death studies in their ability to provide a framework for funerary rites, death, and dying, but differed in notable ways. Whereas Van Gennep accrued numerous examples in a synchronic manner, Hertz's more detailed, Durkheimian approach focused on one example (Borneo) in greater detail. Analyzing funerary rites primarily in the Olo Ngaju of Indonesia, Hertz – a student of Durkehim – observed the importance of what he termed "double-burial": the shifting of the deceased from a transitional, primary, 'wet' burial to a secondary, 'dry' burial (Hertz 1960b, 28). Hertz noted the importance of the physical transition and transformation of the bodily remains were imbued with social and psychological sentiments – the first 'phase' encapsulated mourning, loss, and grieving during bodily decomposition and putrefaction, while the second 'phase' facilitated the transition of the body into osseous remains which signified their passage into a new social identity and afterlife. Only when the body has fully skeletonized, thus purging itself putrefactive liquids, had the deceased transgressed the social-funerary threshold. Hertz was careful to highlight how the physical transformation of the body was imbued with social consequences and psychological responses on behalf of the living community (i.e., the mourners). As Metcalf and Huntington

(1991, 37) articulate it, Hertz's thesis was that "Close attention to the combined symbolic and sociological contexts of the corpse yields profound insights regarding the meaning of death and life." Hertz therefore showcased the protracted potential of death, and illustrated how decay itself was both temporal and imbued with symbolism.

At the same time as Hertz was deciphering funerary rites, Van Gennep was attempting to describe initiation rituals in his well-cited *Rites de Passage* (1909). Analyzing the Merina of Madagascar, in addition to numerous other examples, Van Gennep (1960) articulated rites of passage in a tripartite manner, whereby a person or group of persons underwent three distinct phases of initiation: pre-liminal rites, liminal rites, and post-liminal rites. The first phase, *pre-liminal rites* or *rites of separation*, is characterized by the departure, if not outright 'death,' from a previous social sphere. This is followed by the *liminal* or *rites of transition* phase, whereby the person experiences a transitional hiatus characterized by a 'threshold' between separation and reintegration. Finally, the person is re-incorporated into a new sphere of being in the final *post-liminal* or *rites of integration* phase. The prefix *limen* is Latin for 'threshold,' and was used by Van Gennep to analogically describe these phases as if one were moving through distinct rooms of a house. Like Hertz's 'double burial,' Van Gennep underscored the importance of the transitional nature of social rituals, and how such transition was predicated on unilateral movement, be it physical, metaphorical, social. Death brings about important transformations for both decedent(s) and mourners alike — their transitions through liminal sequences often mirror one another as the dead transition into new social roles just as mourners separate and reintegrate into society (Cerezo-Román 2015, 354; Williams 2004). His model, particularly his discussion of 'liminality', was later expanded upon by Turner (1967) to help further cement the tripartite framework. In the late 1960s, Peter Ucko (1969) famously tethered ethnographic archaeology with funerary treatment of the corpse, and cemented funerary archaeology as a sub-disciplinary approach (B. Beck 1995; L.A. Beck 1995; Chapman 1981; 1987; O'Shea 1984; Parker Pearson 2000).

The germinal doctoral research by Arthur Saxe (1970) sought to integrate ethnographic observations with archaeological analyses to generate a theoretical approach for mortuary analyses in the archaeological record. While Saxe generated eight working hypotheses centered around mortuary representation, the overall conception of mortuary practices being highly reflective of social complexity became a major tenet of mortuary archaeology, and was supported by subsequent writings by Binford (1971). Both Saxe and Binford drew on Goodenough's (1965) articulations of 'social identity' and 'social persona,' which sought to differentiate one's aspects of identity in social situations (*identity*) from the "composite of several activities selected as appropriate to a given interaction" (*persona*; Goodenough, 1965, p 7). Together, this approach ultimately emphasized that mortuary rites were *reflective* if not *indicative* of social identity, and became collectively known as the Saxe-Binford program or 'representationalist approach' (Tainter 1978; Brown 1981; 1995; Pader 1982).

By the 1980s as post-processual archaeology began to take shape, significant criticisms were leveled against the Saxe-Binford program (Goldstein 1976; Hodder 1980; 1982a; 1982b 1982c; Chapman 1981; Parker Pearson 1993). Crucially, the program had situated social organization as "the primary determinate of variation in mortuary practices and burial form" (Carr 1995, 106) and thus failed to underscore how the role of ritual, religion, and historical contingencies might also explain variation (Morris 1991; Carr 1995). This is in part, due to the representationalist viewpoint of the Saxe-Binford program, which heavily emphasized the role of class and social status as reflected in mortuary rites (Binford 1971; Peebles 1971; Saxe 1971;

Peebles et al. 1977). For instance, Binford (1971, 22) suggested that the quantity of grave goods is likely reflective of social status and hierarchies, but such a premise was based on ethnographic 'snapshots' and is not necessarily indicative of class in other contexts (Chapman 2013). Furthermore, the Saxe-Binford program treated mortuary contexts as static indices without acknowledging the changing, fluid, transformative, and protracted impacts that funerary rites could have (Fowler 2013).

In the wake of post-processual critiques of the Saxe-Binford program, came a shift in analyzing funerary rites through agency and practice-based approaches (Ritzer et al. 1994; Dobres et al. 2000). These approaches often borrowed heavily from social theorists like Giddens (1984), Bourdieu (1977), Gell (1998) and Foucault (1977; 1982) and sought to re-articulate mortuary practices in light of agency, practice, and structure. While these approaches did help to transcend some of the representationalist reductions in processual funerary archaeology, early agency theorists were often too focused on rationalized "interest theory" (Ortner 1984, 151) — framing people in terms of self-interested, overly pragmatic and rational actors with a tendency to maximize their behaviors for gain. 'Agents' were often conflated with individuals with 'structure' existing extra-somatically as institutions, which only helped to reify the Individualism : Holism divide (Gillespie 2001; Joyce et al. 2005). Dobres and Robb (2005, 162–163) underscore that part of this issue arises from the canonical treatment of theory, method, and methodology as "sequential" steps, whereas agency approaches are better understood as contextually and inductively derived "middle-range interpretive methodologies." In essence, they are braided and tethered rather than a chained operation.

Since the latter half of the 20th century, funerary archaeology has exploded. The human body often acts as a window into religious conceptions of corporeality, personhood, and spirituality (Coakley 1997; Law 1995). Religious funerary rites, and their ritualized practice in particular, offer a means to elucidate aspects of personhood, as the materiality of the deceased body is often imbued with "spiritual qualities" (Fowler 2011, 137). Concerns of personhood before, during, and after death are intimately tied with religious worldviews, and the ritualized acts of funerary treatment of the dead can illuminate embodied aspects of personhood across the lifecourse. Crucially, identity and personhood are conceptually distinct, as markers of identity do not always correspond so neatly to a sense of person (Fowler 2010). The early work of Maurice Bloch (Bloch 1971; 1989; Bloch et al. 1982) helped to situate death and funerary archaeology in respect to personhood. Archaeologists have since been keen to incorporate notions of personhood as interpretive framework in relation to funerary treatment (Barrett 2000; Gillespie 2001; Fowler 2004; Robb 2010; Cerezo-Román 2013; McClelland et al. 2016; Moutafi et al. 2016). Personhood is conceived not as a synonym for individual, but instead focuses on *relationships* that are enacted, forged, and practiced within a society (Ritzer et al. 1994; Gillespie 2001). Crucially, these relationships are nebulous and contextual, existing between people, persons and groups, persons and objects, persons and non-persons, living and dead, and countless other vectors of possibility. As such, personhood is not limited exclusively to living individuals, but can extend to non-human, non-living entities (Gillespie 2001). In analyzing exchange networks of the Māori, Mauss (1954, 10) famously demonstrated how the object in an exchange not only "pertains" to personhood, but that the act itself of giving was in essence a gifting of one's own personhood. Later scholarship underscored how personhood is contextually contingent, and codified in social arenas — that it is in essence a social construct (Fortes 1987). Thus non-living human beings, such as bodies and bones, can simultaneously be subjects of personhood and objects of manipulation by the living (Moutafi et al. 2016, 782), which helps transcend aforementioned dualisms often inherent in archaeological theory surrounding the dead (Sofaer 2006c, 31–61).

One of the key aspects of personhood is that biological death does not necessarily terminate life course (Fowler 2002; 2003; 2004; 2008; Fowler et al. 2014). Rather, a distinction between biological death and social death is often made, with the former corresponding to death of an individual organism, and the latter as often more protracted social transition (Bloch et al. 1982; Fowler 2004; Robb 2013). Tarlow (2011, 5) for example does well to highlight the materiality of the dead, as *more* than remnants of a biological organism. Indeed, personhood of corporeal remains can become embodied, extend beyond the body, or, become "alternatively bodied," especially in funerary contexts (Robb 2013, 455). Mortal remains can become entangled in varying transformations after death, ranging from objectification into a 'passive' aggregate of remains, to more 'active' states of being, either through living on through the remains themselves, or extending into socio-legal arenas (Crandall et al. 2014; Crandall 2014; Gramsch 2013; Sofaer 2006c). In analyzing personhood among the Classic Maya, Meskell and Joyce (2003, 142) eloquently demonstrate how decomposition and bodily decay following death did not detract from personhood, but rather fostered its transformation into new distributions of extended person in the form of ornamentation and costume. Thus bodily 'integrity' was not of tremendous concern as it enabled the partibility of the body into extensions of personhood through anatomical ornamentation and decoration.

Some of the recent developments in anthropological studies of personhood have focused on conceptions of 'dividual' personhood, or how what constitutes a person need not be tethered to an *in*dividual but rather across or between 'dividuals' (Busby 1997; Fowler 2004; 2008; Strathern 1988). Conklin's renowned ethnographic study of the Wari' in Western Brazil illustrated how personhood was dividually distributed through exchanges in bodily fluids and with the consumption of the recently deceased (Conklin 1993; Conklin et al. 1996). Cerezo-Román's work on cremated remains in Hohokam (2013) has demonstrated how conceptions of personhood likely changed from the Preclassic (A.D. 700-1150) to the Classic (A.D. 1150-1450/1500) period. Preclassic funerary rites utilized cremation, with scattering fragmented remains in a distributed spatial and social manner. The transformative role of fire played an important part in constructing notions of self, and "part-person, part -object." Later rites during the Classic period appeared to have been transferred in their entirety to secondary deposits, coinciding with changing notions of personhood as more 'bounded' than distributed. Cradic's thorough work (2017) in Bronze Age (200-1200 B.C.E) Levant has shown how personhood became embodied posthumously through funerary treatments, particularly in cases of residential burials. She carefully considers the newfound social dimensions and arenas that corporeal remains experience after death, and through synthesizing funerary taphonomic methodologies with social theory, is able to underscore how funerary treatment and engagement of bodies changes with relationships to the household. In numerous cases, remains were fragmented and re-arranged into new burial contexts, including comingling, which she posits may be indicative of transitional forms of personhood and achieving ancestor status. The burgeoning vocabulary to describe aspects of dividual personhood is already rich, focusing on aspects like 'partibility' (Busby 1997; Novak et al. 2016), 'permeability' (Busby 1997), and 'fractal' personhood (Fowler 2008). While notions of personhood can correspond to the material aspects of partibility, such are often complex and culturally contingent. As some scholars have cautioned, personhood is not a simple calculus of primary burial = individual and secondary burial = dividual (Chapman 2010, 30–31; Fowler 2004, 83–92; Moutafi et al. 2016, 781).

Often tied to of aspects personhood are discussions of social memory and remembrance, especially in relation to cemeteries. Kuijt's (2008) germinal analysis of early Neolithic Near Eastern settlements found that it only took 2-3 generations before ancestors could be forgotten. Secondary mortuary practices, such as removal of skeletal elements from a primary inhumation followed by their transportation elsewhere, form a literal and symbolic means of memorialization. In the case of *Çatalhöyük,* Boz and Hager (Boz et al. 2013, 433) suggest that if sufficient time has passed to where remains become skeletonized, secondary mortuary engagements may become more readily practiced. Crucially, memory cuts both ways. Even if the living community 'forgets' the dead, or at the least does not engage with them, death may not inherently sever social ties with the living. As seen below, Maliki jurisprudence seems to have advocated for shallow burial dimensions, in part in order to hear the call to prayer from the *muezzin* (Insoll 1999) as well as the funerary prayers from the living cemetery goers (Fortier 1997; 2010; Ghazâlî 1974). In the case of medieval Abrahamic religious funerary rites, eschatology is thus paramount to preserving an ontological and contextually contingent approach to understanding the ongoing relationships between the living and the dead.

Ritual is arguably one of the most utilized archaeological terms, and it's tethering to religious and numinous actions is often not far behind. Hawkes's famed "ladder of influence" served as a cautious warning for archaeologists that their findings simply could not elucidate ritual, belief, or ontology due to their 'high' positioning on the ladder. In effect, they required too much of an inferential leap for Hawkes, a sentiment adopted by archaeologists for decades that followed (Nilsson Stutz 2016, 16). Yet a reappreciation for the ritualized elements of burials and cemeteries was seen in archaeology with the post-processual movements, and in the social sciences more broadly with the 'spatial turn.' Here, ritual is defined following Livarda and Madgwick (2018:1) as "the materialization of a form of group values, which result from a series of negotiations that bridge potentially conflicting interests and new realities, and can be experienced and interpreted differently by each participating agent." While ritual need not always be religious (Joyce 2011), in many cases they are closely linked, and in the present study, ritual is considered in a religious framework. Bell's (2009, 138) well cited trait list outlines various dimensions of ritual, and its role within larger religious practice: 1) formalism, 2) traditionalism, 3) invariance, 4) rule governance, 5) sacral symbolism, and 6) performance. Borrowing from a practice-based approach, Bell's (1992) articulation of "ritualization" helped to reframe rituals in terms of behavior and accumulative processes and actions (Joyce 2011, 181). Bradley (2003, 5) for example warned of the overreliance on ritual: "Archaeologists discuss the lives of the dead in a language that is dying too…One of those words is 'ritual.'" A similar stance is echoed by Joyce who cautions that "Not all repetitive stereotyped activities should be understood as ritual, and not all apparently ritualized actions are linked with belief in the way that seems distinctive of religious rituals" (2011, 181). Both Bradley (2003) and Joyce (Joyce 2011; Joyce et al. 2010) discuss ritual and religion in relation to the concept of "structured deposition", stemming from Richards and Thomas (1984) who sought to identify assemblages that seem to have been created 'intentionally' or 'deliberately.' While the presence of a single buried item may not evoke ritualistic behavior, repetitive deposition of similar items over a period of time may accommodate the criteria of being deposited in a structured manner, and therefore ritualization. Burials are often imbued with rituals and beliefs, especially in the middle ages, as Gilchrist and Sloane (2005, 13) eloquently articulate:

> "In contrast with approaches that define graves as static, self-contained archaeological features, we view the grave as the physical residue of a chain of social events, in which material culture is active in commemorating an individual and his/her place within the community. We emphasise the themes of the body and of the landscape in our analysis of individual interments and the creation of cemeteries as landscapes of remembrance."

This harkens to Ricoeur's (2004) insights on the act of sepulcher, which articulated death and the resting place of mortal remains as more than just a space, but also an ongoing process. He states (Ricoeur 2004, 366):

> Sepulcher, indeed is not only a place set apart in our cities, the place we call a cemetery and in which we depose the remains of the living who return to dust. It is an act, the act of burying. This gesture is not punctual; it is not limited to the moment the burial. The sepulcher remains because the gesture of burying remains; its path is the very path of mourning that transforms the physical absence of the lost object into an inner presence. The sepulcher as the material place thus becomes the enduring mark of mourning, the memory-aid of the act of sepulcher.

The enduring act thus serves not only as a means of memorialization and negotiating the living's relationship with the deceased, but is also materialized – it *becomes* and continues to *be* simultaneously an act and place. In outlining his theory of landscape temporalities, social anthropologist Timothy Ingold (1993) coined the term "taskscape" to refer to the socio-temporal construction of spaces. He states, "Just as the landscape is an array of related features, so – by analogy – the taskscape is an array of related activities" which reflects the "entire ensemble of tasks, in their mutual interlocking." (Ingold 1993, 158). Ingold defines tasks as "any practical operation, carried out by a skilled agent in an environment, as part of his or her normal business of life" (Ingold 1993, 158). Through broad, Ingold intentionally defines tasks as such in attempts to blur the boundaries on what constitutes passive place and active space. Taskscapes, just like landscapes Ingold argues, are never fixed, passive, nor immutable but always in a perpetual state of active flux and becoming. Thus, cemeteries, burials, and all manner of spatial locales for the dead are in effect acts of sepulcher and taskscapes — they are both reflective of events that have happened and those that continue to happen, playing out and materializing on the landscape.

One thoroughfare into ritual and ritualization and deathways, therefore, is through centering burials and cemeteries in terms of place and space. Social sciences and humanities experienced a 'spatial turn' in the 20th century, a process which started in the 19th century but crystalized with the introduction of quantitative methodologies such as geographic information systems (GIS). Such systems helped to make mapping and cartography more accessible, and in turn frame quantitative methodologies in social geography and a tethering of social meaning-making with space and place (Warf et al. 2008; Withers 2009). Francaviglia (1971) was an early proponent of framing cemeteries as 'culturally constructed landscapes', an example of the social turn's emphasis on place, space, and meaning-making. Daniell's (1997) approach synthesized historical and archaeological evidence on medieval British burials to underscore how medieval cemeteries could be conceived as landscapes. Appadurai's (1996) articulation of various '-

scapes' (e.g., "technoscape") helped to linguistically articulate the spatial aspects of other socio-economic phenomena. This permitted various Australian social geographers such as Kong (1999) and others (Hartig et al. 1998) in analyzing cemeteries and road-side memorials to formally coin "deathscapes" (Maddrell et al. 2010). As Maddrell and Sidaway define it, deathscapes refer to "both the places associated with death and for the dead, and how these are imbued with meanings and associations" (2010, 4). According to Muzaini (2017), "necrogeography," the formal study of deathscapes, often contains four principal threads: 1) how places become linked with death, dying, and end-of-life processes, 2) the design and maintenance of deathscapes (e.g., cemeteries), as well as the logic behind them, 3) the meaning-making (and in some cases, the co-option of meaning) in relation to deathscapes, and 4) representation of deathscapes, such as in art or media. Such axes provide bioarchaeologists an opportunity to examine the systematic and "structured deposition" (Richards et al. 1984) of burials in a more comprehensive, informed manner. Although the formalization of "deathscapes" is still young, it has begun to see a burgeoning appreciation in funerary archaeology, thanatology, and bioarchaeology (Gilchrist 2022). This is especially the case in terms of religion, as deathscapes such as cemeteries are often imbued with logics, rationales, and meanings in religious funerary rites. As such, careful attention to deathscapes and their religious underpinnings can help elucidate the material dimensions (such as burials, cemeteries, headstones, etc.) of eschatology.

Despite a rich history of anthropological engagement with religion and ritual, bioarchaeology has been comparatively slow to engage with religion more systematically. To date (2022), there is only one volume that explicitly links bioarchaeology with religion in its title: *The Bioarchaeology of Ritual and Religion* (Livarda & Madgwick 2018). While this is by no means the only scholarship that focuses on bioarchaeology and religion (Inskip 2013b; Zakrzewski 2011; 2015), it is one of the more explicit engagements, despite the fact that bioarchaeology is utilized in the more European sense to encompass any biological remains, rather than the Americanist tradition of referring specifically to human skeletal remains. And yet, Americanist formulations of bioarchaeology have much to learn from more general extensions of archaeological approaches to biotic organisms, as communities of the past certainly did not extend ritual and religion solely to humans. Morris (Morris 2011; 2012) for example focuses on the processes that *pre*-date deposition of animal burials, not just the final deposition. As stated above, both Hertz (1960b) and Van Gennep (1960) emphasized the importance of the transitional, kinetic role of funerary rites – focusing exclusively on the 'second burial' or 'post-liminal' phase is likely to omit the social and physical importance of the prior phases.

In addition to the comparative dearth of bioarchaeological approaches to religious and ritual contexts, funerary archaeology in medieval Iberia has experienced relatively little appreciation until recently. Livarda and Madgwick (2018, 3) lament that bioarchaeological approaches and data-sets are often employed only in the absence of other material data. This is surprising given the wealth of information that biological remains and taphonomy in particular can yield in regards to religion and ritual (Madgwick 2008; 2010; 2016; Madgwick et al. 2015; Morris 2011; Magnell 2012; 2013). This dearth of bioarchaeological approaches to religion was driven in large part by the general absence of funerary grave goods associated with medieval Islamic and Christian burials (Cressier et al. 2020), something that has been noted in other medieval contexts as well (Scott 2011). In these cases, funerary archaeology was not widely adopted, as the grave goods that came to define much of funerary archaeology in previous decades were notably absent. Only since the latter portion of the 20th century do we see a burgeoning of scholarship dedicated to characterizing and understanding tomb structures, bodily positions, and the osteological remains themselves as body of worthwhile inquiry. However, the recent development of funerary taphonomy (Knüsel et al. 2016) has helped harness a framework for bridging the burier/buried divide, and integrating bioarchaeological and osteological analyses with funerary archaeology. Effectively, it offers a unique means of assessing both the lifeways and deathways of past communities.

Funerary Taphonomy: An Integrated Approach to Lifeways and Deathways

Origins

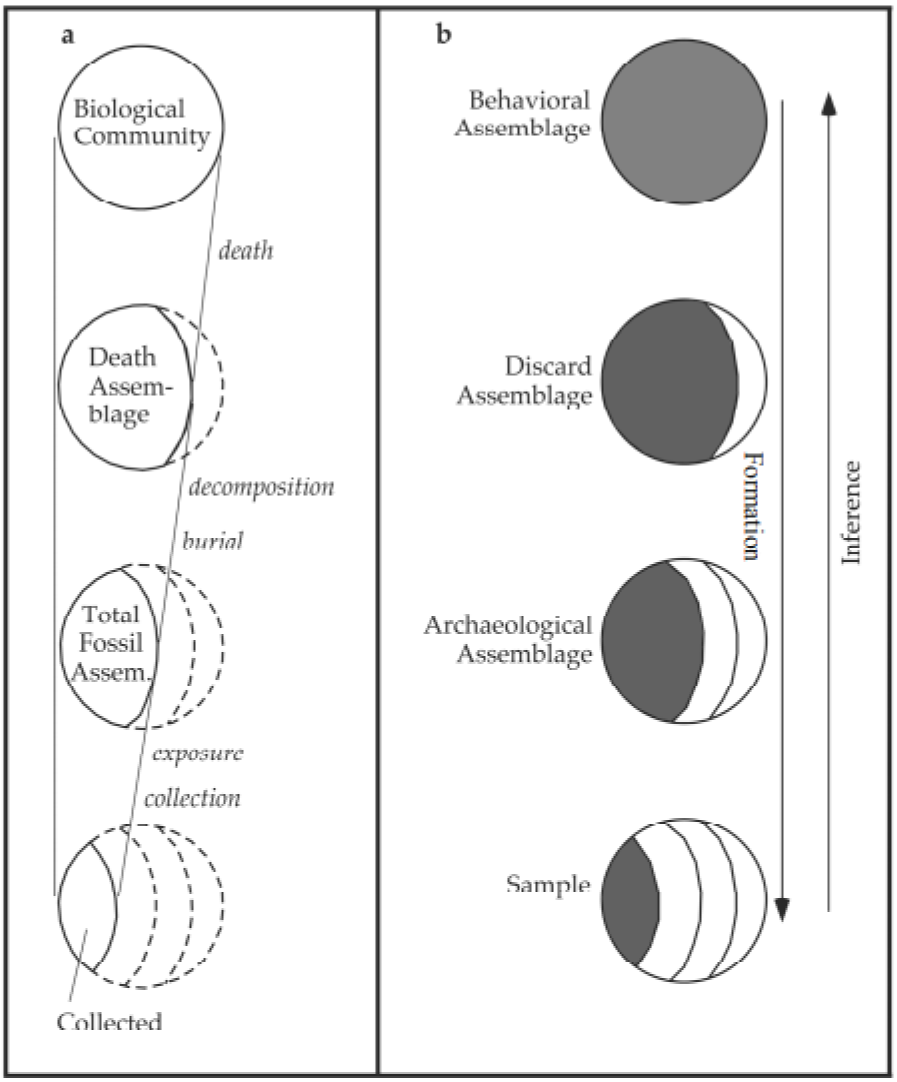
Taphonomy concerns the processes by which animal and plant remains undergo in their transition into an assemblage. The term was originally coined by paleontologist Ivan A. Efremov in 1940 (1940:85) as "the study of the transition of animal remains from the biosphere to the lithosphere," etymologically deriving from Greek *taphos* — meaning burial — and *nomos* — meaning laws (Cadée 1991). Taphonomy was so coined by Efremov in an attempt to conjoin "biostratinomy" — the stage between an organism's death and final burial — and "diagenesis" — the stage corresponding to post-burial processes that affect an organism's remains (R. Lyman 2010, 3). Early taphonomic frameworks sought to temporally and sequentially distinguish between death events ("necrology"), and subsequent phases that would ultimately lead to an organism's degradation or fossilization.

It wasn't until the end of the 20th century that taphonomy became more popularized in anthropology, thanks to the pioneering work of Behrensmeyer (1978), as well as Hill (1976), who alongside others (Shipman et al. 1976; 1977) were grappling with how to distinguish early hominin behavioral modification of materials (e.g. animal bone) from ecological factors, such as weathering. It was also Behrensmeyer and Kidwell (1985, 105) who brought taphonomy fully into the fold of anthropology, as well as eloquently introduce "preservation" into taphonomic vocabulary. While taphonomy's foray into anthropology was through hominin paleoanthropology and paleoecology, as we shall soon explore below, it developed in parallel to archaeological concerns over site formation processes. Archaeologists in the later 20th century attempted to reconcile just how well archaeological materials truly represented and reflected the communities they once harkened from (Ascher 1968; Binford 1981a; Schiffer 1985a). The thorny issue was apparent: how much distortion and alteration had taken place between the deposition of artifacts and discovery and excavation by archaeologists (Schiffer 1983)? Taphonomy, and its focus on the incorporation of both pre-burial (biostratinomy) and post-burial (diagenesis) processes, offered a parallel theoretical foundation for archaeologists to similarly address the bias and sub-sampling that occurred in archaeological assemblages (Figure 2.1).

Notably, early views of taphonomy characterized taphonomic processes as the progressive loss or *removal* of biotic material and information and failed to recognize the *additive* information that could also be gleaned, such as gnaw-marks, cracking, and weathering. The employment of taphonomy in this manner is in many respects similar to the 'entropic' view of progressive archaeological fragmentation popular in archaeology in the latter half of the 20th century (Schiffer 1983). This view held close adage to Ascher's (1968) famously conceived "time's arrow" which suggested that the archaeological record experienced successive 'decays' in both quality and quantity over time. Taphonomy, or at least, archaeological conceptions of it and its accompanying 'degradation', are thus heavily intertwined with estimable chronologies and temporalities. Datable materials, whether using absolute dating or relative dating, are susceptible to diagenesis and preservation biases. Absolute dating techniques such as ^{14}C require adequate preservation of organic materials, which are subject to diagenetic alterations as well as contamination through curation and preservation efforts (Bronk Ramsey 2008; Margariti et al 2023). Conversely, materials that may be chronologically meaningful (e.g., a textile produced in a historically-known period) could also aid in relative dating based on *terminus post-quem*/*ante-quem* estimation and seriation, but are similarly subject to preservation biases. Thus whether organic materials 1) preserve at all, or 2) preserve enough organic content to yield absolute methods greatly influence archaeological potential to characterize chronologies in the past. The resolution of chronology is highly mediated by taphonomic filters and processes, furthering the need to center taphonomic study as a variable in nearly all archaeological endeavors.

Crucially, a hallmark of later taphonomy studies was the acknowledgement that taphonomic processes are not unidirectional in loss of information, but are also *additive* (R. Lyman 2010; Ringrose 1993). Indeed, just as vertebrate paleontologists helped to resituate taphonomy as not a solely degradative process (Behrensmeyer 1978; Olsen 1980; Behrensmeyer et al. 2000), processual archaeologists similarly argued against the progressively reductionist view held by entropic proponents (Binford 1978; Sullivan 1978; Wood et al. 1978; Wilk et al. 1979; Schiffer 1983).

Figure 2.1 - Progressive loss of information/specimen in paleontology (a) and archaeology (b). The directional loss of information depicted as the down-ward arrow in (b) is in many senses reminiscent of Ascher's (1968) entropic "time's arrow." (retrieved from Lyman 2010, 7)



Archaeological Adoption: Problems and Potential

Issues remain in the both the definition and subsequent framing of taphonomic research across differing disciplines (for a review see Lyman, 2010). Lyman (2010) and others (Bristow et al. 2011, 279) have noted how other disciplines outside of paleontology, and archaeologists in particular, have "coopted" the original definition of taphonomy for their own disciplinary uses. Since Efremov's (1940) original coinage and its adoption by other disciplines such as archaeology and forensic anthropology, taphonomy has been expanded in two major ways. The first is the archaeological expansion of taphonomy beyond the biosphere to include non-living organisms (i.e., artifacts). While taphonomy proffers an easily palatable parallel for archaeologists, such expansion has not come without criticism (Lyman 2010). Second, taphonomy has become more generalized to include consideration for all manner of site-formation processes, and has been temporally expanded beyond the interval between death and discovery to include pre-burial factors. The archaeological adoption of taphonomy to include archaeological remains suddenly brings culture within the realm of what was once a paleoanthropological and ecological discipline. As such, it partially explains the philosophical debate within archaeology concerning taphonomy's involvement within the nature/culture 'divide.'

The philosophical dimensions of this disagreement harken to long-standing if not entrenched views within archaeology. Since at least the 19th century, archaeologists have acknowledged that "Only a small part of what once existed was buried in the ground; only a part of what was buried has escaped the destroying hand of time" (Montelius 1888, 5). Such concerns became the focus of archaeological debate nearly a century later in the 1960s, which brought about important theoretical discussions centering on just how representative are archaeological assemblages. Ascher questioned whether archaeological assemblages really were "…the remains of a once living community stopped, as it were, at a point in time" (Ascher 1961, 324), rather than mere distortions. Binford suggested that archaeological assemblages were a "'fossil' record" of past societies (1964, 425), while Schiffer retorted that such objects "…have been subjected to a series of cultural and noncultural processes which have transformed them spatially, quantitatively, formally and relationally" (Schiffer 1976, 11). This initial exchange helped to spark significant debate surrounding what would be termed 'site formation processes,' or the processes that affect the potential material universe into the observed archaeological sample (Binford 1978; 1981a; Sullivan 1978; Wood et al. 1978; Schiffer 1983; 1985a). This debate reached its zenith with the "Pompeii Premise" (Binford 1981a; Schiffer 1985a), where Schiffer posited that modifications by both non-natural entities (C-transforms) and natural ones (N-transforms) ultimately distort the archaeological record, where Binford suggests that such distortions *are* the archaeological record, and that anything else could only be likened to rapid-deposition of Pompeii, or as Newell likened it to a "neutron bomb notion" (Newell 1987, 136). Since Schiffer's initial retort, archaeologists have heuristically attempted to separate cultural transformations (or C-transforms) from natural ones (or N-transforms) (Schiffer 1983; 1985a; 1988). In a similar vein, it is common practice for archaeologists to articulate taphonomy as the "non-cultural formation process concepts" (i.e. N-transforms) (e.g. White, 1979; Whitlam, 1982; Dibble et al., 1997). Even when taphonomy has been expanded to include cultural (i.e. C-transforms) and other non-natural formation processes, archaeologists have tended to still view taphonomy with in a distortive, entropic framework. As Lyman (2010, 11) aptly stated:

> "this conception of taphonomy is discipline-centric because human behaviors are the major subject of interest to archaeologists whereas anything that might obscure or destroy indications of human behavior must be taphonomic because taphonomic processes are (mis)conceived as biasing."

In this sense, archaeologists have tended to treat taphonomy as a methodological approach to addressing perceived bias in the archaeological record by heuristically maintaining a separation of cultural transforms from natural ones. Though, there have been exceptions. Kluskens (1995, 241) stated that taphonomy should "include cultural remains as well as animal remains." Johnson

(1999, 56) posits taphonomy is the study of how the archaeological record is created from ‘cultural’ and ‘natural’ behavior”, whereas Rapp and Hill (1998, 50) attempt to underscore the “usefulness of a parallel taphonomic approach” to be applied to archaeological remains and not simply animal remains. Kadrow was keen to suggest “The relationship between natural and cultural depositional processes is very often so close, that they should be analyzed in the light of their reciprocal association” (1998, 296). Noe-Nygaard (1987) was particularly keen to point out how zooarchaeological remains, specifically fish and terrestrial mammals such as deer, were ‘biased’ by human fishing, hunting, and food preparation techniques. Not only do they problematize how assemblages come to be, but also underscore how various cultures and their food preparation techniques differentially affect skeletal preservation and integrity. Atici’s articulation of “taphonomic filters” helps to transcend the heuristic nature/culture distinction, as it includes:

> “a combination of complex, interacting factors *including human activities*, nonhuman animal ravaging, and diagenetic processes. These taphonomic filters do not necessarily operate simultaneously and may affect an assemblage differentially, increasing the preservation potential of some bones while destroying others”

(2014, p. 214; emphasis mine). Atici’s position as a zooarchaeologist helps her to avoid a Natural vs. Cultural dialectic, as she is careful to recognize the impact human engagement with faunal remains has on the overall preservation, presence, and distribution of zooarchaeological remains. Indeed, she articulates humans as “a sort of extrinsic biogenic bone-accumulating agent or…predator,” which certainly has an impact on structuring faunal assemblages (Atici 2014, 216). These synthetic approaches; however, have been the exception rather than the rule. Lyman aptly notes: “To escape this ontological morass, archaeologists must recognize that taphonomy concerns both natural *and* cultural processes and agents that influence the biotic record.” (Lyman, 2010, p. 12; emphasis mine).

Taphonomy and Human Remains: Challenges and Solutions

The difficulty here arises with what materials are considered appropriate for taphonomic analysis. Lyman (2010, 4) suggests one major error in the adoption of taphonomy for archaeologists is the over-reliance on inference in assessing taphonomic impacts on artifacts compared to biological organisms. In essence, paleobiologists don't have to 'infer' as much since they have an anatomical reference (i.e., the skeleton, or whole body) to work with, whereas archaeologists have to 'infer' more since they don't have a true reference for the artifacts they find. Indeed, Lyman strictly adheres to the ‘biotic record’ in the above passage, and such an appeal to an anatomical basis of taphonomy adheres strictly to the paleontological origins of taphonomy. Which begs the question: what about human remains? Human skeletal remains accommodate Lyman’s criteria for an anatomical basis and reference point — after all, we know what a ‘normal’, complete skeleton ought to look like, and can assess taphonomic impacts (e.g. weathering, fragmentation, missing elements) from that baseline. But at the same time, human remains (and given the agentive power of non-human entities and materials, many other artifactual remains) are not merely biotic organisms nor exclusively occupy the biosphere — they are inextricably linked and imbued with social and cultural values, meanings, and treatments after death. Were they not, neither biocultural approaches nor funerary archaeologists would exist. Schiffer's (1972) own flow model for how artifacts transition from their "systematic context," or use within the society that utilized them, and "archaeological context," the ways in which archaeologists discover them, offers a theoretical alternative to taphonomy, but explicitly considers abiotic artifacts. While 'refuse' can certainly be considered the final transitional stage from systematic to archaeological context for many artifacts, human remains, and many other materials for that matter, are not often casually discarded — they are often *intentionally* disposed of in a deliberate and cultural manner.

While some archaeologists have since made strides in conservatively incorporating taphonomy into archaeological research without coopting it into an entirely new term, anthropologists working with human skeletal remains have lagged comparatively. Forensic anthropologists have undoubtedly embraced taphonomy as a crucial aspect of their work (Haglund et al. 1997; Haglund et al. 2002; Haglund et al. 1997; Tibbett et al. 2009), so much so that Dirkmaat *et al* (2008, 34) considered it "the most significant development [to] alter the field of forensic anthropology." Considering the importance of establishing rigorous scientific methods for understanding how taphonomy may aid or complicate proper identification of a decedent, and how such standards become evaluated in a medico-legal context, it's not surprising that forensic anthropologists have embraced taphonomy head on (Bristow et al. 2011).

And yet, there are still philosophical disagreements surrounding the nature of taphonomic analysis concerning human remains in bioarchaeological contexts. Consider the following: should taphonomy be concerned with the discernment of whether processes that affect human remains are natural *or* cultural, or is the heuristic opposition of 'natural' and 'cultural' phenomena ultimately misleading (see Knüsel and Robb, 2016, p 656 for further discussion)? Such debates harken, once again, to archaeology's difficulty in grappling with cultural and 'non'-cultural factors that affect the materials they study. Notably, some early proponents called for an integrated model of both biological and cultural effects on human taphonomy (Boddington 1987; Boddington et al. 1987; Bonnichsen et al. 1987; Duday et al. 1987; Roksandic 2002a), but occasionally framing 'non-cultural' factors in a distortive framework. Roksandic highlights the importance of integrating cultural attitudes in its relation to human taphonomy as a means of understanding mortuary behaviors, but ultimately suggests that "noncultural taphonomic factors are important in determining disturbance (bias)…in order to eliminate their effect and the possible misinterpretations they can cause" (2002a, 101). Lyman's laments echo once again as the biocultural dimensions of funerary taphonomy are cleaved as soon as they are conjoined. Thus much like their archaeological predecessors, physical anthropologists working with human skeletal remains recovered from archaeological sites have typically treated post-depositional influences as "interference rather than as information" and prioritized (relatively) complete human skeletons (Knüsel et al. 2016, 655).

If human agency is likely to impact many faunal assemblages, as zooarchaeologists have clearly demonstrated, then certainly funerary gestures and rites have taphonomic consequences for human remains as well. The integration of mortuary archaeology with attention to taphonomic filters has been termed "funerary taphonomy" (Knüsel et al. 2016). This approach helps to dialectically synthesize bioarchaeological and funerary methodologies, transcending the aforementioned historical divides between archaeology, paleontology, taphonomy and physical anthropology/osteology, and forms the basis of this study. As a wealth of vibrant bioarchaeological and archaeological research has shown, human remains are more than mere relics of biological organisms, but additionally forms of material culture (e.g. Sofaer, 2006) that can be manipulated, transformed, and politicized post-mortem (Verdery 2000; Crossland 2009;

Pérez 2012; Young et al. 2013; Crandall et al. 2014; Crandall 2014; Nystrom 2014; Tung 2014; Novak et al. 2016). In a funerary taphonomic framework, such cultural and societal engagements with mortal remains undoubtedly have consequences on the body's preservation and taphonomic trajectory. As Bello and Andrews keenly note, "Particular funerary practices may result in the unequal representation of specific anatomical elements or entire skeletons" (2006, 7–8). An attention to funerary rites as a "taphonomic filter" not only helps to transcend the archaeological cleavage of Cultural vs. Natural transforms, but helps to facilitate an archaeology of death and dying (Robb 2013), and understand how the ontological engagement with death and dying is likely to impact the very remains recovered by (bio)archaeologists.

Similar to their paleontological colleagues, bioarchaeologists employing a funerary taphonomic framework have noted the importance of highlighting the funerary sequence: a temporal reconstruction of 1) pre-interment (pre-burial rites such as washing, embalming), 2) interment (the physical deposition of the body in the earth), and 3) post-interment (disturbance, bioturbation, etc.) practices (Andrews et al. 2006; Bello et al. 2006; Cradic 2017, 30; Duday et al. 2006; Nilsson 1998, 6). Not unlike biostratinomy and diagenesis for paleontologists, Forbes (2008, 226) distinguishes between the 'post-mortem interval' as the period of time shortly before, during, or after death and generally corresponding with funerary rituals and rites, and the 'post-burial interval' which encompasses an often more protracted temporal occurrences after interment until discovery or excavation. Indeed, one may consider how the post-death, pre-burial 'biostratinomy' of paleontology might proffer a 'bio(cultural)stratinomy' for bioarchaeologists, as cultural funerary customs undoubtedly influence the deposition of human remains, and thus affect their taphonomic trajectory. Attention to both the funerary rites that accompany death ("necrology"), and subsequent time before ("biostratinomy") and after interment ("diagenesis"), is thus paramount to understanding taphonomic histories in human skeletal remains.

While this section has covered the theoretical origins and basis for conceptualizing taphonomy in relation to human skeletal remains, the next section will focus on the bridging methodology of funerary taphonomy: principally, archeothanatology and assessments of preservation.

Archeothanatology

While Kellehear (2007) helped to provide the theoretical basic for mobilizing an archaeology of death, the methodology can be traced to the 1980s with Duday's seminal *anthropologie "de terrain"* or archaeothanatology (Duday et al. 1990; 2006; Duday 2009). Duday sought to refine field methodologies for recording and observing the relationships between gravity, human anatomy, decomposition, skeletonization, and the burial microenvironment. Human decomposition is canonically described in three processes: autolysis, putrefaction, and decay. Autolysis begins when the heart ceases and various aerobic microorganisms within the body begin depleting oxygen within tissues (Carter et al. 2008) and cell death (Gill-King 1997a). Crucially, autolysis begins within minutes of death (Vass et al. 2002). Human cadavers constitute dense loci of microbial communities (Clark et al. 1997; Hill 1995; Noble 1982; Wilson 2005), water (often between 60-80%,) as well as fat and protein concentrations (Swift et al. 1979; Tortora et al. 2000). Human decomposition is affected by numerous factors, ranging from aridity (Galloway 1997; Galloway et al. 1989), to soils (Carter et al. 2008), bone density (Galloway et al. 1997), insects and other soil organisms (Anderson et al. 2002; Hopkins 2008; Voss et al. 2011a), and clothing (Janaway 2002), to name only a few. Thus decomposition is a point of convergence of many different factors operating simultaneously

(Duday et al. 2006; Ferreira 2012; Haglund et al. 1997; Manhein 1997; Mann et al. 1990; Pinheiro 2006a; Pinheiro et al. 2006; Vass 2001). Ferreira aptly suggests that each body should be treated as a unique "micro-ecosystem" (Ferreira 2012, 143). In the event of a human cadaver decomposing *in situ* without major post-depositional disturbance (e.g. movement by scavengers), cadaveric material interacts with soil horizons to create gravesoils (Carter et al. 2007). Gravesoils are the product of localized soil-bodily reactions, which fundamentally alter both the biological and chemical profile of burial soils. Despite its prominent use in forensic contexts, the term of cadaver decomposition island (CDI) is employed to showcase just how localized decomposition and burial environments are (Carter et al. 2008; Carter et al. 2007).

Archaeothanatology emphasizes knowledge of the decomposition process and encourages careful attention to anatomical connections, termed "first rate links" (Duday et al. 2006, 152), particularly joint articulations, as they are indicative of decay and post-mortem movements. For instance, a comprehensive understanding of which joints are *persistent*, such as the lumbar vertebrae and long bone articulations, versus *labile*, such as the cervical vertebrae and hands, is critical in field recordings and reconstructing decay processes (Table 2.1). Counterintuitively, persistent joints, though easiest to record due to their often direct articulation *in situ* (e.g. humero-ulnar articulation), are less informative than their labile counterparts, which can reveal much more about decay and movement (Duday et al. 2006, 127). Attention to joint articulations is crucial in reconstructing interment processes – termed "necrodynamics" – (Ortiz et al. 2013; Wilhelmson et al. 2015) and further helps to demonstrate that the disarticulation of human remains does not necessarily preclude a secondary burial treatment, such as a primary burial upon an organic material platform that is also subject to decay. Careful attention to these joints can also help to detail whether the body was buried surrounded in earth or within empty space, such as a coffin or architectural feature, even when the feature no longer exists. For instance, in extended supine burials within empty space such as a coffin, the pelvis flattens with decomposition, with pubic symphyses dis-articulating resulting in the lateral rotation of the femora, and the external deposition of the patellae. In burials where the individual is on their side, bones that are not on the floor of the grave such as the scapula or os coxae often fall posteriorly. Patellae, os coxae, scapulae, and other labile joints found in direct articulation with interstitial sediment often suggests lack of empty space, or the progressive filling of sediment that replaces voids created by decomposition. Thus, the positioning of the patellae and scapulae/os coxae are crucial indicators of whether burials were surrounded with earthen fill, or contained empty space (Duday et al. 2006).

Table 2.1 - Types of burial spaces and their associated soil and skeletal characteristics (adapted from Harris and Tayles 2012, 231).

Space	Description	Skeletal observation
No space	No observable space, whereby the body was interred in an earthen inhumation and was in direct contact with dry or fine-grained soils that filled body cavities during decomposition (*progressive infilling*).	Hyoid in articulation, no flattening of thoracic cage or pelvis. Minimal to no-movements observed.
Internal	Space created within the original confines of the body (i.e. skin), whereby soils were not able to immediately fill voids (*differential filling*). This could be due to either a burial container's provision of a boundary or wet/non-porous soils.	Collapsing of thoracic cage, dislocation of the sternum, vertebral torsion, splaying of pelvis/pubic symphysis, and/or fall of elements (e.g. hands) into pelvic cavity. Patellae are typically still in articulation.
External	Space beyond the confines of the body, often delineated by architectural elements (e.g. coffins) that experienced delayed infilling of soils.	Evidence of internal space in addition to falling of skeletal elements outside of bodily confines. Lateral fall of patellae, flattening of pelvis, lateral rotation of femora (supine), and dorsal fall of scapula/os coxa (lateral)
Secondary external	Space that is formed outside the confines of the body but as a product of bodily decomposition interacting with burial microenvironment, such as the buildup of gases, liquefaction, and turbation.	Skeletal elements have fallen outside of confines of body, but no other evidence of empty/external space.

The shape, dimensions, and positioning of burial containers also carry taphonomic impacts. Burial depth has tremendous influences on decomposition and biodiversity (Rodriguez et al. 1985), with shallower graves experiencing generally more rapid decay (Janssen 1984; Garland et al. 1987; Micozzi 1991; Janaway 1997). Narrow interment containers and tight shrouding can result in "transversal compression," particularly in supine burials (H. Duday et al. 2006, 144). This can be seen in the 'shrugging' of the shoulders, so that the lateral aspects of the clavicles are often raised antero-superiorly, and the medial aspects descend disto-inferiorly. The manubrium often 'falls' with the rib cage and the humeri rotate so that the medial epicondyles face distally and the lateral epicondyles face anteriorly. However, the placement of the hands are also crucial, as the superior placement of hands across the chest can also result in the proximal movement of the humerii (Harris et al. 2012, 232). The os coxae are usually close to their position in life, regardless of empty space or fill given the narrow environment and prevention of the os coxae falling laterally. Finally, the floor of the grave is also crucial in demarcating the potential narrow limits.

Challenges of Archaeothanatology

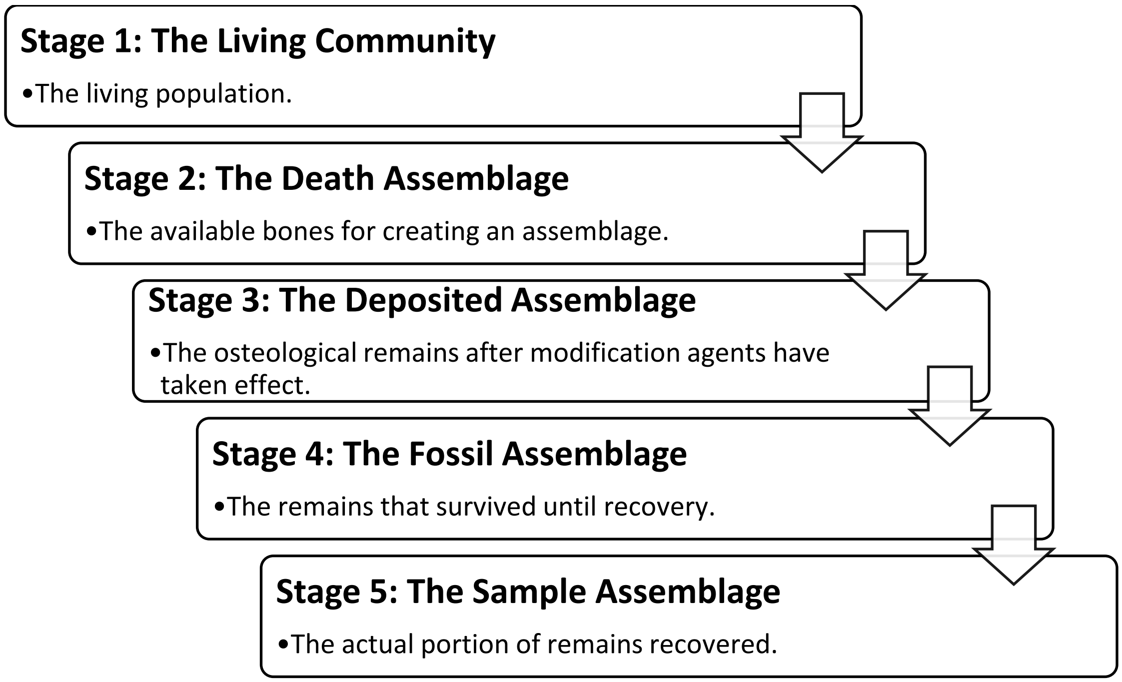
Given its detail-oriented approach to human decomposition, it is not surprising that archaeothanatology was developed as a methodological means of distinguishing natural factors from cultural ones. Duday states that archaeothanatology is concerned with the "interaction between funerary practices and the distorting influences of taphonomic factors precipitated by the initial construction of the grave" (2006, 33). He goes on to underscore the aim of differentiating between "taphonomic effects that occur during the decomposition of the corpse and through the intervention of natural agents (erosion, water action, compaction, physio-chemical alteration, the action of micro-organisms and burrowing animals)" (2006, 33) from funerary treatment of the corpse. Much like Schiffer (1972; 1983) attempting to distinguish the distortive N-transforms from the desirable C-transforms, archaeothanatology was developed as a means of stripping away natural factors that 'distort' the body as observed by bioarchaeologists, to get at intentional, social ones that put the body there in the first place. Once again, taphonomy finds itself in a seemingly endless nature vs. culture debate.

Additionally, while archaeothanatology has provided a detailed field methodology for approaching death and mortuary treatment, it is often concerned with single, primary inhumations. Given that multiple bodies are often found within the same funerary space (Bloch 1971; Chambon 2003; Chapman 1981; Parker Pearson 2000; Weiss-Krejci 2004), Duday and colleagues have been careful to note that the "first rate links" and reconstruction of joint articulations is difficult in heavily comingled or dislocated contexts, often requiring careful steps to try and re-associate articulations in sequential steps termed "second rate links" (Duday et al. 2006, 153). This only gets more complicated with increasingly friable and fragmented assemblages. As James Anderson (1964, 29) eloquently stated: "one deals not with populations of people, but with populations of humeri, femora, temporal bones, and so on." Finally, archaeothanatology is incredibly time-consuming and costly, as it often requires specialized expertise, training, extended excavation timelines or large workforce, especially in larger cemetery contexts.

Preservation and Demography

Regardless of where one stands in relation to taphonomy's theoretical dimensions, its relationship to demography of past communities cannot be overlooked. The number of skeletons recovered from archaeological sites are impacted by a myriad of both external and intrinsic factors, from burial depth (Lewis 2006, 28), to pathology (Brickley et al. 2010, 13), and even excavator's prowess (Mays 1998b, 15) to name only a few. Zooarchaeologists and paleozoologists have long grappled with these issues. Ringrose (1993), building on Clarke and Kietzke (1967), Meadow (1980), and Klein and Cruz-Uribe (1984), outlined the successive stages by which taphonomic filters alter recovered faunal remains:

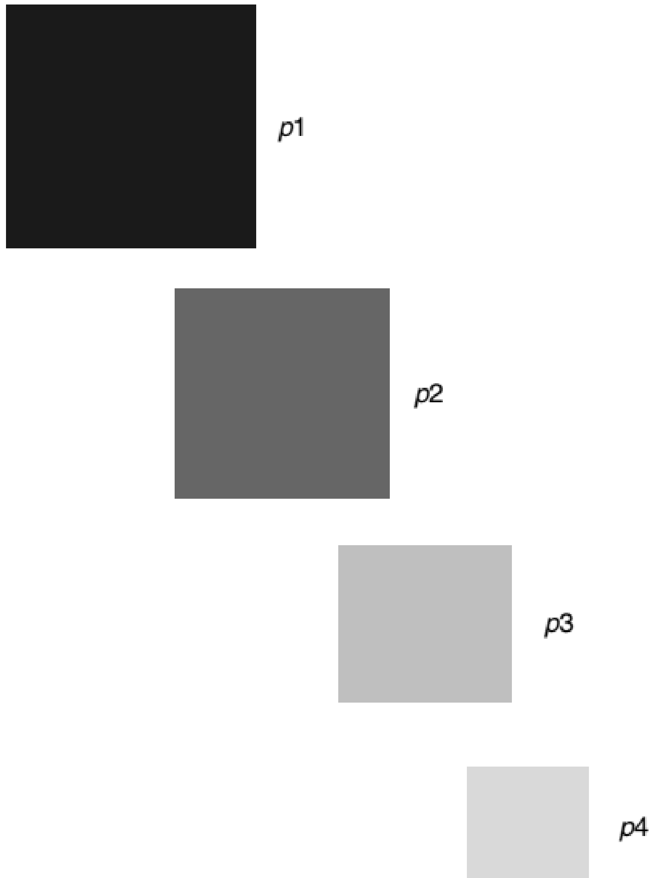
Figure 2.2 - The five stages of taphonomic histories affecting bones
(adapted from Ringrose 1993, 123).



Not unlike Figure 2.2 above depicting the entropic potential of taphonomy in affecting archaeological remains, filters undoubtedly alter the overall *potential* assemblage into the *actual* assemblage archaeologists recover. While Ringrose is careful to urge that taphonomic filters are not solely reductive, he acknowledges that transition between the above stages almost always results in information loss, whether by alteration, fragmentation, or overall sample loss (1993, 124). What is even more crucial for Ringrose is understanding the area of interest behind the framework. Paleozoologists, seeking to reconstruct or understand the living community (Stage 1), will likely have a distorted, skewed, or biased sample to work with (Stage 5) given the interceding stages and likely have to work with estimates. However, zooarchaeologists on the other hand are often more interested in the Death and Deposited assemblages (Stages 2 and 3), and thus can focus on the *transition* between stages themselves (e.g. bone accumulating agents, processing and butchering, refuse pits, etc.). The research focus clearly scales with taphonomic histories and their possible cascading impacts.

Not surprisingly, such impacts are very much the same for bioarchaeology, which have historically trended more similarly to paleozoologists in aims to reconstruct aspects of past communities (Stage 1) from sample assemblages (Stage 5). It is here, again, where the separate bioarchaeological emphasis on reconstructing aspects of life and funerary archaeology's focus on death rites breeds issues, as death and deathways and their resulting demographic impacts are inherently linked with their potential to reconstruct lifeways. Waldron (1987; 1994; 2007) has long problematized the relationship between preservation and demography in human skeletal assemblages. While bioarchaeologists tend to treat skeletal assemblages as samples of past communities, Waldron cautions that "an assemblage of human remains is neither a population nor a sample, since it is neither living nor a random selection of those who were once living" (2007, 27). Borrowing from epidemiology, he proposes the use of "study-base" over "sample" or "population," but acknowledges that its use is both "ugly" and unlikely to replace common bioarchaeological usage of the latter terms. He aptly distinguishes both the extrinsic and intrinsic factors that affect the very assemblages that bioarchaeologists examine. Factors that are characterized as 'extrinsic' are due to being independent from the actual assemblage itself, but ultimately reduce the overall size of the assemblage. Conversely, 'intrinsic' factors are ones tethered to the assemblage itself — they are built into the nature of the assemblage. Similar to Ringrose (1993) above, Waldron lists four extrinsic factors that reduce the overall 'study-base' of a skeletal assemblage: 1) proportion of those who died being buried at the study site ($p1$), 2) the proportion of buried remains which were discovered ($p2$), 3) the actual proportion discovered ($p3$), and 4) the total number recovered ($p4$). Waldron chose to pictorially depict these loses in terms of square areas, as seen in Figure 2.3. Thus, the final number of skeletons actually recovered ($p4$) represent a small proportion ($p1 – p4$) of the overall living community ($p1$).

Figure 2.3 - Diagram from Waldron (2007, 29) showing the loss of in number of skeletons at differing stages. Where *p*1 = the proportion of those dying are buried at the site of interest, *p*2 = the proportion with potential to be discovered, *p*3 = the actual proportion discovered, and *p*4 = the total number of skeletons recovered.



Unfortunately, as Waldron (2007, 28) is keen to note, it's often difficult if not impossible to quantify these actual proportions and the stages between them (e.g. *p*1 – *p*2). In the case of the community buried at the site (*p*1), outside of a sudden catastrophic event or historical assemblages such as battles or shipwrecks with known quantities of individuals, the total proportion is often unknowable. This is because burial assemblages are frequently non-random — they are socially- and culturally-mediated. Modes of disposal vary widely across time and space, and death assemblages therefore do not represent a 'random sample' of the once living population or community. Even circumscribed spaces for the specific purposes of disposing of the dead, such as cemeteries, are subject to taphonomic filters and disruption, suggesting that not even the full extent of those buried within such spaces will preserve or survive to discovery (*p*2). The case of "space saturation" (Ruiz Taboada 2015, 65), where preceding burials and cemeteries are often forcibly disrupted due to continued living of communities within the relatively same geographic space, is one that has been observed throughout continental Europe and the United Kingdom (Gittings 1984; Legacey 2019; Richardson 1988), and frames some of the particularly pressing issues in the case of cultural resource management in North American contexts. Despite their cultural significance and sacral qualities which imply permanence, cemeteries throughout the world are often subject to disturbance by later communities. This is especially true in the medieval period, where cemeteries appear to have been repeatedly opened, resulting either in the formation of ossuaries collecting previously interred remains to make space for new decedents, or in outright damage or destruction of previous remains, burials, and tomb-structures (Gilchrist 2022; Knüsel et al. 2004; A Ruiz Taboada 2015; Waldron 2007, 28). Not surprisingly then, taphonomic filters play a significant role in the transition between *p*1 and *p*2.

The proportion actually discovered (*p*3) is heavily influenced by a myriad of factors, such as contemporary development (especially in the case of cities), public works, private property, extents of archaeological intervention, funding, to name only a few. Generally, it is rare for the entirety of a cemetery to be fully excavated, often because they are obscured by contemporary construction, urbanization, or religious edifices. In many cases, the full extent of the cemetery may not even be known, making the transition from *p*2 to *p*3 almost always a reductive process. Finally, the actual proportion excavated (*p*4) under ideal circumstances should not be much smaller than *p*3, so long as careful excavation procedures, photographs, and note-taking are practiced. Reductions in *p*3 to *p*4 occur most often when remains are highly fragmentary and/or friable, to the extent that they can prevent proper excavation. Waldron notes that there are additional factors in transportation of remains from a site to a place of curation (e.g. cleaning, packaging, transporting) that could result in reduced numbers. However, the stages of extrinsic factors seemingly stop after excavation. Additionally, the transition could also be affected by local legal, cultural, or community directives which prohibit excavation of the remains, such as the case of relatively contemporary Islamic remains in Muslim countries (Insoll 1999, 169), or the intentional uncovering and subsequent leaving of skeletal remains *in situ* for community display purposes in the case of Ban Pong Manao, Thailand (Palefsky et al. 2022). Curation procedures also vary considerably, and while there has yet to be a systematic, comparative study of curation procedures affecting human skeletal remains post-excavation, it is certainly possible that factors, ranging from destructive sampling to exposure to the elements, could affect skeletal remains. While it is of course ideal to curate and preserve skeletal remains and archaeological materials with great care, such ideals can be complicated by issues of funding, space, or even municipal, legal, or cultural protocols (Baker 2021).

Which leaves us with the intrinsic factors, of which Waldron only lists one: skeletal assemblages are *death* assemblages, not *life* assemblages. This is the basis of what Wood and colleagues (1992) termed the "Osteological Paradox" already discussed above. While we have already seen just how problematic skeletal assemblages are for reconstructing aspects of health according to Wood et al. (1992), their concerns for demographic nonstationarity echo Waldron's early skepticism regarding the 'open' nature of most populations from which bioarchaeological samples derive. In essence: taphonomic filters and sample winnowing aside, even if a skeletal assemblage were perfectly preserved, it would never truly reflect the living community. Thus, the Osteological Paradox poses problems both for bioarchaeologists intent on reconstructing lifeways and health profiles in the past and for funerary archaeologists.

Chapter Summary

This chapter attempted to characterize, and subsequently integrate, bioarchaeology's potential to elucidate both lifeways and deathways in past communities. The chapter began by detailing the theoretical and methodological suite bioanthropologists employ to demonstrate the embodiment of social and environmental perturbations. Outlining the dimensions of biocultural approaches, as well as the issues and debates therein, helps to tether theory with method in a more integrated fashion and avoid overly simplistic, recipe-like prescriptions. I then explored the arc of bioarchaeology integrating more social and humanistic approaches, in tandem with its more processual, positivist origins.

The latter portion of this chapter traced the genealogy of funerary archaeology, ranging from processual economic assessments to post-processual criticisms and contemporary frameworks informed by social theory. While there have been tremendous strides in furthering funerary archaeology, analyses of the body have often focused on the body as a social or physical index rather than a means of material investigation. Frequently, the funerary body is the focus of interpretation but not necessarily the focus of analysis. Conversely, bioarchaeologists and osteoarchaeologists can occasionally focus too narrowly on corporeal remains, and privilege methodological refinement and protocols rather than situating the body in a socio-funerary framework. Funerary taphonomy offers a synthetic, middle-range approach to conjoin funerary archaeological insight and detailed bioarchaeological methodologies. Funerary taphonomy is thus an important framework in synthesizing 1) anthropological understandings of death and dying, 2) the material and social dimensions of engaging with the dead, 3) the theoretical dimensions of funerary/mortuary archaeology with the methodological demands of human osteology, 4) transcendence of the burier : buried divide, and 5) characterization of the relationship between preservation and demography in skeletal assemblages.

While funerary taphonomy cannot overcome the demographic drawbacks outlined by Waldron (2007) among many others (Bocquet-Appel et al. 1982; Wood et al. 1992; Jackes 2011a; DeWitte et al. 2015; Novak 2017), as it is built into the very nature of the data, it can help assess the qualitative and quantitative consequences preservation may have on a given skeletal assemblage. Additionally, it helps to contextualize the very nature of skeletal assemblages in the first place, and tackle issues of equifinality and the osteological paradox head on. The issue stands that much of bioarchaeology, despite working on death assemblages and mortal remains, often focuses on reconstructing aspects of life and the living. Conversely, mortuary archaeologists examine the body and burial contexts but for information on how the living confronted death, and with typically little emphasis on the remains themselves once excavated from the burial. As such, this chapter aimed to highlight some of the key scholars who have worked tirelessly to bridge those gaps and integrate bodies both within graves and outside of them into anthropological analyses.

Chapter 3: Historical, Historiographical, and Archaeological Background on Portugal and Santarém

In order to operationalize a biocultural funerary taphonomic approach, and bridge lifeways and deathways in a meaningful manner, deathways must be contextualized within an ontological framework. Fierro argues that funerary treatment as practice in medieval Iberia was a means of reinforcing and negotiating religious identity: "*quien imita a los otros se convierte en uno de ellos*" ("he who imitates others turns into them") (Fierro 1992, 471). Indeed, it could be that death, and the rituals surrounding death, was an even more prominent means of religious distinction in communities where it may not have been so easy to do so in life (Echevarría Arsuaga 2009, 45; Ruiz Taboada 2015, 66). Understanding the funerary, taphonomic, and osteological dimensions of each burial offers a far greater means of understanding the ways that religious identity affected both lifeways and deathways in past peoples. Employing a funerary taphonomic approach often furnishes a classic middle-range approach, and as such, the following section briefly considers religion in anthropology/archaeology before examining the predominate religious practices and funerary rites within medieval Iberia.

Religion in Anthropology

Religion has been a major interest of social science scholarship and has often been the analytical focus of well-cited scholars such as Durkheim (2001), Heidegger (1962), and Derrida (1995). Both the definition and focus of religion in anthropology have varied considerably. For instance, whereas Marx is often characterized as defining religion in terms of ideology and social control (Furseth et al. 2006), Durkheim (2001) is frequently characterized as having defined religion in more social-cohesive terms. Geertz (1973, 90) famously defined religion as a cultural system, an articulation that still has relevance today. Evolutionary approaches to religion have also been seen in both anthropology and archaeology which sequentially ranked religious systems (Sharpe 1986). Early works such as Frazer's canonical *The Golden Bough* (1936), as well as works by Danish antiquarians Thomsen and Worsaae all helped to establish religion and spiritual belief as some hierarchical zenith (Insoll 2004, 45; Sharpe 1986). Early anthropological endeavors hierarchically ranked religion in an evolutionary framework (Taylor 1903), and unsurprisingly, placed Western monotheistic religion at the pinnacle in doing so. Evolutionary analogues continue to permeate anthropological assessments of religion (Boyer et al. 2008). Anthropology has long been biased by Christian-centric tendencies, and anthropologists have recently attempted to try and increase reflexivity and self-awareness of Christianity's permeation into anthropological scholarship on religion (Asad 1993; Cannell 2005).

The 1960s brought about major shifts in theoretical framing of religions in anthropology, from focusing on structures and functions of religions "…to a concern with the interpretation of meanings, symbols and social process" (Erisken 1995, 198). Building on MacIntyre's (1990) articulation of three incommensurable approaches to moral inquiry, Lambek (2013, 4–5) articulates three typical anthropological framings of religion: encyclopedic, genealogical, and the tradition. The encyclopedic approach "attempts to accurately depict and compare particular religions, religious traditions, or religious movements" with attention to historical, cultural, and ethnographic context. This approach is often framed in an empirical manner, documenting histories of religion, or articulating religion as the crux of a testable hypothesis. The genealogical approach, on the other hand, borrows heavily from Foucault and post-colonial scholarship, and concerns more the interrogation of religion in society and history. Genealogical approaches are hyper-reflexive and "skeptical," tacking between social construction and deconstruction. The final approach, called "tradition", frames religion in relativist, comparative terms, but retains interpretive leeway compared to its encyclopedic counterpart. While MacIntyre originally framed such approaches as rivals, Lambek proposes that the work of anthropology of religion is actually a means of tacking *between* such categories, not heuristically separating them as incommensurable perspectives. Lambek (2013, 9) asserts "religion is a mode of producing a certain kind of truth or certainty that operates explicitly in certain relatively pure rituals and diffuses throughout social action." Insoll eloquently states that religion "includes the intangible, the irrational, and the indefinable" (Insoll 2004, 7). He goes on to suggest that it cannot be framed solely in 'rational' or 'logical' terms.

While the past history of comparative religions is an old enterprise dating to at least the 18th century, with roots in both philology (Masuzawa 2005) and insidious race science seeking to taxonomically classify religious identities (Hausner 2020, 488), contemporary comparative religious studies can be traced, in part, to Eliade (1961), whose coinage of 'sacred' sought to encapsulate meaning making within religions across time and space. This differs from typical anthropological investigations of religion, which generally follow Durkheim, and focus less on universalities and more on the social conditions for religious identity and expression (Hausner 2020, 485). Early anthropological and social science work by Geertz (1968) highlighted local and regional variability in Islam, a thread that became expanded eloquently in Asad's (1986, 14; 1993) work on highlighting the "discursive tradition" of Islam and the role of interpretation in producing localized manifestations of Islam.

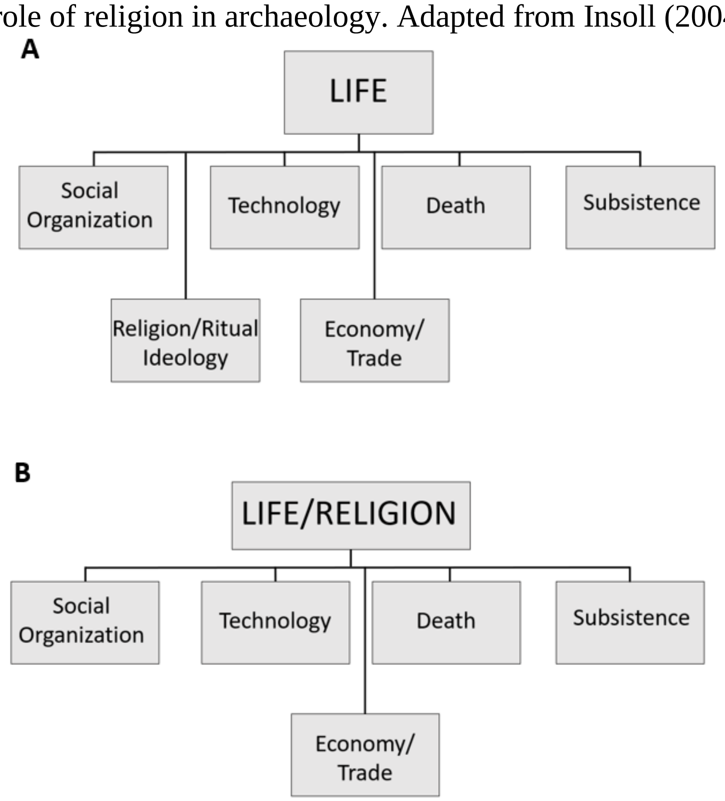
While anthropological endeavors have generally sought to compare intra-religious manifestations rather than comparing across or between religions, Hausner (2020, p. 486) aptly inquires: what are the consequences of such framing? Has anthropological fascination with intra-religious variability ultimately lost the potential to speak between religions? Not entirely, but anthropologies of religion must be willing to admit that comparison within heuristically demarcated religions and the quest for nuanced variability often trumps interest in universality or commonality across them.

Religion has been a particularly difficult concept to tackle archaeologically. Furthermore, religion as a theme in archaeology often recapitulates numerous aspects of religious scholarship in other disciplines. The genesis of religious discussions in archaeology often proceed in evolutionary and hierarchical terms (Sharpe 1986), before transitioning during the processual movement in the 1960s. This transition was accompanied by a reframing of religion in the past as an adjacent category of ideological classification (Binford 1967; 1983), whereas others positioned religion in a less fringe manner, and more encompassing of social (Clarke 1978) and psychological (Fritz 1978; Renfrew 1985) experience. These approaches are linked in their employment of scientific and empiricist methodologies, as a means of getting at 'the intangible' (Fagan 1998, 8), though Insoll (2004, 52) aptly underscores that such approaches are never 'neutral' or devoid of researcher bias. Marxist approaches developed in tandem with processual and, later, with post-processual approaches. The early work of V. Gordon Childe (1945) notes the importance of religion in past societies, but framed it in terms of ideological and "theocratic despotism" (Childe 1945, 73), akin to Marx's often negative portrayal of religion as ideological and economic control.

Concepts and ontological entities central to medieval religions — including (but not limited to) the soul, spirit, *pneuma*, etc., — are often 'invisible,' but materially tethered to rites, practices, and material substances, especially bodies. As such, archaeologists often focus on the body as a material manifestation, oriented in relation to other substances which may index spiritual and numinous aspects of personhood (Fowler 2011). Otto (1923) famously coined "numinous" to describe the experiential and emotive dimensions of religion, which became foundational for later phenomenological approaches. While Otto's work has since been criticized, the coinage of 'numinous' helped to provide a crucial theoretical foundation for the aspects of religion that exist beyond mere materials, but also the metaphysical. Both Hawkes (1954) and later Renfrew (1994) warned against archaeology's inability to reveal past beliefs, which later inspired scholars such as Insoll (2004) and Boyer and Bergstrom (2008) to shift the focus from what people believed to instead what they did and left behind. In essence, the shift was from the unobservable, to the tangible and observable.

Insoll (2004, 13) states that the archaeology of religion "can be conceived of as the superstructure into which all other aspects of life can be placed — it is not necessarily a stand-alone category." Insoll is careful to avoid essentialist, totalitarian inquiries into religions in the past, by noting the importance of the individual's experience within religion, while also not going too far as to color the past in a Western, individualist ontological framing. Another risk of contemporary scholarship is portraying people of the past as somehow more religious than people today, where secularization of contemporary society permeates into archaeological and historical scholarship (Insoll 2004, 18). On the other hand, a longstanding lack of discussing religion in archaeological scholarship is likely "more a reflection of the archaeologists' viewpoint rather than past realities" (Insoll 2004, 19). Insoll's framework was positioned in direct response to the frequent omission of religion in archaeological discourse, which often sequestered religion and ritual as a category rather than a structuring principle (Figure 3.1).

Figure 3.1 - A) the traditional archaeological view of religion, and B) a proposed alternative for the role of religion in archaeology. Adapted from Insoll (2004, 24).



An issue in this model is the totalistic nature of religion — a collapsing of the 'sacred' and the 'profane' by centering religion as an all-encompassing phenomenon — something Rowan (2011) cautions against.

The 'Medieval Islam' Problem

Nearly fifty years ago, Marshall Hodgson (1974) eloquently outlined the chronological and terminological challenges that accompany historical scholarship of Islam. Throughout nearly the entirety of his exhaustive three-volume corpus, *The Venture of Islam*, Hodgson makes a tedious effort to avoid the term "medieval" except for in spaces of revision, expansion, and theoretical tinkering. Instead, he opted for a distinction between 'Islamic' — a religious adjective — and 'Islamicate' — the community or civilization of which Islam was a major contributive system of faith. Hodgson's plea (1974, 57) focuses on the fact that "it has been all too common, in modern scholarship, to use the terms 'Islam' and Islamic' too casually both for what we may call religion and for the overall society and culture associated historically with the religion." In contrast to Bernard Lewis, who argued for 'Muslim' to be used in describing religion while 'Islamic' be used in describing the larger cultural apparatus, Hodgson proposes 'Islamic' "must be restricted to 'of or pertaining to' Islam *in the proper*, *the religious*, *sense*" and 'Islamicate' "would refer not directly to the religion, Islam, itself, but to the social and cultural complex historically associated with Islam and Muslims…and even when found among non-Muslims" (1974, 59).

The distinction is clear and illustrative: to describe artistic, architectural, or cultural phenomena in lumping religious (i.e., 'Islamic') terms doubly frames everyday things in religious auras (when they quite possibly are not). In doing so, such a broad conception of religion simultaneously abstracts the importance of true sacred items, acts, or places of worship in broader societal terms. It collapses the sacred and the profane into the same dimension by sacralizing the banal and secularizing the sacred. Hodgson is careful to acknowledge that "to separate out religion from the rest of life is partly to falsify it" (1974, 57), but cautions that by collapsing religious and societal and cultural complexes in one adjective, one risks rendering all manner of societal acts, things, and products in religious terms, when in actuality they are merely the products of a society that predominately practices Islam.

Some two decades later, Morony (1995) posited rather bluntly: "Is 'Medieval' Evil?" He pointedly underscores that while the 'Middle Ages' have been translated into Arabic (*al-usur al-wusta*), the concept of 'medieval' when applied to Islamic history is ultimately Euro-centric and even pejorative. Using 'medieval' as a chronological concept ultimately frames non-European history in distinctly European chronological terms. Additionally, sympathetic analogies drawn between Islamic contexts and European ones, such as likening the caliphate to the Papacy, is ultimately a means to "enable western audiences to relate to Islamic civilization in terms they can understand, and also sometimes to identify Muslim contributions to European civilization" (Morony 1995, 5). While sympathetic, it can border the pejorative as scholars and media have framed Islamic societies throughout the twentieth century in "medieval" terminology, so as to render them 'stuck in time' or "backwards". Ultimately, Morony reflexively asks — but does not answer — what can and should be substituted to better frame Islamic chronologies in the past so that they do not risk doing so in solely European temporal terms.

Since Morony's grappling provocations, scholars have made strides to revise such terms. Sam Gellens stated that the term 'medieval' in relation to Islamic history "just does not work.

It's a misnomer in every sense of the word, an outmoded Eurocentric construct that is not even appropriate for Europeans, much less Islamic or Japanese history during, for example, the Tokugawa period (1600-1868)" (Gellens 2000, 34). Varisco, in a pointed critique where he struggles to reconcile anthropological sensitivity with historical homage, leverages his own experience of conducting ethnography in Yemen to underscore the "anachronistic, misleading, and disorienting" sentiment that accompanies framing Yemeni history in 'medieval' chronological terms (Varisco 2007, 386). He ultimately concludes that "the Italian humanist hubris of an antiquity followed by the Dark Ages until the Renaissance set things right again is an absurd historical grid to place over the events that unfolded before and after the formation of Islam *in situ*" (Varisco 2007, 397). Varisco likens the baggage of "Medievalist" to that of "Orientalists," which Said (1979) sought to dismantle.

According to Petersen (2011, 968), the academic study of Muslim material culture and archaeology has largely followed two paths: one, of European secular interest, and the other born out of indigenous Muslim traditions. European scholarship largely employed an Orientalist model to Islamic history and material culture, through exoticization and decontextualization of Islamic materials from their societal milieus.

Medieval Iberian Historiography

In many respects, twentieth century scholarship and political regimes have had tremendous impacts on history and historiography in medieval Iberia. In the case of Spain, the famous debate between Américo Castro and Claudio Sánchez-Albornoz was a critical moment in shaping views of Iberian scholarship, heritage, and national identity. Castro, a Spanish culture historian and philologist, released the groundbreaking *España en su historia* (1948), which posited two major arguments. The first argued that Spanish national identity was a product of different religious and cultural groups, namely Christians, Jews, and Muslims, living together throughout the medieval period in what he termed *convivencia* – "cohabitation" or "conviviality." In this sense, Castro suggested that Spanish (and likely Iberian) identity could not be understood without the contributions of various religious and cultural traditions coming together to produce a 'hybrid' society since at least the early 8th century. The second argued that the Reconquista, and its accompanying consolidation of a militarized Christian faith, had negative consequences on Spanish and Portuguese identity. Some eight years later, the medievalist Sánchez-Albornoz responded in *España: Un enigma histórico* (1956) which not only questioned Castro's use of literary sources and methodology, but additionally argued that Islamic and Jewish contributions to Spanish identity were likely minor in comparison to the Roman community that pre-dated Islamic arrival in the 8th century. This debate continued into the latter half of the twentieth century, where Pedro Laín Entralgo (1971) aligned more closely with Castro's model of *convivencia*, but provoked a further response by Sánchez-Albornoz (1973) some two years later.

Crucially, these debates became not only important within academic circles, but were the focus of nineteenth century historiography and twentieth century Iberian political regimes as well. Nearly four decades of Iberian dictatorships, with Spain's Francisco Franco (1936-1975) and Portugal's *Estado Novo* under António de Oliveira Salazar (1933-1974) tremendously impacted Iberian scholarship, identity, and national narratives (Ballard 1996; Lopes de Barros 1999; Vakil 2003; García Sanjuán 2008). Both regimes, though to differing extents, highlighted the importance of 1) a Greco-Roman and Christian substrate pre-dating Muslim occupation, and 2) the Reconquista as a decisive victory in re-claiming Christian lands. The emphasis on

Christian continuity from the Roman period throughout the Medieval Period into contemporary Iberian national identity was emphasized along with the 'disinheritance' of an Islamic past (Díaz-Andreu 1996; Kamen 2007). Close affiliation with *Romanitas* in the creation of national identity is not entirely unsurprising , given the long and selective curated historiography of emphasizing Greco-Roman empires at the behest of other European influences (Dietler 2005; Liberato 2018). The regimes' respective influence on scholarship is no more apparent than the forced retirement and exiling of various faculty members throughout many Iberian universities and institutions. Rodríguez Ramos coined what her termed the "third Spain" as the space "Between the uniform and repressive Spain that emerged with the definitive territorial conquest of al-Andalus, and the diverse and repressed Spain that died with expulsion of the Spanish Moriscos" (Rodríguez Ramos, 2010, p. 29; cited and translated in Hirschkind, 2021, p. 57). Spain, as well as Portugal, were largely effective in erasing religious communities and positioning them in foreign, otherized terms.

Unsurprisingly, this long held debate has still continued in some academic circles. Some scholars still debate how to characterize this period, the changes that occurred, and the movements of people that took place as either "settlement" or "colonization." Menocal's rather glowing portrayal of Islamic occupation in Iberia characterizes the establishment of the Umayyad caliphate and al-Andalus as "vast improvements over the half-ruined place they had found. Unlike their much resented Visigoths who preceded them" who were "dreary…living in squalor" and occupying a "moribund peninsula" (2002, 73, 24–25, 85). The arrival of Islam was, according to Menocal, an enlightening candle brought to shine away the brutish 'dark' ages during which time Islamic authority figures granted religious and social autonomy to their Christian and Jewish counterparts under the *Dhimmi* (literally, "protected person") system. On the other hand, Fernandez-Morera (2016) has argued recently that *Dhimmi* system was a clever colonial agenda that was masked behind the linguistic façade of 'protection' but in reality the system created a poverty trap for non-Muslim communities. For Fernandez-Morera, the *Dhimmi* and accompanying *jizya* tax system imposed on non-Muslim subjugates permitted religious autonomy not for the purpose of benevolence or inclusivity, but rather as an apparatus for the manipulative colonial agenda in response to the demographic realities of incipient settlements where the first invaders were out-numbered by autochthonous Iberians (Fletcher 2001, 37). As such, some scholars have suggested that the *jizya* and religious autonomy were actually part of the colonial agenda as a means to 'soften' hegemonic presence, either to earn status with the local communities or to avoid inciting any uprising until further troops arrived (Fernandez-Morera 2016; García Sanjuán 2008; Imamuddin 1981; Mata et al. 2004). Gonzalez Ferrín's provocative *Historia General de Al Ándalus* (2016) suggested that Islam, at least before the ninth century CE, could hardly be considered a unifying principle of identity or organization. Rather, he posits that the portrayal of Islam as a unified group contra (Christian) autochthonous Iberians was really an invention of later Christian chroniclers during the tenth century.

Despite the entrenched historiography, some scholars have chosen to avoid the debate entirely. Nirenberg (1998, 9) aptly stated that violence and tolerance were likely co-constitutive in medieval Iberia, and that only by understanding their co-dependence can we navigate the historiographical "rose-tinted haven of tolerance and a darkening valley of tears." The turn of the twenty-first century in particular brought about major changes to the ways in which archaeologists and historians approached the settlement of Iberia. Clarke (2012) is particularly keen in highlighting the difficulty of medieval Iberian historiography, emphasizing the role of narrative in shaping documentary evidence. She aptly states: "Like any society; medieval Islam remembered, selectively, what mattered to it" (Clarke 2012, 25), and continues to highlight four major responses to the Islamic settlement of Iberia. The first are Barbarian narratives, whereby autochthonous Iberian communities conveyed Muslims war-mongering invaders, set upon conquering Iberia *en masse*. The second portrays Islamic 'conquests' as temporary punishment for Christians, whereby Muslims are interpreted as a divine, and often violent, punishment in Christian apologetics. The third, and like the previous narrative, portrays Muslims as the embodiment of penance. While the previous narrative emphasizes violence, this narrative argues that Muslim's *non*-violent dominion over Christian communities was practiced due to a God-given predilection to hold Christians in penitent, yet respectful subdual. Thus, in these two narratives the ontological apologetics of Christianity relinquishes the agency of Muslims, but in differing ways. Finally, the last narrative acknowledges Islam as a separate faith community, rather than a schema to be interpreted in Biblical terms. Clarke goes on to highlight issues in over-reliance on canonical documentary sources. The Treaty of Tudmir (also known as the Treaty of Orihuela/Theodemir) in 713 C.E., negotiated by 'Abd al-'Aziz and the Christian Visigoth Theodemir and best known for its description of colonial relations between Muslims and non-Muslim communities, is often cited for its detailing of surrender and subsequent tribute-based religious autonomy. However, as Christys points out, it is likely that the treaty was not drafted until centuries after the encounter had occurred (Christys 2013). Similarly, the canonical Chronicle of 754 is often cited for its description of the settler colonial encounters between invading Muslims and autochthonous Christians, was not only written some 40 years after the reported battles, but further refers to the invading Muslims as "*mauri*" (Berbers) and "*arabes*" rather than 'Saracen' (Clarke 2012, 21). Thus, interestingly, the chronicler fails to differentiate the invaders in religious terms, but rather in terms of ethnicity. Keaney (2013) similarly showcases the multiple ways in which memory and curation factored into archival accounts of Islamic conquests.

Given these historiographical debates, scholars of medieval Iberia around the turn of the twenty-first century have been keen to question the role of *convivencia* (Nirenberg 1998; Ray 2005) and increasingly incorporate archaeology (Barceló 1993; Boone 2009; Glick 1995). Indeed, in a rather famous article questioning the role of archaeology in medieval Iberian historiography, Barceló lamented that al-Andalus was a "lost civilization" not because of "some dense tropical jungle or some trackless desert" but rather lost "in our own historiography" (Barceló 1993; Boone 2009, 10). This is in part due to the long exclusion of archaeology both by traditional historical Iberianists and Arabic literary scholars (Glick 1995). But as Barceló went on to eloquently point out, al-Andalus is a "palimpsest, difficult to read" (1993, 250) and requires careful consideration for a variety of methodologies, approaches, and datasets.

Culture History of al-Andalus

Before Settlement – Islamization of North Africa in the Early Middle Ages

The arrival of Islam in the Iberian Peninsula in the early 8th century C.E. is predicated on the previous expansion of Islam from the Arabic Peninsula across North Africa. Prior to Islamic conquests of North Africa in the seventh century, much of the indigenous community was comprised of Berber communities, practicing often a variety of either Christian or Pagan faiths (Kennedy 1996). Arabic conquest of North Africa begin in 642 C.E. with 'Uqba b. Nāfi'al-Fihrī, son of Nāfi and one of the first Quraysh Muslims, to settle in Egypt. While 'Uqba b. Nāfi'al-Fihrī worked hard to enlist various autochthonous groups, he met much resistance, and established the settlement of Qayrawān, Tunisia in 670 C.E. before raiding Tangier and the

Atlantic Coast by 681 C.E. The settlement of Qayrawān fell soon after its establishment to various indigenous autochthonous Berber communities, but was retaken in 694 C.E. by a Syrian army lead by Ḥassān b. al-Nu'mān al-Ghassānī who defeated the Berber leader and priestess Kāhina (Kennedy 1996). After the fall of Qayrawān, many more Berbers, including Kāhina's sons, joined with Arabic forces, setting the stage for the settlement of Iberia.

Brett and Fentress (1996) aptly lament that the historiography of the Berbers and autochthonous North African communities is challenging, almost entirely focusing on their conquerors and less on their own communities and diversity. Indeed, the 'unification' of Berber communities through Islam was in itself based on Arabic linguistic ascription to the peoples of North Africa as *Barbar* or *Al-Barbar*, translated from the Greco-Roman concept of *barbaros* (βάρβαρος / βάρβαροι), exonymically referring to foreign groups who speak different languages and practice differing customs. Upon first encounter, Arabs utilized the term *kuffār* – "unbelievers," though with increasing conversion substituted *mawāli*, or "clients" (Brett et al. 1996). It is likely that many of the converting Berber communities, principally the Butr group(s), did so through the *wālā'* clientage system by exchanging loyalty and support for positions within the Muslim community (Crone 1980; Kennedy 1996).

The issue compounds when analyzing Berber history within al-Andalus. While numerous scholars acknowledge the diversity that comprised the medieval Iberian population (Taha 1989; Benaboud 1991; Collins 1995), the process of "Berberization" was far more than just a "peopling of the landscape" (Dinsmore 1994). Dinsmore laments that Berbers only become archivally "visible" during rebellions or battles, and otherwise are ignored historically and historiographically. She interprets this historiographical issue in light of Gellner's (1969) articulation of *siba* – a "rejection of the state's imposed political authority." Conducting ethnographic research throughout the twentieth century on remote and marginalized hill tribes of Atlas Mountains in Morocco, Gellner (1969) suggested that tribal attitudes towards state authorities was best explained in terms of *siba*, and Dinsmore makes a similar case for understanding revolts, battles, and insurrections conducted by Berbers within the Iberian Peninsula. Without a doubt, various Berber factions were instrumental in both the creation and subsequent dismantling of al-Andalus.

Settlement of Iberia

The Islamic settlement of the Iberian Peninsula by and the establishment of al-Andalus is canonically treated in militarized and semi-colonial terms. The conquest of Iberia often starts with the fractured Visigothic kingdoms that preceded Islamic invasion(s). Though often characterized as a homogenous Christian ethnic group, the non-Muslim communities of Iberia were differentiated and complex. Glick (2005) estimates that in the case of late-antique Iberia, some 200,000 Visigoths – Germanic-speaking Christians – ruled over some seven million Hispano-Romans – Latin-speaking Catholics. Thus, while both Visigoths and Hispano-Romans were likely Christian in a general sense, it's likely that inter- and intra-group experiences varied considerably. Generally speaking, Visigothic kingdoms in Iberia were fragmented and ethnically stratified, which fostered increasing tensions throughout the late antique period and even after Islamic settlement (Barceló 1981). Around July 20, 711 C.E., Ṭāriq b. Ziyād, converted Berber and established governor of Tangier, crossed the strait of Gibraltar into Iberia, defeating the Visigothic Roderick in battle. Mūsā b. Nuṣayr, governor of Egypt and successor of Ḥassān, was impressed by Ṭāriq's success, and brought approximately 18,000 troops to Algeciras before conquering Carmona, Seville, Merida, and eventually Toledo (Kennedy 1996).

By the 8th century C.E., much of the Peninsula had experienced increasing Islamic influence, and by the tenth century, 'Abd al-Rahman III ascended to Caliph in 929 C.E. and firmly established the Umayyad Caliphate in Córdoba (Table 3.1). 'Abd al-Rahman III helped to unify much of the diverse peninsula by employing *saqalibah*, Eastern European slaves, alongside Berber supporters to quash Muladi separatists such as Umar ibn Hafsun in the South and eventually lead military raids against Christian kingdoms in the north such as Asturias and Navarre (Glick, 2005; Kennedy, 1996). 'Abd al-Rahman III's military victories, paired with his self-proclamation as spiritual and military leader of al-Andalus and tolerant protector of non-Muslims (*dhimmis*) living within the emirate, is what helped to establish a powerful state with Arab elites occupying the highest level of government (Glick, 2005, p. 26). He was eventually succeeded by al-Hakam II (961-976 C.E./) followed by the *hajib* (chamberlain) Muhammad ibn Abi 'Amir, colloquially known as al-Mansur. While Hisham II al-Hakam was technically the successor to al-Hakam II, he was still a child and so the vizier al-Mansur took charge of the Caliphate during Hisham II's youth. The death of al-Mansur in 1002 C.E. resulted in a relatively rapid crumbling of the Caliphate of Córdoba, leading to the *fitna*, or 'anarchy,' that lasted from 1008-1031 C.E. This commenced with a coup that was launched on behalf of the remaining Umayyad's who had felt their throne was usurped by al-Mansur and subsequent Berber favoritism. What followed was a period of tremendous factions and military coups, resulting in some nine self-appointed Caliphs in a less than thirty-year time span. This unrest and decentralization of Arabic and Berber factions resulted in the *taifal* period, whereby Iberia divided into some twenty-four small states ruled by "Party Kings" (*muluk al-tawai'if*) (Glick, 2005).

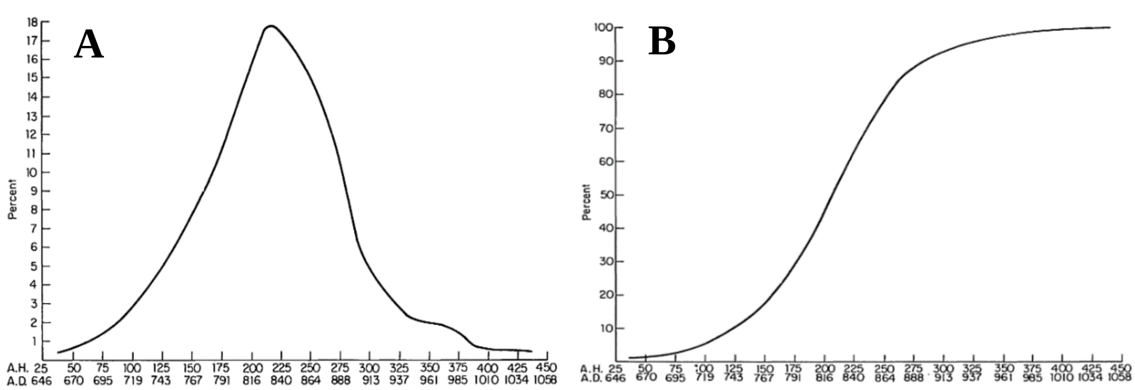
The highly fragmentized *taifal* period likely made it relatively easy for Christian kings in the north to begin raiding southwards. It is during this *taifal* period that D. Afonso Henriques, first king of Portugal, moved South from Galicia and conquered much of what would become modern Portugal. With increasing pressure from militarized Christian forces in northern Spain, the *taifa* kings called upon the Moroccan Almoravids, principally Usuf ibn Tashufin, to cross the strait and help repel Christian forces. Yusuf and his Almoravid forces were able to defeat the Christian Alfonso VI's army, but he eventually supplanted the *taifal* leaders, expelling them and attempted to re-centralize al-Andalus as an Almoravid emirate (1090-1102 C.E.). This only lasted some fifty years, before Berber rebellions (1144-1145) overthrew the Almoravids and once again established fractured *taifa* states (1146-1147). Just like their Almoravid predecessors, the Almohad Berber confederation led by Ibn Tumart from southern Morocco replaced their Almoravid and *taifal* counterparts, establishing once again a centralized state in 1172 C.E. The Almohad dynasty lasted only some forty years, as Christian kings continued to successfully raid and conquer southern lands, eventually taking Córdoba (1236) and Seville (1248). The fall of Granada (1492) marked the final expulsion of Islamic leadership, ending the Christian conquests and the presence of an Islamic-dominated cultural domain that lasted nearly eight centuries.

Table 3.1 - Basic Chronology of al-Andalus, with special attention to Santarém (adapted from Boone 2009, 28). For a more detailed chronology, see Appendix – Chapter 3.

Period	**Dates (AD)**	**Characterization**
Late Roman	409 - 711	Disappearance of Roman imperial state apparatus
Conquest	711 - 756	Initial Arab and Berber invasions from North Africa; Santarém transitions from Visigothic to Islamic city
Emiral	756 – 929	Increasing cultural dominance of Islam
Califal	929- 1009	Unification of al-Andalus under the Umayyad caliphate
Taifal	1009 - 1140	Caliphate breaks up into independent city-states called *taifas*
Almohad Rule	1147 - 1238	Berbers from North Africa conquer Arabic Muslims throughout Iberia; Santarém taken in the Portuguese Reconquista led by D. Afonso Henriques.
Nasrid	1230 - 1492	Córdoba falls to Christians in 1236, Granada falls in 1492

While most historians agree on the general chronology of al-Andalus and documented battles that took place, much of the recent scholarship has focused on two primary questions 1) to what extent did Islamization occur, and 2) when did ‘Islamization’ of the Peninsula commence. From an archival and historical standpoint, tracking migration into medieval Iberia has proven exceptionally challenging. Bulliet’s well-cited and germinal study (1979) helped to underscore rates of conversion to Islam in the middle ages. Analyzing biographical dictionaries from medieval Iran, Bulliet quantitatively assessed conversions by noting when Persian families had chosen to name their children in an Arabic naming tradition. Bulliet reasoned that the naming of one’s offspring within the Arabic linguistic tradition rather than Persian likely signaled conversion (though see 1979, pp 18–19 for further discussion). Consequently, Bulliet suggested that initially Islamic presence was likely minimal but grew cumulatively with time, as evidenced by the ‘contagion’ curves which have become canonically referenced in medieval Iberian scholarship (Figure 3.2).

Figure 3.2 - Bell Curve (A) and Cumulative S-Curve (B) of Bulliet’s conversion in



Despite focusing on the Arabian Peninsula rather than the Iberian one, Bulliet’s study (1979) created an important foundation for understanding Islamization throughout the Middle Ages.

Bulliet noted that the act of conversion was socially entangled, as conversion to Islam entailed no formal baptism, or much more than a few linguistic utterances as a proclamation of faith (Bulliet 1979, 33). In this sense, formal conversion meant little when compared to the social consequences of conversion and the transition into a new social community. Glick (1995) similarly suggests that, in the case of al-Andalus, adherence to newfound conversion could vary spatially. Given than much of Arabic aristocracy was centered in major cities, rural converts were more likely to retain aspects of previous material culture, customs, languages, and practices. While on the one hand conversion could help in providing job security, procurement, and tax exemptions (Fletcher 1992; Kennedy 1996), it likely entailed a restructuring of one's daily practices, particularly in urban centers. Overall, conversion to Islam was likely both challenging and highly variable throughout the early medieval period (Boone 2009).

While Bulliet's (1979) quantitative approach helped to address the extent of conversion, the issue of *when* 'Islamization' took place is even more complex. The foreign nature of Islam had canonically been treated as such in part due to Guichard's germinal work (1976). A structural-functionalist, Guichard argued that Islamic influence in the Iberian Peninsula was radical due to opposing "principles of organization." These polemics were employed in a comparative manner to underscore mental differences between foreign Muslims and non-Muslims. This was the dominant framework for most of the late twentieth century, and often corresponded with a more sudden influence of Islam. Wickham's (1984) influential expansion of the Medieval transition helped to set the stage for subsequent Iberianists to question the abruptness with which they characterized Islam's arrival (Gutiérrez Lloret 1996, 21–25). This fundamentally altered the ways in which some Iberianists came to view the Islamization of the peninsula, emphasizing the gradual, transitional role of settlement rather than an abrupt one (Boone 1994; Boone 2009; Gutiérrez Lloret 1996). Crucial to this paradigm shift was the incorporation of archaeology and material evidence, which, as stated previously, had been largely excluded (Glick 1995).

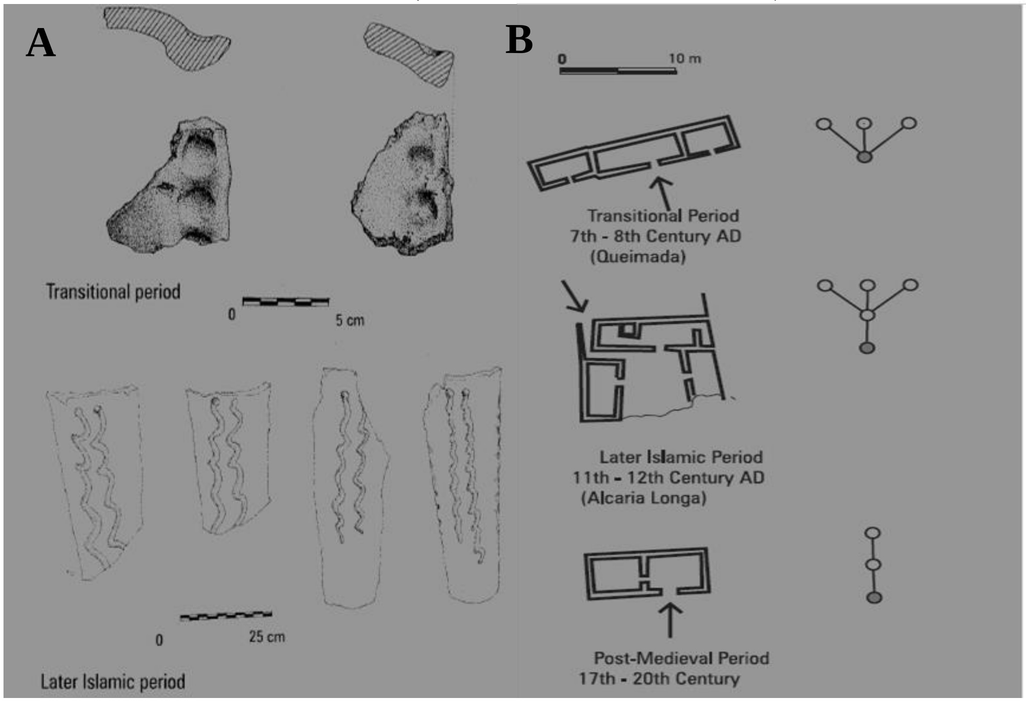
Archaeological evidence

Archaeological approaches to settlement patterns within medieval Iberia have been instrumental in complicating prevalent notions of Islam as external, foreign, and abrupt. By shifting away from an explicitly structural-functionalist perspective focused on archival information, the settlement of the Iberia can be explored more contextually and indigenously, and allows for more variation between ethnic, political, and economic organization (Boone 2009, 106).

Working in southern Alentejo, Boone has examined the material dimensions of what he terms the "transitional period" between Late Roman, Visigoth, and early Islamic epochs. He has found that the presence of L and U-shaped house compounds in Alcaria Longa are typical of Berber domestic architecture (Boone 1993; 1994; 1996), characterized by the central private patios found in the Rif (Mikesell 1961, 74). This type of domestic architecture not only differs from previous styles, but corresponds to cultural patterns in use of space, such as entryways and patios, which are absent autochthonous architecture. Imbrex ceramics (Figure 3.3) also feature prominently as a signature of Islamic material culture in the southern region (Boone 2002). Interestingly, ethnoarchaeological work on weaving traditions have also showed strong similarities with those of the mountainous Rif zone of northern Morocco (Torres 1984), which when paired with other archaeological work in the Algarve (Martínez et al. 2009) suggests strong ties with Maghreb.

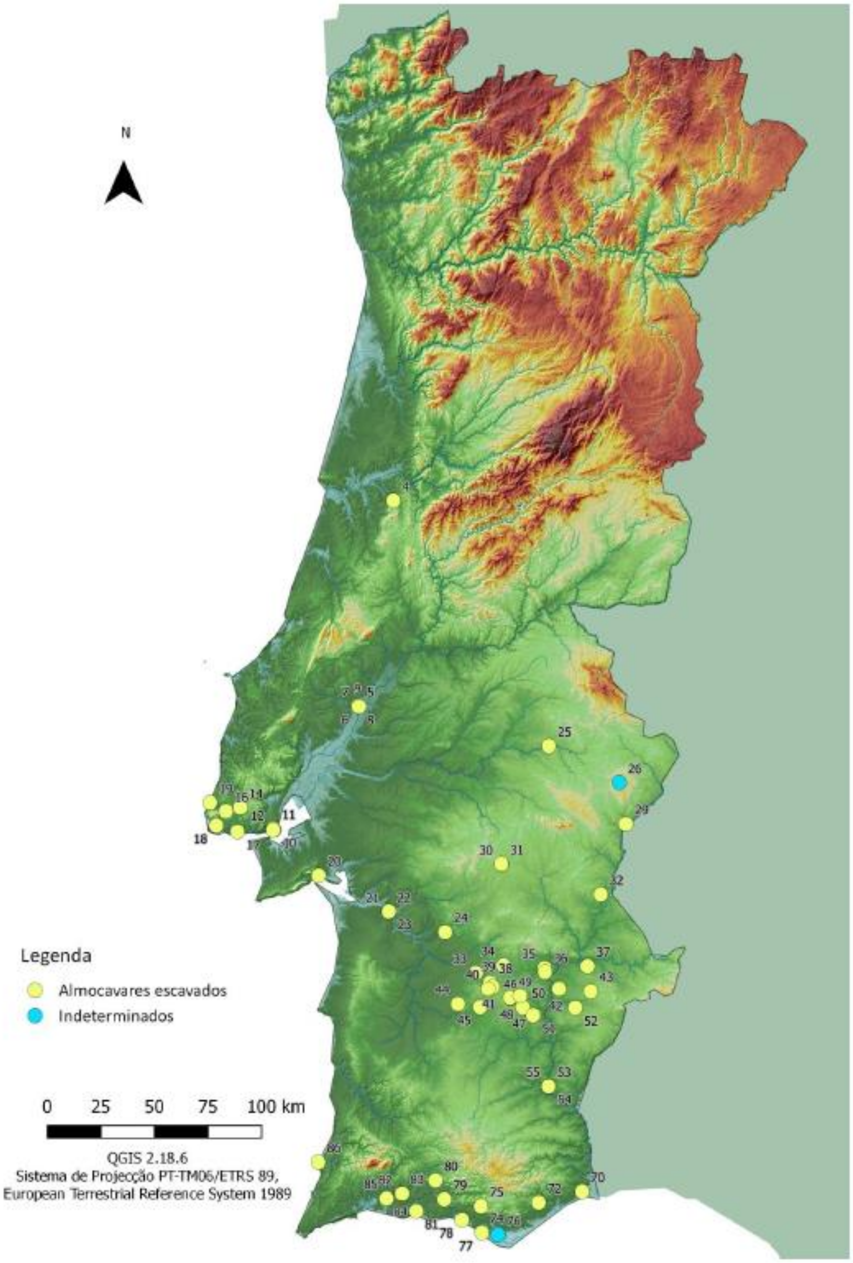
The presence of Islamic signs of material cultural throughout the Southern Peninsula prior to the eighth century has led some archaeologists to suggest that Islamization of Iberia was not only gradual, but that military conquests likely paled in importance compared to mercantilism. As the renowned archaeologist Cláudio Torres stated when asked about his life's work in the Alentejo: "O islão não foi imposto na Península Ibérica à espadeirada. Foi através dos comerciante" [["Islam was not imposed on the Iberian Peninsula by the sword. It was through the merchants"]]. In this sense, Islam did not exclusively arrive through the portcullises, but rather through the ports and rivers. Indeed, numerous scholars have highlighted water as an integral resource to Islamization of the peninsula. This agrees with some historians who have argued for the importance of hydrology and irrigation within Islamic Iberia (Glick 1970; Watson 1974). Generally speaking, the Iberian Peninsula saw increasing irrigation throughout the Islamic period via artificial and modified water supplies, in addition to capitalizing on existing riverine trade networks and the Mediterranean, transforming the preceding status of the sea as a "Roman lake" to that of a massive mercantile network (Glick 2005). While some have been tempted to link this with Wittfogel's "hydraulic" society, the term has been somewhat contentious within anthropological notions of statecraft (Hunt 1988; Price 1994). Watson's influential thesis (1974) posited an "agrarian revolution" took place with the influx of Islam, focusing on the novel introduction of farming techniques by Muslim merchants and colonists in addition to the introduction of key crops and cultigens. However, a number of scholars have remained skeptical of Islamic cultivation and irrigation being so novel or widespread. For instance, Butzer and colleagues (1985) suggested that Roman and Islamic irrigation "differed in degree rather than kind", and that Islamic irrigation merely "augmented" previous Roman infrastructure rather than outright replace it (Decker 2009, 190). Both Decker (2009) and Squatriti (2014) are careful to underscore Islamic contributions to farming and crop diffusion, but also take critical stances on the linear and simplistic way that some influential historians have framed the arrival of Islam by focusing on the pre-Islamic presence of crops themselves such as durum wheat (*Triticum durum*), Asiatic rice (*Oryza sativa*), cotton (*Gossypium* sp.) and artichoke (*Cynara scolymus*). While the technological and geographical dimensions of Islamic innovation are still contested, the peninsula certainly changed culturally and linguistically throughout with the influx of Islam. Arabic was indeed the bureaucratic, if not an economic, language of the peninsula, evidenced by Arabic minting of *dinar* coins, the main form currency (Kennedy 1996). The exhaustive work by Helena Catarino (and her students) has also showcased the tremendous material culture (especially ceramics), toponyms, and historical sources of Islamization throughout Portugal (Catarino 2005; Catarino et al. 1981; 2009; 2012; 2006; Liberato et al. 2021).

Figure 3.3 - (A) Thumb-impressed and imbrex-style roof tiles. (B) Seriation of domestic architecture (from Boone 2002, 112, 116)



Perhaps no greater material sign of Islamization of the peninsula is the presence of Islamic burials. Given the distinct funerary treatment of the corpse and burial construction (see below), Islamic burials are some of the most direct indicators of Islamic presence within the peninsula. In her impressive master's thesis, Gonzaga (2018a) employs toponymic, archaeological, and historical sources to characterize the distribution of Islamic cemeteries throughout Portugal. Her work showcases the density of Islamization in Gharb al-Andalus, and the clinal decrease in known Islamic cemeteries extending northward (Figure 3.4).

Figure 3.4 - Location of excavated Islamic cemeteries/burials throughout Portugal (retrieved from Gonzaga 2018, 226)



Funerary Bioarchaeology of Islam

Bioarchaeological and osteological assessments of Muslim remains are limited, due to the crucial role of ethical and religious restrictions enforced. Muslim cemeteries are often protected under Islamic law (Insoll 1999, 169; Maynard et al. 2011; Petersen 2013), and as such, the majority of studies that have been conducted are within the Iberian peninsula (Inskip 2013b), as it is a region where *shari'a* law does not take precedence over other laws, and is a region where salvage archaeology is frequently practiced as a result of urban development.

Just as there is spatial, temporal, and denominational variation throughout Islamic beliefs and practices, similar variation exists in regards to funerary treatment of the dead (Buturovic 2017). As a general premise, death and dying in Islam are often approached in an eschatological framework within the Qur'an and *hadith*:

> *Every soul will taste death. And We test you with evil and with good as trial; and to Us you will be returned.*
>
> Qur'an 21:35

> *We made you out of it and into it we return you, then from it we shall raise you again*
>
> Qur'an 20:55

However, funeral rituals are notably absent from the Qur'an (Smith et al. 1981; Welch 1978), and as a result, overarching funerary practices often coincide with a mixture of *hadith* and *sunna*, particularly the *Kitāb al-janā'iz* ("The book of funerary rites"). Petersen (2013) suggests that, given the general paucity of funerary rites described within the Qur'an (Casassas 2007; A Petersen 2013), variation in funerary customs are more likely to originate from *hadith* through deductive logic (*ijthihad*) which the principles of Islamic law (*fiqh*) are derived to develop the basis of funerary manuals (Sadan 2000). Indeed, it's likely that *hadith* were the second source of authority in these matters in regards to funerary rites (Chávet et al. 2006). Crucially, much of the jurisprudence in al-Andalus followed that of the jurisprudential-religious writings of Malik ibn Anas (711-795 C.E.), who's foundational founding of one of the four schools of Sunni law became widespread throughout the Islamic world throughout the eighth century C.E. and beyond. By the ninth century, the Andalusian caliph al-Hakam I institutionalized Malikism as law (S. Payne 1973), and with the continued support of caliphs such as Abd al-Rahman III and al-Hakam II, Malikism continued to play a major role in the jurisprudence and religious funerary rites in al-Andalus (Chávet et al. 2006, 151) and beyond (Fortier 2010). Thus, the following prescriptions are detailed for general purposes of Islamic funerary treatment, but with a specific attention to Maliki jurisprudence that predominated Medieval Iberian Islamic faith.

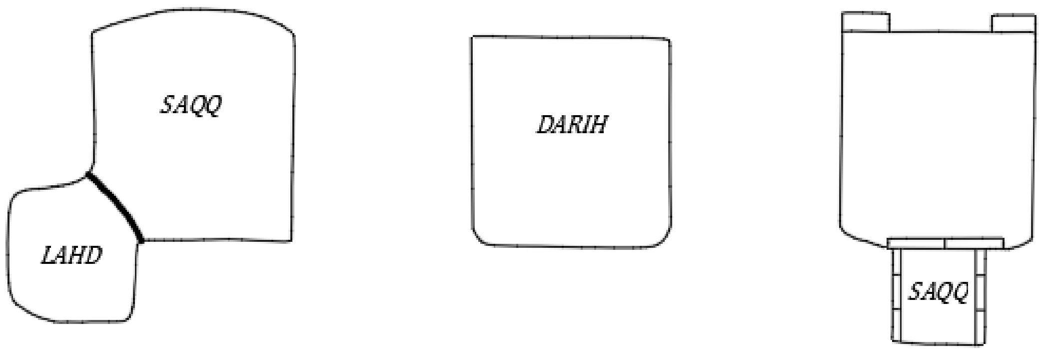
Chávet and colleagues consider ritual funerary interment in medieval Islam as a "*zona fronteriza entre los dos mundos*" for its simultaneous public exhibition and sacred exclusivity (Chávet et al., 2006; emphasis in original). Indeed, Muslim burials follow the death events and burial preparation for the Prophet Muhammad, which were deliberately opposed to other funerary customs (e.g., Christian funerary rites) at the time (Gleize 2022). This frontier can also be seen in the eschatological and metaphysical act of dying in Islam, whereby the death brings a departure from the physical world (*dunya*) into the afterlife (*al-akhîra*) (Casal 2003, 23–37). Thus, the soul is believed to leave the body at death, which requires rapid burial within the following 24 hours (Petersen 2013). Indeed, one prophetic speech insists: "Bury him in the same night!" (Bukhârî 1977, 1 404; Fortier 2010, 304).

After death, the corpse is stripped of clothing and the washing of the corpse (*ghusl*) commences, with some notable prescriptions: starting on the right side of the body and moving to the left (Amilia Buturovic 2017), washing an odd number of times, using water infused with flowers, and the last wash should be accompanied by camphor (*Cinnamomum camphora*; Chávet et al., 2006). Malīkī jurisprudence strongly advocated for the performance of *ghusl* along kinship and gendered lines, whereby spouses were preferred to perform the ritual washing, followed by relatives and finally someone of the same gender (Fortier 2010, 303). The performance of *ghusl* was likely an important and honorary action, as one hadith states "God shall forgive forty times over anyone who washes the dead body and conceals its state" (Nawawy 1991, 258).

After the ritual washing, bodies are then shrouded in "Yemeni cotton" (*kafan*) with jaws tied to the skull to prevent it from opening (Gatrad 1994; Tritton 2008, 441; Petersen 2013; Buturovic 2017). In most cases, the shrouding of the body can vary by gender, with women being enshrouded in five pieces of cloth whereas men are enshrouded in three pieces. Interestingly, few individuals were allowed to be buried with their clothing, such as martyrs, victims of drowning, respiratory illness, internal ailments, fire, falling structures, and women who die in pregnancy (Buturovic 2017). Bodies are then transported on biers (*janâ'iz*) to carry the body to the grave as part of the funerary prayer and congregation: *janazah* or *salat al-janazah* (Torres et al. 1996). Earthen inhumations are a hallmark of Islamic funerary customs. Even pre-Islamic nomadic Arabic groups began disposing of the dead in graves – a transformation to a sedentary state of being evidenced by the linguistic reference to the graves as *muqīm* or "the staying" (Bravmann 2008; Buturovic 2017). Generally, burials adhered to basic prescriptions such as: the situating of the body directly with the floor of the grave (Khalîl 1995, 107), the exclusion of grave goods in order to preserve uniformity (Halevi 2007; López Quiroga 2010), the individuality of a grave so that each grave only contain one individual (Insoll 1999), and the separation of adults and children (Petersen 2013), though considerable variation exists (Sadan 2000, 183). Casal (2003, 33–34) for instance outlines the numerous grave goods that have been found within medieval Islamic cemeteries in Spain. It is generally forbidden to cremate, artificially treat, or interfere with the corpse, as it meant to be intact for resurrection and "decompose naturally" (Insoll 1999; Buturovic 2017, 102).

In the case of al-Andalus and Malīkī jurisprudence, single inhumation was greatly emphasized (Fierro 2000; León Muñoz 2008). This uniformity is based within Islamic jurisprudence stating that all are equal in death (Gleize 2022; Gonçalves 2009; Halevi 2007; Torres Balbás 1970), and thus levelling previous hierarchies and inequalities in life. In fact, the normative and homogenous nature of Islamic graves is likely what contributed to their archaeological underappreciation, as they were seen as relatively uninformative (Gleize 2022). Graves were constructed often as rectangular pits, with a smaller, human-sized trench at the bottom (*shiqq* or *shaqq)* for interment (*dafan*) without the use of a coffin (López Quiroga 2010; A Petersen 2013; Torres et al. 1996). Notably, there is variation with tomb profiles (Figure 3.5), corresponding to differences in the conjunction of distinct funerary compartments (*lahd* and *šaqq*) or in the creation of a single trench (*darih*). Some scholars have suggested that these variations developed in two distinct phases within al-Andalus: one between the 8th-9th centuries and the second between the 9th-10th centuries (Chávet et al. 2006; Ruiz Taboada 2015).

Figure 3.5 - Variation in Islamic tomb styles (adapted from Chávet et al 2006, 152). Where *darih* refers to a cross-sectional tomb style without a *lahd* (niche), and *saqq* refers to the burial space.



Evidence for this comes not only from diachronic variation in tomb typology but also from historical reference by Abū ‘Abd Allāh Muḥammad ibn Ismā’l Ibrāhm ibn al-Mughrah ibn Bardizbah al- Ju‘fī al-Bukhārī (9th c.) who identified three predominate tomb styles (Ruiz Taboada 2015, 56). Torres Balbás’s (1957, 137–144) foundational work helped to establish an early three-typology system for Islamic graves in medieval Córdoba. Casal (2003, 121) later exhaustively expanded on this work, furthering the three-type system but with subsequent variants (Appendix 9.13-9.14). Taking a more regional approach, both Inés Fernández (Fernández Guirado 1995) and Carmen Peral (Peral Bejarano 1995) have helped to expand upon the variation in typologies for medieval Islamic burial styles throughout Andalusia and their potential chronological correlates (Appendix 9.15-9.16). The placement of wakes or stelae at either the head or foot of an interment could also take place, though is not universal (Casa et al. 1995; Chávet et al. 2006; Fierro 2000; López Quiroga 2010; Mazzoli-Guintard 1996). Occasionally, graves were not filled with earthen fill but rather capped with wood, tiles, or slabs, as has been observed in Córdoba (León Muñoz 2008), Beja (Martins et al. 2013), Aljezur (Gomes et al. 2015), Vale do Bôto (Catarino et al. 1981), and Rossio do Carmo (Candón Morales 2001). Altogether, there is no doubt that considerable variation exists within Islamic approaches to death and tomb construction throughout the Iberian Peninsula.

While general tomb construction varied, inhumations also adhered to prescriptions for burial dimensions. According to Chávet and colleagues (2006), burial depth typically varied between 80 to 100 cm for adults and 45 cm for children, whereas León Muñoz (2008) found depth to vary between 40-60 cm. According to Malīkī jurisprudence, prescribed depths aided in the protection of the remains from scavengers (Chalmeta Gendrón 1968; Fierro 2000, 177), but may have remained shallow enough to hear the call to prayer from the *muezzin* (Insoll 1999). The latter point is worth further consideration, as there appears to be a long history in Islam of the deceased retaining the ability to hear (Fortier 1997). Fortier highlights (Fortier 2010, 308) that while the Quar’an states “You cannot make hear those who are in their graves” (35, 22), the Sunni jurist al-Ghazâlî (1058-1111) argued that “the last thing which disappears in the dying, is hearing, since sight is lost the moment when the spirit is completely separated from the heart.

However hearing is preserved until the soul has been removed" (Ghazâlî 1974, 9). Given the importance of oration in reciting funerary prayers during visits to a grave, it's likely that hearing played an important role in mediating between the living and dead (Fortier 2010). Notably, other prescriptions advocated for a deeper grave cut, such as hadith following the Battle of Uhud (625 C.E.) which pleaded for deeper graves and commingling given the number of dead (Saabiq 1991).[2]

Burial width also appears to have received considerable attention and debate. Burial width was typically narrow in order to prevent post-depositional alteration of the body. The 12th century "Treatise of Ibn 'Abdun" from Seville attests to just how narrow tombs could be in prescription no. 149 (Garcia Gómez et al. 1998, 149):

> "Debe aumentarse un poco el largo y el ancho de los huecos de los sepulcros, porque yo he visto que a un cadáver hubo que sacarlo três veces de la tumba para arreglar el hueco convenientemente, y que outro cadáver hubo de ser metido a fuerza de apretar"
>
> ["The length and width of the graves must be increased a little, because I have seen that one corpse had to be removed three times from the tomb to fix the hole, and that another corpse had to be forcefully squeezed [into the grave]."]

Gleize (2022, 382) notes that archaeological surveys of Muslim graves indeed adhere to narrow dimensions, with some measuring only 60 cm wide. Given the narrowness of Islamic graves, it is not surprising that variation has also been noted in the bodily position of Islamic graves within Spain, with differing elements showcasing varying angles of flexion and extension (Casal 2003, 31). Lozano Cosano (2016, 100) notes this could be due to both "internal" (ritual positioning, shrouding), and "external" (grave limits, shape, covering) factors. In some cases, small stones, ceramic sherds, or even wood have been found as a means of supporting or propping certain anatomical articulations to facilitate bodily position and intactness (León Muñoz 2008, 43). Thus, ensuring minimal post-depositional disturbance and movement was fundamentally linked to tomb construction. Graves are intentionally dug to allow for the head to be turned right, in accordance with *qibla* — the direction of Mecca — southeast in the case of Iberia (López Quiroga 2010; Mazzoli-Guintard 1996). While the placement of the corpse in order to face Mecca is typically a hallmark of Islamic burials (Qayrawânî 1968, 111), Gorzalzcany (2007) noted a variation of 35° in Islamic burials likely due to seasonal changes in the position of the sun, though variation in orientation at the Portuguese site of Avenida 5 de Outubro may be due to chronological refinement in the location of *qibla* more than seasonal variability (Santos, personal communication).

In some cases, there appear to be prescriptions detailing which soils and sediments to prefer and which to avoid. For instance, the avoidance of lime appears to be canonically referenced, as lime was "thought to increase dryness and therefore thirst, which was regarded as one of the torments of death" (Leisten 1990, 13e; Abdesselem 2008, 910). Indeed, the eschatological importance of hydration and water in near proximity to Islamic cemeteries (*maqabir)* has been observed in numerous Spanish excavations and historical sources (Casal 2006; León Muñoz 2008, 41; Lozano Cosano 2016, 92; Robles Fernández et al. 1993; Arturo Ruiz Taboada 2015, 57). Examples such as Necropolis 2 of Marroquíes Bajos in Jaén (Serrano

[2] Fiqh us-Sunnah, Vol. 4, Fiqh 4.62a

Peña et al. 2000), the necropolis of Tossal de Manises in Alicante (Olcina Doménech et al. 2008), and the Roman circus *maqbara* of Toledo (Ruiz Taboada 2015, 57–58), all showcase extensive aquatic networks, channels, and springs surrounding the cemeteries further suggesting the importance of hydrological infrastructure as occasionally part of the larger Islamic deathscapes.

Despite their apparent simplicity, medieval Islamic graves were constructed deliberately in a complex eschatological and theological framework. Grave space likely marked an important ontological and eschatological factor for the Day of Judgement (*al-Akhir*), as the angels of the grave, Munkar and Nakir, would visit the dead and deliver sentences of punishment or release from graves following interrogation (Dickie 1985, 44–45; Castillo 1987, 56–57; Chávet et al. 2006, 153). Petersen (2013) notes how depth of burials could be gendered, with females having slightly deeper (1.5m) graves than their male counterparts (1.3m) to permit more space during the Day of Resurrection (*al-Qiyamah*). Buturovic (2017, 102) showcases how bodies lied in the *barzakh*, a "form of ontological interspace" between the living in death. In this sense, bodies physically remain situated in earthen tombs, but ontologically are situated within the *barzakh* until *al-Qiyamah*. Both Sunni texts such as the an-Nafîs (Savage-Smith 1995, 107) and *hadith* (Ghazâlî 1974, 25) attest that the body and soul continue to experience pain and suffering post-mortem, owing importance to the burial as a place of peaceful rest.

The management and oversight of *maqabir* during the Middle Ages appears to have been integrated within public works infrastructures. Two principle administrators, the *qadi* and *muhtasib*, were likely instrumental in the oversight, supervision, and regulation of cemetery management, particularly in preventing the desecration of graves (Chávet et al. 2006; Garcia Gómez et al. 1998; Torres Balbás 1970). The *qadi* was an important magistrate who oversaw the supervision of civil projects by virtue of rendering edicts, whereas the *muhtasib* was a scholar in *Shari'a* but helped to physically oversee and supervise public works. For instance, the location of *maqabir* are often preferentially situated outside city walls and downwind (Petersen 2013), typically situated along major roads and city gates (Mazzoli-Guintard 1996; Ruiz Taboada 2015; Torres Balbás 1970). Indeed, numerous Islamic cemeteries in Spain were named after the gates next to which they were situated, such as the *maqbarat bab Ilvbira* in Granada and *maqbarat al-Hanas* in Valência, whereas in the case of *bab al-maqábir* in Lisbon, the gate took the name of the cemetery (Torres Balbás, 1970, pp. 239, 266, 274; but see Gonzaga, 2018: 13 for further review). Both within Spain (Serrano Peña et al. 2000; Carballa et al. 2007) and Portugal (Macias 2005; Serra 2012; Liberato et al. 2017), the presence of Islamic cemeteries likely signals interstitial open spaces either outside or delimiting urban spaces. Space was also maintained between burials to allow for mobility and funerary processions (López Quiroga 2010). Even the spatial organization of graves appears to have been carefully managed, whereby graves were organized in proximity to kin or other pious community members (Fortier 2010, 307), as suggested by Ibn 'Asâkir (d. 1176): "Bury your dead amidst pious folk, for indeed a dead individual is wronged by a wicked neighbour just as a living person is wronged by a wicked neighbour" (Halevi 2007, 228).

While these suggest some of the general tendencies for Islamic funerary treatment, it is crucial to archaeologically situate Islamic funerary rites locally and contextually, especially in multi-faith settings. For example, when analyzing burials from Tell el-Hesi, Israel and Late Islamic sites in Iraq, Simpson (1995) found that it was nearly impossible to distinguish between Islamic and non-Islamic burials on the basis of archaeology alone. Simpson suggests that in numerous Near Eastern contexts, intra-religious funerary variation is much higher than inter-religious variation, suggesting that the funerary rites along religious lines were not always monolithic or typological. Similarly, variation in grave construction (Chávet et al. 2006), soils (Matias 2008b), depth (Chávet et al. 2006), use of tiles (Candón Morales 2001; Catarino et al. 1981; Gomes et al. 2015; León Muñoz 2008; Martins et al. 2013), wakes/stellae (Gonzaga 2018a), and orientation (Gorzalzcany 2007; Santos et al. 2011), have all been observed in medieval Islamic graves. Additionally, given the influence of Mwallad, Mozarab, and Mudejar cultural groups and vernacular funerary rites, it is paramount to understand inter- and intra-cemetery funerary variation, both typologically and diachronically. Echoing Boone's (2009) aforementioned call for an indigenous and chronologically situated archaeology of al-Andalus, Islamic funerary contexts should be analyzed no differently.

The Christian Conquests ("Reconquista")

The expulsion of Islamic cultural leaders by Christian kings in the northern peninsula is canonically called the *Reconquista* — the faith-based crusade by which northern Iberian kings drove out their southern Islamic counterparts. However, the concept of *Reconquista* presents itself as particularly challenging for historians and archaeologists. While the Reconquista generally is agreed to begin the twelfth century and end in 1492 C.E. with the fall of Granada, the historiographical dimensions of the event are complicated, particularly within Portugal due to its coincidence with the Second Crusade. The Second Crusade (1147 – 1150 C.E.) was declared by Pope Eugene III after the fall of the County of Edessa (1144). The crusade was led by European Kings Louis VII of France and Conrad III of Germany, crossing through Anatolia to lay siege upon Damascus. The siege overwhelmingly failed, and in fact, the only major success of the Second crusades was the taking of Lisbon in 1147. Roughly 13,000 troops sailing from Dartmouth, England (May 1147 C.E.) to Jerusalem stopped in Porto, Portugal (June 16, 1147 C.E.) due to bad weather, and aided Afonso Henriques I and his army (~7,000) to lay siege upon Lisbon (July - October, 1147 C.E.). While the taking of Lisbon in 1147 was certainly aided by Crusader forces, it's canonization as part of a religious battle is still somewhat questionable and quite possibly *post-hoc*. More than likely the Order of Cluny (thirteenth century) followed by the Order of Cister helped to cement the zenith of militarized Christianity.

Issues of the Reconquista become compounded when analyzed in the context of the Iberian fascist political regimes. Recently, Iberianists have been keen to highlight how the aforementioned twentieth century political regimes effectively glorified the Reconquista (Vakil 2003; Mattoso 1997; Ballard 1996), and indeed, some scholars today have abandoned the term *Reconquista* altogether in favor of *conquista cristã* (Liberato 2018; Santos et al. 2018). The ascription of the prefix "*Re-*" invokes a desire to show continuity with the leaders of the 'Reconquista,' and thereby contemporary Catholic peoples of the Iberian Peninsula, and a pre-Islamic Roman substrate. This echoes the long and curated history of *Romanitas* (Dietler 2005), and collapsing of pre-Islamic autochthonous Iberians and post-Reconquista Christians into a ethno-religious group, while further characterizing Islam as foreign, alien, and "other" (Ballard 1996; Vakil 2003). The renowned archaeologist Cláudio Torres, who has spent a career excavating in the Alentejo region, provocatively stated in a science communication interview that the Christian conquests are better understood in geographic terms than religious ones.[3] He suggests that the conflict was likely born out of a sacking of wealthy cities and urban areas to the south than religious zeal, but relatively little scholarly literature has been dedicated to this

[3] See for example Cláudio Torres https://www.sabado.pt/vida/detalhe/claudio-torres-d-afonso-henriques-nao-conquistou-lisboa-aos-mouros-foi-aos-cristaos

sentiment. Historians such as Lynn Nelson (1984) discuss how part of the Christian settlement of Spain was an incremental process of individuals and families (not mass migrations) moving a few kilometers south in a depopulated frontier for a better life, a process that was then iterated inter-generationally over multiple centuries. Emigration in Aragon, and other parts of frontier Spain, was likely the result of push/pull factors that encouraged settlement in depopulated areas for more favorable circumstances rather than just faith-based conflict (Nelson 1984, 147).

Without a doubt, in some contexts, the Christian conquests had tremendous social, cultural, and economic impacts. By the twelfth century onwards, most of Portugal underwent drastic urban changes after the Christian conquests that dismantled Islamic urban networks, forced Islamic residents into spatially segregated neighborhoods, and restructuring of domestic spaces (Trinidade 2007a). The Christian conquests damaged previous trade networks such as those in Mértola (Martínez et al. 2009, 410). Glick (Glick 2005) suggests that in contrast to the Islamic 'urban artisan' emphasis, Christian conquerors instead channeled funds into rural, agrarian economies and parishes.

Given the political and fascist baggage, I choose to avoid the term '*Reconquista'* in favor of Christian conquests. Additionally, I seek to synthesize the skepticism of the conquests in solely religious terms with Torres' emphasis on the role of geographical and economic differences between northern Iberian kings and their southern counterparts. As a result, I choose to frame the Christian conquest of Santarém in geo-religious terms more than solely religious or latitudinal ones. In doing so, I suggest that we can still acknowledge the role that faith played in community organization, daily life, and eschatology while simultaneously underscore the importance of space, which is especially crucial in the case of Santarém given it's positioning as a geo-religious intermediary and frontier.

Funerary Bioarchaeology of Christendom

Daniell (1997) suggests that "the key to medieval religion is the fate of the individual's soul after death", furthering the importance of eschatological framework. At a fundamental level, medieval Christianity subscribed to a dualistic model separating the living, mortal body from the immortal soul. Medieval Christian funerary rites were often concerned with the deceased's fate after death, in preparation for Resurrection (Gilchrist et al. 2005). Death brings about the separation of the soul and body, and counter to common belief, mortal (i.e. skeletal) remains were not prerequisites for the resurrection (O'Sullivan 2013a, 26). There is a long theological history that accredits God with the power to resurrect and reconstitute bodies without mortal remains (Brown 1981, 242), though it was debated (Bynum 1995a). In both *De civitate Dei* and *De cura pro mortuis gerenda* Augustine likened bodies to clothes, suggesting the concern over mortal remains was largely trite given the separation of the soul upon death (E. A. R. Brown 1981).[4] The eleventh and twelfth centuries in particular seem to have instrumental in theological discourse surrounding the spatial, physical, and metaphysical dimensions of the afterlife, with increasing attention on distinct 'spheres' such as Earth, Hell, Heaven, Paradise, and Purgatory (Le Goff 1984; McGuire 1989; Horrox 1999).

Thus, from the eleventh to twelfth centuries onwards, "Medieval beliefs about the afterlife are encapsulated not so much in the treatment of the corpse as in the resources devoted to supporting ongoing intercession on behalf of the soul in Purgatory" (O'Sullivan 2013a, 274). While the immortal soul may have been the primary focus of late medieval Christian

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[4] Augustine, *De civitae Dei* 1.12-13, 22.8-9; PL 41.26-28, 771-772; *De cura pro mortuis gerenda* 2.4-3.5, 7.9-13.16, PL 40.594-595, 598-605.

eschatology, mortal remains did continue to receive careful attention. Middle English poetry such as Signs of Death attempted to focus on the moment of death (Wenzel 1989, 719):

> "When the head trembles,
> And the lips grow black
> The nose sharpens,
> And the sinews stiffen,
> The breast pants,
> And breath is wanting,
> The teeth clatter,
> And the throat rattles
> The soul has left
> And the body holds nothing but a cloud —
> Then will the body be thrown in a hole
> And no-one will remember your soul"

By the thirteenth century, major changes were introduced via canonical decretals and papal bulls. The *Corpus Juris Canonici*, a compendium of thirteenth century canonical law, contains references both in *Liber extra* (3.28.1-14), the Papal decretals not contained in Gratian's original *Decretum*, and *Liber sextus* (3.12.1-5) published by Pope Boniface VIII on March 3, 1298. Boniface VIII in particular was disgusted by the practice of eviscerating, boiling, and dismemberment of dukes, saints, and members of the aristocracy throughout France, England, and Germany throughout the central middle ages. Prior to his bull, the practice of removing the intestines and heart prior to boiling and cleaning the bones for transport appears to have been relatively wide-spread if not "ancestral" (Brown 1981). Emperor Henry III who despite dying in Bodfeld in 1056 had his body buried in Speier next to his father, while his entrails were interred in Goslar next to his daughter Matilda (Brown 1981, 228). In England, Henry I was eviscerated and partitioned for transportive purposes, while his grandson Richard the Lion-Hearted was partitioned so that his heart was buried at Rouen next to his grandfather, while his brain, blood, and entrails were interred at Charroux, and the rest of his body at Fontevrault (Brown 1981). This practice seems to have been largely practiced in northern Europe, though the case of Alfonso X of Castile is noteworthy as it likely is a product of his ties to aristocracy across the Pyrenees. In his second will issued January 10, 1284, he stated that upon his death his body should be interred in Santa María de Murcia, while his heart was to be taken to Jerusalem and his entrails to either Santa María de Murcia or Santa María in Seville (Brown 1981, 234).

As a result, Boniface VIII issued the decretal *Detestande feritatis* on September 27, 1299 (later incorporated into *Extravaganted communes*), decreeing that the dismemberment, evisceration, and boiling of corpses would deny the individual of Christian salvation (Brown 1981). Brown (1981, 226) aptly summarizes the rationale:

> "Until the flesh had dissolved and the bones been bared, the deceased person's spirit has not fully divorced itself from the body, which is thus not fully dead. Why else the revulsion that Boniface expressed toward separating the dead flesh from the bones, and, in contrast, his willingness to permit the exhumation of bones, stripped by natural processes of decay, for transferal to another burial place?"

As Brown effectively demonstrates (Brown 1981, 253), the decretal was largely effective in quashing the partitioning and boiling of corpses for means other than transportation – partible burials heavily declined by the mid-fourteenth century, some 50 years after the papal bull was issued.

While Boniface's decretal became institutionalized as Canon Law, the ecumenical impact of the bull likely did not affect members of the general public so strongly as their aristocratic counterparts. Generally speaking, late medieval Christian funerary customs for the majority of people were typically simple and prescribed, though considerable vernacular variation exists (Gilchrist 2022, 124). The body was frequently stripped naked, washed, and extended in an East-West orientation, with head facing West towards the rising sun and arms typically placed at the side or crossed over the breast (O'Sullivan 2013a). The employment of "furnishings" (Litten 2007) has been noted in both burial and embalming throughout the middle ages, as evidenced by the employment of cerecloth (fabrics inundated with wax, often beeswax) or numerous monastic burials laid atop or dressed in sackcloth – a coarse-fibered material often made of animal hair (Korpiola et al. 2015, 22–23). Post-mortem/interment intervals could vary considerably, as the Church generally advocated for burials within five days (Korpiola et al. 2015, 22), while members of the aristocracy would occasionally be embalmed, protracting the post-mortem/interment interval (Gittings 1984; Weiss-Krejci 2008). O'Sullivan suggests that grave goods, eschatologically speaking, are "fairly meaningless" in late medieval Christian contexts and are more likely to reflect sentiments than accompaniments to the afterlife (2013a, 264), though considerable variation exists. These acts often accompany a transition of spaces and locations, often from the home, to the church, to the cemetery (Long 2009; Rowell 1977).

Mortal remains were also greatly entangled with the importance of Christian spaces and landscapes – what Hausmair (2017) has aptly termed "topographies of the afterlife." In this sense, eschatological considerations for the dead were increasingly linked to Christian notions of place, space, landscape, and architecture. Just as it was common for liturgical practices within the church as well as church architecture to reinforce Christian cosmology (Kilde 2008), cemetery spaces were increasingly attached to churches and places of worship likely as a means of facilitating entry into Purgatory (Saul 2009). For example, Ruiz Taboada (2015) suggests that the shift from extramural cemeteries to intra-mural and architectural ones in medieval Iberia began during the sixth century but culminated in the eleventh century with the Christian conquests as a result of longer changes in Christian theology and eschatology concerning treatment of the dead. In this sense, the greater religious emphasis placed on space and location of Christian cemeteries and burials resulted in the increasing development of inter-mural parish cemeteries from the eleventh to the nineteenth century (Ruiz Taboada 2013). This can be seen in the increasing association of Christian cemeteries with a multitude of religious structures, such as parishes, hospitals, convents, and churches (Ruiz Taboada 2015). Spatial proximity to sacred places and objects such as altars became increasingly emphasized due to its proximity to God (Martínez Gil 1984, 83) and thus were "coveted" spaces (Ruiz Taboada 2015, 62).

Indeed, increasing emphasis in proximity to sacred places such as the altar likely originates from the ninth century with the Council of Mainz (813 AD) which detailed special accommodation for social elites such as senior members of the clergy, patrons, and elites to be buried within the church walls (O'Sullivan 2013a, 271). Canon law also appears to have played an important role in detailing the importance of consecrated ground and who was to be buried where (Gilchrist et al. 2005; Korpiola et al. 2015, 1). Rosenwein deftly traces some of the early origins of consecration, showcasing how the "hallowing" of Christian cemeteries began in the

Carolingian period with earliest evidence in the late ninth century (1999, 179; Treffor 1996, 141–143). During the tenth century, bishops appear to have "led liturgy that included singing the seven penitential palms; marking the circuit of the cemetery by four lighted candles; sprinkling the ground with holy water; and chanting three prayers" (Rosenwein 1999, 179). By the eleventh century, at least in the case of Catalonia, bishops began fully demarcating *sagrera* ("cemeteries") in tandem with the consecration of associated parish churches, which appeared to have spanned only "thirty paces in diameter" (Bonnassie 1975, 653–656; Kennelly 1968, 107–136; Rosenwein 1999, 179).

Interestingly, the legal and spiritual protections that accompanied *sagrera* seems to have provoked all manner of living residents and even accompanying livestock to occupy the area, not just the deceased, to the extent that *sagrera* could become densely populated nuclei with accompanying shops, animal pens, and residences. Consecration of cemetery spaces seems to have increased at the end of the eleventh century, and became even more institutionalized and widespread during Pope Urban II's (d. 1099) tour to Cluny. While Urban was traveling mainly to preach in support of the First Crusades, he simultaneously associated consecration and hallowing of cemeteries with the Papacy, such as extending spiritual and legal protections in the pilgrim cemetery at Tarascon en route to Cluny (Rosenwein 1999, 181; Zadora-Rio 2000).

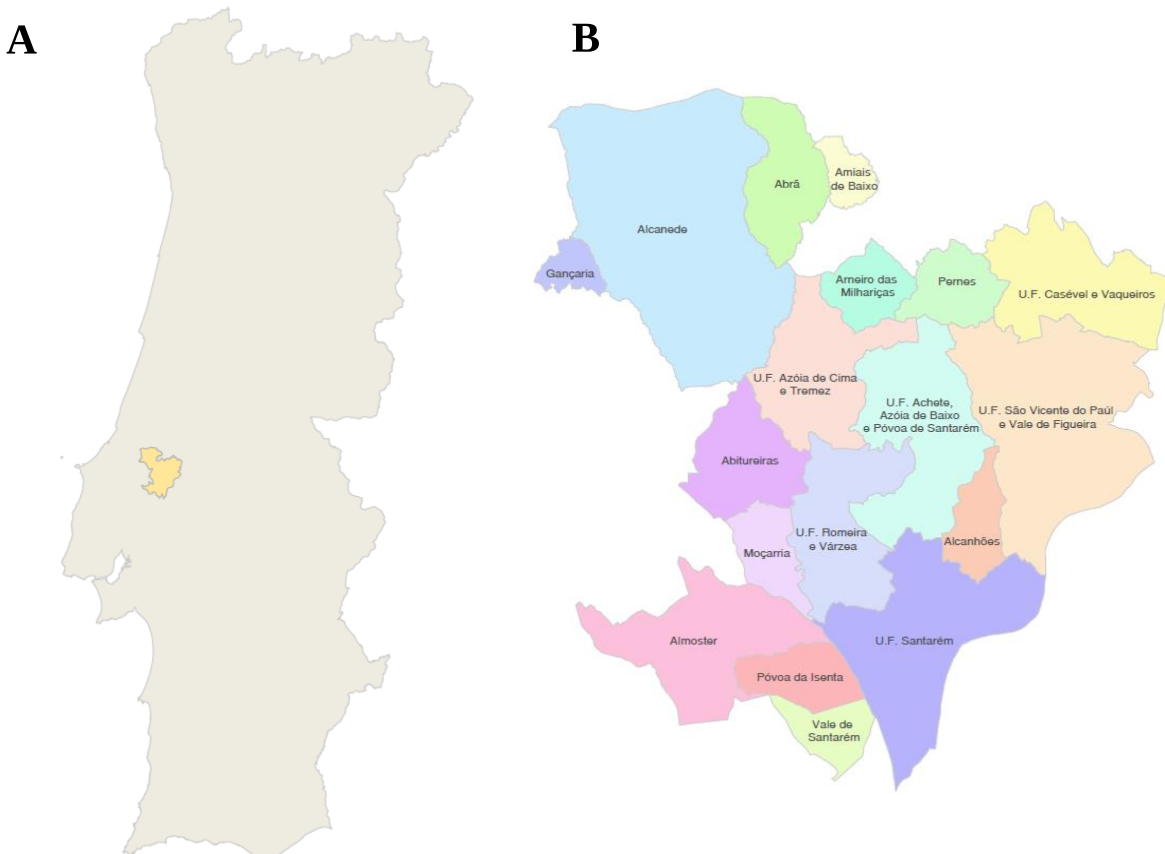
While intra-mural church burials and proximity to sacred objects may have been a concern for social elites, the majority of commoner burials took place outside in associated cemeteries. Numerous medievalists have underscored just how integral the dead were in daily life, city planning, and urban spaces (Binski 1996; Geary 1994; Gordon et al. 2000; Paxton 1990; Schmitt 1998; Tracy 2009). Similar to English churchyard cemeteries, the shift from church cemeteries to public ones in Portugal did not formally take place until the eighteenth century (Laqueur 2015). Beyond the theological concerns of caring for the dead voiced in the twelfth and thirteenth centuries, cemeteries also became a service increasingly attached with other church-supported public service institutions in Portugal, such as *albergias*, and *Misericórdias*, and hospitals (Sá 1995a). In the case of no physical church, *passais* (presbytery lands) were used for cemeteries instead (Oliveira Marques 1971). By the thirteenth century, it appears that this practice had become relatively standardized throughout much of Christendom (Schmitt 1998). This practice often reflects preexisting social hierarchies in life, with social and religious elites being buried closest to the alter and members of the public being buried extramurally in the churchyard (Saul 2009). These topographies are interesting in that they reveal inherent tension between late medieval Christian theology, marked by the idea of equality in death and the afterlife, and practice, whereby social hierarchies are spatially reinforced in burial location (Gilchrist et al. 2005).

With the general regional context of Iberia discussed and the ontological and eschatological concerns outlined, the following section will focus on the region of this dissertation research, focusing on Santarém in central Portugal.

Regional Context of Santarém.

Santarém is currently conceptualized as both a county (*concelho*) as defined by the Nomenclatura de Unidades Territoriais para Fins Estatística (NUTS), as well as a city which sits atop the plateau overlooking the Tagus river valley. Located 75 kilometers northeast of Lisbon, Santarém is located within the larger Ribatejo region. Since January 28th 2013, the county of Santarém represents a 552.5 km^2 area divided into 18 parishes (*freguesias;* Figure 3.6) as legally defined by Lei n° 11-A/2013 (Matias 2018).

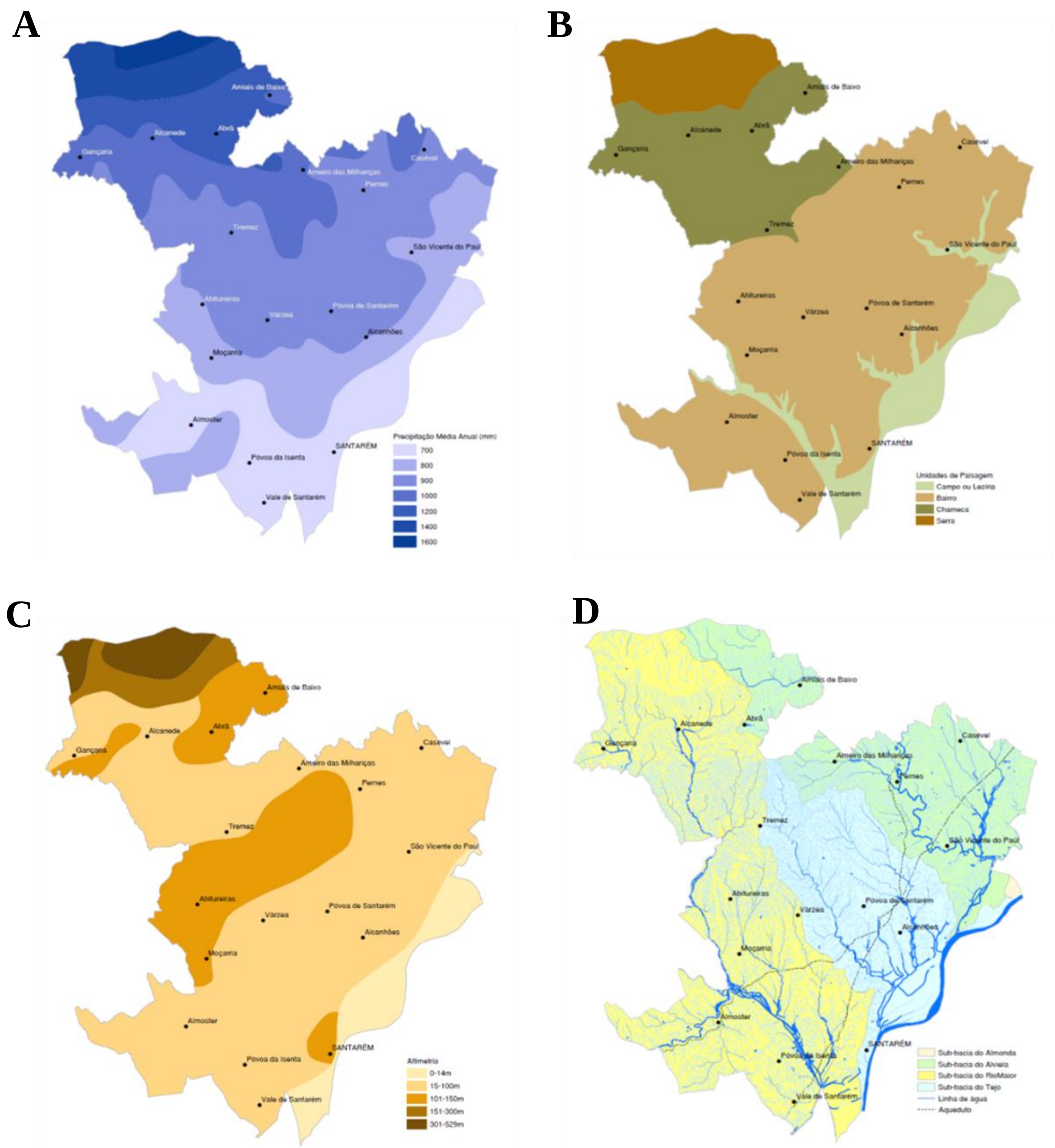
Figure 3.6 - (A) Map of Santarém in relation to Portugal. (B) Legal perimeters of the county and its associated parishes. Courtesy of Câmara Municipal de Santarém Carta Arqueológica (pg. 13-14). Drawings by Inês Serafim



Situated within the interior, Santarém has a temperate and semi-arid Mediterranean climate with hot and dry summers in the southern region and more moderate summers in the northern region. Precipitation varies throughout the region, from northwest to southeast [Figure 7 – pg. 16 from Ines] with an average rainfall of 696.5mm with highest quantities of rainfall during December (104.1mm) and lowest in August (6.2mm) (Matias 2018). The region can be further conceptualized in four principal landscape profiles (Figure 3.6; B): floodplains (*campo*/*leziria*), rolling hills (*bairro*), transitional depressions (*charneca*), and a mountainous ridge system (*serra*). The floodplains are situated in close proximity to the Tagus River and other hydrological networks, and are composed primarily of fertile alluvial soils. The majority of the area is composed of rolling hills, which is comprised of sandy clays and limestone. The transitional depressions form an intermediary between the rolling hills and ridge system in the northwestern portion of the region, consisting of predominately poor soils and forested land. Finally, the mountain ridge is situated in the most northwestern portion of the region with the highest altitude (500+ meters above sea level; Figure _C). Notably, the city proper, particularly the historical center sits atop a steep plateau (~101-105m). Hydrologically, the region is dense with riverine networks, with the principal source originating from the Tagus River, owing to its fertile fluvial landscape and aforementioned floodplains (Figure 3.7).

Geologically, the region sits predominately within the Tagus Cenozoic sedimentary basin, a smaller subset of the Tagus-Sado geologic basin. The region is comprised of three principal types of distinct geomorphology: 1) the Extremadura limestone massif within the north/northwestern areas comprised of sequential limestone deposits from the middle and upper Jurassic period (144-213 mya) and clastic sediments of the Lower Cretaceous, 2) the lowland and floodplain Tagus basin in the southeast, and 3) the transition reliefs consisting of Pliocene plateaus between the aforementioned zones (Matias 2018). The historic center of the city is situated on a limestone plateau which formed through tectonic activity paired with human interaction and superimposition.

Figure 3.7 - (A) Precipitation, (B) Principle landscape geographical features, (C) Altitude, and (D) Hydrological networks throughout the county. Courtesy of Câmara Municipal de Santarém Carta Arqueológica (pg. 13-22) . Drawings by Inês Serafim.



Culture History of Santarém

Santarém has been occupied since at least the fifth millennium B.C.E. (Matias 2018), with artifacts recovered from the Chalcolithic through the Phoenecian period. The indigenous *Moron* were colonized by Romans likely sometime in the second century B.C.E., who misinterpreting the indigenous word(s) *Sqlab* (likely from the Siriac amalgam of *šql* – 'to take,' and *ab* – 'ancestral') as a toponymic indicator, Latinized the term into *Scallabis*. By the end of the first century B.C.E., it had become an important administrative center in the Roman Empire due to its strategic location overlooking the Tagus River and agriculturally fertile landscape. *Scallabis* was one of the three *conventus iuridicus* (juridical meeting places) of Lusitania mentioned by Pliny, and was instrumental in connecting *Olisipo* (Lisbon) with *Bracara Augusta* (Braga) and the Lusitanian capital *Emerita Augusta* (Mérida, (Arruda et al. 2002; 2014).

The Hispano-Roman community of *Scallabis* was eventually conquered by Sunerico and the Visigoths in 460 C.E. who further reshaped the urban city center and plateau. Unfortunately, the knowledge of the Visigoth period of Santarém is virtually nonexistent. This is likely due to 1) issues in historiography, particularly in Romanophilic erasure of pre-Islamic inhabitants in the region as anything but Roman (Liberato 2018), 2) lack of understanding in regards to Visigoth materialities, 3) lack of many historical sources, and 4) issues in archaeological sampling. The Visigoths maintained control of the city until 714 C.E., when it was subsequently transferred to Muslim control and renamed *Shantarîn*. Whether the city was formally conquered by the son of Musa ibn Nusayr, 'Abd al-Aziz in 714 (Matias 2018) or administratively transferred as according to Muhammad ibn Musa al-Razi (Custódio et al. 1996a) is still unclear. While the city was incorporated under the Umayyad Caliphate from 714-756 C.E., it continued to remain under Islamic control during the Abassid period from 756-929 C.E. and reached its "Golden age" under the emirs of Badajóz, who administrated much of central Portugal and what is now Extremadura during the Caliphate of Córdoba (929-1031 C.E.) and Taifa period (1009-1111 C.E.). Interestingly, Santarém was granted by the king of Badajóz 'Umar al-Mutawakkil to the Christian king Leão D. Afonso VI in 1095 C.E., where it became an important outpost for the Christian kingdom of Léon for a brief period between 1095-1111 C.E. in an otherwise Islamic territory. The final Islamic occupation period of the city was by the Almoravids, who re-took Santarém from the Christian kings. In a letter to the caliph Yusuf, Sir Ibn Abe Bar stressed the important strategic location of Santarém: "its location commands all of the access to the South of the Tagus, connecting Lisbon, Sintra, and Balata to this city" (Custódio et al. 1996a, 70), warranting its reacquisition into the Islamic cultural domain. A revolt in 1144-1145 C.E. weakened the Almoravid's control of the city and likely permitted the Christian conquests to be so successful in 1147 C.E.

Throughout the larger Islamic period, the city underwent urban changes and renovations. It is likely that the early phase of Islamic occupation was accomplished by the expansion and under the influence of the caliphate in Córdoba, and that Santarém constituted a religious frontier between the Christian kingdoms in the north and the Islamic controlled south (Sidarus 2007). The Islamic incorporation of the city by al-Hakam I in the early 9th century and consequent construction of the main mosque did not seem to coincide with radical Islamization of the region, per se (Sidarus 2007, 321).

Both Christian and Islamic sources describe the defense system of *Shantarîn* as an "open circle," where the *alcáçova* was partially fortified during the first half of the 12th century under the government of Yahya ibn Ghaniya (Abu Zakkariyya). Given the strategic positioning of the *alcáçova* atop the plateau, subsequent networks were developed to link the plateau to the lower riverside areas, such as the *Alpram* – located at the isthmus of the plateau and reinforced with defensive structures (walls, towers, bastions) during the Almoravid period, *Seserigo* - now the Ribeira, east of the citadel alongside the Tagus river, and *Alfansi* - now the Alfange, southeast of the citadel, downstream from *Seserigo* and with more immediate access to the plateau (Matias 2018). The city expanded in multiple directions, North until Vale do Gaião, South until Igreja de Santo Estavão, West until the Porta de Manços and likely included nearly 3,500 people at its height (Matias 2018).

According to the Islamic geographer Ibn Hawqal, *Shantarîn* had already transformed into a "modern" city by the tenth century (Matias 2018, 29). The city was home to many famous Arabic poets, notably Abu Muhammad ʻAbd Allah Ibn Sara (al-Shantarini), Abul I-Hasan ʻAli Ibn Bassam (al-Mutawakkil), Abu ʻUmar Yusuf Ibn Qausar (as-Shantarini), and Abu ʻAbd Allah al-Hijari. Various Islamic geographers highlighted in particular the presence of public hygienic baths along the S. Mateus slope (Matias 2018), in addition to the *Omnias*, or horticultural gardens, and Santarém's important proximity to the "Nile of al-Andalus" – the Tagus river (Custódio et al. 1996a). Agriculturally, the region was known for its rich fluvial floodplains and cultivation of cereals, wine, and olive oil (Custódio et al. 1996a). In the last quarter of the 11th century, Al-Hakkam II commissioned the construction of the mosque within the city in order to further develop Islam's presence within the region (Conde 2007). It is likely the mosque was constructed where now the Igreja de Santa Maria de Marvila (39.235, -8.681) stands today, and was not only the central point of the city from the 11th century onwards, but became the major civic center and host to the large open-air market (*sûq*) that existed from what is now Praça Visconde Serra do Pilar to the Igreja de São João de Alporão (Matias 2018). It is unknown whether other mosques existed throughout the city either preceding or post-dating al-Hakam II's commission. It is possible that a mosque was erected within the *alcáçova* during the early Islamic period, but as of yet, neither archaeological nor archival evidence supports this (Liberato, personal communication 2020).

Despite this urban expansion and renovation, the city likely did not experience overcrowding or over-densification, at least until the 12th century. Throughout numerous cities in Iberia, Islamic influence in urbanization was not about density, but rather maintaining a balance of urban nuclei with dispersed open spaces (Navarro Palazón et al. 2004; Santos et al. 2018). One of the goals of this dissertation was to evaluate this process in more detail by obtaining radiocarbon dates from Islamic burials throughout the city, which can be seen in the next chapter (Chapter 4).

Religious Minorities in Šhantarîn

Given it's positioning between the Islamic-controlled South and northern Christian kingdoms, Shantarîn is often best characterized as an "ambivalent frontier" (Sidarus 2007, 319). Yet, numerous religious and ethnic minorities lived within the city during periods of control by other religious groups, and this geo/political/religious frontier became a nexus of differing forces of control and tolerance. The takeover of the city itself, according to Muslim chroniclers, permitted relative autonomy by incorporating local pre-existing social structures into the fold of Islam (Sidarus 2007, 320). Non-Muslim religious minority communities (e.g. Christian and Jewish communities) experienced varying degrees of tolerance and persecution during the Islamic cultural period (Ray 2005). Fernando Dominguez Reboiras stated that religious tolerance was likely not explicitly religiously codified so much as a "necessity of integrating under the political system of a factual social reality" (Mata et al. 2004, 13). Relations were likely friendly between Muslim and Christian communities, at least in the case of the Monastery of Lorvão, where monks seemed to have experienced good relationships with neighboring Muslims in the region of Coimbra, as evidence by their testimonies (Mata et al. 2004, 13). But in the case of Santarém, religious tolerance (*convivencia*) may well have been born out of convenience rather than doctrinal or theological acceptance. According to Muhhamad Ibn Mazayn, Santarém was one of three cities where religious autonomy was granted to non-Muslim communities (Domingues 1997, 19; Mata & Mata 2004, 10). Yet Mata and Mata (2004, 11–12) caution that such acceptance and tolerance was likely a strategic maneuver that helped to establish newfound Islamic authority within a pre-existing social system, and exercise tax (*jizya*) payments in exchange for freedom of worship. As stated above, the *Dhimmi* system and accompanying *jizya* tax in Santarém may well have been employed as a means of 'softening' hegemonic presence. Generally, from the Tagus river and north, inter-faith relations were built largely on pacts and negotiations between Islamic and neophyte communities (Real 2015). In fact, it appears that under the Umayyad caliphate, local neophyte ecclesiastical structures were even retained such as in the case of Lisbon (Epalza 1994, 391–392; Real 2015, 40). Rather than emphasizing forceful conversion, retaining religious autonomy under the *Dhimmi* system likely pulled triple weight, in avoiding uprisings, generating revenue on taxable religious minorities, and adhering to scriptural precedence (Real 2015, 40–42). In some cases, hegemonic control was more extreme, such as in the aftermath of the battle of Soure (1145-1146 C.E.), where governor of Santarém Abû Zakariyyâ took the vanquished Christians captive and utilized them as slave labor to construct the walls of the citadel (*alcáçova*) (Cardoso 2001, 64; Custódio et al. 1996a, 74–75; Mata & Mata 2004, 14). However, Sidarus suggests that the fertile river floodplains connecting Santarém and the Tagus river to Coimbra and the Mandego river experienced considerably less Islamization of the region compared to other regions within Portugal and Iberia more broadly (Sidarus 2007). The result likely consisted more of an autochthonous communities under Islamic rule ("*moçárabes*") than Islamic and Berber communities themselves.

Christian conquests and the Later Medieval Period

The Islamic dominion over Santarém came to an end on March 15, 1147, when D. Afonso Henriques I arrived with an army ~7,000 troops and additional ~13,000 crusaders, canonically referenced in *De expugnatione Scallabis* (Lopes de Barros 2004; Calado 1998, 45). *De expugnatione Scallabis* is the colloquial name attributed by Alexandre Herculano in 1854 to the Latin document *Quomodo sit capta sanctaren civitas a rege Alfonso comitis Henrici filio*. The document, likely written by a monk associated with either the Cathedral of Coimbra (Nascimento 2005) or Santa Cruz (Cintra 1951) at the turn of the thirteenth century, celebrates the successful seizure of Santarém from Islamic control by the first king of Portugal D. Afonso Henriques I. The Christian (re)settlement of Santarém is canonically referenced as part of the larger "Reconquista." While there is evidence that Islam was being presented in monastic circles of occupied Spain as an intolerant or violent faith since the ninth century (Mata & Mata 2004, 13), stereotyping increased as part of the larger Crusades movements, stemming from the First Crusades preached by Pope Urban II in 1095 and the accompanying Council of Clermont. Subsequent stereotyping through "Clerical propaganda" ramped up in the twelfth century, as evidence by Roberto the Monk's testimony in 1107 where he described Muslims in an apocryphal manner, followed by subsequent chroniclers such as Lucas de Tui's *Chronicon de Mundi* (c. 1211), Rodrigo Jiménez de Rada's historical analysis (c. thirteenth century), and Afonso X's (1221-1284) *Primeira Crónica Geral de Espanha* (Mata & Mata 2004, 13).

Broadly speaking, the city changed from being an Islamic military and cultural center to an important Christian religious center (Custódio et al. 1996a). Starting in the second half of the twelfth century, the arrival of various religious orders such as Hospitallers, Templars, friars of Santiago de Uclés and the order of Calatrava to the city helped to establish Santarém's religious importance. The subsequent arrival of mendicant orders, principally Dominicans and Franciscans, as well as renowned friars such as Gil of Santarém, Bernardo of Morlans, and Saint Anthony of Santarém, attest to the city's increasing religious importance from the thirteenth century onwards. The mendicant orders and monks established numerous friaries and monasteries beyond the walled fortifications of the city, including the monasteries of Trinidade (1210), São Domingos dos Frades (1225), São Francisco (1242), Santa Clara (1259), and Donas de São Domingos (1289). Various holy miracles, such as the Santo Milagre of 1266 C.E., resulted in the city becoming an important destination for religious pilgrims (Custódio et al. 1996a).

Santarém experienced increasing restructuring and urban densification after the Christian conquests (Liberato 2018; Liberato et al. 2017). By the fourteenth century there were fifteen parishes with numerous religious institutions, and Santarém became solidified as an important religious pilgrimage city both for its own miracles and situation along the Santiago de Compostela. Urban communities resulted in a densification within the city center while maintaining agricultural intensification in the surrounding landscape, and ultimately facilitated mercantilism, trade, and wealth within the city (Freitas Leal 2007). Thirteenth century documents chronicling the presence of jugglers and troubadours attest to the city´s importance and wealth (Freitas Leal 2007, 64). By the fourteenth century, it was likely one of the most urbanized cities within the Portuguese kingdom, as evidenced by number of courts and convents (Freitas Leal 2007), often hosting the Portuguese royal court from the twelfth through fourteenth centuries (Braga et al. 2007). The dense urban meshwork comprising of dendritic avenues and two story edifices seen today are likely a remnant of the later medieval urban network, where shops were often situated on the first floor and familial residences on the second story (Freitas Leal 2007).

Strongly linked to its religious importance, Santarém was an important city for medical treatment as well (McCleery 2005, 198). Dominicans appear to have been particularly sought after, for their role as both friars and healers. Maria Gonçalves, suffering from a fistula, was prescribed earth from the surrounding tomb of Gil de Santarém, which seemed to cure her pain where other prescriptions had failed (Resende et al. 2000, 582). Domingas Pires brought her son suffering from a nosebleed to the friars Andre and Bernardo. After thirty paces of leaving, he was apparently cured (Resende et al. 2000, 504–507). McCleery has astutely noted that Gil de Santarém as "both physician and healing saint, was extraordinarily useful tool to disseminate the faith around Santarém and its environs" (McCleery 2014, 150). In the case of medieval Santarém, the lines between metaphorical and physical prescriptions in the treatment of ailments were likely blurred (McCleery 2005).

In addition to the Mendicant orders, other church-sponsored edifices such as *albergias* and *Misericórdias* helped to provide various social services to pilgrims and the poor. Sá (1995b) has noted that, while in theory *albergias* serve pilgrims and vagabonds and hospitals were reserved for the sick, in practice the establishments were one in the same. The establishment of Portuguese Christian hospitals date to at least the thirteenth century, with the founding of the Hospital dos Meninos Órfãos (Hospital of the Orphaned Youth) in Lisbon, and the early fourteenth century orphanage hospital in Santarém (Reis 1988; Sá 1995b). Similarly, the

Misericórdia system was codified and operationalized by the second half of the twelfth century, and played a major role in the physical and visible means of alms distribution to the poor (Sá 1995b). At a local level, religious confraternities were also instrumental in the performance of various services, such as attending wakes and carrying out burials. Religious fraternities expanded throughout the twelfth century in Portugal, possibly in response to monastic orders devoting little attention to the needs of the poor (Mattoso 1973; 1985). In some cases, various local fraternities joined together to become Misericórdias, whereas in others, they competed with one another, likely as a result of the aforementioned importance placed upon the optics of almsgiving (Sá 1995b). Hospital administration was generally carried out by lay people, except for in the case of Benedictine hospitals in the North (Sá 1995b). While canon law forbade the use of donations outside of what the donor had prescribed, lay administrators often invoked unfamiliarity with cannon law in order to divert donations as needed. Late medieval Portuguese hospitals served two important and 'symbiotic' functions: corporeal services in the form of housing, bedding, and healthcare, and services of the soul in the form of masses and sacraments provided by the clergy. In this sense, late medieval hospitals and their services were constructed much in the very same ontological framing of the body/soul dualism. Due to the religious framing of assistance programs, hospitalization and treatment services became legally subjected to canon law, and were architecturally constructed as similar to cloisters with their own alters, bell towers, and cemeteries (Sá 1995b).

The relationship between piety and suffering is worth further discussion here, even if the geographical scope must be widened. In the case of Verona, Italy, early medieval institutions such as *xenodochia* transitioned from being hostels for pilgrims and travelers to care-giving facilities (Miller 1993, 87). Notably, *xenodochia* were not formally associated with religious institutions, but were often spatially and juridically separate. This contrasts with twelfth century leper hospitals which treated lepers (*malsani*) and were more formally religious in both their establishment and juridical proceedings (Miller 1993, 87). Curiously, those who cared for the *malsani* were themselves lay people (*conversi*), who shared in the religiosity of their patients by helping them. In other words, the lepers of Santa Croce for example were religious precisely *because* of their suffering and sickness — they were valorized for their sharing of Christ's own suffering. As Miller states: "To *be* poor and infirm was a religious life, a Christ-like life" (1993, 91, emphasis in original). As such, by the later Middle Ages, valorization of poverty and suffering may well have facilitated

Significant cultural and legal transformations for the city's residents were enacted as part of the religious and urban restructuring of Santarém and Portugal more broadly after the Christian conquests. Until the end of the fifteenth century, Portuguese monarchs had permitted coexistence among the three religious groups. They often lived in the same physical space, resulting in social ties of coexistence. In cities such as Lisbon, Almada, Palmela and Alcácer, Muslims were permitted to continuing practicing their dress, customs, and rites under D. Afonso's decree in 1170, but while they enjoyed some freedoms, many were heavily dependent on the Portuguese Christian nobility and monarchs (Oliveira 2015, 206). Many of the Islamic public structures such as stores, baths, jails, schools, the corral, cemetery, markets, and places of worship were all taxed, and held little to no political or financial influence in their communities. By 1215, the Fourth Lateran Council imposed segregation laws between religious communities, forcing Jews and Muslims to live apart from their Christian counterparts, typically in the outskirts of the urban city centers (Oliveira 2015, 206–208). Over the next two centuries, Christian leaders ramped up marginalization efforts through the passing of sumptuary laws, marriage prohibitions, and strictures on legal representation, to name only a few (Lopes de Barros 2004; 2005; Oliveira 2015). Sumptuary laws enacted by the church in particular, seem to have enforced bodily prohibitions and separations within and between religious communities. In 1340, a sumptuary law was issued from Cortes of Santarém, consisting of 29 decrees (17 on dress, 6 on food, and 6 other) with the goal of diminishing extravagance and gluttony among the city residents, and likely conserve finances in order to continue funding ongoing wars with Moorish forces in the south (Oliveria Marques 1980; 2015). Article #8 for example depicted what could be worn down to the type of fabric, whereas Article #21 made prescriptions on hairstyles, which could be punishable by fines ("*pagar estas dez libras*") or imprisonment ("*iasca na prisom dez dias"*) (Oliveira Marques 1971, 65). If we are to take Article #8 at face value, it suggests a sufficient piece of fabric was needed in order to meet the length requirements of "three fingers from the earth" ("*andem da terra alçados três dedos"*), at least 7.2 yards by Oliveira Marques' calculations to make the tunic and surcoat (*pelote*), and 6 yards to make the normal mantle (*çorames*) (Oliveira Marques 1971, 66). The poor and general laity were limited to a surcoat, tunic, and mantle, with accompanying price ceilings imposed on the fabric for mantles ("*30 soldos an ell*") so that the general public could not wear the vestments of the nobility, and thus be visually distinguished from the wealthy (Oliveira Marques 1971, 65–72).

While sumptuary laws sought to visually distinguish class difference among members of the same faith community, they also sought to reinforce inter-faith community boundaries. Lopes de Barros (2005) effectively demonstrates that clothing was a major social denominator between faith communities, and such demarcations were likely accentuated as a result of church decrees. In the fourteenth century, Christian sumptuary laws forced specific clothing regimens for Islamic communities — namely the wearing of *aljuba* and *burnous* — which ultimately resulted in protests in Moura during the reign of King Pedro I (1357-1367) (Lopes de Barros 2005, 9). By the fifteenth century, King Afonso V (1438-1481) enacted further sumptuary laws under the *Ordenações Afonsinas* which regulated permissible Islamic garb, such as the *aljuba* (*al-gubba*) and *albornoz* (*al-burnus*). The goal of these laws appears to have been in reinforcing the importance of visual surfaces as signifying and thus distinguishing faith communities, and social status as well. Brafome, a Muslim from Setúbal, was allowed to wear silk garments ('*assy gibooes como em outras rroupas'*) as long as they were covered under his 'Moorish costume […] and not in another manner' ('traje de mouro […] e outra maneira non').[5] As Lopes de Barrros (2005, 10) eloquently argues: "At least throughout the fifteenth century, Muslims dressed exactly like Christians, under those large cloaks." While religious minority communities likely negotiated sumptuary laws through either the layering of vestments or even public wearing of them, public protests continued to take place throughout the later medieval period. In 1451, protests in Santarém took place whereby Christian communities pleaded the court to enact stricter regulations, as Jewish and Muslim communities wore 'Christian' fabrics and clothing which prevented social differentiation and '*a nobreza per vestidos*' ('the nobility of dress') that Christian communities were entitled to.[6] King Afonso V ultimately sided with the Christian laments, but made an exception for parties and receptions whereby religious minorities could wear what they wished without repercussion (Lopes de Barros 2005, 10). Christian protesters in Evora in 1482 ultimately won a legal debate citing canon law in order to dictate that Muslim communities must wear their cloaks closed by default, and when opened must display a "visible

[5] 25 April 1466, I.A.N./T.T., *Chancelaria de Afonso V*, Book 14, fol. 61.
[6] I.A.N./T.T., *Suplemento de Cortes*, Packet 2, fol. 44v.

red crescent at the height of the shoulder" to distinguish them in public.(Lopes de Barros 2005, 10).[7]

These laws even seem to have extended to prohibiting even the touching of Christian items of worship by non-Christian communities. Archbishop of Braga, Luís Pires, decreed on Dec. 11, 1477 that Jews and Muslims could not repair clothing or objects belonging to the Catholic Church[8] due to "*pollo odio e avorrecimento que teem aa nossa sancta fé catholica*" ('on account of their hatred and abomination of the holy catholic faith') (Lopes de Barros 2005, 4). In this sense, the church articulated that contamination via touch was defined on religious lines. Finally, laws extended extra-somatically to restructure space, architecture, and urban planning along religious delineations. In a request to King Pedro I in 1361, Christians demanded spatial segregation from their Muslim and Jewish neighbors, citing the "*scandalo e noio*" ('scandal and disgust') they were forced to endure (Oliveira Marques et al. 1986, 52). Consequently, the king decreed that "in places where more than ten Muslims or Jews lived, they should have separate quarters (Lopes de Barros 2005, 5). Muslim communities were forced to live in circumscribed ghettos termed *Mourarias*, which in the case of Santarém may well have been situated northeast of what is today Praça Visconde Serra do Pilar through the Escadinhas do Santo António.

The king even passed a decree in 1366 banning Christian women from entering neighborhoods of Islamic and Jewish communities unless absolutely necessary.[2] Ironically, this was not out of protection but of fear of the Christian woman giving in to adulterous lust on behalf of the "devilish" religious minorities, which was punishable by death (Lopes de Barros 2005, 8). Not long after, Christians complained and effectively suppressed the Islamic call to prayer by the muezzin (*adan*) citing canon law[3] in their defense (Lopes de Barros 2005). The public baths once used by their Islamic predecessors were condemned by Christian rulers for being too promiscuous (Oliveria Marques 2015). While baths in the city gained appreciation under Islamic rule due to their ritual, spiritual, and hygienic significance, shifting notions of the body in Christian ideology and the subsequent impartation of shame rendered the buildings obsolete (Lopes de Barros 2005).

Recent and ongoing bioarchaeological investigations are beginning to shed light on the potential health impacts of the Christian conquests on residents of the city. Recent research on sub-adult skeletal remains throughout the city demonstrated that Christian skeletal remains after the Christian conquests showed increased signs of stress and compromised growth and development compared to their Islamic pre-Christian conquest counterparts (Gooderham et al. 2019). The authors interpreted these findings as suggestive that the Christian conquests was not only disruptive, but likely accompanied by a decrease in quality of life for subsequent residents of the city, possibly as a result of urbanization, densification, and changes in sanitation and hygienic infrastructure.

Sites and Materials Analyzed in this Study

The materials analyzed in the present study harken primarily from two archaeological cemetery sites: Avenida 5 de Outubro (Av5Out) and Largo Cândido dos Reis (S.LCR). These sites were chosen because: 1) they both contain human skeletal remains from both the Islamic period and post-Christian conquests, and 2) they both are situated within or near the historical

[7] I.A.N./T.T., Núcleo Antigo, n 188, fols 172v-173.
[8] *Synodicum Hispanium*, *II Portugal*, pp. 132-133.
[2] Chancelarias Portuguesas. D. Pedro I (1357-1367), doc. 1131, pp. 535-536.
[3] Arquivo Municipal da Câmara Municipal de Lisboa [A.M.C.M.L.]. Libro Primeiro de Cortes, art. 17, fol. 68v.

city center, and therefore likely represent proximal cemeteries for everyday residents. Both sites were excavated in response to urban development projects, and subsequently deriving their names from the associated toponymic landmarks.

Avenida 5 de Outubro (Av5Out)

Avenida 5 de Outubro (S.Av5Out; also referred to as Rua 5 de Outubro) was carried out in two separate salvage excavations, one from August 2007 - June 2008 and the second in 2009. Situated adjacent to Avenida 5 de Outubro, the avenue where it derives its name (39º14'08.1"N 8º40'45.9"W), the site is located in relatively close proximity (~300 m) to the *alcáçova* (39°14'02.1"N 8°40'33.3"W). Excavations revealed a cemetery complex that spanned from the Roman period through the medieval period, as evidenced by varying funerary deposits (Liberato 2012).

Sample and Demography

A sizeable sample (n = 41) of Roman burials were discovered at the site, characterized by extended decubitus dorsal position of the corpse and generally in a southwest (head) – northeast (feet) orientation, though it was variable (Table 3.2). Some showcase direct relief into the underlying bedrock (e.g. Ent. 777, Ent. 1539) while others showcase larger, delineated tomb structures outlined in stone blocks (e.g. Ent. 1668). Some burials were found with rock or ceramic inclusions, likely from lid coverings to protect the body as evidenced by relief side-walling encircling the outline of the tomb structure (e.g. Ent. 1539). A small series (n = 8) of Visigothic burials were also discovered, often characterized by delineated tomb-like structures constructed of stone blocks, and likely evidence of wooden coffins used as burial containers judging by the presence of associated nails (Liberato 2012, 6). From a funerary perspective, the skeletal evidence appears to confirm this, as numerous individuals (e.g. Ent. 640) showcase signs of disarticulation, rotating lateralization of the femora, and overall signs of decomposing in empty space. The majority (n = 90) of burials excavated were in the Islamic funerary tradition, characterized by relatively narrow and shallow earthen graves, with the bodies found in right decubitus lateral position, with a southwest (head) – northeast (feet) orientation (e.g. Ent. 956), though some minor degrees in orientation were observed (e.g. Ent. 955). Subsequent excavations found a number of burials (n = 60) likely dating to the later medieval Christian (post-Christian conquests) period, though absolute chronometric dating is needed to confirm this.

The total sample analyzed in the present study can be seen in Table 3.3. Unfortunately, no taphonomic study (Chapter 10) was able to be carried out on the remains from Avenida 5 de Outubro, due to timing issues associated with the COVID-19 (SARS-COV-2) pandemic in Spring 2020.

Table 3.2 - Number and distribution of burial typologies at Avenida 5 de Outubro

Typology	N	%
Roman	41	25.00
Visigoth	8	4.88
Islamic	90	54.88
Ossuary	6	3.66
Cremations	9	5.49
Indeterminate	10	6.10
Total	**164**	**100**

Table 3.3 - Distribution of individuals analyzed at Avenida 5 de Outubro

Funerary group	*Sex*	*18-29 yrs*	*30-49 yrs*	*50+ yrs*	*Indet.*	**Total**
Islamic	M	3	4	4	1	**12**
	F	3	10	11	-	**24**
	Indet.	-	-	-	2	**2**
Christian	M	4	5	3	2	**14**
	F	2	3	3	-	**8**
	Indet.	-	-	-	3	**3**
Total		**12**	**22**	**21**	**8**	**63**

Largo Cândido dos Reis (LCR)

The site of Largo Cândido dos Reis (S.LCR, Municipal site n° 74) was carried out as a salvage-municipal excavation between July 12, 2004 and September 30, 2005. Located adjacent to where the W Shopping center is today (39°14'01.8"N 8°41'10.1"W), it is situated just outside of the Porta de Manços and approximately ~830 m from the *alcáçova* and some ~616 m from Avenida 5 de Outubro. The site was carried out in response to urban development projects, principally municipal efforts in reconstructing sanitation and sewer networks throughout the city.

The site is comprised of two principle necropoles: one Islamic (with an area of at least 9681^2 meters) and the other a late medieval transitioning into early-modern Christian cemetery, likely associated with the ancient hermitage of Santa Maria Madalena (13th c.) and now integrated into the Centro de Saúde for the city (Matias 2008a; 2008b). The cemetery was used possibly until the seventeenth century with the establishment of the Third Order of Saint Francis which largely replaced and integrated the previous hermitage of Santa Maria. A total of 639 (n = 422 Islamic, n = 217 Christian) burials were excavated at the site, though this likely represents a smaller portion of the total cemetery currently superimposed by modern urban development. The true extents of the entirety of the cemetery are currently unknown.

Geologically, Largo Cândido dos Reis comprises of chalky limestone and clays, with clay horizons often superimposed on the lime substrates (Matias 2008a). In some cases (n = 72, 17.06%) Islamic burials were situated directly in clays while the majority of tombs were created through the direct relief of limestone (n = 350, 82.94%). However, it appears that graves within the clayey soils were deliberately constructed there in levels preceding underlying limestone (Matias 2008a). Additionally, numerous graves within the northeastern portion of Sector 2 were made in direct relief of limestone, but filled differentially with other sediments, such as clayey soils (Matias, 2008b). Similarly, the majority of Christian primary inhumations (n = 184, 84.79%) were created through the relief of chalky limestone, with the remainder situated in sandy substrates (n = 33, 15.21%).

Sample and Demography

The total sample analyzed in the present study can be seen in Table 3.4 whereas Table 3.5 shows the ratios of non-adults to adults and males to females. Clearly, there is an underrepresentation of sub-adults for both funerary groups compared to what we would expect (Jackes 2000; 2011b; Waldron 2007). Demographic distributions of pre-industrialized communities typically tend to exhibit a U-shaped age-at-death mortality pattern, with upwards of 30% of the total community comprising of juveniles and sub-adults (Waldron 2007, 35). In the case of Largo Cândido dos Reis, only 15% of Islamic and 26% of Christian burials were sub-adults. This suggests that sub-adults were preferentially buried elsewhere, which was a frequent occurrence in medieval Islamic cemeteries (Petersen 2013), disposed of differentially than adults, or simply not within the confines of the excavation. From a demographic perspective the gender breakdown is also concerning, with higher prevalence of males in both funerary groups (Islamic = 1.24, Christian = 1.98). The Christian group is particularly noteworthy, with almost double the number of males as females. Given the relationship between the Christian cemetery and Santa Maria Madalena, it is possible the overrepresentation of males is due to economic access to the burial churchyard rather than a reflection of the living community's demography. When funerary groups are collapsed the ratio of males to females is 1.52, with 50% more males than would be expected in a typical population. Altogether, the demographic distribution of Largo Cândido dos Reis is likely a skewed assemblage of the larger living communities within medieval Santarém.

Table 3.4 - Distribution of individuals analyzed for preservation at Largo Cândido dos Reis

Funerary group	*Sex*	*18-29 yrs*	*30-49 yrs*	*50+ yrs*	*Indet.*	**Total**
Islamic	M	6	13	20	60	**99**
	F	6	10	14	39	**69**
	Indet.	-	-	-	59	**59**
Christian	M	12	25	11	28	**76**
	F	5	8	15	15	**43**
	Indet.	-	-	-	17	**17**
Total		**29**	**56**	**60**	**218**	**363**

Table 3.5 - Ratios of non-adults to adults and males to females at Largo Cândido dos Reis (data from Matias 2008b).

Funerary Group	**Category 1**	**Category 2**	**Ratio**
	Non-adult	*Adult*	
Islamic	48	258	0.19
Christian	57	160	0.36
	Male	*Female*	
Islamic	107	86	1.24
Christian	101	51	1.98

Chapter 4: Radiocarbon dating of Islamic burials in Santarém, Portugal

Introduction

This chapter focuses on radiocarbon samples from the city of Santarém, Portugal, located some 80 km northeast of Lisbon. Documented as one of the most northern Portuguese sites containing burials in the Islamic funerary tradition (see Gonzaga 2018: 226), Santarém can arguably be characterized as a cultural, religious, and geographical 'frontier' during the medieval period (Viana 2004; Sidarus 2007). The role of Islam during the Middle Ages (c. AD 500 — 1492) in the historical formation of both Spain and Portugal was relatively underappreciated until the latter part of the 20th century, which saw a burgeoning with the development of medieval archaeology. Since then, scholars have sought to better understand the social, political, and chronological dimensions of al-Andalus, the Islamic cultural domain (c. AD 711 — 1492) within the Iberian Peninsula. Due to its geographic location in the northern portion of Portugal, the city of Santarém was likely a religious and cultural frontier during the Middle Ages, bordering the Islamic-controlled South and Christian-controlled Northern kingdoms. In response to urban development projects throughout the historical city center, mitigative municipal and private excavations have revealed the presence of numerous Islamic cemeteries ("*maqabir*"), characterized by the immutable presence of burials in the Islamic funerary tradition. This chapter presents 14C samples from n = 18 human bone samples from various Islamic burials throughout the city, in order to: 1) broadly understand the chronological dimensions of Islamic burials, 2) characterize intra-cemetery chronologies, and 3) evaluate whether the geographic positioning of Islamic cemeteries throughout the city coincides with urbanization and expansion during the Islamic period. Results show a strong continuity in religious funerary traditions for nearly four centuries, with some cemeteries being utilized for at least a century or more. Additionally, results support the hypothesis that Islamic cemeteries were increasingly situated westward, coinciding with urbanization and expansion of the city during the Islamic period. Results are discussed alongside other Iberian frameworks for urbanization and funerary treatment in the central Middle Ages.

Although chapter 3 covers much of the historical dimensions, materials, and context of this dissertation, a brief synthesis is worth repeating here for further contextualization. Al-Andalus — the name given to the nearly eight-hundred year (711 AD – 1492 AD) Islamic cultural domain within the Iberian Peninsula — has proven both a fascinating and complicated area of historical and archaeological inquiry. Historiographically, al-Andalus and the Islamic period more generally were de-emphasized during the nearly four decades of Iberian dictatorships (Ballard 1996; Lopes de Barros 1999; Vakil 2003; García Sanjuán 2008). These regimes highlighted the importance of 1) a Greco-Roman and Christian substrate pre-dating Muslim occupation, and 2) the "Reconquista" — the militarized conquests of the Iberian Peninsula by northern Christian kings — as a decisive victory in "re"-claiming Christian lands. The emphasis on Christian continuity from the Roman period throughout the Medieval Period into contemporary Iberian national identity was emphasized along with the 'disinheritance' of an Islamic past (Díaz-Andreu 1996; Kamen 2007). Close affiliation with *Romanitas*, or Roman-ness, in the creation of national identity is not entirely unsurprising given the long and selective curated historiography emphasizing Greco-Roman empires at the expense of other influences (Dietler 2005; Liberato 2018). Accompanied by the end of the respective Iberian dictatorships, the latter half of the 20th century saw a burgeoning of scholarship on the Islamic period and the increasing role of medieval archaeology (Barceló 1993). Perhaps one of the most consistent material signs of Islamic presence throughout Iberia is the presence of Islamic burials (Chávet et al. 2006). Medieval Islamic burials are frequently characterized by being buried on their right side in lateral decubitus position, with a southwest (head) - northeast (feet) orientation, facing the direction of Mecca (Petersen 2013; Chávet et al. 2006). The presence of Islamic cemeteries ("*maqabir*") throughout both Spain (Chávet et al. 2006) and Portugal (Gonzaga 2018) speak to both the geographic and diachronic dimensions of Islam during the Middle Ages.

Despite their strong presence and ease of identification, Islamic burials are often difficult to situate chronologically within Portugal. Much of the Islamic funerary rites in medieval Portugal adhered to Maliki jurisprudence, which advocated for narrow, simple earthen inhumations with a distinct lack of grave goods, in part to 'level' inequalities present within life such that burials appeared similar in death. As such, the lack of grave goods or other materials to help contextualize their depositional history, paired with a general lack of stratigraphic differentiation, has proven difficult to chronologize (Andrew Petersen 2013). While Islamic tombs appear to vary significantly in parts of Spain, such that chronological typologies are possible to distinguish (Chávet et al. 2006), many tombs within Portugal adhered to simple earthen inhumations (Gonzaga 2018). Consequently, many burials excavated throughout the city appear remarkably similar to one another, despite being from completely differing sites and likely occupations of the city, necessitating a direct sampling of burial contexts in order to characterize their chronology.

The Hispano-Roman community of *Scalabis* was conquered by Sunerico and the Visigoths in 460 AD who further reshaped the urban city center and plateau. Unfortunately, the knowledge of the Visigoth period of Santarém is virtually nonexistent, likely due to both historiographic and sampling issues. The Visigoths maintained control of the city until 714 AD, when it was subsequently transferred to Islamic control and refashioned as *Shantarîn* (as well as *Šantīrīn*, *Šantarīn*, see Mata 2018: 152-154 for further discussion). Whether the city was formally conquered by the son of Musa ibn Nusayr, 'Abd al-Aziz in 714 (Matias 2018) or administratively transferred as according to Muhammad ibn Musa al-Razi (Custódio et al. 1996) is still unclear. The city was established under the Umayyad Caliphate from 714-756 AD, and continued to remain under Islamic control during the Abassid period from 756-929 AD. The city purportedly reached its 'Golden age' under the emirs of Badajóz, who ruled much of central Portugal and what is now Extremadura during the Caliphate of Córdoba (929-1031 AD) and Taifa period (1009-1111 AD). Interestingly, Santarém was granted by the king of Badajóz 'Umar al-Mutawakkil to the Christian king Leão D. Afonso VI in 1095 AD either by force or by negotiations, where it became an important outpost for the Christian kingdom of Léon for a brief period between 1095-1111 AD in an otherwise Islamic territory. The final Islamic occupation period of the city was by the Almoravids, who re-took Santarém from the Christian kings. In a letter to the caliph Yusuf, Sir Ibn Abe Bar stressed the important strategic location of Santarém: "its location commands all of the access to the South of the Tagus, connecting Lisbon, Sintra, and Balata to this city" (Custódio et al. 1996: 70), warranting its reacquisition into the Islamic cultural domain. A revolt in 1144-1145 AD weakened the Almoravid's control of the city and likely permitted the Christian conquests to be so successful in 1147 AD. The Islamic dominion over Santarém came to an end on March 15, 1147, when D. Afonso Henriques I arrived with an army of approximately 7,000 troops and additional 13,000 crusaders, canonically referenced in *De expugnatione Scallabis* (Calado 1998: 45; Lopes de Barros 2004).

Despite the historical knowledge of the city, much of the material remnants are understood in broader chronological terms. The majority of archaeological excavations conducted within the city are done so in a mitigative municipal framework, largely in response to urban development. As noted by other scholars (Cressier et al. 2020), understanding processes of urbanization in al-Andalus is particularly difficult, as unlike rural excavations, the continued occupation of urban centers often means that excavations and subsequent analyses are often the result of unrelated phenomenon such as development, construction, or renovations. Thus, the resulting archaeological knowledge produced in accompanying development projects is often a patchwork or palimpsest. Currently, chronological knowledge of the Islamic period of the city is based primarily on ceramic analyses (Liberato and Santos 2013; Liberato 2018) and the presence of *maqbabir* (Liberato and Santos 2013; Liberato and Santos 2017) encountered during salvage excavations. Ceramics excavated throughout the Islamic period in Santarém were largely decorated through exterior painting, often straight or waved lines in white and red pigments, which despite variation in motifs, appears to have continued through the late thirteenth and fourteenth centuries (Liberato 2011). This contrasts with ceramics found in northern portions of Portugal that were outside of the Islamic cultural domain, which exhibit a general lack of exterior painting and design and accompanied by darker colors (Fernandes 2012, Casimiro et al. 2018). Only four such fragments of ceramics typical of northern Portugal have been found within the city dating to the twelfth to thirteenth centuries, and were likely brought into the city rather than produced locally (Liberato and Santos 2015). The majority of ceramics recovered archaeologically from the Islamic and post-Christian conquests periods in Santarém bear resemblance to ceramics found in the southern areas of Portugal which were under more direct Islamic influence. Altogether, the ceramic evidence reinforces the notion that Santarém was likely a cultural, religious, and geographical intermediary throughout the medieval period.

Analyzing the location of *maqabir* in relation to peripheral expansion of the city walls during the medieval period, Liberato and Santos (2017) hypothesize that cemetery locations can help to explain urbanization of the city (Figure 4.1). Numerous cities throughout al-Andalus appear to have maintained a balance of urban nuclei with interstitially dispersed open spaces (Navarro and Jiménez 2007; Santos and Liberato 2018). After the Christian conquests in the twelfth century, Santarém became restructured as an important Christian religious center under the Portuguese crown, drawing numerous mendicant orders and establishing upwards of fifteen parishes and numerous convents and monasteries throughout the city (Custódio et al. 1996). Thus, it is likely that the dense urban meshwork comprising of two-story structures and narrow streets that characterizes Santarém today is more reflective of the later medieval period than the preceding Islamic one (Freitas Leal 2007). Navarro and Jiménez (2007) aptly propose that the densely blocked cities interspersed with dendritic avenues and roads we see today are likely the end product of centuries of urbanization, and not indicative of the actual *process* of urbanization during the Islamic period. They posit that early medieval Islamic cities likely did not have dense urban centers that radiated concentrically outwards into peri-urban zones. Rather, they suggest that medieval walled fortifications likely delimited a more dispersed urbanism that coincided with agricultural areas (e.g. horticultural and arboricultural zones such as orchards), as well as artisanal zones such as pottery workshops or cemeteries. Consequently, cemeteries in Islamic cemeteries could be located extramurally or intramurally, such as those found in the Spanish cities of Denia, Orihuela, Balaguer, Valencia, Alicante, and Pechina. (Navarro and Jiménez 2007: 125).

In the case of Santarém, what *maqabir* have been uncovered in the city do appear to be situated west of walled fortifications. The inability of the city to expand eastward due to steep elevation explains much of the city's stepwise expansion west, north and south upon the plateau. Given 1) the long tradition in medieval Iberia of placing *maqabir* outside of city walls (Petersen 2013; Ruiz Taboada 2015), paired with 2) the apparent abandoning of the cemeteries (as evidenced by silos that reduced/cut previous Islamic burials) and 3) increasing development of walled fortifications surrounding the historic center (Cardoso 2003), this suggests that *maqabir* possibly indicate increasing westward development without necessarily emphasizing densification of the city during the Islamic period (Liberato and Santos 2017).

As the first systematic analysis of 14C samples from cemetery sites within Santarém, the goals are threefold. I seek to 1) broadly characterize the Islamic occupation of the city by virtue of Islamic burials, 2) develop a preliminary understanding of intra-cemetery chronologies, and 3) test the hypothesis that older cemeteries are situated eastward near the citadel (*alcáçova*), and were increasingly constructed westward as the city developed during the Islamic period.

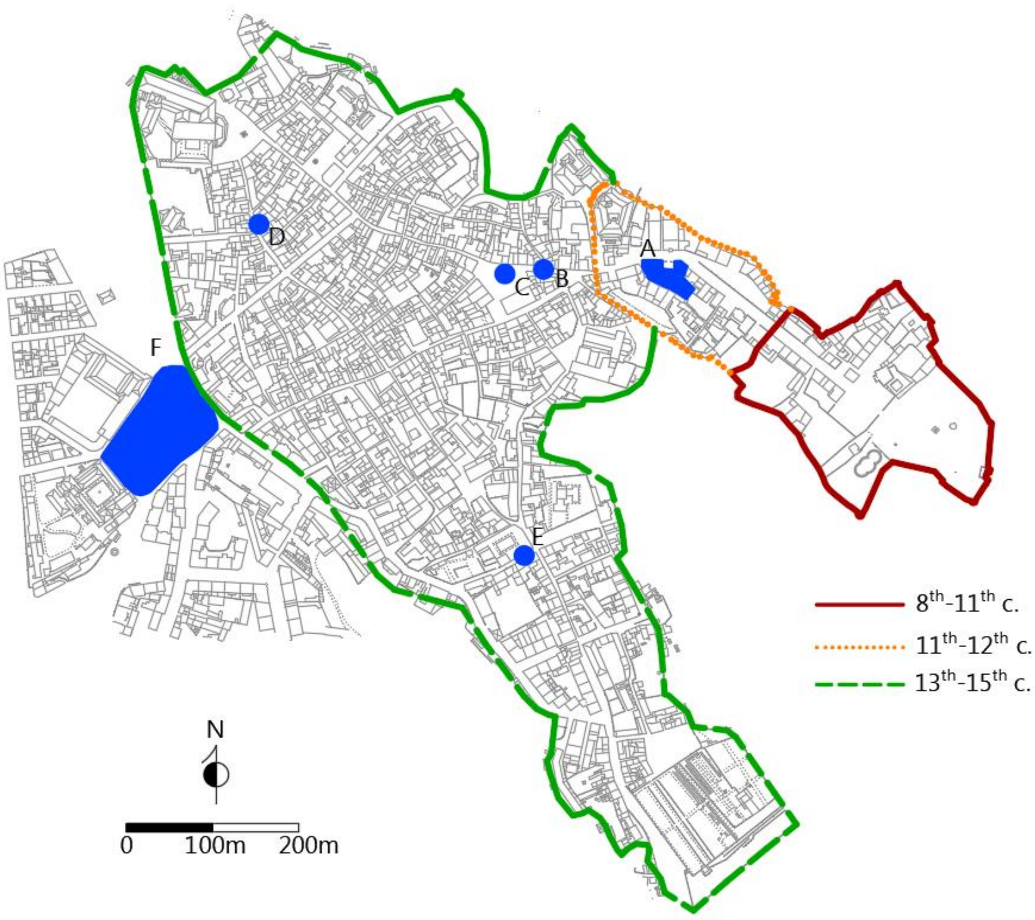
Table 4.1 — Basic chronology of Santarém in relation to al-Andalus. For a more detailed chronology, see Appendix 3.1.

Years (AD)	Period (Boone 2009: 28)	Description: *al*-Andalus	Description: Santarém
1500, 1400, 1300	Nasrid	Increasing success of Christian conquests from northern Iberian kingdoms; Córdoba falls to Christian kings in 1236; Granada falls in 1492, marking end of *al*-Andalus	Revolt(s) in 1144-1145 weaken Almoravid's control of the city. Christian king D. Afonso Henriques conquers city alongside crusader forces on March 15, 1147; city transfers to Christian control and undergoes urban, religious, and demographic changes during the later medieval period
1200	Almohad	North African Berber polities centralize the fragmented *taifas* under their rule	
1100	Taifal	De-centralization and fragmentation of Caliphate into independent kingdoms (*taifas*)	*Taifa* period commences. City briefly transferred to Christian king Leão D. Afonso VI (1095). Almoravids re-instate Islamic control of city (1111)
1000	Califal	Centralization of al-Andalus under the Caliphate of Córdoba	'Golden Age' of the city under the emirs of Badajóz operating under the Caliphate of Córdoba
900, 800	Emiral	Increasing Islamization of the peninsula under the emirs of Córdoba	Increasing Islamic presence within the city; development of urban horticultural gardens and public baths
	Conquests	Initial Arab and Berber conquests into Iberia	City conquered under Umayyad Caliphate; renamed *Shantarîn*
700, 600, 500	Visigothic	Increasing presence of de-centralized Visigothic kingdoms	City remains under Visigothic control
400	Late Roman	Disappearance of imperial Roman state apparatus	Hispano-Roman community of *Scallabis* overtaken by Sunerico and Visigothic forces

Archaeological context

I present here a total of *n* = 18 samples from direct excavations of five Islamic cemeteries throughout the historical city center of Santarém: 1) Avenida 5 de Outubro (S.5Out), 2) Praça Visconde Serra do Pilar (S.PVSP1/2), 3) Rua Capelo Ivens (S.CI90), 4) Travessa dos Capuchos (S.REST) and 5) Largo Cândido dos Reis (S.LCR) (Figure 4.1).

Figure 4.1 - Location of sampled *maqabir* (Islamic cemeteries) in relation to walled fortifications and urban expansion of the Santarém city center.



Sites: A) Avenida 5 de Outubro (S.5Out), B-C) Praça Visconde Serra do Pilar (S.PVSP1/2), D) Rua Capelo Ivens (S.CI90), E) Travessa dos Capuchos (S.REST), F) Largo Cândido dos Reis (S.LCR). Drawn by Trent Trombley, based on drawings by Liberato and Santos (2017) and study of walled fortifications by Cardoso (2003).

Samples consisted of already fragmented human remains from well-documented burial contexts. Fragments of cortical bone weighing approximately 5-6g were collected, in order to minimize the destructive impact of this study. All samples pertain to Islamic burials except for the sample S.LCR Ent. 405 (Oss.), which pertains to a Christian ossuary that reduced the Islamic sample of S.LCR Ent. 440. The choice of dating this ossuary was to help contextualize the interval between Islamic occupation (Ent. 440) and subsequent use by Christians after the Christian conquest (Ent. 405 Oss.).

Methodology

Samples were processed and analyzed at the Keck Carbon Cycle AMS facility at the University of California, Irvine. Samples were decalcified in 1N HCl, before being gelatinized at 60ºC, and finally ultra-filtered to select high molecular weight fraction (> 30k Da). $\delta^{13}C$ and $\delta^{15}N$

values were measured to a precision of < 0.1l and < 0.2l, respectively, on aliquots of ultra-filtered collagen, using a Fisons NA1500NC elemental analyzer/Finnigan Delta Plus isotope ratio mass spectrometers (IRMS). Radiocarbon concentrations are reported as fractions of the Modern standard $\delta^{14}C$ outlined in Stuiver and Polach (1977:355). All results were corrected for isotopic fractionation according to Stuiver and Polach (1977) which $\delta^{13}C$ values measured on prepared graphite using the AMS spectrometer.

For ^{14}C age calibration, I used OxCal v. 4.4.4 (Bronk Ramsey, 1995, 2001, 2009), employing the IntCal20 calibration curve (Reimer et al. 2020). Only simple calibrations are reported here, as further modelling of the radiocarbon results are currently difficult to assess due to the general lack of stratigraphic differentiation between burials and absence of funerary items that may help to 'boundary' or give *terminus post*/*ante quem* to the sampled burials.

Results and Discussion

Results of the radiocarbon measurements are shown in Table 4.2. Simple calibrations are depicted for individual burials can be seen in Appendix (4.1 - 4.18) and the pooled figures can be seen in Figure 4.2. The results show a continuity in Islamic funerary customs within the city center for nearly four centuries. In an almost stepwise fashion, older burials and cemeteries are in close proximity to the *alcáçova* (citadel) and decrease in age westward. This supports the hypothesis that Islamic cemeteries were increasingly situated westward in accordance with expansion and development of the city (Liberato et al. 2017). Based on the current chronology of walled fortifications, it appears that the cemeteries were largely situated extramurally, but likely increasingly incorporated into the urban nucleus with subsequent expansion.

The smaller cemeteries of Praça Visconde Serra do Pilar (S. PVSP1/2), Rua Capelo Ivens (S. CI90) and Travessa dos Capuchos (S. REST) possibly represent peri-urban empty spaces that were incorporated into the larger urban network, though it is difficult with the present information to confirm whether they were constructed intramurally from the onset given the limited sample size of excavated burials. Samples from the sites of Rua Capelo Ivens (S. CI90) and Travessa dos Capuchos (S. REST) could represent minor cemetery interments or even residential burial plots, given the general lack of architectural, structural, or material remains found in stratigraphic context with these remains (Matias, personal communication). However, the results from S. REST require further consideration as other Islamic burials have been discovered in the vicinity through further surveys in response to urban development projects (Santos, personal communication). While these burials were not excavated, their presence in the vicinity of the S. REST sampled burial suggests there might have been an additional cemetery located in the southern portion of the historical city center. The date for the S. REST sample was (1165 ± 15 BP, cal AD 772-951 (2σ)) much earlier than anticipated, contemporaneous with that of Avenida 5 de Outubro. I originally hypothesized that S. REST would be more recent than both Avenida 5 de Outubro (S. 5Out) and the Praça Visconde Serra do Pilar (S. PVSP1/2) samples given its westward positioning. Although we are limited to only one sample from S. REST, the results may well support Navarro and Jiménez's (2007) claim that urbanization during the Islamic period was not strictly concentric, radiating from the citadel, but rather dispersed with distinct urban and peri-urban nuclei. In this case, it is possible that a distinct urban nucleus was situated in the southern portion of the historical city center with its own distinct and associated cemetery, though future sampling on other associated Islamic burials and materials in this area are needed to help clarify this.

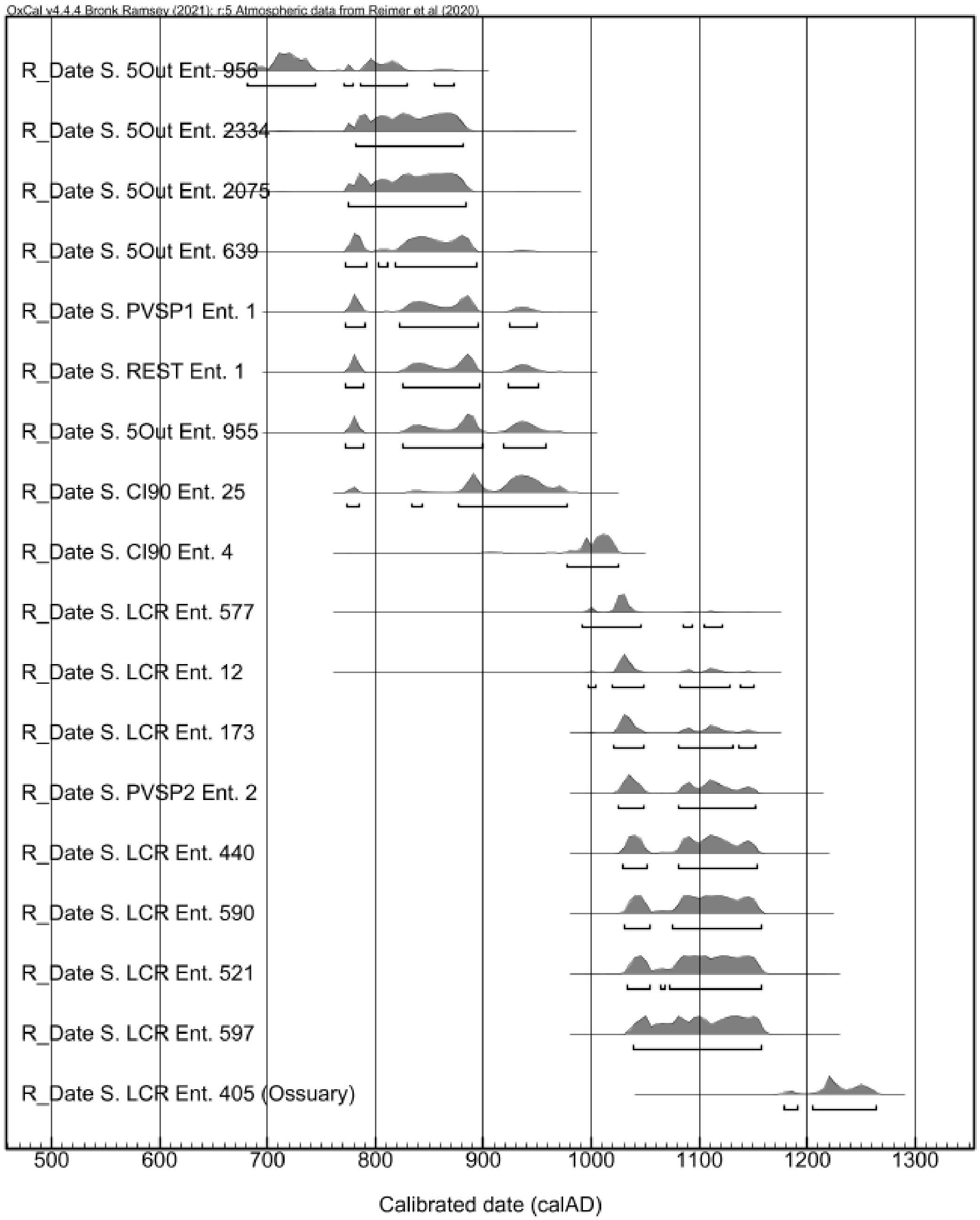
The site of Praça Visconde Serra do Pilar (S. PVSP1/2) is interesting due to the disparate estimations for burials Ent. 1 (1170 ± 15 BP, cal AD 772-950 (2σ)) and Ent. 2 (975 ± 15 BP, cal AD 1025-1152 (2σ)) despite occupying the same stratigraphic sequence. It has been hypothesized that the ancient mosque was constructed nearby, where now the Igreja de Santa Maria de Marvila stands today, and that the surrounding area was possible the large open-air market (*sûq*) (Matias 2018). However, little archaeological nor archival evidence has supported these findings, and the present burials may attest to the differing phases of urbanization in the historical city center. Recent salvage excavations (January 2023) in response to further development in this area have found other Muslim burials, but to date these burials have not been excavated nor analyzed.

The larger cemeteries sampled, Avenida 5 de Outubro (S. 5Out) and Largo Cândido dos Reis (S. LCR), appear to have been respectively used by Islamic funerary congregations for at least a century or longer. In the case of Avenida 5 de Outubro (S. 5Out), burials Ent. 955 and Ent. 956 showcase an interesting dynamic, whereby Ent. 955 (1160 ± 15 BP, cal AD 772-957 (2σ)) reduced the stratigraphically shallower Ent. 956 (1245 ± 15 BP, cal AD 682-872 (2σ)). Notably, the orientation differs by approximately 30º between these burials. Ent. 955 is in a south (head) – north (feet) orientation in lateral decubitus position, facing due east, whereas Ent. 956 is in a southwest (head) – northeast (feet) orientation facing southeast. Variation in orientation of these burials may be due to chronological refinement in the location of *qibla* (direction of Mecca) (Santos, personal communication). Ent. 956 likely represents the earliest phase of Islamic occupation of the city recently post-dating the transition from Visigoth control, whereby the location of Mecca (*qibla*) may not have been firmly established. However, other burials such as Ent. 2075 (1200 ± 15 BP, cal AD 774-884 (2σ)) and Ent. 639 (1180 ± 15 BP, cal AD 772-893 (2σ)) showcase orientations more in line with the actual direction of Mecca and the aforementioned Ent. 956, positioned in southwest (head) – northeast (feet) orientations. Thus, alternatively, the variation in orientation could be a product of seasonality due to seasonal changes in the position of the sun. While the placement of the corpse in order to face Mecca is typically a hallmark of Islamic burials (Qayrawânî 1968, 111), Gorzalzcany (2007) has noted a variation of 35° in Islamic burials likely as a result of seasonal differences during interment, though it is difficult to confirm this with the current information. The observed variation in burial orientation, paired with occasional reduction of previous burials by later ones of the same religious funerary group suggest that Avenida 5 de Outubro may have experienced distinct phases of use.

Table 4.2 - Results of AMS ^{14}C samples from various Islamic cemetery sites within the historical city center of Santarém. All samples are from human remains. Calibration is based on IntCal20 (Reimer et al. 2020).

UCIAMS #	Site/Sample	δ ^{13}C (‰)	±	Modern fraction	±	δ^{14}C (‰)	±	^{14}C age (BP)	±	2-σ age range (cal AD)
231878	S. REST Ent. 1	-18.5	0.1	0.8650	0.0011	-135.0	1.1	1165	15	772-951 AD
231879	S. LCR Ent. 12	-18.2	0.1	0.8840	0.0011	-116.0	1.1	990	15	996-1150 AD
231880	S. LCR Ent. 590	-18.9	0.1	0.8880	0.0011	-112.0	1.1	955	15	1031-1158 AD
231881	S. LCR Ent. 597	-18.6	0.1	0.8894	0.0014	-110.6	1.4	940	15	1039-1158 AD
231882	S. PVSP1 Ent. 1	-19.4	0.1	0.8645	0.0011	-135.5	1.1	1170	15	772-950 AD
231883	S. PVSP2 Ent. 2	-18.9	0.1	0.8855	0.0011	-114.5	1.1	975	15	1025-1152 AD
231884	S. CI90 Ent. 4	-19.0	0.1	0.8767	0.0012	-123.3	1.2	1055	15	977-1025 AD
231885	S. CI90 Ent. 25	-18.1	0.1	0.8674	0.0011	-132.6	1.1	1145	15	773-977 AD
231898	S. 5Out Ent. 955	-19.0	0.1	0.8656	0.0012	-134.4	1.2	1160	15	772-957 AD
231886	S. 5Out Ent. 2334	-19.0	0.1	0.8609	0.0011	-139.1	1.1	1205	15	782-881 AD
231887	S. 5Out Ent. 639	-18.8	0.1	0.8632	0.0011	-136.8	1.1	1180	15	772-893 AD
231888	S. 5Out Ent. 956	-19.1	0.1	0.8566	0.0011	-143.4	1.1	1245	15	682-872 AD
231889	S. 5Out Ent. 2075	-19.1	0.1	0.8613	0.0011	-138.7	1.1	1200	15	774-884 AD
231890	S. LCR Ent. 173	-18.3	0.1	0.8847	0.0014	-115.3	1.4	985	15	1021-1152 AD
231891	S. LCR Ent. 521	-18.8	0.1	0.8887	0.0011	-111.3	1.1	950	15	1033-1158 AD
231892	S. LCR Ent. 440	-18.6	0.1	0.8870	0.0012	-113.0	1.2	965	15	1029-1154 AD
231893	S. LCR Ent. 577	-18.6	0.1	0.8831	0.0011	-116.9	1.1	1000	15	992-1121 AD
231894	S. LCR Ent. 405 (Oss.)	-17.0	0.1	0.9019	0.0012	-98.1	1.2	830	15	1179-1264 AD

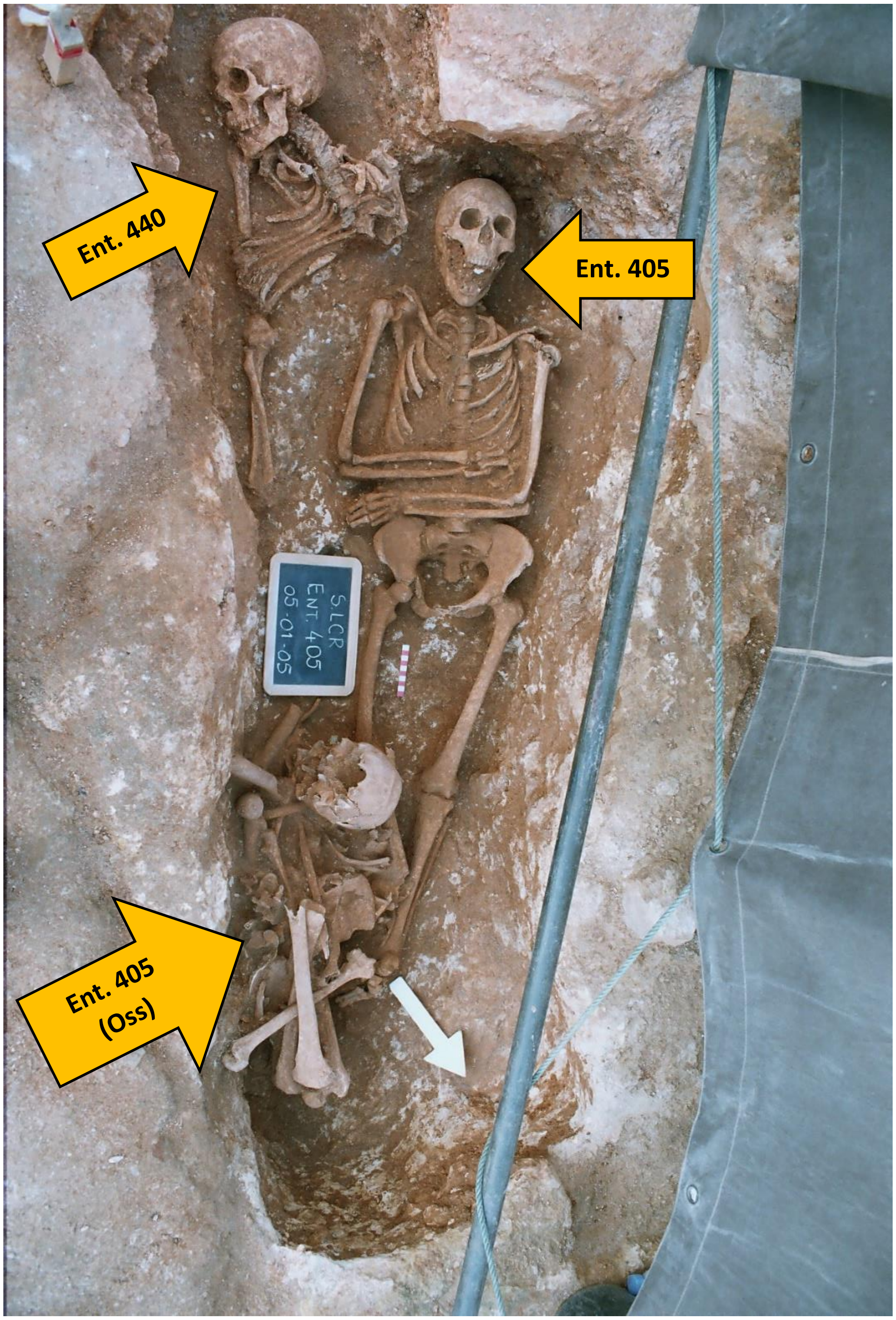
Figure 4.2 — Results of calibrated ^{14}C samples from Islamic cemeteries in Santarém, Portugal. Results are depicted as simple probability distributions using OxCal v. 4.4.4 (Bronk Ramsey 2021).



In the case of Largo Cândido dos Reis (S. LCR), burials appear to follow a general east-west chronology. The burials corresponding to earlier chronological probabilities, Ent. 577 (1000 ± 15 BP, cal AD 992-1121 (2σ)), Ent. 12 (990 ± 15 BP, cal AD 996-1150 (2σ)), and Ent. 173 (985 ± 15 BP, cal AD 1021-1152 (2σ)), all were excavated from Sectors 1 and 10, respectively corresponding to the northeastern portion of the cemetery. In a stepwise fashion, burials decrease in age westward, with the latest sampled Islamic burials Ent. 590 (955 ± 15 BP, cal AD 1031-1158 (2σ)), Ent. 521 (950 ± 15 BP, cal AD 1033-1158 (2σ)), and Ent. 597 (940 ± 15 BP, cal AD 1039-1158 (2σ)) being situated in the Western-most Sectors 7 and 8. This suggests the Islamic burials of Largo Cândido dos Reis were preferentially situated in proximity to the historical city center before situating subsequent interments further from the city center and city walls, contrary to previous hypotheses which proposed that western-most burials were likely older in association with an extramural mosque (Matias 2008a, 2008b).

It is noteworthy that Ent. 577 showcases the earliest calibrated dating for the site of Largo Cândido dos Reis (1000 ± 15 BP, cal AD 992-1121 (2σ)). This burial is the only Islamic burial at the site that shows evidence of ceramic tile coverings (*telhas*) over the tomb, though similar tomb typologies have been uncovered in subadult burials at the excavation of Capelo Ivens and Travessa do Froes (S. CI90). It is possible that more tombs at Largo Cândido dos Reis employed similar tile coverings but were removed through subsequent urban development projects, landscaping, and grading (Matias, 2008a). Alternatively, this could represent an early tomb typology that was later abandoned with subsequent use of the site. Earthen burials covered in ceramic tiles have been observed in the Spanish site of Cortijo de Aragaz in Granada, but appear to be limited to the ninth and tenth centuries AD (Gonzaga 2018b, 17). Thus, it is possible that this particular typology was not emphasized from the turn of the eleventh century onwards. Future research would benefit greatly from sampling the ceramic tiles in association with Ent. 577, as well as individuals from S.CI90 that similarly employed ceramic tile coverings.

Figure 4.3 - Ent. 440 (Islamic) reduced by preliminary Christian interment (Ent. 405 Oss.) followed by later re-use of tomb by subsequent Christian interment (Ent. 405).



The case of Ent. 440 — an Islamic individual — reduced by Ent. 405 — a Christian individual — is also worth further consideration (Figure 4.3). Given that Ent. 440 is a reduction, it is clear that this is an Islamic grave that was disturbed by later Christian interment. Interestingly, Ent. 405 contains a relatively well-preserved ossuary at the foot of the grave, with a minimum number of individuals (MNI) of n = 2. Repeated elements were lower axial and appendicular elements, which when paired with coloring, size, and morphology, all suggest that one of the individuals present in the ossuary were the lower limbs of the Islamic individual Ent. 440. The presence of a cranium and superior elements thus suggest one individual was buried prior to the interment of Ent. 405. Altogether, this tomb illustrates a complex chronological sequence: first an Islamic burial (Ent. 440; 965 ± 15 BP, cal AD 1029-1154 (2σ)), later reduced by a Christian burial (405 Oss.; 830 ± 15 BP, cal AD 1179-1264 (2σ)), and finally re-use of the Christian burial by a subsequent Christian individual (Ent. 405), whereby the previous Christian occupant (Ent. 405 Oss.) was moved to create space for Ent. 405. Despite the active re-opening and movement of individuals within the tomb, it appears that later Christian funerary processions were careful to preserve the osseous remains of the previous Islamic occupant, even with subsequent Christian re-use of the tomb. Future research would benefit greatly from obtaining radiocarbon samples for both the legs of the purported Ent. 440, as well as sampling Ent. 405 to examine just how long this tomb structure was used.

Conclusions

This chapter presents the first systematic ^{14}C samples analyzed from multiple cemeteries within the city of Santarém, Portugal, with a particular focus on the Islamic period. The results are an important first step in characterizing the continuity in funerary rites during Islamic period. Results from the dating series also support the previous hypothesis that Islamic cemeteries throughout the city coincide with westward urbanization and expansion of the historical city center. However, these results additionally suggest the occupation and expansion of the city was more complicated than previously anticipated, with various nuclei of dense areas while also maintaining dispersed interstitial funerary areas.

Unfortunately, subsequent sampling for radiocarbon dating of Christian burials throughout the city could not be accomplished due to the 2020 SARS-Cov-2 Pandemic, which restricted travel access. Future research is needed to elucidate the chronology of Christian burials throughout the city more thoroughly, as well as tease apart hypotheses of Christian comingling and re-use of tomb structures (e.g., familial relations, issues of urbanization, etc.).

Chapter 5: Lifeways — Dental Pathological Lesions and oral health indicators

Introduction

Human dental remains typically preserve well in archaeological contexts, due to their highly mineralized structure, and as a result offer biological anthropologists unique insights into past communities and species (Hilson 1996). Bioarchaeologists and dental anthropologists routinely examine dental pathological lesions in order to elucidate aspects of past diets and subsistence strategies (Cohen et al. 1984; 2007; Driscoll et al. 2000; Powell 1985; Rose et al. 1991; Temple 2006; 2007; Temple et al. 2007; Turner 1979; Walker et al. 1990), underlying frailty (DeWitte et al. 2010), colonial encounters (Klaus et al. 2010; Larsen et al. 1994; Reeves 2000), and sex and gender differences (Avery et al. 2019; Fields et al. 2009; Lukacs 1996; 2011; 2008l 2017; Lukacs et al. 2006; Trombley et al. 2019; Walter et al. 2016; Watson et al. 2010) to name only a few, though the axes by which dental remains can be examined are virtually endless.

Here, I examine the relationship between dental pathological lesions and religious identity. While oral health indicators have been analyzed in relation to burial and/or funerary treatments (Redfern et al. 2015; Tornberg 2016), patterning along religious lines remains a relatively unexplored avenue for bioarchaeological research. Bioarcheological approaches to religion are still in their relative infancy but there is a frutification of new literature in the last decade (Inskip 2013a; 2013b; Inskip 2016; Klaus 2013; Livarda, Madgwick, et al. 2018; Zakrzewski 2011; Zakrzewski 2015). Comparative approaches are even more difficult to come by, in part due to the rare occurrences of multiple religious faith communities employing similar styles of inhumation within relatively contemporaneous and/or geographical contexts. Effectively, bioarchaeologists would require samples where religious funerary treatment of the body is similar enough among religious groups that practice inhumation (thus leading to possible preservation and excavation/analysis by bioarchaeologists), but distinct enough to discern differing religiously-motivated funerary customs. Additionally, the ethics of excavation are also noteworthy, as many surviving stakeholders and descendant communities who share religious affiliation with past faith communities may disapprove of their exhumation and analysis (Colomer 2014).

The Iberian peninsula offers a unique study area to explore and develop a bioarchaeology of religion, both due to the presence of multiple faith communities within the middle ages, and some contemporary religious stakeholders and local communities voicing interest in (bio)archaeological findings resulting from rescue archaeology (Zakrzewski 2011), though there are notable exceptions, especially in the case of Jewish burials (Colomer 2014). Both Spain and Portugal experience shifting religious and political autonomy throughout the medieval period (c. 500 – 1492 C.E.) with Roman, Visigothic, Islamic, Christian, and Jewish communities coexisting within similar geographic and social spheres. The distinct funerary treatments employed by medieval Islamic and Christian communities have allowed funerary archaeologists working within the Iberian peninsula, to distinguish religious identity (at least in death) with relative ease (Chávet et al. 2006; Gonzaga 2018b; Matias 2008a; 2008b; Ruiz Taboada 2015). Islamic burials during the Iberian middle ages are typically characterized by simple, primary earthen inhumations, a general lack of grave goods/vestments, and with the body deposited in right decubitus position oriented towards the southeast, facing Mecca (Chávet et al. 2006; Petersen 2013). While considerable synchronic and diachronic variation does exist, many medieval

Islamic burials in the Iberian peninsula adhered to a relatively prescribed framework set forth by Malīkī jurisprudence (Chávet et al. 2006). Conversely, Christian burials in the later middle ages following the Christian conquests ("Reconquista") typically employed extended, supine burials, with more variable orientation, inclusion of grave goods, and/or co-mingling via secondary burials and ossuaries (Matias 2008b; Ruiz Taboada 2015). Due to increasing urbanization in the later Christian middle ages (Cressier et al. 2020; Freitas Leal 2007; Navarro Palazón et al. 2007; Ruiz Taboada 2015), later Christian cemeteries had the potential to be constructed adjacent, or even within previously existing Islamic and Jewish cemeteries, facilitating the presence of distinct funerary groups within the same city and/or cemeteries, which can be seen in cities such as Toledo, Spain and Santarém, Portugal (Matias 2008b; Ruiz Taboada 2015). The various cemeteries and associated burials excavated throughout Santarém thus offer an opportunity to examine dental pathological lesions in a comparative religious framework.

I examine here three primary research questions: 1) What was the spatial patterning of oral pathological lesions within the oral cavities? 2) Are there differences in oral pathological lesions between sex groups? and 3) Are there differences in oral pathological lesions between religious groups? I anticipate that dental pathological lesions, especially carious lesions, periodontitis, calculus, and enamel chipping, will be patterned predominately in posterior dentition as a result of mechanical demands associated with molars. I hypothesize that females will exhibit increased frequencies in dental pathological lesions as a result of either dietary (Kelley et al. 1991; Klaus et al. 2010; Larsen 1983; Larsen et al. 1991; Lukacs et al. 1993; Lukacs 1996; Novak 2015, 201; Tayles et al. 2000; Temple et al. 2007; Walker et al. 1990) or reproductive demands and fertility (Lukacs 2017; Lukacs 1996; Lukacs et al. 2006; Lukacs 2008; Watson et al. 2010). Finally, I hypothesize that Islamic funerary sub-groups will exhibit lower frequencies in dental pathological lesions than their Christian counterparts as a result of dietary and historical practice of oral hygiene.

Materials:

The details for the sites and historical context utilized in this chapter can be seen in Chapter 3. Two principal sites comprise the skeletal materials for this analysis: Avenida 5 de Outubro (S.Av5Out) and Largo Cândido dos Reis (S.LCR), both from the city of Santarém, Portugal. The distribution of individuals and dental remains analyzed can be seen in Table 5.1.

Table 5.1 - Sample distribution of dental loci/teeth analyzed for dental pathological lesions by site, sex, age, and funerary group. Av5Out = Avenida 5 de Outubro and LCR = Largo Cândido dos Reis.

			Islamic			**Christian**		
Indicator	**Sex**	**Age**	Av5Out	LCR	Total	Av5Out	LCR	Total
AMTL	***Females***	*18-29*	96	141	210	-	107	107
		30-49	182	62	244	-	80	192
		50+	225	159	384	-	221	221
		Indet.	-	60	60	-	80	80
		Total	503	422	925	-	488	488
	Males	*18-29*	64	64	128	-	64	64

		30-49	128	220	348	-	265	265
		50+	89	152	241	-	170	170
		Indet.	32	271	303	-	173	173
		Total	313	707	1020	-	672	672
Caries	***Females***	*18-29*	93	135	228	-	95	95
		30-49	125	31	156	-	65	65
		50+	160	101	261	-	114	114
		Indet.	-	78	78	-	69	69
		Total	378	345	723	-	343	343
	Males	*18-29*	94	63	157	-	78	78
		30-49	105	173	278	-	208	208
		50+	43	102	145	-	102	102
		Indet.	29	228	257	-	135	135
		Total	271	566	837	-	523	523
Tooth Wear	***Females***	*18-29*	92	136	228	-	95	95
		30-49	124	28	152	-	65	65
		50+	158	101	259	-	113	113
		Indet.	-	50	50	-	69	69
		Total	374	315	689	-	342	342
	Males	*18-29*	62	63	125	-	63	63
		30-49	103	174	227	-	203	203
		50+	42	102	144	-	102	102
		Indet.	28	227	255	-	132	132
		Total	235	566	801	-	500	500
Periodontitis	***Females***	*18-29*	79	106	185	-	85	85
		30-49	81	10	91	-	56	56
		50+	70	42	112	-	75	75
		Indet.	-	13	13	-	40	40
		Total	230	171	401	-	256	256
	Males	*18-29*	75	43	118	-	68	68
		30-49	75	137	212	-	148	148
		50+	22	80	102	-	88	88
		Indet.	21	138	159	-	73	73
		Total	193	398	591	-	377	377
Calculus	***Females***	*18-29*	91	131	222	-	94	94
		30-49	107	30	137	-	74	74
		50+	106	99	205	-	112	112
		Indet.	-	78	78	-	68	68
		Total	304	338	642	-	351	351
	Males	*18-29*	88	63	151	-	46	46
		30-49	89	171	260	-	205	205
		50+	21	101	122	-	102	102
		Indet.	29	255	294	-	110	110
		Total	227	590	817	-	466	466
Periapical Lesions	***Females***	*18-29*	96	141	210	-	107	107
		30-49	182	62	244	-	80	192
		50+	225	159	384	-	221	221

		Indet.	-	60	60	-	80	80
		Total	503	422	925	-	488	488
	Males	*18-29*	64	64	128	-	64	64
		30-49	128	220	348	-	265	265
		50+	89	152	241	-	170	170
		Indet.	32	271	303	-	173	173
		Total	313	707	1020	-	672	672
Enamel Chipping	***Females***	*18-29*	-	131	131	-	94	94
		30-49	-	24	24	-	64	64
		50+	-	99	99	-	110	110
		Indet.	-	77	77	-	68	68
		Total	-	331	331	-	336	336
	Males	*18-29*	-	63	63	-	77	77
		30-49	-	171	171	-	202	202
		50+	-	101	101	-	102	102
		Indet.	-	254	254	-	124	124
		Total	-	589	589	-	505	505
Enamel Notching	***Females***	*18-29*	-	131	131	-	94	94
		30-49	-	24	24	-	64	64
		50+	-	99	99	-	109	109
		Indet.	-	78	78	-	69	69
		Total	-	332	332	-	336	336
	Males	*18-29*	-	63	63	-	77	77
		30-49	-	172	172	-	203	203
		50+	-	100	100	-	102	102
		Indet.	-	252	252	-	126	126
		Total	-	587	587	-	508	508

Methodology:

Analytical Procedures

Age was estimated based on progressive degeneration of various skeletal elements, with particular focus on the pubic symphysis (Brooks et al. 1990) and auricular surface (Lovejoy et al. 1985). Age was conservatively categorized as 18-29 years, 30-49 years and 50+ years to avoid some of the problematic assessments of age in older individuals (Jackes 2000). Sex was estimated by similarly emphasizing morphological differences within the pelvic girdle, focusing on the Phenice complex (ventral arc, sub-pubic angle, sub-pubic concavity) (Ascàdi et al. 1970; Brothwell 1981; Buikstra et al. 1994; Phenice 1969), preauricular sulcus, and greater sciatic notch (Walker 2005). Additionally, numerous sex-related features of the skull were also used to help increase accuracy of sex estimation (Buikstra et al. 1994). Finally, numerous studies throughout both medieval Portuguese samples (Cunha 1994) as well as contemporary samples (Cardoso 2000; Wasterlain 2000) have found sexual dimorphism to be present in limb proportions and skeletal elements, which were also implemented as a means of bolstering sex estimation.

Numerous individuals were indeterminate in terms of age but estimable by sex, as a result of sexually dimorphic elements being preserved which could yield an estimation of sex accompanied by a lack of age-estimable elements preserving (e.g., pubic symphysis). This monotone feature ultimately resulted in male and female sub-samples containing individuals of indeterminate age, but were included to maximize sample sizes. As such, while many dental pathological lesions are age-progressive, this preliminary study examines only sex and religious differences with all age-categories collapsed to maximize statistical power.

Statistical comparisons were made primarily utilizing a two-tailed log-likelihood ratio test, also called the *G* test . Similar to a χ^2 test, the G test examines the ratio of observed to expected counts, but is more conservative in its estimation of statistical differences in smaller samples sizes, when observed counts are much larger than expected counts (Klaus et al. 2010, 598). In the event that expected counts were less than five, a Fisher's Exact test with an $\alpha = 0.05$ was used instead. To avoid issues in family-wise error rate (FWER) stemming from multiple comparisons, a Bonferroni correction was employed to help reduce Type I errors. While the Bonferroni correction is more conservative than other correction factors (e.g. Šidák), I employ here a limited number of multiple comparisons (maximum of two for any given sample), and such a correction can help conservatively correct for more spurious effects while still maintaining highly significant effects.

Stable isotope analysis

A small pilot sample of individuals (n = 18) were analyzed for radiogenic isotope analysis (see Chapter 4), which subsequently permitted stable isotope analysis during the analysis process. Analysis was carried out only on collagen for ^{13}C and ^{15}N, which reflect plants and protein sources, respectively (Minagawa et al. 1984; Schoeninger et al. 1984).

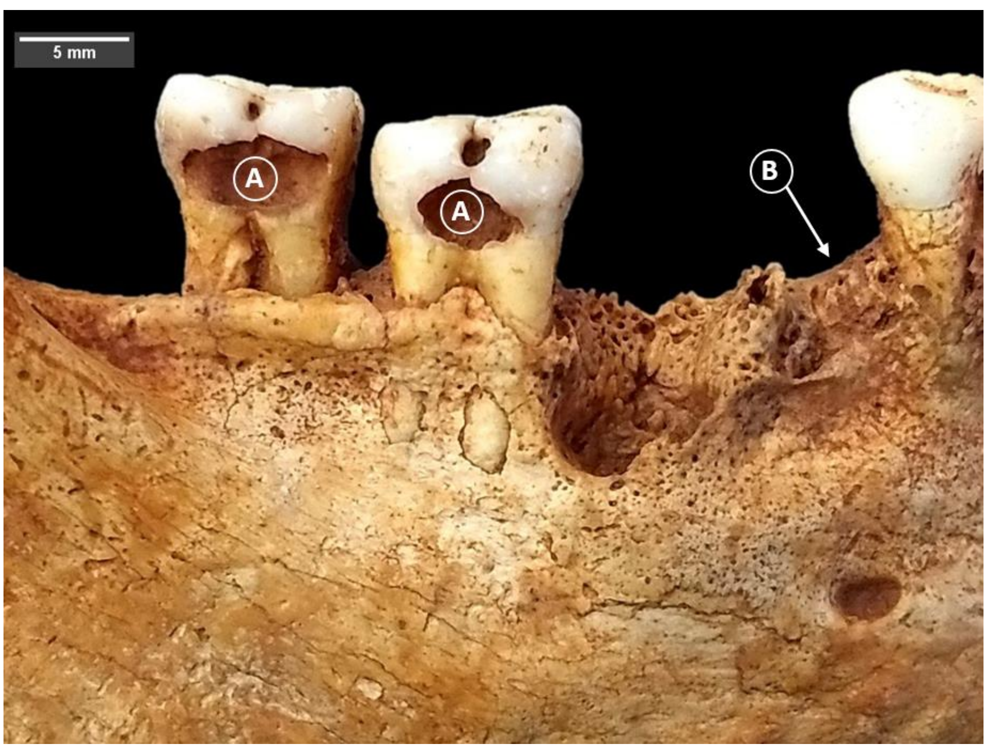
Samples were processed and analyzed at the Keck Carbon Cycle AMS facility at the University of California, Irvine. Samples were decalcified in 1N HCl, before being gelatinized at 60ºC, and finally ultra-filtered to select high molecular weight fraction (> 30k Da). $\delta^{13}C$ and $\delta^{15}N$

values were measured to a precision of < 0.1l and < 0.2l, respectively, on aliquots of ultra-filtered collagen, using a Fisons NA1500NC elemental analyzer/Finnigan Delta Plus isotope ratio mass spectrometers (IRMS). All results were corrected for isotopic fractionation according to Stuiver and Polach (1977) which $\delta^{13}C$ values measured on prepared graphite using the AMS spectrometer. All samples met minimum acceptable collagen yield according to standard metrics (%N, %N, C:N). Values from the stable isotope analysis can be seen in Appendix 5.1.

Antemortem Tooth Loss (AMTL)

Teeth can be lost antemortem from a variety of reasons. Commonly cited factors in bioarchaeology are 1) advanced carious lesions that penetrate the pulp-chamber and eventually compromise the integrity of gomphoses resulting in loss; 2) advanced tooth wear which can subsequently expose the pulp-chamber to cavitation; 3) intentional ablation or removal, and 4) trauma (Lukacs 2007). Notably, teeth can also be lost as a result of increasing alveolar resorption accompanying severe gingivitis and periodontitis. (Clarke et al. 1991; Hildebolt et al. 1991; Varrela et al. 1995; Whittaker et al. 1996). As gum disease results in resorption of the alveolar margin, teeth can continue to erupt slowly in order to continue masticatory capabilities, ultimately subjecting them to higher likelihood of cariogenesis below the cemento-enamel junction (CEJ) and subsequent loss.

Figure 5.1 – Carious lesions (A) and antemortem tooth loss (B) in LCR 183.



AMTL is typically observed in skeletal remains by the characteristic alveolar resorption and remodeling of the alveolar sockets (Figure 5.1). AMTL was calculated by scoring the number of teeth lost antemortem over the total number of observable loci. The distribution of loci by site, sex, age, and funerary group can be seen in Table 5.1.

Dental Caries

Carious lesions were identified by their characteristic demineralization of the enamel and/or dentin surface, ranging from a pin-prick to the complete destruction of a crown's surface (Figure 5.2). In order to calculate the frequency of carious lesions, a variety of calculations have been proposed. Traditionally, and frequently in bioarchaeological literature, caries frequency is calculated using the following:

$$\text{Traditional caries frequency} = \frac{b}{a}\ x\ 100$$

Where *b* refers to the number of observed teeth with caries, *a* refers to the total number of observed teeth, multiplied by 100. While informative, this crude frequency only reports observed carious lesions in relation to remaining observable teeth and fails to account for the relationship between carious lesions and antemortem tooth loss. As a result, numerous scholars have suggested that it is unrealistic, as both antemortem and post-mortem tooth loss causes the observed (i.e. bioarchaeological) frequency "to deviate from its real value" (Duyar & Erdal, 2003, 58; see also Brothwell, 1963; Erdal & Duyar, 1999; Hilson, 1996; Kerr, Bruce, & Cross, 1988; Lukacs, 1992; 1995; 2011; Moore & Corbett, 1971; Whittaker et al., 1981). In essence, many teeth that were lost antemortem likely had carious lesions, or were lost as a result of severe cavitation, to the point where many teeth affected by caries are never seen by the researcher. The issue is exacerbated in samples where antemortem tooth loss rates are high, where observed caries frequency can thus severely under-represent true caries frequency (Lukacs 1992; Lukacs 1995).

Numerous scholars have proposed correction factors in order to try and account for caries that were lost antemortem. Hardwick (1960) was one of the first to suggest that the linkage between antemortem tooth loss and carious lesions was too strong to ignore, and subsequently proposed a correction factor whereby the number of teeth scored as having been lost antemortem should be added to the observed number of caries to better account for teeth that were lost antemortem as a result of carious lesions. Despite the early attempt, bioarchaeologists seldom applied Hardwick's correction, possibly because it over-represented carious frequency by simply adding observed caries with antemortem tooth loss. Some forty years later, Lukacs (1992; 1995) proposed the Caries Correction Factor (hereby referred to as Caries Correction Factor 1; CCF1):

$$\text{Caries Correction Factor 1 (CCF1; Lukacs 1995)} = \frac{(b + (c\ x\ p))}{(a + c)}\ x\ 100$$

Where *b* refers to the number of observed caries, *a* refers to the total number of observed teeth, *c* refers to the number of teeth lost antemortem, and *p* refers to the proportion of teeth with a carious lesion exhibiting pulp exposure to the number of teeth scored as having non-carious pulp exposure (e.g. heavy wear). Lukacs' development of the ratio *p* which weighted the observed rates of carious pulp exposure to non-carious pulp exposure helps to adjust antemortem tooth loss to a given sample, and not assume that all teeth lost antemortem were the result of severe cavitation as Hardwick suggested. In samples with heavy antemortem tooth loss, frequency can sometimes double after implementing this correction factor (Lukacs 1992; 1995).

While the CCF1 can aid tremendously in better assessing caries frequency in skeletal samples, it notably collapses anterior and posterior dentition into one correction parameter. Erdal and Duyar (1999) aptly note that in a most populations, there is a disproportion number of anterior teeth to posterior teeth (3:5) per quadrant which can complicate results, particularly when ante- or post-mortem tooth loss is prevalent. They suggest that post-mortem damage may well lead to increased chances for post-mortem loss of anterior teeth compared to posterior ones, presumably due to the fact that anterior teeth are more 'exposed' to possible post-mortem perturbations and damage due to their position in the anterior-most portion of the skull. Anterior dentition also have comparatively simpler crown morphology, and typically have single roots which provide comparatively less anchoring into the alveolar sockets, both of which can make them more susceptible to loss (Duyar et al. 2003, 67). Conversely, the complex crown morphology of posterior teeth is often thought to make them more susceptible to cariogenesis than their anterior counterparts (Hillson 2008). By lumping anterior and posterior tooth loss rates together, often overestimates carious lesions in anterior teeth and decreases them in posterior teeth (Duyar et al. 2003, 66). As such, they build on Lukac's equation by considering anterior and posterior teeth separately, so as to avoid the assumption that teeth may decay or be lost post-mortem equally throughout the oral cavity:

$$\text{Caries Correction Factor 2 (CCF2; Duyar and Erdal 2003)} = \frac{(b_1 + \ (c_1\ x\ p_1))}{(a_1 + c_1)}\ x\ 100$$

Similar to CCF1 above, *b* refers to observed caries, *a* refers to the total number of observed teeth, *c* refers to the number of teeth lost antemortem, and *p* refers to the proportion of teeth with pulp exposure to those without, except the subscript for each variable classifies the tooth as anterior (e.g., b_1) or posterior (e.g., b_2). Only in cases where *p* is observed to be equal between anterior and posterior teeth will CCF1 and CCF2 be the same.

Finally, the results from the CCF2 can be used to calculate the proportional correction factor (PCF), which multiplies the anterior and posterior caries rates by their respective proportion of teeth within the 'typical' dental arcade (3/8 for anterior, 5/8 for posterior):

$$\text{Proportional Correction Factor (PCF; Duyar and Erdal 2003)} = (CCF2_{anterior}\ x\ 0.375) + (CCF2_{posterior}\ x\ 0.625)$$

The distribution of teeth analyzed in the present study can be seen in Table 5.1.

Tooth Wear

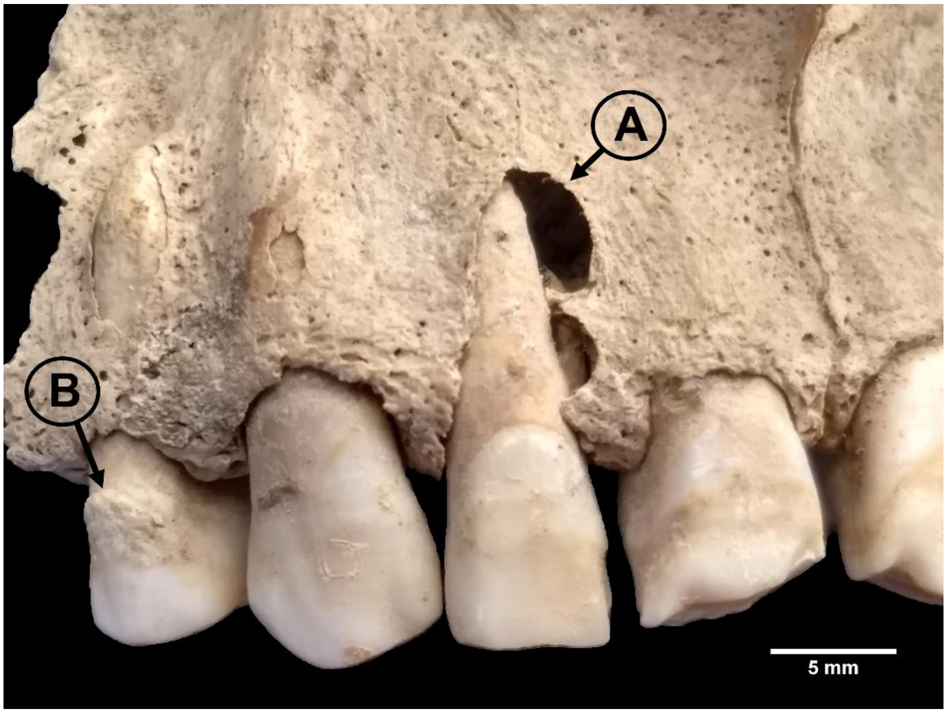
Tooth wear is the process by which enamel and dentine are removed from teeth through mechanical contact, either with one another (attrition) or with exogenous materials such as coarse, gritty, and/or fibrous foodstuffs (abrasion) (Kaidonis 2008; Lucas 2004). Differentiating between attritional and abrasion tooth wear is often difficult without the aid of advanced microscopy (Kaidonis et al. 1993; Kaidonis 2008). As a result, most bioarchaeologists analyze tooth wear as part of a broader mechanical process to glean information on dietary, mechanical, or non-alimentary activities of past communities (Larsen 1998). Tooth wear can significantly affect a tooth's susceptibility to cariogenesis, as sufficient wear can either expose the pulp-chamber and underlying dentine to acidogenic and cariogenic bacteria.

Given the differing morphology between anterior dentition and molars, tooth wear is often scored separately, though both through the use of ordinal scales (Scott 1979; Smith 1984). Smith's (1984) scale is often more desirable for anterior dentition but, whereas Scott's (1979) method is more sensitive to scoring molar wear since it separates the occlusal surfaces into quadrants and scores each quadrant separately, before aggregating the scores for any given molar. Frequently, when statistical comparisons for tooth wear are made between differing sub-groups, molar scores are averaged separately from anterior dentition (Klaus et al. 2010; Trombley et al. 2019). Thus, despite the lack of granularity in dental wear using the Smith (1984) method for scoring molars, subsequent averaging, especially multiple times, of Scott's (1979) scoring technique may well override its proposed resolution. This study employed only the Smith (1984) scoring method for both anterior and posterior dentition, in order to maintain consistency within author methodologies, and to avoid excessive averaging. Additionally, it is common bioarchaeological practice to compare dental wear between groups using a *t*-test (Klaus et al. 2010; Trombley et al. 2019). While this can be a helpful heuristic in revealing group differences, the biological differences when compounded with effect size between wear scores can inflate differences, especially since dental wear scores are not normally distributed. As such, I chose to visualize the results here rather than rely on a statistical comparison. The distribution of teeth analyzed for tooth wear in the present study can be seen in Table 5.1.

Calculus

Calculus is a mineralized form of plaque which forms as a result of salivary minerals (principally, calcium-phosphate) precipitate to leave a hardened substance adhering to the tooth. While the formation of plaque and calculus are impacted by a variety of factors, oral hygiene and the employment of dentifrices has been observed to minimize formation and accretions (Jepsen et al. 2011). Lack of oral hygiene and consistent use of dentifrices often results in moderate to severe plaque (and subsequently, calculus) buildup, which can be additional risk factors for gingivitis, alveolar recession, and periodontitis (Jepsen et al. 2011; White 1997). In skeletal remains, calculus is often observed as anything from a small deposit to a larger 'shelf' of mineralized plaque adhering to one or more surfaces of the teeth. Calculus was scored using the three-stage ordinal scale proposed by Brothwell (1981), while also scoring its specific location on the tooth's surface (Figure 5.2). If calculus was present along multiple dental surfaces, the location was scored as "multiple." The distribution of teeth analyzed for calculus can be seen in Table 5.1.

Figure 5.2 – Periapical lesion (A) and calculus (B) in LCR 238.



Periapical Lesions

Though commonly referred to as 'abscesses' or 'abscess cavities,' the more precise term used here is 'periapical lesions', which can refer to granuloma, cysts, and/or abscesses. Periapical lesions form when cavities penetrate a tooth's pulp chamber before draining out of the apical foramen. While the means by which pulp chambers become exposed can vary, from carious lesions to extreme dental wear, severe infection can become pyogenic, which results in a drainage of pus, localized inflammation, and the formation of a granuloma, or mass of inundated inflammatory cells such as modified macrophages and lymphocytes (Dias et al. 1997; Ogden 2008, 295). The granuloma can result in osteoclastic activity, which resorbs adjacent bone structures, skeletally manifesting as an acute periapical lesion observable by a cavity of resorbed bone, typically located on the buccal side (Hillson 2008). Necrotic pulp cavities and granulomas/cysts can become infected via foodstuffs or blood-borne infection (Abbott 2004; Trowbridge et al. 1992), which can facilitate the formation of an abscess. Periapical lesions were scored only in the event that there was a clear, observable drainage channel of necrotic resorption associated with the apices of one or more tooth roots and > 2 mm in diameter (Ogden 2008, 297) (Figure 5.2). A total number of 1,020 Islamic male and 925 Islamic female loci, and 672 Christian male and 488 Christian female loci were scored for periapical lesions (Table 5.1).

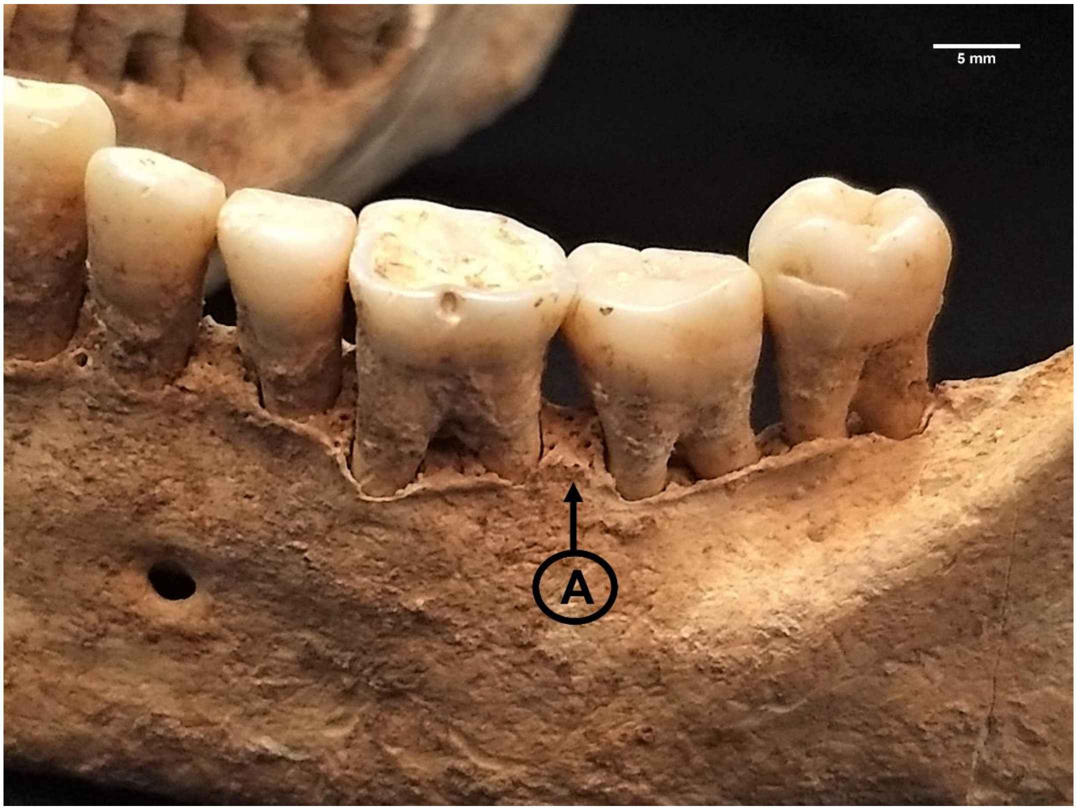
Periodontitis

Periodontitis, or periodontal disease, is an infectious disease whereby the gingival margin experiences degeneration as a result of bacterial infection (Armitage 1995; Hernández et al. 2011). While its more benign condition, gingivitis, is characterized by inflammation of the gums and affects adults who do not practice regular oral hygiene (Albandar et al. 2002; Eke et al.

2015), periodontitis results in loss of irreplaceable bone in the alveolar margin. The etiology of periodontitis is still not entirely understood, but molecular studies and genetic sequencing in the last few decades have helped illustrate the complex process of infection and risk factors. Studies employing 16s amplicon ribosomal RNA (16s rRNA) sequencing techniques have found that human oral microbiomes are dense ecological niches, consisting of some 700 differing taxa (Aas et al. 2005; Choi et al. 1994; Dewhirst et al. 2010; Griffen et al. 2012; Moore et al. 1994; Socransky et al. 1998). Some 400 taxa have been identified to occupy the alveolar pockets alone (Paster et al. 2001; Paster et al. 2006). Alveolar resorption appears to be the product of the oral biofilm experiencing dysbiosis, where pathogenic bacterial communities such as the canonical 'red complex' (*Porphyromonas gingivali*s, *Treponema denticola*, and *Tannerella forsythia*) interact with other microbial communities and complexes to facilitate an increase in fermentable proteins, thus weakening periodontal ligaments and resorbing underlying alveoli (Abusleme et al. 2013; Hajishengallis et al. 2012).

In archaeological skeletal samples, the presence of periodontitis is typically characterized by porosity, exposure of the underlying trabecular bone, and reduction of the alveolar margin (Clarke et al. 1991; Kerr 1988; 1991; Larsen 1997). Some scholars have adopted a metric means of scoring periodontitis in skeletal remains whereby the distance between the alveolar crest and cemento-enamel junction (CEJ) exceeds 2 mm (Sharon N DeWitte et al. 2010). However, metric thresholds can fail to account for the continued eruption of teeth throughout the lifecourse (Kerr 1988; Varrela et al. 1995; Whittaker et al. 1996), especially in response to maintaining a level occlusal plane (Clarke et al. 1991; Craddock et al. 2004; Hildebolt et al. 1991). As a result, it's possible that a metric method may overestimate the prevalence and frequency of periodontal disease in skeletal populations. Pioneering work by Kerr (Kerr 1988; 1991) and others (Costa 1982; Ogden 2008) instead proposed a more detailed, ordinal scale which analyzes each of the inter-dental septa individually for texture, architecture, porosity, and contouring. While more time-intensive and dependent on good preservation of alveolar margins, the Kerr method allows one to distinguish between healthy gums (score = 1) from forms of gingivitis (score = 2), localized periodontitis (score = 3), and quiescent or rampant periodontitis (scores 4 and 5; Figure 5.3). While Ogden (2008, 289) cautions that gingivitis cannot be detected in skeletal remains as the periodontal ligament and alveolar bone are not affected, Kerr's (Kerr 1988; 1991) score of 2 often is attributed to pre-periodontitis. The distribution of interdental septa analyzed for periodontitis can be seen in Table 5.1.

Figure 5.3 – Interdental septa (A) showing signs of periodontitis due to jagged, irregular architecture, sloping, and microporosity accompanying alveolar recession in LCR 432.



Enamel Chipping and Notching

While the hypermineralized composition of enamel makes enamel hard, sufficient stress can cause enamel to fracture or become notched. Both chipping (Belcastro et al. 2007; Bonfiglioli et al. 2004; Milner et al. 1991; Molnar 1972; Turner et al. 1969) and notching (Bonfiglioli et al. 2004; Cruwys et al. 1992; Schour et al. 1942) can result from both alimentary and non-alimentary induced dental modifications (AIDMs), either through mastication of gritty/fibrous foodstuffs, or extramasticatory activities such as craft production, or using the teeth and mouth as a "third hand." The presence of V-shaped dental crowns and incisor notches, for example, comprise a typical AIDM resulting from the repeated placement of a foreign object bucco-lingually between occluding teeth, such as needles, pins, or nails (Bonfiglioli et al. 2004; Capasso 1999; Lorkiewicz 2011). As such, scoring of enamel chipping and notching can be informative on both food textures and possible craft production in past communities.

Enamel chipping was identified and scored following Bonfiglioli et al (2004), where scores of 1 corresponded to slight cracks or fractures (0.5mm), scores of 2 were square irregular lesions (1mm) with enamel more deeply involved, and scores of 3 corresponding to cracks bigger than 1mm and involved enamel, dentine, or a large irregular fracture (Figure 5). Notching was scored following similar rationale, with scores of 1 being slight superficial indentations, scores of 2 referring to wider, deeper orientation and polished dentine, and scores of 3 pertaining to very deep and equally wide depressions with heavily polished dentine (Figure 5.4). Scores are presented here only on a subsample from Largo Cândido dos Reis (Table 5.1), as the Avenida 5 de Outubro sample was not able to be scored for enamel chipping and notching due to travel-related issues of data collection with the COVID-19 pandemic.

Figure 5.4 – Examples of enamel notching (A) and chipping (B) observed in maxillary central incisors.

Results

Antemortem Tooth Loss (AMTL)

When analyzed by anterior and posterior dentition, all groups (Islamic Females, Islamic Males, Christian Females, Christian Males) showcased extreme AMTL in their posterior dentitions compared to anterior dentitions, ranging between 5.44% and 13.29% of anterior dentition and 22.75% and 31.16% of posterior dentition lost antemortem (Table 5.2).When analyzed by tooth-type (Incisors, Canines, Premolars, Molars) and by sex, Islamic females showcased no significant differences in AMTL when compared to their Islamic male counterparts (Appendix 5.2). Christian females showed significantly higher AMTL in incisors compared to their male counterparts (G = 4.07; p = 0.04)When total AMTL within funerary groups were compared by sex, Islamic females showcased significantly higher rates of AMTL (21.70%) compared to their Islamic male (17.49%) counterparts (G = 5.22, p = 0.04; Table 5.3). Christian females showed higher rates of AMTL (24.12%) than their male counterparts (19.78%) but the difference was not statistically significant. When total AMTL rates of same-sex groups were compared by funerary group, Christian females showcased higher rates of AMTL (24.12%) compared to their Islamic female counterparts (21.70%), and Christian males showcased higher

AMTL (19.78%) compared to their Islamic male counterparts (17.49%) but the differences were not significant (Table 5.4). Visual results by sex and funerary group, alongside periodontitis, can be seen in Figure 5.5.

Calculus

When analyzed by anterior and posterior dentition, all groups (Islamic Females, Islamic Males, Christian Females, Christian Males) showcased higher rates of calculus in their anterior dentition compared to posterior dentition, ranging between 59.88% and 68.65% of anterior dentition and 41.21% and 52.71% of posterior dentition affected by calculus (Table 5.2). When analyzed by tooth-type (Incisors, Canines, Premolars, Molars) and by sex, Islamic females showcased significantly higher frequency of molars affected with calculus ($G = 12.85$, $p < 0.01$) and total calculus ($G = 13.36$, $p < 0.01$) when compared to their Islamic male counterparts (Appendix 5.3). In the Christian funerary group, no significant sex differences in calculus by tooth type was observed. When calculus severity was analyzed by sex and separated by funerary group (Appendix 5.4), Islamic females showed significantly higher rates of score = 1 ($G = 6.05$, $p = 0.03$) and score = 3 (Fisher's Exact $p = 0.02$) compared to Islamic males. Christian females and males similarly showcased a majority of score = 1 (77.94% and 65.12% respectively) but higher frequency of score = 2 (16.67% and 28.68%) and score = 3 (5.39% and 6.20%) compared to their Islamic counterparts. When calculus severity was analyzed by funerary group and separated by sex (Appendix 5.5), both Islamic females and males showed significantly higher frequency of score = 1 compared to their Christian counterparts (Females: $G = 17.57$, $p < 0.01$; Males: $G = 34.56$, $p < 0.01$ respectively). However, both Christian females and males showcased higher frequency of scores = 2 (Females: $G = 38.33$, $p < 0.01$; Males: $G = 26.25$, $P < 0.01$) and males showed increased scores of 3 compared to their Islamic counterparts. When calculus location was analyzed by sex and separated by funerary group (Appendix 5.6), Islamic males showed a significantly higher frequency of lingual ($G = 6.09$, $p = 0.03$) whereas females exhibited higher interproximal calculus ($G = 7.55$, $p = 0.01$). No other significant sex differences were found for the Islamic funerary group. Christian females exhibited higher calculus across multiple locations than their male counterparts ($G = 17.61$; $p < 0.01$). When calculus location was analyzed by funerary group and separated by sex (Appendix 5.7), Islamic females showed higher frequencies than their Christian female counterparts for every surface except for buccal. Conversely, Christian males showed significantly higher frequency of lingual calculus (32.25%) compared to their Islamic male counterparts (20.50 %; $G = 20.74$, $p < 0.01$). When total calculus rates of same-funerary groups were compared by sex, only Islamic females had significantly higher frequency of calculus compared to Islamic males (Table 5.3). When total calculus rates of same-sex groups were compared by funerary group, both Christian females (58.62%) and Christian males (55.72%) showcased higher rates of calculus than their Islamic female (58.57%) and male (48.96%) counterparts, but only males showed a significant difference (Table 5.4). When sexes were collapsed, no significant differences were observed.

Periodontitis

Periodontal scores separated by funerary group and sex showed that only two Islamic males showcased exclusively healthy (category 1) septa (Appendix 5.8). The remaining 93 individuals analyzed showcased signs of either gingivitis or periodontitis. Relatively few Christian females (*n* = 2, 15.31%) showcased signs of only gingivitis, whereas Christian males (*n* = 5, 22.73%), Islamic females (*n* = 5, 25.00%) and Islamic males (*n* = 7, 23.33%) showcased higher signs of exclusively gingivitis or otherwise healthy dental septa. The majority of individuals (75.00 – 84.62%, regardless of sex or funerary group, showcased signs of periodontitis (score > 2). Only n = 7 Islamic females (11.11%) showcased signs of periodontitis in greater than 50% of observable septa, while n = 11 Islamic males (38.10%), n = 8 Christian males (36.36%) and n = 3 Christian females (23.08%) showed more than 50% of septa with periodontitis. When analyzed by score (Appendix 5.9), Islamic males showed a sizeable presence (43.32%) of category 1 (healthy) interdental septa, while Islamic females (37.41%), Christian females (38.67%) and Christian males (36.07%) all showcased comparatively lower frequency of healthy septa. All groups analyzed showed relatively similar frequencies of septa affected by gingivitis (category 2), ranging from 20.98% to 25.46%. When categories 3, 4 and 5 were collapsed for total periodontitis ranging from acute burst to larger angular defects, all groups showed approximately 35.70 – 39.90% of septa affected. When analyzed by anterior and posterior septa, no significant differences were found for either sex or funerary group (Table 5.2). When sexes were compared within funerary groups for total periodontitis (Table 5.3), for either funerary group. When funerary groups were compared between same-sex sub-groups, no differences were observed (Table 5.4). When maxillary and mandibular septa were compared by sex and funerary group, only Christian females showed significantly higher frequency of periodontitis in maxillary septa (47.27%) compared to mandibular ones (33.56%; Appendix 5.10). No other significant differences between maxillary and mandibular septa was found for Islamic females, males, or Christian males.

Table 5.2 – Anterior vs Posterior frequencies of dental pathological lesions by funerary group and sex.

		Anterior		**Posterior**				
Analysis	**Sex**	**N observed /Total**	**Crude frequency (%)**	**N observed /Total**	**Crude frequency (%)**	***G***	**P value**	**Interpretation**
AMTL[†]	Islamic Female	42/316	13.29	149/564	26.42	21.77	<0.01	Significantly more posterior AMTL
	Islamic Male	31/361	8.59	139/611	22.75	34.44	<0.01	No Significantly more posterior AMTL
	Christian Female	18/160	11.25	91/292	31.16	24.51	<0.01	Significantly more posterior AMTL
	Christian Male	13/239	5.44	112/393	28.50	57.91	<0.01	Significantly more posterior AMTL
Caries[‡]	Islamic Female Uncorrected	22/288	7.64	79/435	18.16	17.11	<0.01	Significantly more posterior caries
	Islamic Male Uncorrected	17/342	4.97	62/495	12.53	14.55	<0.01	Significantly more posterior caries
	Total Islamic Uncorrected	39/630	6.19	141/930	15.16	31.83	<0.01	Significantly more posterior caries
	Islamic Female Corrected	59/330	18.02	202/584	34.64	30.27	<0.01	Significantly more posterior caries
	Islamic Male Corrected	27/373	7.33	158/634	24.96	54.91	<0.01	Significantly more posterior caries
	Total Islamic Corrected	86/703	12.23	360/1,218	29.56	79.84	<0.01	Significantly more posterior caries
	Christian Female Uncorrected	1/142	0.7	28/201	13.93	-	<0.01*	Significantly more posterior caries
	Christian Male Uncorrected	9/231	3.90	51/272	18.75	29.11	<0.01	Significantly more posterior caries
	Total Christian Uncorrected	10/373	2.68	79/473	16.70	50.25	<0.01	Significantly more posterior caries
	Christian Female Corrected	19/160	11.88	119/292	40.75	44.86	<0.01	Significantly more posterior caries
	Christian Male Corrected	22/244	9.02	156/384	40.61	82.21	<0.01	Significantly more posterior caries
	Total Christian Corrected	41/404	10.15	275/676	50.68	126.82	<0.01	Significantly more posterior caries
Calculus[§]	Islamic Female	173/252	68.65	203/390	52.05	17.64	<0.01	Significantly more anterior calculus
	Islamic Male	203/339	59.88	197/478	41.21	27.81	<0.01	Significantly more anterior calculus
	Christian Female	97/145	66.90	107/203	52.71	7.09	<0.01	Significantly more anterior calculus
	Christian Male	137/213	64.32	121/250	48.40	11.89	<0.01	Significantly more anterior calculus

Periodontitis⸸	Islamic Female	53/131	40.46	107/270	39.63	0.03	0.87	No difference
	Islamic Male	73/201	36.32	138/390	35.38	0.05	0.82	No difference
	Christian Female	41/100	41.00	60/156	38.46	0.16	0.69	No difference
	Christian Male	52/139	37.41	93/238	39.08	0.10	0.75	No difference
Enamel Chipping	Islamic Female	63/135	46.67	35/196	17.86	31.68	<0.01	Significantly more anterior chipping
	Islamic Male	129/248	52.02	83/341	24.34	47.79	<0.01	Significantly more anterior chipping
	Christian Female	54/141	38.30	34/195	17.44	18.29	<0.01	Significantly more anterior chipping
	Christian Male	111/230	48.26	49/275	17.81	54.39	<0.01	Significantly more anterior chipping
Enamel Notching	Islamic Female	55/136	40.44	7/196	3.57	75.77	<0.01	Significantly more anterior notching
	Islamic Male	106/247	42.91	14/340	4.11	140.44	<0.01	Significantly more anterior notching
	Christian Female	18/142	12.68	3/194	1.55	17.97	<0.01	Significantly more anterior notching
	Christian Male	97/231	41.99	10/277	3.61	122.68	<0.01	Significantly more anterior notching

† Number of discernable teeth lost antemortem/Number of observable loci
‡ Number of observed and/or estimated carious lesions/Total number of teeth observed. See text for details on calculating corrected vs. uncorrected prevalence
§ Number of observed teeth with calculus/Total number of teeth observed
¶ Number of discernable loci with periapical lesions/Total number of observable loci
⸸ Number of discernable interdental septa with scores > 2/Total number of observable interdental septa
**P-value resulting from a Fisher's Exact test (α =.05) due to expected counts being less than 5*
ᵅ P-value adjusted with a Bonferroni correction

Caries

Groups analyzed showed higher uncorrected rates of posterior carious lesions compared to anterior ones, regardless of sex or funerary group, all of which were statistically significant (Table 5.2). In both uncorrected and corrected measures, Islamic females showcased higher frequency of carious lesions than their male counterparts, with only anterior uncorrected carious lesion being non-significant (Table 5.3). No significant sex differences were found for the Christian funerary group, regardless of uncorrected or corrected analyses. Islamic females showed higher frequency of uncorrected anterior and total carious lesions compared to their Christian female counterparts, but the differences were not significant once corrected (Table 5.4). Christian males showed significantly higher uncorrected posterior caries compared to Islamic males, and corrected posterior and total caries compared to Islamic males. When compared by location, Islamic females showcased higher frequency of carious lesions found on smooth surfaces and roots compared to their Islamic counterparts (Appendix 5.11). Christian males exhibited higher proportion of caries on cervical surfaces compared to Christian females, while all other differences were nonsignificant

Periapical Inflammation

When intra-funerary groups were analyzed by sex (Table 5.3), no significant differences in periapical lesions were observed. Similarly, when sexes were compared by funerary group (Table 5.4), no significant differences were observed.

Enamel Chipping and Notching

Significantly more chipping and notching was found in in anterior dentition compared to posterior dentition, regardless of sex or funerary treatment (Table 5.2). No significant sex differences were observed in enamel chipping among funerary groups (Table 5.3). However, significantly higher frequencies of notching was observed in Islamic and Christian males compared to their female counterparts. No significant differences were detected between Islamic and Christian funerary groups for enamel chipping, regardless of sex (Table 5.4). Islamic females did; however, exhibit significantly higher frequency of teeth affected by notching than their Christian female counterparts.

Dental Wear

Results from the dental wear can be seen visually in Figure 5.6. The majority of scores (75.00% - 83.62%), regardless of funerary or sex group, were relatively minor in wear severity (Scores < 5).

Table 5.3 – Sex comparison of frequencies of dental pathological lesions.

		Female		Male				
Analysis	**Funerary Group**	**N observed/Total**	**Crude frequency (%)**	**N observed/Total**	**Crude frequency (%)**	***G***	**P value**	**Interpretation**
AMTL[†]	Islamic	191/880	21.70	170/972	17.49	5.22	0.02[a]	Significantly more AMTL in females
	Christian	109/452	24.12	125/632	19.78	3.61	0.06[a]	No difference
Caries[‡]	Islamic Uncorrected	101/723	13.97	79/837	9.44	7.78	<0.01*	Significantly more caries in females
	Christian Uncorrected	29/343	8.45	60/503	11.93	2.67	0.10	No difference
	Islamic Corrected	262/914	28.67	186/1007	18.47	27.88	<0.01*	Significantly more caries in females
	Christian Corrected	138/452	30.53	178/628	28.34	0.61	0.44	No difference
Calculus[§]	Islamic	376/642	58.57	400/817	48.96	13.36	<0.01*[a]	Significantly more calculus in females
	Christian	204/348	58.62	258/463	55.72	0.68	0.82	No difference
Periapical lesions[¶]	Islamic	14/925	1.51	15/1020	1.47	0.01	0.99[a]	No difference
	Christian	14/488	2.87	7/422	1.66	1.51	0.44[a]	No difference
Periodontitis[⸸]	Islamic	160/401	39.90	211/591	35.70	1.79	0.36[a]	No difference
	Christian	101/256	39.45	145/377	38.46	0.06	0.99[a]	No difference
Enamel Chipping	Islamic	98/331	29.61	212/589	35.99	3.91	0.10[a]	No difference
	Christian	88/336	26.19	160/505	31.68	2.95	0.17[a]	No difference
Enamel Notching	Islamic	62/332	18.67	120/467	25.70	5.52	0.04*[a]	Significantly more notching in Islamic males
	Christian	21/336	6.25	107/508	21.06	38.24	<0.01*[a]	Significantly more notching in Christian males

[†] Number of discernable teeth lost antemortem/Number of observable loci
[‡] Number of observed and/or estimated carious lesions/Total number of teeth observed. See text for details on calculating corrected vs. uncorrected prevalence
[§] Number of observed teeth with calculus/Total number of teeth observed
[¶] Number of discernable loci with periapical lesions/Total number of observable loci
[⸸] Number of discernable interdental septa with scores > 2/Total number of observable interdental septa
** Significant at the a = 0.05 level; **P-value resulting from a Fisher's Exact test (a =.05) due to expected counts being less than 5; [a] P-value adjusted with a Bonferroni correction*

Table 5.4 – Funerary comparison of frequencies of dental pathological lesions.

Analysis	Sex	Islamic N observed/Total	Islamic Crude frequency (%)	Christian N observed/Total	Christian Crude frequency (%)	*G*	P value	Interpretation
AMTL†	Female	191/880	21.70	109/452	24.12	3.50	0.12[a]	No difference
	Male	170/972	17.49	125/632	19.78	1.33	0.50[a]	No difference
Caries‡	Female Uncorrected	101/723	13.97	29/343	8.45	7.00	0.02	Significantly more caries in Islamic females
	Male Uncorrected	79/837	9.44	60/503	11.93	2.06	0.30	No difference
	Female Corrected	262/914	28.67	138/452	30.53	0.51	0.95	No difference
	Male Corrected	186/1007	18.47	178/628	28.34	21.40	<0.01	Significantly more caries in Christian males
Calculus§	Female	376/642	58.57	204/348	58.62	0.00	0.99[a]	No difference
	Male	400/817	48.96	258/463	55.72	5.42	0.04*[a]	Significantly more calculus in Christian males
Periapical lesions¶	Female	14/925	1.51	14/488	2.87	2.90	0.18[a]	No difference
	Male	15/1020	1.47	7/422	1.67	0.07	0.99[a]	No difference
Periodontitis⸸	Female	160/401	39.90	101/256	39.45	0.01	0.99[a]	No difference
	Male	211/591	35.70	145/377	38.46	0.75	0.80[a]	No difference
Enamel Chipping	Female	98/331	29.61	88/336	26.19	0.97	0.65[a]	No difference
	Male	212/589	35.99	160/505	31.68	2.26	0.27[a]	No difference
Enamel Notching	Female	62/332	18.67	21/336	6.25	24.61	<0.01[a]	Significantly more notching in Islamic females
	Male	120/467	25.70	107/508	21.06	2.92	0.17	No difference

† Number of discernable teeth lost antemortem/Number of observable loci

‡ Number of observed and/or estimated carious lesions/Total number of teeth observed. See text for details on calculating corrected vs. uncorrected prevalence

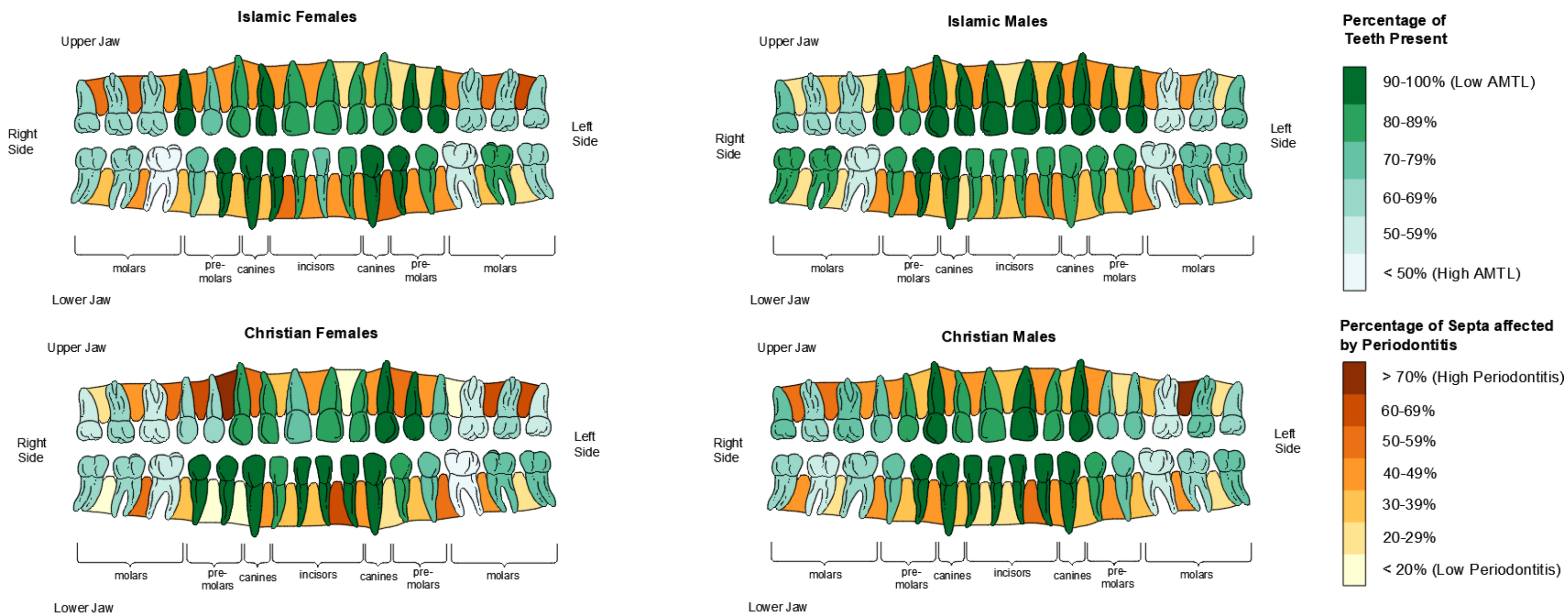
§ Number of observed teeth with calculus/Total number of teeth observed

¶ Number of discernable loci with periapical lesions/Total number of observable loci

⸸ Number of discernable interdental septa with scores > 2/Total number of observable interdental septa

** Significant at the a = 0.05 level; **P-value resulting from a Fisher's Exact test (a =.05) due to expected counts being less than 5; [a] P-value adjusted with a Bonferroni correction*

Figure 5.5 - Visualized 'heat map' of antemortem tooth loss (AMTL) and periodontitis by sex and funerary group.



For teeth, dark green corresponds to high likelihood of tooth being present (low AMTL) and white corresponds to higher likelihood of tooth being lost antemortem. For interdental septa, dark brown corresponds to high prevalence of periodontitis for that septum, where tan/buff corresponds to low likelihood of periodontitis being present in that interdental septum.

Figure 5.6 - Dental wear scores by sex and funerary group.

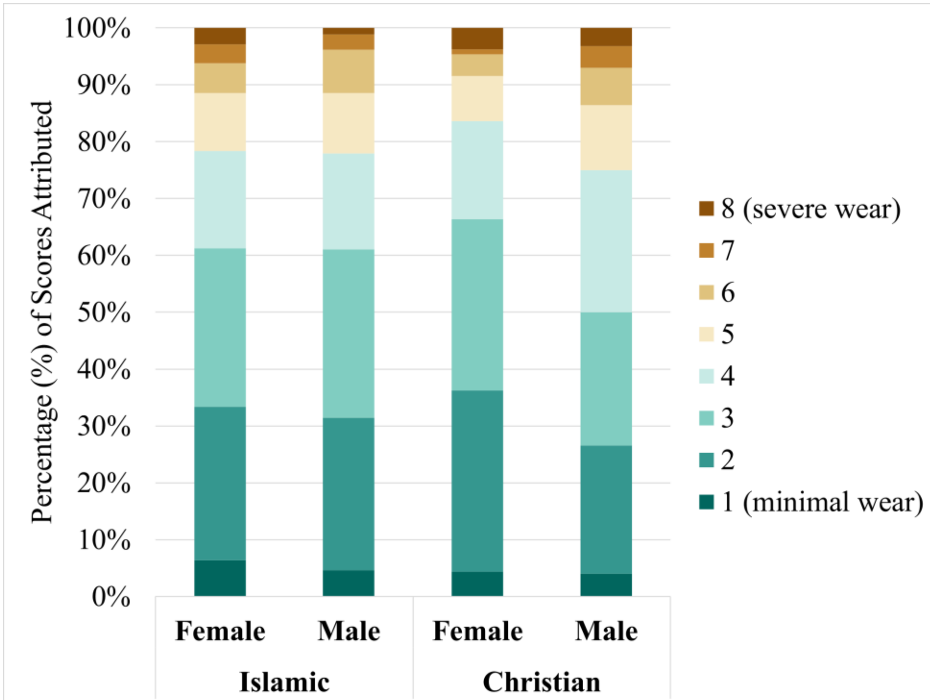


Figure 5.7 - Stable isotope results by funerary group.

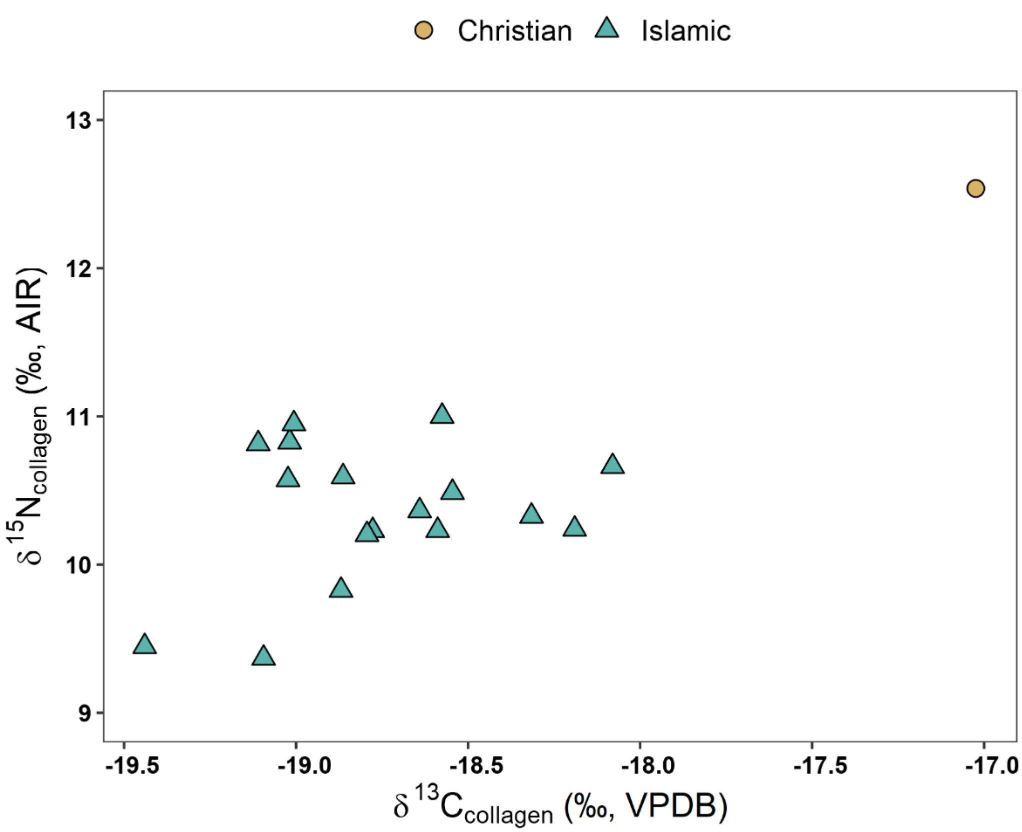
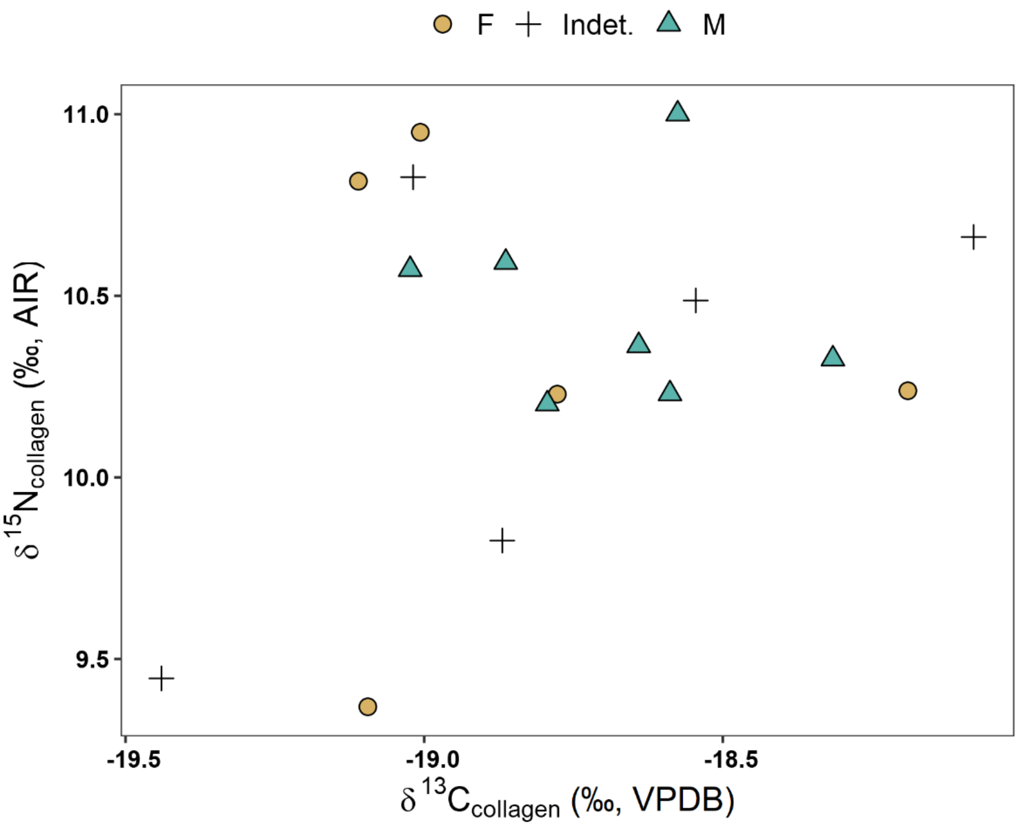


Figure 5.8 - Stable isotope results by sex in Islamic group only



Discussion

Food, Religion, and Landscapes in Medieval Portugal

The patterned antemortem loss of posterior dentition is unsurprising, given the mechanical demands of occlusion paired with complex crown morphology (Hillson 2008) that often makes molars more prone to cavitation (and, subsequently, loss if the cavity expands). While teeth can be dislodged from their alveolar sockets antemortem through traumatic injury, there was no patterned signs of traumatic injury to the facial region nor the alveolar structures that suggested teeth were lost systemically due to trauma. Rather, it appears that teeth were lost as a result of pathological lesions (cavitation, periodontitis, abscesses) and/or the biomechanical influences of mastication.

Agriculturally, central Portugal was focused on a cereal complex comprised predominantly of wheat (*Triticum*), barley (*Hordeum vulgare*) and rye (*Secale cereale*) (Gonçalves 2004). During the Islamic period (c. 711 – 1149), numerous Arabic references to the success and proliferation of buckwheat (*Fagopyrum esculentum*) suggest it become one of the more dominant cultigens throughout the central and later middle ages (Marques 2021). The arrival of Islam additionally resulted in the intensification and proliferation of arboriculture and fruit gardens, and subsequent drying of particular fruits such as figs (*Ficus*), grapes (*Vitis*), and plums (*Prunus*) (Marques 2021). Orchards containing stonefruits (*Prudus*), gourds (*Cucurbitaceae*), apples (*Malus*), pomegranates (*Lythraceae*), lemons (*Citrus limon*), and bitter oranges (*Citrus x aurantium*) were particularly prevalent throughout the Islamic period, and accompanied by careful hydrological innovation and irrigation such as the development of water wheels, watermills, and aquifers (Marques 2021). Various Islamic geographers during the middle ages highlighted the presence of public hygienic baths within Santarém specifically (Matias 2018), in addition to the *Omnias*, or horticultural gardens, and Santarém's important proximity to the "Nile of al-Andalus" – the Tagus river (Custódio et al. 1996a). Agriculturally, the region was known for its rich fluvial floodplains and cultivation of cereals, wine, and olive oil (Custódio et al. 1996a; Gonçalves 2004). While sugar cane (*Saccharum*) was introduced into the Iberian peninsula by Arabic traders in the 10th century (García-Sánchez 1990; García-Sánchez 1995), its initial introduction was specific to the Spanish Mediterranean coast due to its specific ecosystem (coastal, calcareous soil, frost-free, etc.) suitable for sugar cane cultivation (Jiménez-Brobeil et al. 2022). While sugar cane production was expanded under the Nasrid period, the cultivation was generally limited to the southern coast of Spain such as Almería, Granada, and Málaga (Jiménez-Brobeil et al. 2022). As such, to our knowledge, sugar cane was never introduced to central Portugal during this period.

Unfortunately, there has been a dearth of published archaeobotanical work on Roman and medieval Iberian sites (Peña-Chocarro et al. 2019), though there is promise for emerging patterns. For instance, archaeobotanical remains dating to the Islamic period from a salvage excavation in the Alentejo city of Évora (Coradeschi et al. 2017) found high prevalence of fruits, such as grapes (*Vitis vinifera*), figs (*Ficus carica*), blackberries (*Morus sp.*) and possible melon seed (*Cucumis sativus/melo*), and cereals such as barley (*Hordeum vulgare*), wheat (*Tricitum aestivum/durum*) and oats (*Avena* sp.). Undoubtedly, there is exciting potential for the integration of archaeobotanical findings with other information on foodways and diet in medieval Portuguese contexts. Much of our understanding of medieval foodways in Iberia stems from traditional ethnohistorical accounts (García-Sánchez 1983; García-Sánchez 1986; García-Sánchez 1996) supplemented with archaeology. Cooking and food preparation during the Islamic period seemed to employ clay containers over wood hearths, emphasizing stews and soups with various legumes such as fava beans (*Fabacae*), lentils (*Lens*), chickpeas (*Cicer arietinum*) in addition to faunal bones as thickening/flavoring agents (Marques 2021). Islamic traders not only seemed to have introduced citruses, rice, and sorghum to the peninsula, but also reinvigorated cultivation of millet and alfalfa which had been generally de-emphasized during the Visigothic period (García-Sánchez 1995).

Livestock farming formed an important economic activity throughout the peninsula (Estaca-Gómez et al. 2018), with documentary evidence suggesting sheep and goat being preferred in the Islamic period followed by beef, fowl, and rabbit, while the Christian conquests shifted to an emphasis on pig, cattle, and marine resources as well as bread and wine (García-Sánchez 1986; Marques 2021; Waines 1994; Waines 2010). Sheep and pigs seemed to have been generally more emphasized than cattle throughout the later medieval period, such that Gonçalves suggests nearly every peasant household had a pig (2004). The 12^{th} – 13^{th} centuries saw a burgeoning in bread production as Christian conquests swept throughout Portugal, with variation in bread recipes as a result of regional and climatic variability in cereal cultivation (Marques 2021). Secondary crops such as sorghum and millet seem to have been introduced, and can be seen both archaeobotanically as remains and isotopically due to their C^4 photosynthetic pathway. Interestingly, times of scarcity following the Christian conquests utilized sorghum and millet as fallback crops (Marques 1987). Faunal remains from zooarchaeological analyses seem to generally confirm these documents, with Islamic faunal assemblages showing a general dearth of pig, whereas Christian contexts exhibit higher frequencies of pig and occasionally cattle compared to their Islamic counterparts (García-García 2017; Grau-Sologestoa 2017). Notably, both groups tend to exhibit sheep/goat remains as the most prevalent remains, likely as a result of their broad utility in not only providing meat, but also wool and milk (Grau-Sologestoa 2017). While little published zooarchaeological studies have been conducted within the city of Santarém, analyses of faunal remains from the *alcáçova* (citadel) carried out by Davis (2003) showcased that most faunal remains in the Islamic period belonged to terrestrial mammalian domesticates, principally sheep/goat (Caprines sp.), cattle (*Bos*), pigs (*Sus*), deer (*Cervus*), equids (*Equus*), rabbit (*Leporidae*), cat (*Felis*), and dog (*Canis*), as well as avifauna (*Gallus*/*Numida*/*Phasianus*) and some fish remains (*Acipenseridae, Mugilidae*, *Babus, Sparus*, and *Pagrus*). Excavations of a sizeable silo ($6m^3$) near the Sant Francis convent in association with the Islamic period has uncovered further dietary information (Ramalho et al. 2001). While not as large as other silos excavated near the *alcáçova* (citadel), this silo would have been sufficient to feed a family of 8-10 for approximately 2 years. Faunal remains of sheep (*Ovis aries*/*Capra hircus*), cattle (*Bos taurus*), horse (*Equus caballus*), rabbit (*Oryctolagus cuniculus*), bivalves (*Easthonia rugosa*; *Pecten maximus*) as well as indeterminate fish and bird remains were all recovered from the silo, with ovi-caprids comprising the majority (56.6%) of determinable remains (Ramalho et al. 2001, 160). Given the systematic presence of cut marks, fractures, and occasional charring, the authors posit these remains likely reflect dietary remains. Notably, there was a distinct lack of pig (*Sus*) remains found in this silo assemblage, contrasting with the larger temporal assemblage recovered from the *alcáçova* assemblage (Davis 2003) but adhering to the general trend observed elsewhere in Iberian Islamic contexts.

Marine sources appeared to have held a varied and debated influence in medieval Iberia. While Portugal's proximity to marine resources on the Atlantic and Mediterranean, paired with extensive river and lakes, would presume a strong presence of marine and aquatic foodstuffs, there is a surprising lack of both historical and zooarchaeological data to confirm this. For instance, ethnohistoric accounts from Arab authors seemed to have debated the benefits of fish consumption, with only ~4-10% of recipes listed in Andalusian cookbooks employing fish (García-Sánchez 1986). However, the Qu'ran generally permits the consumption of fish (*halal*), referenced in 5:96:

> "It is lawful for you to hunt and eat seafood, as a provision for you and for travelers. But hunting on land is forbidden to you while on pilgrimage. Be mindful of Allah to Whom you all will be gathered."

Fishing likely comprised an activity for the laity living in littoral zones as a means of meat/protein procurement, but did not receive the comparative attention of chroniclers as terrestrial meat (García-Sánchez 1983). Historically, the Christian period emphasized a scaling up of off-shore fishing and emphasis on fish protein, ranging from the laity to the high courts and royalty (Coelho 1995; Coelho et al. 2016). Fish also became an important resource throughout Christendom during fasting and lent in abstaining from terrestrial ('warm blooded') meat, with 150 days per year listed as fasting dates in the liturgical calendar (Adamson 2004; Grumett et al. 2010; Pérez-Ramallo et al. 2022). Unfortunately, there have generally been a dearth of fish remains recovered in faunal assemblages largely due to recovery techniques (Grau-Sologestoa, 2017, p. 190; footnote 2). Other than a refuse pit in Silves (Davis et al. 2008), the aforementioned assemblage from the citadel of Santarém (Davis 2003) are one of the few published recoveries of fish and marine remains from the medieval period.

Finally, dietary histories are becoming clearer via the burgeoning application of stable isotope analysis. While most isotopic studies that have been conducted on the medieval period in the peninsula have been limited to Spain (Alexander et al. 2015; 2019; Dury et al. 2019; Guede et al. 2017; Jordana et al. 2019; López-Costas et al. 2019; Lubritto et al. 2017; MacKinnon et al. 2019; Pérez-Ramallo et al. 2022; Pickard et al. 2017; Salazar-García et al. 2016), preliminary publications are beginning to emerge for medieval Portugal as well (Curto et al. 2019; Toso et al. 2019; 2021). The emerging trend in these studies seem to suggest that Islamic communities consumed predominately terrestrial resources outside of a few exceptions (Alexander et al. 2019). Conversely, Christian diets appeared to be highly variable depending on geographic location and emphasis on marine resources, with some such as Galicia exhibiting heavy reliance on marine resources (López-Costas et al. 2019) where others such as the Portuguese site of Tomar seemed to rely on a mix of terrestrial and low-trophic fish (Curto et al. 2019). Toso and colleagues (2021) found a general lack of statistically significant sex differences for nearly all sites except for the high-status Muslim cemetery associated with the São Jorge castle in Lisbon (Toso et al. 2019). This compliments other studies within Spain that similarly have found a lack of dietary differences via isotopes for both the general Muslim communities (Alexander et al.

2015; Salazar-García et al. 2016) and Christian laity (Jordana et al. 2019; Lubritto et al. 2017; MacKinnon et al. 2019). Toso and colleagues (2021) notably found evidence of marine consumption in both Islamic and Christian burials associated with urban Lisbon, and urge us to not only consider faith and cultural preferences, but acknowledge the importance of trade, mercantilism, and economics in facilitating access to various resources.

The pilot stable isotope data presented here (Figures 8-9; Appendix 5.1; 5.13-5.14) is exciting in that it presents some of the first stable isotope results from human remains within the city. Within the Islamic group, males (n = 7) had a δ^{15}N 10.5 ± 0.3‰ whereas females (n = 5) had a δ^{15}N 10.3 ± 0.6‰, suggesting virtually no sex differences in diet, though sample sizes are small. From a temporal perspective (Figures S1-S2), the subsample of Islamic individuals shows generally little variation in δ^{13}C values. While earlier burials visually exhibit more δ^{13}C variability ($\bar{x}$ = -18.9 ± 0.4‰) than later burials ($\bar{x}$ = -18.7 ± 0.3‰), the differences are less than 1‰ and barely above analytical error, so I caution against interpreting these as signaling any temporal change. In terms of δ^{15}N values, most Islamic individuals fell between 10 to 11‰, though two early burials (Av5Out Ent. 956 and PVSP1 Ent. 1) exhibited lower δ^{15}N values (9.4‰). It is curious to see the only Christian individual as a clear outlier (+2.1‰ from Islamic δ^{15}N group mean, +1.8‰ from Islamic δ^{13}C group mean). This may suggest that this individual consumed a higher trophic position diet consistent with marine resources or terrestrial meat coupled with C^4 crops such as sorghum and millet (Ambrose 1990), as discussed above in some other medieval Iberian Christian burials (Alexander et al. 2019; López-Costas et al. 2019). Higher δ^{13}C paired with δ^{15}N values can correspond to consuming more marine sources, which typically have higher δ^{15}N values than consuming terrestrial resources due to expanded trophic levels within marine food systems (Schoeninger et al. 1984). However, small sample size and lack of sufficient Christian burials severely limit our potential for interpretation and comparisons. Additionally, since these data were obtained through pilot radiocarbon dating, we additionally lack baseline faunal and floral data, further limiting interpretations. Future research is needed to characterize the baseline food web within the region, as well as elucidate whether this Christian individual is a true outlier, or possibly reflective of larger religious, socio-economic, and agronomic changes following the Christian conquests.

Differences in oral pathological lesions may be contextualized in relation to changing foodways and agricultural landscapes during the Portuguese Middle Ages. Uncorrected, crude caries frequencies suggest Islamic females had higher caries than their Christian female counterparts, but once corrected for antemortem tooth loss, Christian frequencies in caries were actually higher. In fact, Christian males exhibited a significantly higher frequency in caries compared to their Islamic male counterparts once corrected for antemortem tooth loss. These results suggest that correction factors continue to play an important role in elucidating caries frequencies in the past, especially in its relation to pulpal exposure, dental wear, and antemortem tooth loss. Additionally, these results may suggest that a reliance on heavy cereal diets in the later Christian Middle Ages could result in higher caries frequency compared to the dietary landscape during the Islamic period. However, dental wear was observed to be relatively minor in severity, with only ~20% of dental remains exhibiting severe wear (scores > 6), regardless of sex or funerary group. Most of the dental remains analyzed in this study exhibited moderate amounts of wear (Scores 3-4) such that a moderate-to-large area of dentine was exposed with enamel rims still complete. An analysis of dental wear from the Islamic necropolis of Al Fossar, Spain found males to exhibit more wear than their female counterparts (Gómez González 2013, 138). Future studies conducting stable isotope analysis will aid immensely to better characterize the regional baseline, faunal variation, and human dietary patterns, especially among and between religious funerary groups. This study is therefore a preliminary analysis on possible diet and oral health within the city.

Reproductive Ecology and Fertility

Numerous bioarchaeological and clinical studies have observed significantly higher frequencies in antemortem tooth loss (al Shammery et al. 1998; Corraini et al. 2009; Cucina et al. 2003; López et al. 2006; Meisel et al. 2008; Nelson et al. 1999; Oyamada et al. 2007; Shigli et al. 2009; Watson et al. 2010) and caries (Lukacs 2008; 2017; Lukacs et al. 2006; Watson et al. 2010) in females compared to males, and interpreted such differences in light of reproductive ecology. In addition to potential sex and/or gendered differences in diet, increased caries and AMTL frequencies are interpreted as a product of age- and fertility-related alterations in hormones (e.g., estrogen and progesterone) which have cascading effects on salivary quality and quantity (Steinberg 2000; Laine 2002; Burakoff 2003; Silk et al. 2008). Clinically, saliva has been shown to be a crucial inhibitor to cariogenesis through its role as a lubricant, as a pH buffer, and in remineralizing enamel (Dowd 1999; Lenander-Lumikari et al. 2000; Amerongen et al. 2002; Vitorino et al. 2006; de Almeida et al. 2008). Increased estrogen levels, especially during pregnancy, appear to result in decreased salivary flow and quantity, which can lead to changes in the overall oral microbiome and subsequent dental pathological lesions such as tooth loss, cariogenesis, and plaque build up (Kolenbrander et al. 2004; Marsh 2004; Arantes et al. 2009; Fields et al. 2009). However, in bioarchaeological studies, salivary factors are difficult to control for given the in ability to reconstruct saliometric and saliochemical profiles, though some studies have considered such factors in light of dental remains (Lukacs et al. 2006; Lukacs 2017; Trombley et al. 2019).

While numerous sources have analyzed medieval fertility, biology, and motherhood in the Islamic Middle East (Kueny 2013; Verskin 2020), unfortunately, there is a dearth of ethnohistorical sources relating to specific birthing and reproduction within central Portugal during the medieval period. Paleodemographic assessments and fertility estimates, such as D_{30+}/D_{5+} ratios (Buikstra et al. 1994, 534) can aid in contextualizing patterning in dental pathological lesions (Klaus et al. 2010; Trombley et al. 2019). This ratio examines the number of individuals over 30 years of age (D_{30+}) to the number of individual over 5 years of age (D_{5+}), as the ratio is negatively associated with birth rate. Unfortunately, D_{30+}/D_{5+} require a preservation of sub-adults to more accurately reflect fertility estimates. Both Largo Cândido dos Reis and Avenida 5 de Outubro showed a general dearth of sub-adults at the site, either as a result of excavation/intervention areas, preservation, deliberate burial of sub-adults in a separate location from adults, or a confluence of all of these factors (Matias 2008a; Andrew Petersen 2013). As a result, D_{30+}/D_{5+} could not be calculated with accuracy. Consequently, the interpretation of dental pathological lesions in light of reproductive demands are preliminary. Our results suggest a general elevation of dental pathological lesions frequencies in Islamic females compared to Islamic males, with Islamic females exhibiting higher frequencies of AMTL, both corrected and uncorrected caries, and calculus compared to their male counterparts. Conversely, no such sex differences were observed in Christians. When females were compared by funerary group, Islamic females showed a higher crude frequency of caries compared to Christian females, but the difference was not significant when corrected for antemortem tooth loss. Given that Islamic females exhibited higher frequencies of dental pathological lesions compared to Islamic males, but not Christian females, it follows that Islamic and Christian females exhibited similar levels of reproductive demands, and that sex differences were likely more a product of dietary and/or hygienic differences within funerary groups rather than reproductive ones, though future research is needed to clarify this further.

Sex, Gender, and Religious Attitudes Towards Oral Hygiene and Craft Production

Here, I seek to consider how gendered and religious conceptions on oral cleanliness may explain some of the variation observed in dental pathological lesions. Interpreting textual and oral evidence directly in light of bioarchaeological remains is often tenuous and challenging (Perry 2007), and oral hygienic regimens in particular prove difficult to document in bioarchaeological samples. However, contextualized analysis of dental tissues in light of ethnohistorical accounts and sources can provide unique and textured insights into oral hygiene and lesion patterning (Hosek et al. 2020).

I begin by examining some of the broader Islamic conceptions surrounding oral hygiene, and in turn examine conceptions and prescriptions within later medieval Christendom. Throughout much of the medieval Islamic world, the teachings of the Holy Prophets of Islam appear to have institutionalized oral hygiene as a practice of piety in *ḥadīth*. Occasionally referenced is the brushing of the teeth and mouth with *siwāk* (or *miswāk*) – a toothbrush, preferentially made from the bark, branches, and roots of the *arāk* tree, a variety of *Salvadora persica*:

> "If I did not feel that it would be difficult upon my *Ummah* [believers, people], I would have commanded them to perform *miswāk* with every *Wudu* [ablution]"[9]
>
> "Make it a habit to perform *miswāk*, as it is a means of cleansing the mouth and a means of attaining the pleasure of Allah"[10]
>
> "When any one of you stand at night to offer Salah, you should clean your teeth with a *miswāk* because when you recite the Quran, an angel places his mouth on yours and anything coming out of your mouth enters the mouth of that angel"[11]

These *ḥadīth* sought to institutionalize oral hygiene as both a daily practice and more importantly an aspect of piety. The performance of *miswāk* became incorporated not only into the habitus of Islamic daily life but became part of a religious hygienic imaginary in the form of a *Sunnah* – the path of the Holy Prophets. In fact, the four noted *Sunnah* of the Holy Prophets were 1. *Haya* (modesty, shyness), 2. Perfume, 3. *Miswāk* and 4. *Nikah* (marriage).[12] Ibn Al-Nafis (1211-1288

[9] Mu'jam al-Awsat, Vol. 1, Page 341, *ḥadīth* 1238
[10] Musnad Ahmad, Vol. 2, Page 438, *ḥadīth* 5869
[11] Shu'ab al-Iman, Vol. 2, Page 381, *ḥadīth* 2117
[12] Sunan-e-Tirmidhi, vol. 2, p 382, *ḥadīth* 1080

AD) compiled a renowned encyclopedia titled "Mujiz al-Qanun" which advocated numerous prescriptions for treating "the disease of the gum and the teeth and the lips" (Mawaldi et al. 2008, 36). These ranged from avoiding excessive chewing/mastication and breakage of hard foods to the use of miswak and employing other dentifrice techniques to keep the teeth clean of debris (Mawaldi et al. 2008, 37). Pormann and Savage-Smith (2007, 138) for example, discuss how the maintenance of oral hygiene was crucial in Islamic jurisprudence, as words were often the currency of the court, and thus the mouth was to be kept clean and sterile in such high-stakes venues. Contemporary studies have examined the role that *miswāk* plays in oral hygiene and combating dental pathological lesions in combating cariogenic bacteria, periodontitis, and its potential as a dentifrice for inhibiting plaque formation (Al lafi et al. 1995; Almas et al. 2005; Almas et al. 2004; Dahiya et al. 2012; Ezmirly et al. 1979; Ezmirly et al. 1979; Farooqi et al. 1968; Khatak et al. 2010; Niazi et al. 2016; Sote et al. 1995; Wolinsky et al. 1996; Wolinsky et al. 1983). An *in vitro* study carried out by Almas and colleagues (2005) compared a 50% aqueous *miswāk* solution with commercially available mouth rinses, and evaluated their respective antimicrobial effectiveness. While *miswāk* was not as effective as commercially available options containing chlorhexidine, it was minimally effective against *Streptococcus mutans* and effective against *Enterrococcus faecalis.*

From a bioarchaeological stand point, the employment of *miswāk* would most likely have effects on cariogenesis, periodontitis, and calculus formation resulting from plaque buildup. Significantly higher prevalence of calculus in Islamic females compared to Islamic males could be the result of both dietary and oral hygienic differences practiced across gendered lines. Conversely, calculus was not significantly different between Christian sex groups, but Christian males exhibited higher frequencies of calculus compared to Islamic males. Together, these may suggest Islamic males consumed diets that differed from their same-faith female and Christian counterparts, or practiced dentifrice techniques at heightened capacities/frequencies, or a combination of the two. However, to our knowledge, *Salvadora persica* was never introduced to the Iberian peninsula, and continues to remain predominately within the Levant and Africa (Khan et al. 2016). Thus, while the employment of *miswāk* constructed from *Salvadora persica* specifically within the Iberian peninsula is unlikely, it is possible that local, vernacular adaptations could have occurred with locally available materials as dentifrices. Indeed, in regions where the Arak tree does not grow, use of other local trees and shrubs such as orange (*Citrus sinensis*), lime (*Citrus aurantifolia*) and neem (*Azadirachta indica*) has been observed (Dahiya et al. 2012). An old folkloric coverage by Kanner (1935, 80–81), building from 10th century Islamic compendiums found that *miswāk* could be made from at least 17 different kinds of plant material (Appendix 5.12). While we should remain cautious that any of the materials referenced were specifically used in the case of Santarém, I think it is noteworthy that *miswāk* could be constructed from a variety of locally available plant materials for the purposes of oral hygiene. Unfortunately, biotic remains of tree branches, animal bristles, or even textiles, especially those that would have been discarded, seldom survive archaeologically outside of specific conditions (e.g., anoxic). Future research may be able to examine how microscopic phytoliths trapped within dental calculus may correspond to non-alimentary, therapeutic oral hygienic regimens.

Medieval Christian conceptions, at least those represented in textual and artistic sources, of oral health and hygiene are generally less prescribed and more variable than Islamic prescriptions. The underpinnings of Christian piety in oral hygiene are not entirely unlike the aforementioned Islamic prescriptions. Sermons, writings, artistic depictions, and hagiographic materials throughout the Christian Middle Ages attest to the concern for treating tooth aches, tooth loss, cavities, abscesses, and all manner of oral pathological lesions (Trombley et al., in press; Burridge 2020). A survey by Burridge (2020) on a corpus of Carolingian manuscripts found 229 ailment recipes specific to tooth problems, with the majority (n = 186; 81%) being highly specific towards tooth ache (*dentium dolorem*) and tooth loss (*Ad dentem cauum*). Remedies within the Christian middle ages could take numerous palliative forms, such as herbal treatments and poultices employing mullein (*Verbascum thapsus*), pellitory (*Anacyclus pyrethrum*) and ginger (*Zingiber officianalis*), fumigations using henbane (*Hyoscyamus niger*) and leek (*Allium porrum*), or the brushing of teeth with strips of linen or herbs such as sage (*Salvia officinalis*) and elecampane (*Inula helenium*) (Anderson 2004, 420; Getz 1991, 89–97; Green 2002; Hunt 1994; Pughe 1993, 344). In Portugal specifically, tooth ache could be treated with radish (*Raphanus sativus*) and mauve (*Malva sylvestris*) roots, juice from onions and cucumbers, as well as more peculiar animal products such as hog manure, milk, hot weasel liver, and cooked snake meat (Oliveira 2015, 169). Similar to the aforementioned Islamic hygienic regimens, scant (if any) archaeological evidence exists of preserved oral hygienic regimens in medieval Christendom, especially those associated directly with bioarchaeological remains. Considering the observed data, Islamic females exhibited higher frequencies of antemortem tooth loss, caries, and calculus compared to their Islamic male counterparts. Additionally, Chrisitan males exhibited higher caries and calculus frequencies compared to Islamic males. In addition to dietary and reproductive differences, it is possible that gendered differences in oral hygiene may have been practiced within the Islamic community, such that Muslim males may have been comparatively buffered from dental pathological lesions compared to their Muslim female and Christian male counterparts.

Interestingly, both Islamic and Christian males exhibited higher frequencies of enamel notching compared to their female counterparts. Previous analyses (Rodrigues et al. 2021) on a subsample (n = 43) of individuals from the site similarly found the presence of non-alimentary dental modifications and atypical wear, including transversal grooves on mesio-distal occlusal surfaces (TGMOS) and lingual surface attrition of maxillary anterior teeth (LSMAT). In this study, I found enamel notching was predominately observed in anterior dentition, specifically incisors, with the majority of notches found on incisal surfaces. While enamel chipping is typically thought to result from both masticatory and non-alimentary mechanical effects, notching is often interpreted in light of non-alimentary/non-masticatory use of the mouth as a "third hand" (Bonfiglioli et al. 2004). However, notches have been observed in some contemporary communities and individuals who position roasted seeds between the mandibular and maxillary central incisors in order to crack them open (Al-Habahbeh et al. 2011; Amin et al. 2007; Rath et al. 2017). Whether this behavior was practiced specifically within Santarém is difficult with the current evidence to confirm. Smoother grooving on enamel is thought to be the result of enamel coming into repeated contact with exogenous materials such as needles, sinew, fibers, leather, cordage, nails, or other materials associated with craft production or oral hygiene (Bonfiglioli et al. 2004; Capasso 1999; Cruwys et al. 1992; Lorkiewicz 2011; Schour et al. 1942). It is conceivable that males, regardless of religious funerary treatment, practiced potential crafts such as sewing, weaving, carpentry, shoemaking, or basket-weaving that left discernable notches among anterior dentition, possibly as a result of gendered labor practices (Bonfiglioli et al. 2004; Capasso 1999; Cruwys et al. 1992; Erdal 2008; Larsen 1985; Lorkiewicz 2011; Molleson 1994; Rodrigues et al. 2021; Schour et al. 1942). A 15th century register from Évora documents a list of commonly practiced urban professions, including cloth merchants, jewelers, carpenters, shoemakers, fisherman, and tailors (Beirante 1995, 503), all of which could involve the use of the mouth as a third hand. Although difficult to confirm conclusively, I posit that cultural and/or gendered hygienic regimens and professions may further impact dental tissues and subsequent pathological lesions.

Conclusion

The Middle Ages are often assumed to be one of poor oral health and hygiene, though such caricatures are often unsubstantiated in terms of historical and/or bioarchaeological data. Meta-analyses conducted on European caries and antemortem tooth loss frequencies and prevalence have shown the Medieval period to be one of generally high caries incidence, but not nearly as severe as the following Early Modern period likely as a result of the increased sugar trade (Roberts et al. 2003; Pezo et al. 2012; Müller et al. 2017; Witwer-Backofen et al. 2019; Bertilsson et al. 2022). Indeed, when Medieval dentition are examined more closely, I found substantial variability in both caries and AMTL frequencies and prevalence, suggesting such experiences were highly regional as a result of dietary variability, and differences in food preparation, reproductive demands, and oral hygiene (Trombley et al., in press). While these results are preliminary, I find that the patterning of dental pathological lesions is best understood in a contextualized manner, attentive to the varying ways in which daily life, diet, nutrition, reproduction, and oral hygiene may have been practiced within and between religious identities and sexes. The observed patterning of dental pathological lesions in this study is likely a confluence of multiple proximate and ultimate biocultural factors that contribute to complex etiologies. Future research will benefit greatly from stable isotope, zooarchaeological/faunal, and archaeobotanical analyses to further contextualize dietary practices within the city and the region.

Chapter 6: Lifeways — Biocultural approaches to growth and development

Introduction

This chapter continues the investigation of lifeways by examining non-specific skeletal indicators of stress during growth and development in a comparative framework. Stress here is conceptualized as physiological change resulting from environmental, nutritional, and/or otherwise biocultural strain (Goodman et al. 1988; Huss-Ashmore et al. 1982). The examination of childhood, and the growth and development period more broadly, have a longstanding area of interest in bioarchaeology (Goodman et al. 1989; Hoppa 1992; Lewis 2007; 2022; Saunders et al. 1993; Saunders 2008), in part because children are particularly susceptible to physiological disturbances and are therefore seen as a proxy of larger sample/population experiences. Growth here refers to an increase in size, while development corresponds more closely to maturity, as the increase in functional abilities (Cameron 2012). Physiological perturbations during the growth and development period often result in delays and/or deficits as energy is preferentially used for other important structures and functions. This is largely due to growth being mediated by the endocrine system (Rosenfeld 2012), whereby environmental insults can result in a reduction of growth hormone (GH) being released, cascading into a restricted release of insulin-like growth factor 1 (IGF-1) which is responsible for musculo-skeletal development (Cameron 2012). At an extreme level, severe stress will result in early mortality before the adult ever reaches maturity. However, even if the individual survives the stressor, significant and sustained perturbations during growth and development seem to predispose survivors to disease susceptibility in later life and/or early mortality (Barker 2001; Barker et al. 1986; 1989). Often termed the Developmental Origins of Health and Disease (DOHaD) or 'Barker hypothesis' following the long work of Barker and colleagues, this approach illustrates how both fetal and post-natal development are sensitive periods with long-lasting consequences both individually and intergenerationally (Armelagos et al. 2009; Bogin et al. 2007; Kuzawa 2005; 2008; Worthman et al. 2004; 2005). As such, the growth and development period continues to be a key window of investigation for epidemiologists and anthropologists alike, given its varied patterning (Bogin 1999; 2001;) and health consequences later in life (Bogin et al. 2007).

Bioarchaeological approaches to growth and development, especially in relation to adult health and mortality, stem from the notion of skeletal heterochronicity (Agarwal 2016). Skeletal heterochronicity refers to how differing skeletal elements, tissues, envelopes, and matrices correspond to differing temporal signatures. The enamel of anterior dentition, for example, forms between approximately 1 and 6 years of age (Reid et al. 2000; 2006), such that any perturbation significant enough to produce an enamel defect will correspond to that window of stress, and furthermore remain permanent as enamel does not remodel. Conversely, the vertebral neural canal (VNC) corresponds to thyrolymphatic development, and is mostly (>80%) completed by five years of age, but can continue to growing through later adolescence (Hinck et al. 1965; 1966). A stress event may result in restricted VNC dimensions (stenosis) during this sensitive period, and therefore become locked in by late adolescence and early adulthood. Since stressors during growth and development can produce indelible markers within skeletal and dental tissues, these indicators can be analyzed in adults to shed light on both individual and sample-level variation during ontogeny (Agarwal 2016; Cardoso et al. 2009; Gooderham et al. 2019). Thus, various skeletal tissues not only record aspects of growth and development even in adult remains, but systematically analyzing such tissues and their chronologies can help provide a more robust understanding of stress events as being systemic rather than episodic. Bioarchaeologists have found numerous skeletal indicators of non-specific stress during the growth and development phase associated with early mortality, such as porotic hyperostosis (Klaus et al. 2009), linear enamel hypoplasia (Boldsen 2007a; Wilson 2014b), fluctuating asymmetry (Deleon 2007; Gawlikowska et al. 2007; Weisensee 2013), vertebral neural canal dimensions (Clark et al. 1986; Watts 2011; 2013; 2015), and stature (Vercellotti et al. 2014), to name only a few. Following the pioneering work of Selye (1973) who noted the limited product of responses to a myriad of stressors, the etiology of these skeletal manifestations are complex and multifactorial, and as such bioarchaeologists tend to treat these indicators as non-specific manifestations of general stress response rather than direct corollaries of a particular stressor (Goodman 1993; Goodman et al. 1988; Temple et al. 2014b). Additionally, early life stressors should be interpreted cautiously in skeletal remains, not as destiny, but rather in light of plasticity and the life course (Agarwal et al. 2011).

Like other chapters in this dissertation, this chapter employs a comparative framework in order to characterize non-specific indicators of stress during growth and development within and between distinct religious funerary groups. Within Portugal, bioarchaeological assessments of growth and development from medieval contexts is small but growing (Cardoso et al. 2009; Cunha et al. 2017; Cunha 2015; Gooderham et al. 2019). A comparative analysis of skeletal growth profiles (SGPs) between a medieval sample from Leiria and a 20th century sample from Lisbon found that while growth deficits in children were similar between the subsamples, adults were significantly taller in the medieval Leiria sub-sample than their 20th century Lisbon counterparts (Cardoso et al. 2009). The authors cautiously interpret these results in light of differing environmental circumstances between the samples, such that Lisbon adolescents experienced more unfavorable conditions, such as urbanization, increased potential for disease communicability, sanitation problems, and integration into a physically demanding work force (Cardoso et al. 2009). The data seem to suggest that the potential for catch-up growth was greater in the medieval sample compared to the 20th century one. More recently, innovative analyses by Cunha and colleagues (Cunha 2015; Cunha et al. 2017) have examined data on linear enamel hypoplasia (LEH) alongside paleoparasitological remains from sediments recovered from pelvic and cranial regions of Islamic burials at Largo Cândido dos Reis in Santarém. While non-specific in their etiology, LEH can occasionally result from parasitic load (Goodman et al. 1990), as the host's normal development can become compromised via nutritional malabsorption and gastrointestinal disease (Blom et al. 2005; Sullivan 2005) which in turn can affect amelogenesis. Though a small sample (n = 30 individuals), the authors found 46.67% of individuals to exhibit LEH, and additionally identified two species of helminths associated with burial soils: *Ascaris lumbricoides* and *Trichuris trichiura*, though the presence of helminth eggs did not appear to correlate with presence of LEH (Cunha et al. 2017). Finally, Gooderham et al (2019) examined linear and appositional growth of Islamic (n = 27) and Christian subadults (n = 15) sourced from various excavated cemeteries throughout the city. The authors found no significant differences between Islamic and Christian growth variables, with both groups exhibiting significant growth deficits in linear and appositional bone, stunting, and periosteal apposition compared with modern healthy children. However, they did find a reduction in growth deficits between Early and Late Islamic growth variables, which reversed with the Early Christian group following the Christian conquests (1147 C.E.) and deficits increased even further by the Late Christian period (Gooderham et al. 2019). Notably, lower limbs exhibited the most significant deficits which is often observed and interpreted as a product of lower limb susceptibility to living conditions (Cameron 2012). Despite no statistically significant differences, the authors encourage future research to explore the possibility of extrinsic/environmental stress accompanying the Christian conquests given their temporal observations.

This study differs slightly from previous research in that I examine indicators of growth and development exclusively in adult skeletal remains, and I examine multiple indicators of non-specific stress in concert. Principally, I analyze the presence and prevalence of: 1) terminal adult stature, 2) linear enamel hypoplasia (LEH) as well as the timing of a sub-sample of estimable LEH, 3) cribra orbitalia, 4) porotic hyperostosis, and 4) periostosis. While I also collected vertebral neural canal (VNC) data, the end subsample fit for complete case analysis was severely limited due to taphonomic influences (missingness, fragmentation), and/or pathology (e.g., ossification of the ligamentum flavum, Schmorl's nodes, osteophytosis, etc.). As such, I have excluded the VNC data in this analysis. Despite the difference in methodology and overall sub-sample analyzed, I seek to build upon the preliminary scholarship that has been previously conducted in this sample. Given the observed presence and patterning of LEH, helminths, and growth deficits in previous research at this site (Cunha et al. 2017; Gooderham et al. 2019), I anticipate various indicators of non-specific stress to be present within the adult skeletal subsample. Additionally, building on the work of Gooderham and colleagues (2019) which outlined the possibility of religious/temporal differences, I hypothesize that there will be a significant increase in non-specific indicators of stress associated with Christian individuals compared to their Islamic counterparts.

Materials

The background on the region, site, and materials can be seen in Chapter 3. The list of individuals analyzed by indicator and separated by funerary group and sex can be seen in Table 6.1. Unfortunately, limited sample sizes limited our potential to conduct statistical comparisons with age groups. As such, I primarily examine these indicators between sex groups and religious funerary groups, but attempt to analyze age-related changes when possible by grouping sex-groups together.

Table 6.1 – List of individuals analyzed by funerary group, sex, and indicator.

Indicator	Sex	Islamic N individuals	Christian N individuals
Stature	Females	39	30
	Males	48	47
	Total	**87**	**77**
LEH	Females	13	15
	Males	23	28
	Total	**36**	**43**
Cribra orbitalia	Females	26	9
	Males	38	21
	Total	**64**	**30**
Porotic hyperostosis	Females	25	17
	Males	39	33
	Total	**64**	**50**
Periostosis	Females	19	28
	Males	31	53
	Total	**50**	**81**

Methodology

Terminal Adult Stature

Adult stature is a complex product of hormones, genetics, and other biocultural factors such as nutrition working together during growth and development. Systemic stress during this sensitive period can result in stunted adult height (Bogin 1999; Bogin et al. 2007; Eveleth et al. 1990), as long bone growth longitudinal growth (Mays et al. 2008; Saunders et al. 1993) and appositional development (Garn et al. 1969; Mays et al. 2009) can become compromised. Here, stature is analyzed as part of a larger suite of indicators that correspond to growth, development, and sub-adult stress.

There are two major methods for reconstructing terminal adult stature in bioarchaeological samples: the anatomical ('Fully') method, and regression estimates. The anatomical method developed by Fully (1956) is preferable in estimating stature to regression estimations (Vercellotti et al. 2011; Vercellotti et al. 2014), but requires nearly complete preservation of the axial skeleton and additional appendicular elements. Given the variable preservation of skeletal material at the site (see Chapter 9), long bone regressions were employed here instead. Here, stature was estimated following Buikstra and Ubelaker (1994, 82), whereby the maximum length of the femur was measured using an osteometric board to the nearest 0.10 mm. Left femora were preferentially measured, though in the event that the left femur was missing or damaged, rights were used instead. In order to assess whether the use of right femora may affect stature results, a subset of n = 74 individuals (n = 36 Christian, n = 38 Islamic) with paired right and left femora were analyzed. Neither Christian ($t = -0.16$, $p = 0.87$) nor Islamic ($t = -0.11$, $p = 0.92$) subsamples showed significant difference in length, and therefore suggest that right femora could be used in absence of the left. Stature was estimated by inputting femoral measurements into the following regression equations by Mendonça (2000):

$$Female\ Terminal\ Adult\ Stature\ (cm) = [57.86 + (0.2359 \times Femur\ max\ length)] \pm 5.96$$

$$Male\ Terminal\ Adult\ Stature\ (cm) = [46.89 + (0.2657 \times Femur\ \max\ length)] \pm 6.96$$

Given that many femora were from secondary contexts (e.g. ossuaries, co-mingling, reductions), only femora from primary burial contexts that could be confidently attributed to religious burial treatments as well as age and sex were used here. A total of 164 individuals (39 Islamic female, 48 Islamic male, 30 Christian female, and 47 Christian male) were analyzed for terminal adult stature.

Linear Enamel hypoplasia (LEH)

Enamel is secreted during growth and development as part of amelogenesis via ameloblasts (Hillson 2014). However, severe stress can compromise ameloblast cells and cause a disruption in the normal secretion of enamel, resulting in a hypoplastic defect (FitzGerald 1998; Goodman et al. 1990; Hillson et al. 1997). While hypoplasias can take numerous forms (e.g., pits, furrows, band) (Fédération Dentaire Internationale 1982; Fédération Dentaire Internationale 1992), linear enamel hypoplasias (LEH) are the most commonly studied in bioarchaeology, and are characterized by linear troughs that typically form mesio-distally as a reflection of the underlying organization of perikymata and striae of Retzius. These effects are transitory: as the ameloblasts recover, they return to prismatic shape of enamel which can be seen in the cervical walls of these defects (Guatelli-Steinberg et al. 2004; Hillson et al. 1997). The cause of LEH is multifactorial, ranging from episodic events such as fevers and traumatic injuries to more systemic episodes such as parasitic load, disease, anemia, and congenital anomalies, though LEH typically form in response to nutritional deprivation (Goodman et al. 1990; Suckling 1989; Zhou et al. 1998). Traditionally, to rule out episodic events, LEH should be observed on multiple teeth as any perturbation systemic enough would theoretically affect other teeth developing when the event occurred (Goodman et al. 1990). Hillson (1996) furthered this criterion by arguing systemic stress could be considered if LEH are present on all teeth forming during the event, though preservation of numerous dentition and antimeres is not always tenable in archaeological contexts. More recently, microscopic assessments using both measuring microscopes (Cares Henriquez et al. 2018; 2020; Temple et al. 2012) and scanning electron microscopy (Guatelli-Steinberg 2008; Guatelli-Steinberg et al. 2004; Guatelli-Steinberg et al. 2014; King et al. 2005) have refined criteria for LEH scoring by counting exact perikymata (and thereby days) associated with events. These microscopic techniques help by 1) distinguishing between episodic and systemic events, 2) matching events across teeth, 3) discovering LEH and stress events not visible to the naked eye, and 4) analyzing age-at-formation, periodicity, and recovery of stress events. The culmination of these studies suggest that macroscopic assessments underrepresent true prevalence of LEH (and thereby stress) and fail to match events across multiple teeth accurately.

Despite the enormous accuracy and precision microscopic analyses afford, there are several drawbacks. Microscopic techniques are costly, requiring either costly scanning electron microscopes and/or measuring microscopes. These analyses are also time consuming, often yielding incredibly detailed information but on a limited number of individuals, with one of the larger studies to date analyzing n = 34 individuals (King et al. 2005). Finally, microscopic assessments often require excellent preservation among anterior dentition, with little dental wear in order to more accurately reconstruct perikymata counts (Guatelli-Steinberg et al. 2004; 2014; Hubbard et al. 2009; King et al. 2005; Temple et al. 2012). In archaeological samples with heavy antemortem tooth loss and/or tooth wear, the likelihood of conducting microscopic assessments diminishes, and can be limited to only subadults who have lived long enough for permanent teeth to fully form but not long enough to experience gradual tooth wear throughout the life course (King et al. 2002; Temple et al. 2012). As such, many bioarchaeologists continue to analyze LEH according to the more “subjective” field method (Cares Henriquez et al. 2020, 2).

Due to some of the limitations mentioned above, LEH was carried out macroscopically in this study (“subjective field method”) according to previously established standards (Goodman et al. 1990; Buikstra et al. 1994). Only anterior teeth (Canines and Incisors) were examined for LEH, since the crown morphology of posterior dentition can make identification of linear enamel hypoplasias difficult (Hillson 2008). Defects were scored with the naked eye with the aid of diffuse light, and the presence was confirmed with the depression (Figure 6.1) being felt by a fingernail (Steckel et al. 2006). Prevalence of LEH was scored in 15 Christian females, 28 Christian males, 13 Islamic females and 23 Islamic males. A subsample from each funerary group and sex was also analyzed for LEH chronology. In the case of dentition with relatively little wear (<20%), the position of each LEH on the crown surface was calculated by using digital calipers (Paleotech Inc.) to measure the distance between the cemento-enamel junction (CEJ) and the occlusal-most portion of the LEH to the nearest 0.01mm (Krenz-Niedbała and Kozłowski, 2013; Nakayama, 2016; Cares Henriquez and Oxenham, 2019). Degree of wear was assessed by measuring crown heights for each tooth class (medial and lateral incisors, canines) with little-to-no wear and generating both mean unworn crown heights and maximum values (Appendix 6.1 - Unworn crown height metrics). Teeth with significant dental wear (e.g., heavy dentine exposure), or metrics that fell well beneath the mean value were excluded. The position of each LEH were then entered into exponential regression equations following Cares Henriquez and Oxenham (2018) to yield age-at-formation for each event:

Table 6.2 - Age at Defect formation (from Cares Henriquez and Oxenham 2018).

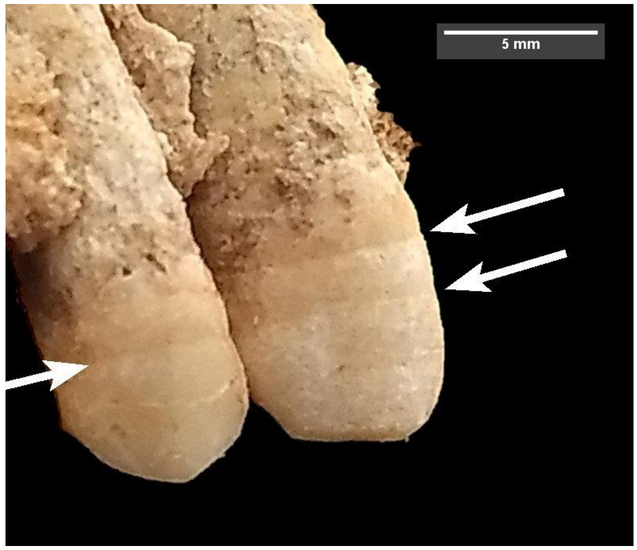
Tooth	**Equation**	R^2	S
Upper central incisor (I^1)	Age = $5e^{-0.146x}$	0.9975	0.09
Upper lateral incisor (I^2)	Age = $5.1e^{-0.106x}$	0.9978	0.04
Upper canine (C^1)	Age = $5.3e^{-0.112x}$	0.9992	0.03
Lower central incisor (I_1)	Age = $3.8e^{-0.135x}$	0.9964	0.07
Lower lateral incisor (I_2)	Age = $4.2e^{-0.144x}$	0.9975	0.06
Lower canine (C_1)	Age = $6.2e^{-0.141x}$	0.9969	0.11

Where *e* is the mathematical constant, *S* is the Standard Error, and *x* is the distance of the defect from the CEJ in mm as a proportion of crown height available, which is achieved by taking the distance from the CEJ (*d*) divided by the total length of the tooth in mm (*I*), which itself is divided by percentage of the tooth that is missing (1 – *m*), then multiplying by 10:

$$x = \left(d \Big/ \frac{I}{1-m} \right) x\ 10$$

These equations are based on previously analyzed histological data of surgically removed anterior teeth from a northern European population (*n* = 115) conducted by Reid and Dean (Reid et al. 2000). Whereas traditional regression estimates based on CEJ-defect distances underrepresent defect formation by not accounting for imbricational enamel and assume linear crown growth (Massler et al. 1941; Swärdstedt 1966; Goodman et al. 1990), this method not only takes into account hidden cuspal enamel, but also considers the non-linearity of tooth growth (Goodman et al. 1999; Ritzman et al. 2008; Martin et al. 2008; Krenz-Niedbała et al. 2013; Lukasik et al. 2014; Cares Henriquez et al. 2018). While microscopic methods are more precise and permit investigations of stress duration and recovery (Guatelli-Steinberg 2008; Guatelli-Steinberg et al. 2004; 2014; Temple et al. 2012; King et al. 2005; Hilson et al. 1997), exponential regressions help to similarly estimate age-at-occurrence of each defect while maximizing sample size. A total of 14 Islamic Females (n = 140 teeth), 16 Islamic males (n = 144 teeth), 7 Christian females (n = 46 teeth) and 8 Christian Males (n = 48 teeth) were analyzed for LEH chronology.

Figure 6.1 - Example of linear enamel hypoplasias (LEH) in Ent. 65.



Cranial pathology (cribra orbitalia and porotic hyperostosis)

The primary forms of cranial pathology corresponding to non-specific stress during growth and development scored in this study were cribra orbitalia and porotic hyperostosis. Traditionally, both cribra orbitalia and porotic hyperostosis were thought to be coupled as similar responses to iron-deficiency anemia which resulted in hematopoietic expansion of the diploë and characteristic porous lesions (Blom et al. 2005; Stuart-Macadam 1987). Notably, porotic hyperostosis is specifically defined as the "porous enlargement of bone tissue" (Ortner 2003, 55) but is often used to describe spongey lesions and porosity in the cranial vault. In the last few decades, scholars have cautioned the coupling of these lesions as the etiology of porous enlargement both in the cranial vault and orbits can be the cause of numerous processes beyond iron-deficiency anemia, such as tumors, hemmorrhagic/inflammatory processes, genetics, and parasite-induced anemia (Cole et al. 2019; Ortner 2003, 89; Rivera et al. 2017; Walker et al. 2009). The lesions can co-occur (sometimes as high as 92%; Cole and Waldron, 2019), but are likely the result of differing anemic conditions (Rivera et al. 2017). Typically these lesions form from 4 to 6 months after birth up to 4 to 6 years, due to children retaining a greater capacity for skeletal plasticity via marrow hyperplasia and expansion of the cranial vault (Blom et al. 2005). While these lesions can be observed in adult skeletal remains (Mensforth et al. 1978), they are often in a healed state corresponding to previous childhood experience (Blom et al. 2005).

Porotic hyperostosis and cribra orbitalia were both scored in a binomial manner, marked only as present in the case of porosity accompanied by an enlargement/thickening of the diploë (Buikstra et al. 1994). Unfortunately, taphonomic and recovery/cleaning factors severely limited overall sample sizes (see Chapter 9), and as such, only individuals with at least one observable orbit and/or parietal bone were analyzed. A total of 30 Christian and 64 Islamic individuals were scored for cribra orbitalia, which included some individuals of indeterminate age/sex. A subset of 23 Christian and 47 Islamic individuals were scored with estimable demographics. For porotic hyperostosis, 50 Christian individuals and 64 Islamic individuals were scored, with a subset of 40 Christian and 47 Islamic scored with estimable demographics.

Periosteal Inflammation (Periostitis and Periostosis)

Periostitis refers to the inflammatory response within the periosteum, while periosteal reaction is more specific to the formation of new bone at the periosteal surface. Crucially, periosteal reactions are a complex nexus of fat, fascia, and muscle interacting with one another (Ragsdale et al. 2011, 229). Bioarchaeologists have traditionally held that periosteal lesions are non-specific in etiology, but often result from infections from agents such as Staphylococcus or Streptococcus (Goodman et al. 2002). Lesions are typically scored in the tibia, as it is less vascularized than the rest of the skeleton and has minimal soft tissue between it and the environment in addition to osteoblastic activity (Gallay et al. 1994; Klaus 2014). The periosteal membrane consists of a thin layer of fibroconnective tissue which interfaces with the cortical bone surface via a cellular cambium layer. The cambium in particular has osteoblastic potential and is susceptible to stressors, which often result in reactive proliferative changes (Kenan et al. 1993; Wenaden et al. 2005). If infection is chronic, localized cell response can result in pus which can cascade into additional inflammation and osteogenic changes. Subadults in particular are more prone to periosteal inflammation due to a more reactive and loose membrane (Wenaden et al. 2005).

In a series of papers by Weston (2008; 2009; 2009) critically assessed periostitis diagnosis in paleopathology, as well as its linkage with stress. In part, Weston outlines how many researchers continue to rely on the non-specificity of periostitis as a catch-all for generalized stress without further questioning its etiology and relationship with hormones (Weston 2008). Klaus (2014) traces this argument and responds in kind, underscoring the notable contributions Weston's skepticism has made in considering periostitis while also highlighting some of the simplistic dismissals of inflammatory response and stress. Ultimately, Klaus (2014, 299) suggests that the outright rejection of periostitis as an indicator of stress is likely extreme, despite its complicated relationship with mortality (DeWitte 2014). More recently, bioarchaeologists and paleopathologists (e.g., Klaus 2017; Roberts 2019) have adopted periostosis in place of periostitis, as periostosis is a more conservative description of the process of inflammation rather than infection (as periostitis often implies). Here, periostosis was scored in a present/absent manner based on the presence of proliferative changes within the tibia.

Figure 6.2 - Examples of cribra orbitalia (A) in Ent. 415, porotic hyperostosis (B) in Ent. 458, and periostosis (C) in Ent. 113.

Analytical Procedures

Normality was assessed using normal quantile plots and Shapiro-Wilk tests. Stature estimates were compared using two-tailed *t*-tests with an $\alpha = 0.05$, whereas proportion data were compared using χ^2 tests, or Fisher's Exact test in the case of expected counts being less than five. Given the issues of underlying age structures in bioarchaeological assemblages and their relationship to frequency data (Boldsen et al. 2011; Waldron 1994; 2007; Wood et al. 1992), crude prevalence and statistical comparisons alone can be biased. As such, I utilize crude prevalence and hypothesis tests in concert with odds ratios (OR) which examine the proportion of an occurrence compared to a non-occurrence for both case and control groups:

$$Odds\ Ratio\ (OR) = \frac{\frac{p_1}{1 - p_1}}{\frac{q_1}{1 - q_1}}$$

Where p_1 corresponds to the probability of disease state (event) in an exposed compared to non-disease state ($1 - p_1$), and q_1 corresponds to the probability of no disease state in an unexposed (control) group ($1 - q_1$).While Waldron (1994; 2007) was an early proponent of employing odds ratios in place of frequency data, only more recently have bioarchaeologists begun to employ epidemiological statistics rather than crude frequency comparisons (Klaus 2014; Klaus et al. 2009; 2010). Odds ratios were calculated in R.Studio v 4.2.2 (RStudio Team 2020) using the

In the case of measurable LEH events, Christian females and males were found to be normally distributed by both normal quantile plots and Shapiro-Wilk tests, but Islamic females and males were not (Appendix 6.2). However, given the large sample sizes (n = 400+ events) normality should not factor as a Type I Error (Glass et al. 1972), due to the same size's relation to the central limit theorem, where even highly skewed distributions approach normal distribution with increasing number of observations (Stevens 2013, 52), something observed in bioarchaeological datasets as well (Cheverko et al. 2017). Equality of variances were visually analyzed with Box and Whisker plots (Figure - Box) and a dot plot (Appendix 6.3), supplemented with a Levene test which found no significant differences in variances between subgroups ($F = 0.48$, $p = 0.70$). Mean age-at-occurrence for LEH events between funerary groups were compared using a One-Way ANOVA followed by Tukey's HSD tests, which provide adjusted p-values to minimize overall family-wise error rates (FWER). Given the large sample sizes for each group (>100) paired with the small measurement scales, effect sizes are also reported through calculation of Cohen's *d* where:

$$d = \frac{\bar{x}_1 - \bar{x}_2}{Pooled\ sample\ SD}$$

Cohen (1988) cautiously advocated for a tiered approach to interpreting *d*, such that d = 0.2 represents a "small effect", d = 0.5 represents a "medium effect" and d = 0.8+ as a "large effect." Notably, these are meant to function more as general guidelines and not rules (Thompson 2007). The calculation of effect size helps to understand the magnitude of difference, and addresses discrepancies in measuring units (Lee 2016).

In addition to frequentist analysis for stature estimate distributions I employed a Bayesian analysis to supplement these models and comparisons of funerary and sex groups. While a complete coverage of Bayesian analysis is beyond the scope of this section, I encourage readers to consult the work of Kruschke (2013; 2015; 2018; 2021; Kruschke et al. 2018) among others (Western et al. 1994; Albert 2009; Lambert 2018) who clearly explain Bayesian analysis, especially in relation to software such as R. Analyses were carried out in R.Studio v 4.2.2 (RStudio Team 2020) in tandem with the JAGS software package, which stands for Just Another Gibbs Sampler, and can facilitate Markov chain Monte Carlo (MCMC) methods either via Gibbs sampling or by employing the Metropolis-Hastings algorithm (Metropolis et al. 1953). This facilitates a probabilistic approximation of the posterior distribution given the observed data.

All MCMC simulations were ran with a burn-in period of 1,000 steps to allow for convergence (Appendix 6.4 – 6.39). Diagnostics on all parameters (mean, standard deviation, and degrees of freedom) exhibited dense superimposed trace plots with no orphaned chains (Kruschke 2015, 179–180). Density plots for all parameters similarly exhibited overlap after the burn-in period and reaching convergence. Gelman-Rubin statistics for all parameters exhibited low shrink factors (~1.0) with no chain variance exceeding 1.1 (Brooks et al. 1998; Gelman et al. 1992). Finally, to evaluate potential for autocorrelation, the effective sample size (EES) proposed in Kass et al (1998, 99). Kruschke (2015, 184) advocates an ESS of approximately 10,000 for accurate estimates of the posterior 95% highest density interval (HDI). Given that all of the EES values well exceeded this threshold, and are all unimodal, all diagnostics suggest that the MCMC are representative of posterior distributions of interest.

I utilized the conservative prior from the normal *t* distribution. Our justification of this prior choice stems from previous research which tend to find height as normally distributed (McElreath 2015), though the posterior predictive checks of the modelled distributions over the observed distributions do suggest other priors would be more preferable for future research, or at least one with slightly wider tails. To facilitate comparisons between funerary groups, a region of practical equivalence (ROPE) was used, following Krushke (Kruschke 2013; 2015; 2018). Default values for differences in scales (-0.5, 0.5) and effect size (-0.1, 0.1) were used, but a larger ROPE for difference in means was used (-2.5, 2.5). This larger ROPE was chosen as this is a preliminary Bayesian analysis, and a larger, more conservative ROPE should be idea for early studies whereas later studies with more robust/specific priors can facilitate narrower ROPE parameters (Kruschke 2018).

Results

Stature – Bayesian

Posterior Bayesian estimate outputs comparing sexes with funerary groups lumped can be seen in Figure 6.3. The difference of means falling well outside of the ROPE as well as being above zero and a significant effect size all suggest highly significant differences between the sexes. When funerary groups are separated and Females and Males are subsequently compared, both Islamic and Christian males are significantly taller than their female counterparts (Figures 6.4 – 6.5 - Bayesian estimate with funerary separated).

When comparing stature by funerary groups with sexes pooled, no significant difference in means nor effect size was detected, with distributions overlapping 0 and falling well within their associated ROPEs (Figure 6.6). Similarly, when funerary groups were separated but compared with same-sex groups, Islamic Males were slightly taller than their Christian male counterparts (Figure 6.8), but the difference in means distribution and effect size distribution overlapped 0 and fell within the ROPE. However, Islamic Females did exhibit a notably higher posterior distribution of stature estimates compared to their Christian Female counterparts (Figure 6.7), with the difference of means distribution falling largely above 0 (99.1%) and the majority of the distribution (69.5%) falling outside of the ROPE. Similarly, the effect size distribution fell largely above 0 (99.1%) and the majority of the distribution fell outside of the ROPE (97.7%).

Stature - Frequentist

In the frequentist analysis, both Islamic and Christian males showed significantly larger stature results than their female counterparts (Table 6.3). Comparisons between same-sex funerary groups showcased that Christian females have significantly smaller stature than their Islamic female counterparts (Table 6.4). Conversely, Islamic males show signs of increased stature compared to their Christian male counterparts, but the difference was not significant.

Linear Enamel Hypoplasia (LEH)

When age categories were compared by funerary group, no significant differences were observed (Table 6.5). Similarly, no significant differences were observed when sexes were compared (Table 6.6) nor when funerary groups were compared against each other (Table 6.7).

When age and sex groups were pooled by funerary group, Christians showed a slightly higher prevalence (62.79%) of LEH compared to their Islamic counterparts (61.11%), but the difference was not significant No significant differences were observed in LEH prevalence when indeterminates were excluded (Table 6.8) nor included (Table 6.9).

The subset of individuals whose LEH could be chronologically estimated can be seen in Table 6.10 and Figures 6.9 – 6.10. While the average number of defects per individual was higher in Islamic males (27.31) and females (28.79) compared to Christian males (15.00) and females (15.57), the average number of events per tooth was similar, suggesting this could be an artifact of dental preservation and underrepresentation of individuals in the Christian subsample. The mean age at occurrence was similar across funerary groups and sexes, though Islamic males had a significantly lower meant age at occurrence (2.86 years) compared to the other groups (3.10 – 3.31 years; Table 6.11). Effect sizes for these significant results range between "small" (0.28) to "medium" (0.52).

Cribra orbitalia (CO)

When funerary-specific age-categories were compared, Christians showed a significant lower prevalence in older age groups (Table 6.5). No significant differences between sex groups (Table 6.6) nor funerary groups were detected (Table 6.7). No significant difference was observed between funerary groups when indeterminates were excluded (Table 6.8) nor included (Table 6.9).

Porotic Hyperostosis (PH)

When funerary-specific age-categories were compared, no significant differences in prevalence with age were observed for either funerary group (Table 6.5). No significant differences between sex groups (Table 6.6) nor funerary groups were detected (Table 6.7). When indeterminates were excluded, Christians showed increased signs of prevalence and risk for porotic hyperostosis compared to their Islamic counterparts, but the difference was not significant (Table 6.8). However, Christians showed a significant increase in odds for porotic hyperostosis when indeterminates were included (OR = 3.24, 95% CI = 1.07 - 11.25; Table 6.9).

Periostosis

When funerary-specific age-categories were compared, no significant differences in prevalence with age were observed for either funerary group (Table 6.5). No significant differences between sex groups (Table 6.6) nor funerary groups were detected (Table 6.7). When indeterminates were excluded, Christians showed an increased risk of periosteal lesions compared to their Islamic counterparts, though the difference was not significant (Table 6.8). When indeterminates were included, Christians showed significantly higher odds (OR = 3.07, 95% CI = 1.22 - 8.10) of periosteal lesions compared to their Islamic counterparts (Table 6.9).

Figure 6.3 - Output of Bayesian estimation analysis for Female and Male stature estimates (in cm), with funerary groups lumped.

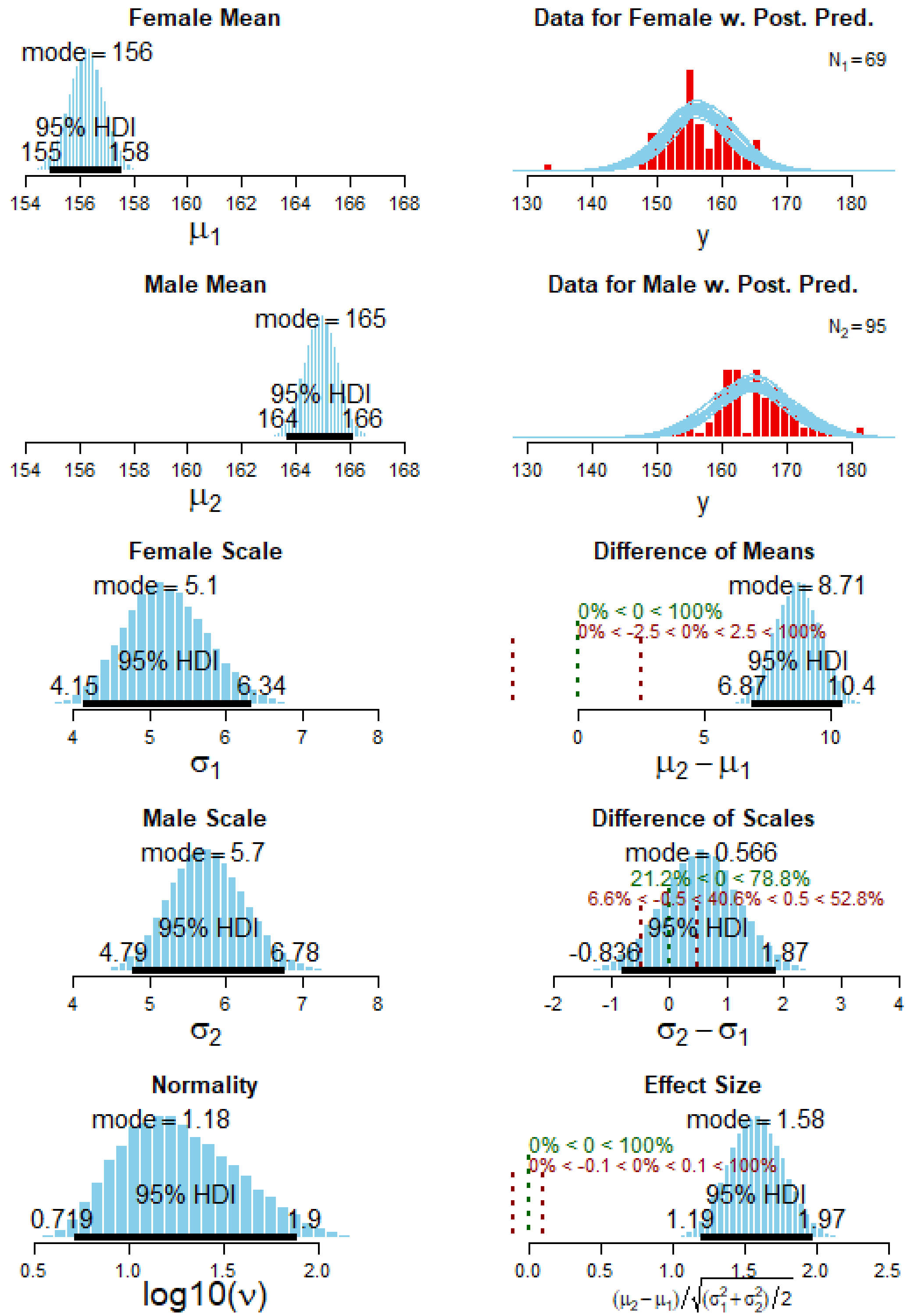


Figure 6.4 - Output of Bayesian estimation analysis for Islamic Female and Islamic Male stature estimates (in cm).

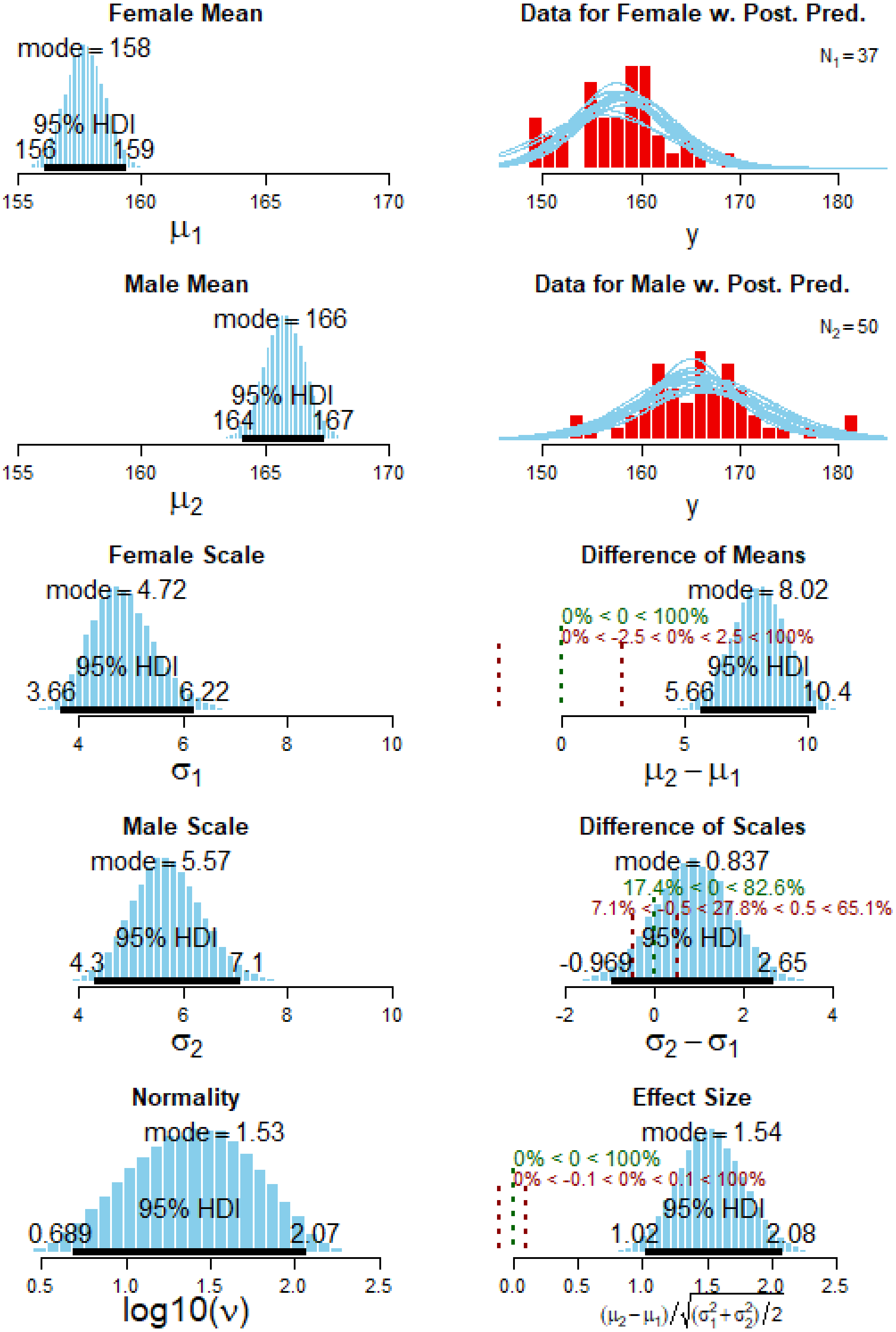


Figure 6.5 - Output of Bayesian estimation analysis for Christian Female and Christian Male stature estimates (in cm).

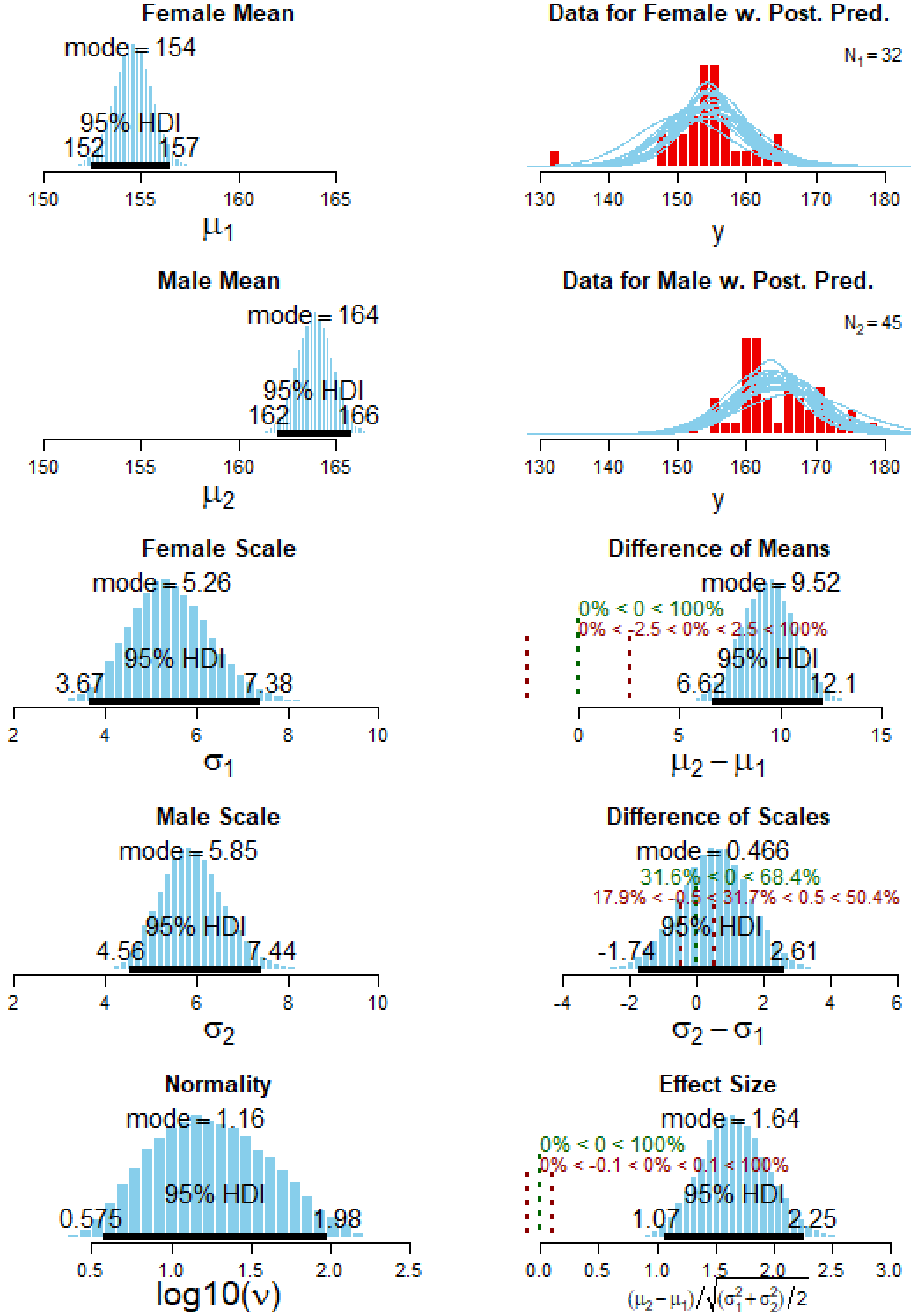


Figure 6.6 - Output of Bayesian estimation analysis for Christian and Islamic stature estimates (in cm), with sexes lumped.

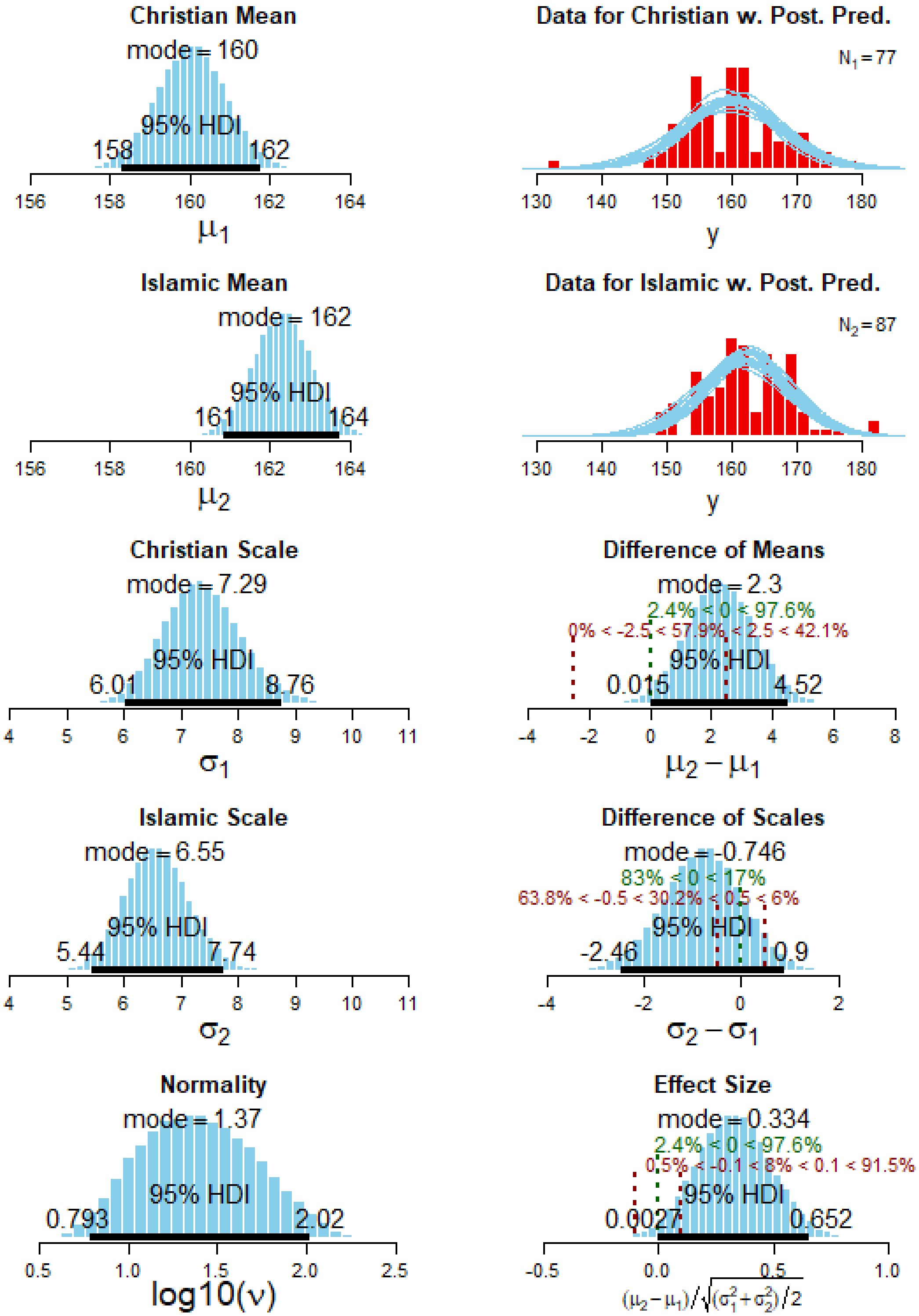


Figure 6.7 - Output of Bayesian estimation analysis for Christian Female and Islamic Female stature estimates (in cm).

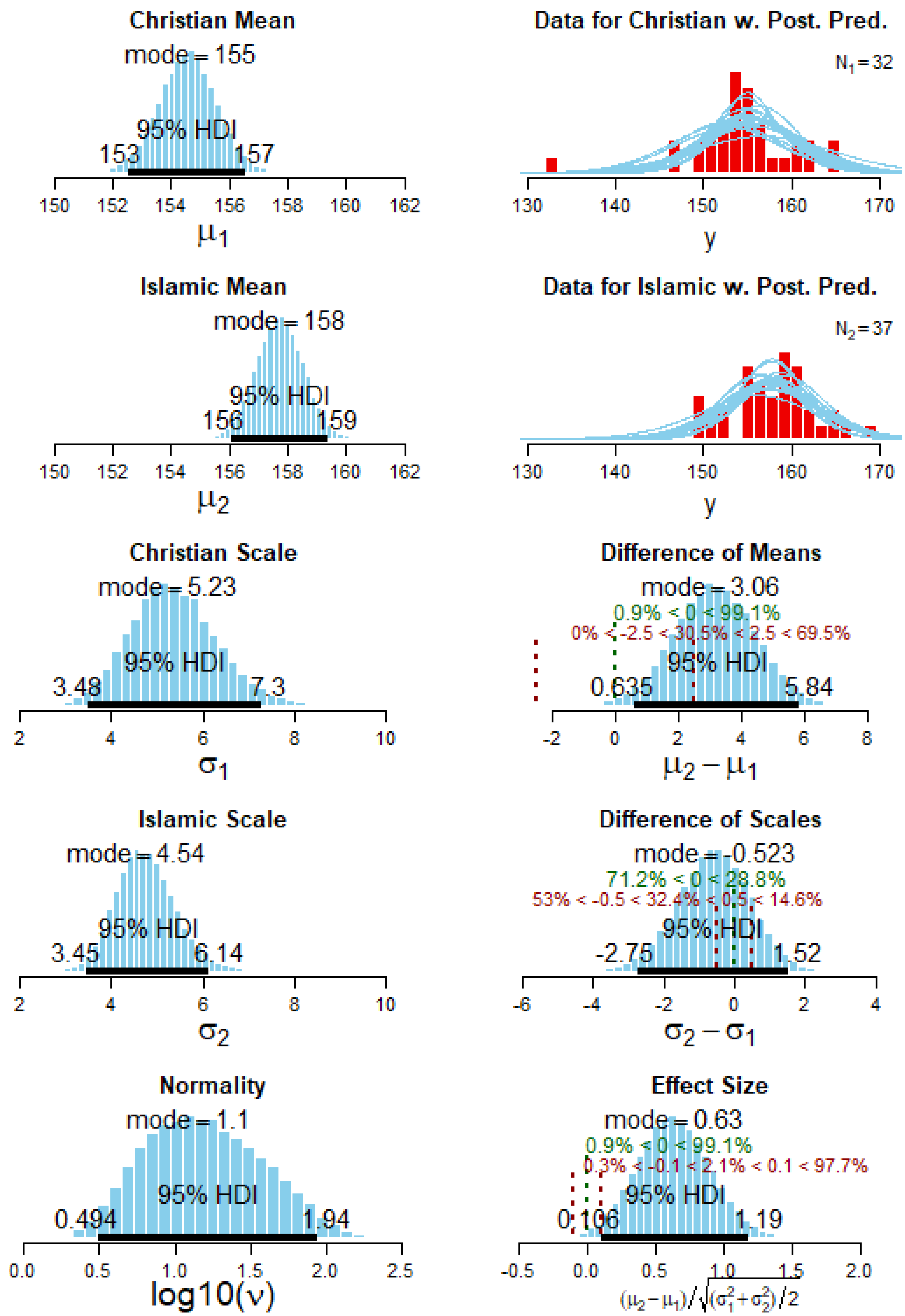


Figure 6.8 - Output of Bayesian estimation analysis for Christian Male and Islamic Male stature estimates (in cm), with funerary groups lumped.

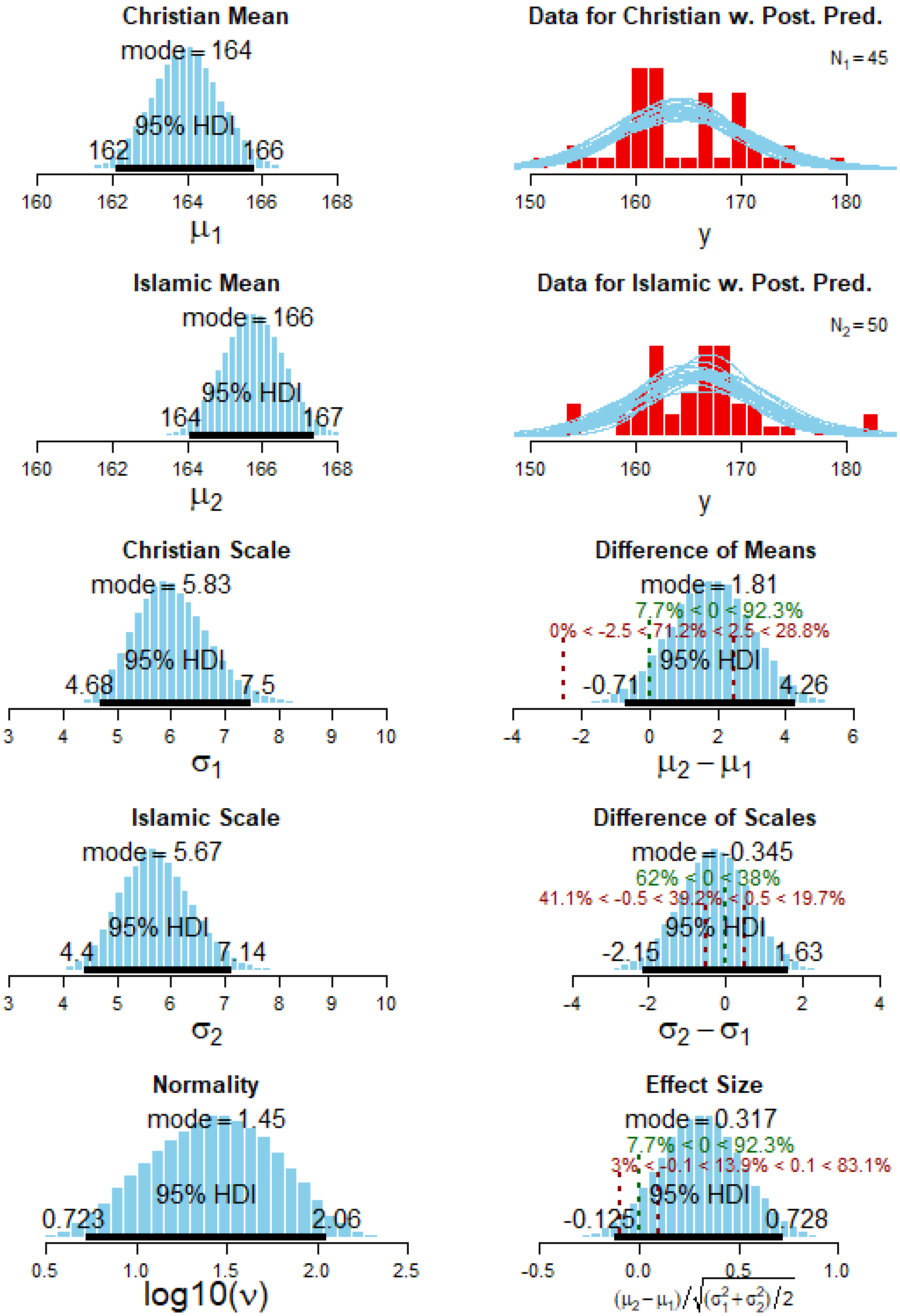


Table 6.3 - Comparison of mean stature results by sex at Largo Cândido dos Reis.

Category	Females *N*	Females $\bar{x}$ (s)	Males *N*	Males $\bar{x}$ (s)	*t*	*p*	Adjusted *p*
Islamic	37	157.70 (4.90)	50	165.85 (5.94)	-7.01	< 0.01*	<0.01*
Christian	32	154.36 (6.01)	45	164.05 (6.08)	-6.95	< 0.01*	< 0.01*

Table 6.4 - Comparison of mean stature results by funerary group at Largo Cândido dos Reis.

Category	Christian *N*	Christian $\bar{x}$ (s)	Islamic *N*	Islamic $\bar{x}$ (s)	*t*	*p*	Adjusted *p*
Females	32	154.36 (6.01)	37	157.70 (4.90)	2.51	0.02*	0.03*
Males	45	164.05 (6.08)	50	165.85 (5.94)	1.46	0.15	0.30

Table 6.5 - Prevalence of stress indicators by age and funerary group at Largo Cândido dos Reis (Fisher's Exact Test). Sexes pooled.

Stress Indicator	Category	18-29 years N/Total	18-29 years %	30-49 years N/Total	30-49 years %	50+ years N/Total	50+ years %	*p*
Linear Enamel Hypoplasia	Christian	7/7	100	9/13	69.23	6/11	54.54	0.12
	Islamic	4/7	57.14	6/9	66.66	6/7	85.71	0.63
Cribra Orbitalia	Christian	3/5	60.00	0/8	0.00	3/10	30.00	0.04*
	Islamic	3/8	37.50	6/17	35.29	9/22	40.91	0.92
Porotic hyperostosis	Christian	2/6	33.33	3/18	16.67	5/16	31.25	0.54
	Islamic	0/9	0.00	2/18	11.11	3/20	15.00	0.71
Periostosis	Christian	13/15	86.67	19/22	86.36	14/17	82.35	1.00
	Islamic	6/7	85.71	5/9	55.56	11/17	64.71	0.49

Table 6.6 - Prevalence of stress indicators by sex separated by funerary group at Largo Cândido dos Reis (χ^2).

Stress Indicator	Category	Female N/Total	Female %	Male N/Total	Male %	OR (95% CI)	*p*	Adjusted *p*
Linear Enamel Hypoplasia	Christian	8/15	53.33	19/28	67.86	0.55 (0.14 – 2.06)	0.53	0.99
	Islamic	8/13	61.54	14/23	60.87	1.02 (0.25 – 4.47)	0.99	0.99
Cribra Orbitalia	Christian	3/9	33.33	5/21	23.81	1.59 (0.24 – 9.23)	0.66[a]	0.99
	Islamic	9/26	34.62	17/38	44.74	0.66 (0.23 – 1.85)	0.58	0.99
Porotic hyperostosis	Christian	6/17	36.29	5/33	15.15	2.96 (0.73 – 12.74)	0.15[a]	0.30
	Islamic	2/25	8.00	3/39	7.69	1.06 (0.12 – 7.51)	0.99[a]	0.99
Periostosis	Christian	24/28	85.71	48/53	90.57	0.62 (0.15 – 2.85)	0.71[a]	0.99
	Islamic	13/19	68.42	23/31	74.19	0.76 (0.21 – 2.82)	0.91	0.99

[a] P-value resulting from a Fisher's Exact test due to expected counts being less than five.

Table 6.7 - Prevalence of stress indicators by funerary group separated by sex at Largo Cândido dos Reis (χ^2).

Stress Indicator	Category	Islamic N/Total	Islamic %	Christian N/Total	Christian %	OR (95% CI)	*p*	Adjusted *p*
Linear Enamel Hypoplasia	Female	8/13	61.54	8/15	53.33	1.34 (0.29 – 6.75)	0.96	0.99
	Male	14/23	60.87	19/28	67.86	0.74 (0.23 – 2.41)	0.82	0.99
Cribra Orbitalia	Female	9/26	34.62	3/9	33.33	1.04 (0.21 – 6.26)	0.99[a]	0.99
	Male	17/38	44.74	5/21	23.81	2.51 (0.78 – 9.21)	0.19	0.38
Porotic hyperostosis	Female	2/25	8.00	6/17	35.29	0.17 (0.02 – 0.93)	0.04[a]	0.09
	Male	3/39	7.69	5/33	15.15	0.48 (0.09 – 2.21)	0.46[a]	0.91
Periostosis	Female	13/19	68.42	24/28	85.71	0.37 (0.08 – 1.59)	0.28[a]	0.55
	Male	23/31	74.19	48/53	90.57	0.31 (0.08 – 1.04)	0.06[a]	0.12

[a] P-value resulting from a Fisher's Exact test due to expected counts being less than five.

Table 6.8 - Prevalence of stress indicators by funerary group at Largo Cândido dos Reis, indeterminates excluded and sexes pooled. Where LEH = linear enamel hypoplasia, CO = cribra orbitalia, and PH = porotic hyperostosis.

Stress Indicator	Christian		Islamic		OR (95% CI)	X^2 *p*	Adjusted *p*
	N/Total	%	N/Total	%			
LEH	22/31	70.97	16/23	69.55	1.07 (0.31-3.55)	0.91	0.99
CO	6/23	26.09	18/47	38.30	0.57 (0.18-1.71)	0.31	0.62
PH	10/40	25.00	5/47	10.64	2.73 (0.86-9.80)	0.08	0.15
Periostosis	46/54	85.19	22/33	66.67	2.82 (0.99-8.40)	0.04*	0.06

Table 6.9 - Prevalence of stress indicators by funerary group at Largo Cândido dos Reis, indeterminates included and sexes pooled. Where LEH = linear enamel hypoplasia, CO = cribra orbitalia, and PH = porotic hyperostosis.

Stress Indicator	Christian		Islamic		OR (95% CI)	X^2 *p*	Adjusted *p*
	N/Total	%	N/Total	%			
LEH	27/43	62.79	22/36	61.11	1.07 (0.42-2.70)	0.88	0.99
CO	8/30	26.67	26/64	40.63	0.54 (0.20 – 1.37)	0.19	0.38
PH	11/50	22.00	5/64	7.81	3.24 (1.07-11.25)	0.03	0.03*
Periostosis	72/81	88.89	36/50	72.00	3.07 (1.22-8.10)	0.01	0.03*

Table 6.10 - Distribution of LEH events by funerary group and sex.

	Islamic		Christian	
	Female (N = 14)	Male (N = 16)	Female (N = 7)	Male (N = 8)
Age at formation (years)	N events (%)	N events (%)	N events (%)	N events (%)
0.00-0.49	0 (-)	0 (-)	0 (-)	0 (-)
0.50-0.99	0 (-)	0 (-)	0 (-)	0 (-)
1.00-1.49	7 (1.74)	12 (2.75)	0 (-)	0 (-)
1.50-1.99	30 (7.44)	63 (14.42)	8 (7.34)	9 (7.50)
2.00-2.49	78 (19.35)	94 (21.51)	14 (12.84)	18 (15.00)
2.50-2.99	78 (19.35)	93 (21.28)	18 (16.51)	29 (24.17)
3.00-3.49	79 (19.35)	65 (14.87)	27 (24.77)	28 (23.33)
3.50-3.99	68 (16.87)	61 (13.96)	18 (16.51)	14 (11.67)
4.00-4.49	33 (8.19)	31 (7.09)	15 (13.76)	15 (12.50)
4.50-4.99	23 (5.71)	14 (3.20)	5 (4.59)	3 (2.50)
5.00-5.49	6 (1.49)	4 (0.92)	4 (3.67)	4 (3.33)
5.50-5.99	1 (0.25)	0 (-)	0 (-)	0 (-)
6.00-6.49	0 (-)	0 (-)	0 (-)	0 (-)
Total (events)	403 (100)	437 (100)	109 (100)	120 (100)
Avg. events per individual	28.79	27.31	15.57	15.00
Total teeth	140	144	46	48
Avg. events per tooth	2.88	3.03	2.37	2.50
Mean age at occurrence (SD)	3.10 (0.88)	2.86 (0.85)	3.31 (0.88)	3.14 (0.83)

Figure 6.9 - Distribution of LEH events by funerary group and sex.

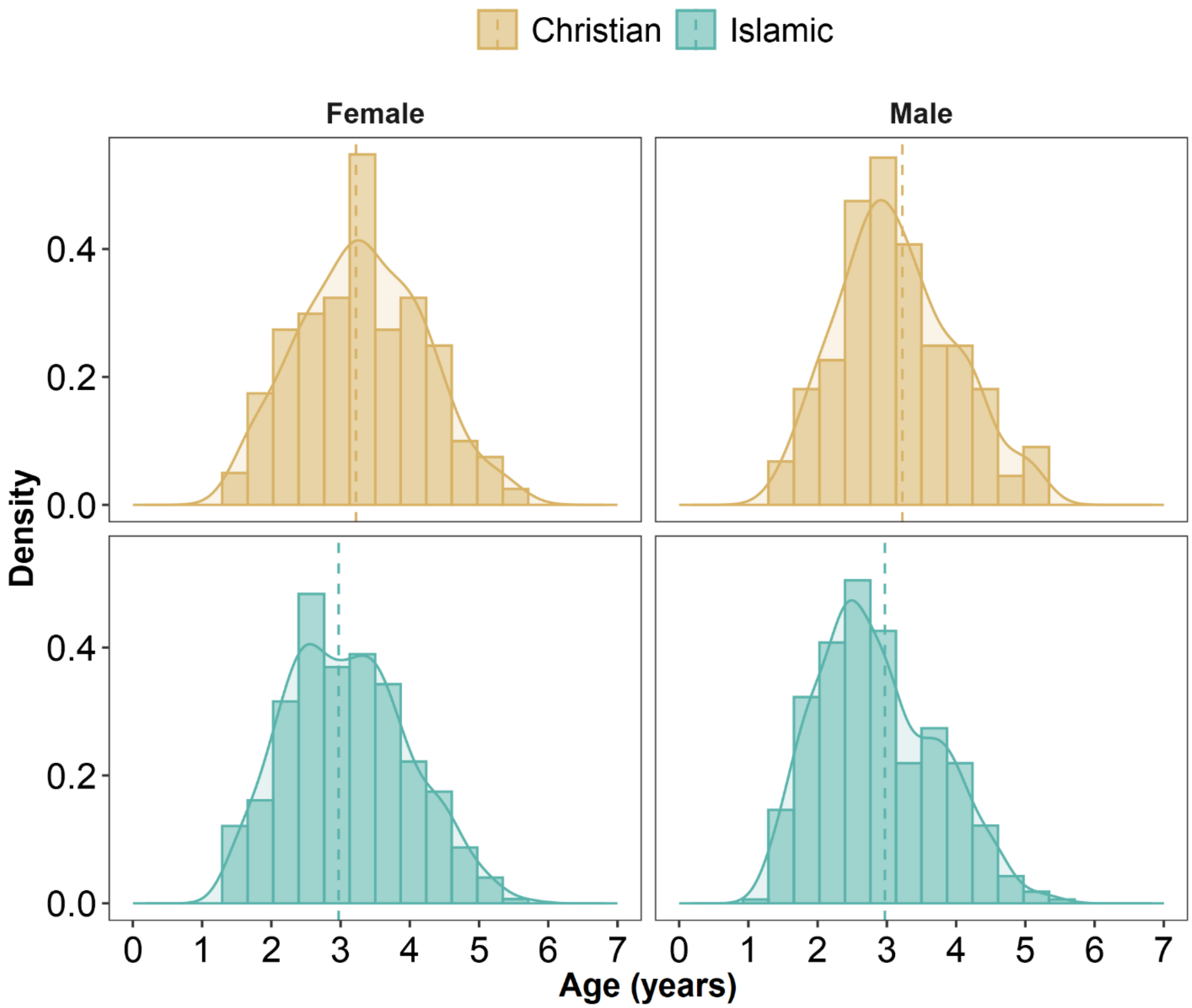


Figure 6.10 - Box and whisker distribution of LEH events by funerary group and sex.

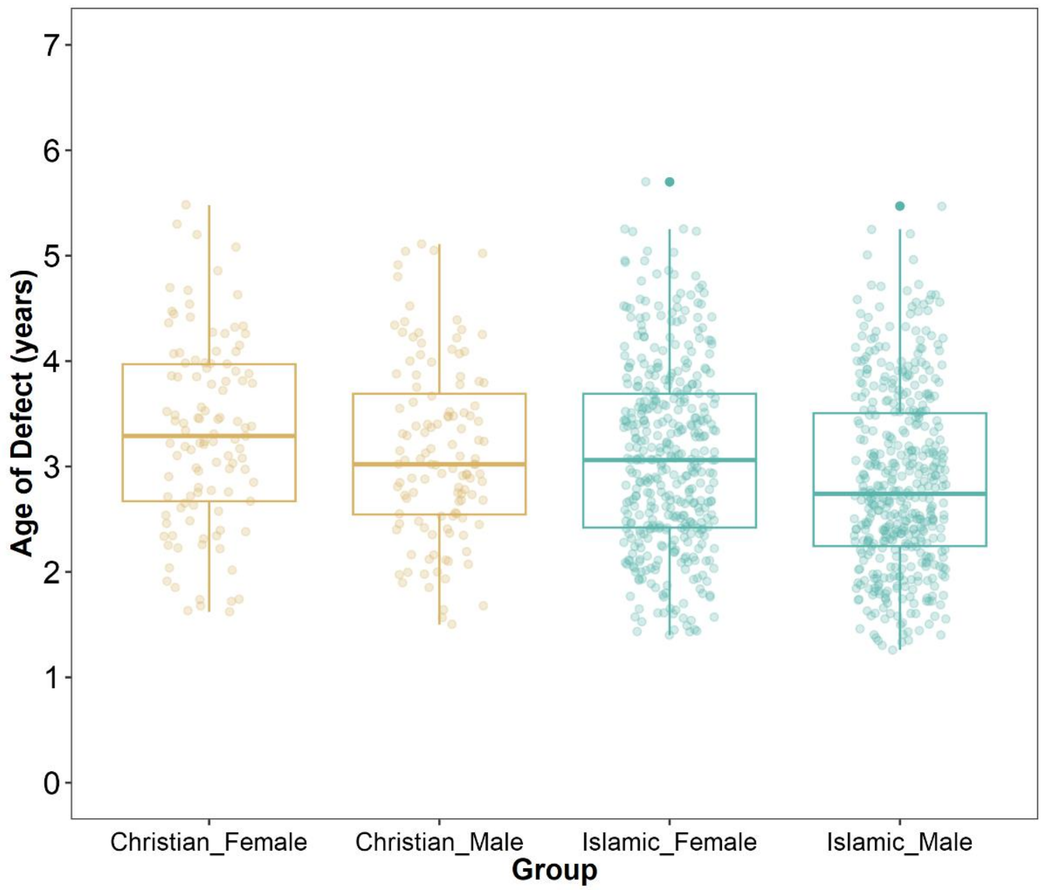


Table 6.11 - One-way ANOVA results for mean age-at-formation for measurable defects by funerary group and sex.

Christian Female	Christian Male	Islamic Female	Islamic Male
Christian Female	-0.17[a] (0.11)[b] -0.46, 0.12[c] 0.44[d], 0.20[e]	-0.22 (0.09) -0.46, 0.02 0.09, 0.05	-0.45 (0.09) -0.69, -0.22 <0.01***, 0.33
	Christian Male	-0.05[a] (0.09)[b] -0.28, 0.18[c] 0.95[d], 0.24	-0.28 (0.09) -0.51, -0.05 <0.01**, 0.52
		Islamic Female	-0.24 (0.06) -0.39, -0.08 <0.01***, 0.28
			Islamic Male

[a] $\bar{x}_i - \bar{x}_j$
[b] Std. error of difference
[c] Lower Confidence Level, Upper Confidence Level
[d] Adjusted *p*-Value
[e] Cohen's *d*
[*] Statistically significant at the $\alpha = 0.05$ level, ** Statistically significant at the $\alpha = 0.01$ level, *** Statistically significant at the $\alpha < 0.001$ level

Discussion

Religious, Child-Rearing, and Urbanistic Considerations for Stress

Our results suggest a possible shift in stress prevalence associated with the Christian conquests, such that Christian individuals in the later medieval period experienced elevated exposures to non-specific stress. I interpret these results in context of the shifting religious-political transition from an Islamic cultural, religious and military center (*Xantarîn*) to an important Christian religious pilgrimage center (*Sanctaren*) focusing on ethnohistorical and broader archaeological data.

Ethnohistorical sources for medieval childrearing in Islam are numerous (Gil'adi 1992), such as the *Kitāb siyāsat al-ṣibyān wa-tadbīrihim* (The Book of Child-rearing) by Ibn al-Jazzār of Qayrawān (al-QWayrawānī; d. 979/980), the *Kitāb khalq al-janīn wa-tadbīr al-ḥabālā wa-al-mawlūdīn* (The Creation of the Foetus and the Treatment of Pregnant Women and New-Born Infants) by Aḥmad b. Muḥammad b. Yaḥyā al-Baladī (10th c. C.E.). These manuals borrow from classicist Galeno-Hippocratic notions while supplementing them with individual insights and prescriptions from their respective authors. The *Tuḥfat al-Mawdūd* for example is a 14th century childrearing manual written by Ibn Qayyim al-Jawzīyah (d. 1350; Syria) which emphasizes important psychosocial hallmarks. One major phase refers to the ability for children to grasp the severity of Islam, ranging between ages three and ten years, but often occurring at age seven (Gil'adi 1992). While al-Jawzīyah does not give a categorical definition of puberty and acknowledges the tremendous variation in growth and development, he does offer prescriptions related to the rearing of children. Two such important concepts he articulated were: 1) children are different than adults, requiring differential care, and 2) Events and treatments in an infant's life have long lasting physical and psychological consequences (Gil'adi 1992). The Qur'ān (2:233; 31:14) as well as renowed physicians such as Ibn Sīnā (d. 1037), al-Qurṭubī (d. 1273), and al-Baladī (11th c. C.E.) all generally advocated for weaning after two years of age, which generally agrees with larger classical notions (Gil'adi 1992). Conversely, Christian sources are more geographically and thematically varied, largely stemming from sources in Northern Europe or Italy. These sources similarly emphasize various psycho-social stages of development and lice course hallmarks, such as infantia (infancy), pueritia (childhood), adolescentia (adolescence), Juventus (youth), senectus (adulthood) and senium (senescence) (Shahar 1990). Numerous scholars have converged on the notion that age seven (years) was particularly important, as it was the age where children not only transitioned from *infantia* to *pueritia*, commence schooling, apprenticeship and work (Orme 2001, 46; Shahar 1990, 24–27), but could also commit mortal sin (Ferraro 2013, 69). However, many of these works were written at varying times and in geographic locations differing from central Portugal. Thus, any direct interpretation of textual sources in these bioarchaeological remains is tenuous, and I instead draw upon these sources to instead frame the larger cultural context.

Significant sexual dimorphism in stature is not entirely surprising, as has been observed in other medieval contexts either as a result of genetics, and/or physical activity and nutrition during growth and development (Candilio et al. 2016; Vercellotti et al. 2014; Vercellotti et al. 2011; Watts 2011). Nutrition during growth and development is particularly important to consider for its biocultural impacts on terminal adult stature. As explored elsewhere, both dental (chapter 5) and archaeological/ethnohistorical sources suggest a shifting of from legumes and mixed animal protein during the Islamic period to a 'triad' of bread, wine and terrestrial/marine meat following the Christian conquests (Marques 2021). Stable isotope evidence, which comprises a more direct form of evidence from embodied tissues of individuals, suggest that Islamic diets were generally more terrestrially focused while later Christian diets varied considerably based on geography, with a tendency towards marine resources when available (Alexander et al. 2015; Alexander et al. 2019; Curto et al. 2019; Dury et al. 2019; Guede et al. 2017; Jordana et al. 2019; López-Costas et al. 2019; Lubritto et al. 2017; MacKinnon et al. 2019; Pérez-Ramallo et al. 2022; Pickard et al. 2017; Salazar-García et al. 2016; Toso et al. 2019; Toso et al. 2021). Interestingly, Toso and colleagues (Toso et al. 2019) found a lack of sex significant differences in both Christian and Islamic communities except for the sub-sample from urban Lisbon, possibly signaling gendered differences in diet within urban spheres. Notably, many of the results from these studies are from bulk collagen and adults, which limits the potential to analyze diet during childhood outside of sampling teeth enamel/dentine. Taken together with the stature results, these could suggest a significant nutritional shift that accompanied the Christian conquests and subsequent restructuring of agriculture and food production. In particular, Islamic females were found to be significantly taller than their Christian female counterparts, possibly underscoring differential gendered access during childhood and adolescence. Unfortunately, small sample sizes for age prevented further comparisons and granularity. Ideally, a sufficient sample for young (18-29 years), middle (30-49 years), and older (50+) groups stratified by sex and funerary group would help elucidate these patterns further, but the overall sample and preservation issues limited the potential to do so.

Despite the apparent sex differences in stature, there were very few significant sex differences for other indicators of non-specific stress. This could be the product of underlying tempos of growth and development, and when specific stress events have a potential to occur. Here, lack of sex differences in dental hypoplasias, cribra orbitalia, and porotic hyperostosis which form during childhood (~1 – 12 years) may suggest relatively equal levels of stress by sex, but differences later manifested during puberty and adolescence when appendicular growth is accelerated (Bass et al. 1999). In terms of funerary comparisons, Christians were found to exhibit higher odds of porotic hyperostosis and periostosis compared to their Islamic counterparts. At a surface level, these results would seem to partially confirm the hypotheses that Christian individuals experienced elevated exposure to stressors accompanying the Christian conquests and subsequent urbanization. However, it is worth contextualizing these results further. These differences were significant in the case of individuals of indeterminate age being included in the comparison (Table 6.9), though adjusted p-values were not significant when only individuals of estimable age were included (Table 6.8). These results underscore the importance of demography's relationship with taphonomy (Jackes 2000; 2011b), whereby individuals cannot be assigned an age at death due to issues of skeletal preservation despite interpreting funerary tradition with relative ease. I present results of both including and excluding individuals of estimable age to underscore the issues of complete case analysis in overall restricting sample size. However, I also caution that differences between religious funerary groups may well be the product of underlying age structures that we are unable to discern nor evaluate as a corollary of stress indicators to address selective mortality (DeWitte et al. 2015; Wilson 2014b).

The subset of LEH that could be estimated may possibly reflect weaning related stress, as the events are largely formed between one and six years of age from the underlying development of enamel secretion (Reid et al. 2000; 2006). It was curious to see that Islamic males had a significantly lower mean age-at-formation (2.5 years) compared to the other subgroups who did not statistically differ from one another. The distribution for both Islamic males and Christian males did skew slightly towards a lower age-at-formation, possibly signaling an aggregate earlier weaning for males in general. Patriarchal social organization is a common observance in both medieval Christianity and Islam, with gendered influences on childrearing and a general desire and emphasis on boys as they were more economically advantaged and socially mobile (Alexandre-Bidon et al. 1999; Ferraro 2013; Shahar 1990). Yet, it is important to consider that enamel hypoplasias and weaning do not have linear or predictive relationship (Corruccini et al. 1985; Goodman et al. 1987; Goodman et al. 1984; Handler et al. 1986; Lanphear 1990; Moggi-Cecchi et al. 1994). In numerous cases, it seems that LEH and weaning may co-occur, but their relationship is not causative (Blakey et al. 1994; Katzenberg et al. 1996; Larsen 1997).

Epidemiologists have demonstrated the importance of urbanization as a major factor in facilitating infectious disease and quality of life (de Hollander et al. 2003; Neiderud 2015). More recently, bioarchaeologists have followed suit, investigating and documenting the ways in which urbanization in the past explains patterned variation in disease and health outcomes (Betsinger et al. 2020). Access to potable water sources, personal/community hygiene and sanitation infrastructure are crucial in their relationship to health and mitigation of disease (Mara et al. 2010). Undoubtedly, the Christian conquests and centuries after altered the urban meshwork of many Iberian cities (Trinidade 2007b), including sanitation and hygienic spaces (Réklaityté 2005). Public baths featured prominently in Islamic accounts and spaces (Trinidade 2015), in part due to their ritual, spiritual, and hygienic significance (Lopes de Barros 2005). *Waqf*, or religiously endowed property, was a crucial institution in the management and built environment of Islamic cities (Bonine 2009). Though its main goal was the support of religious properties, *waqf* played an additional supporting role in city planning and management, such as potable drinking water and food distribution, and was instrumental in underwriting the overall planning and maintenance of Islamic medieval cities (Bonine 2009, 615–616). However, the Christian conquests (12th century C.E.) and Black Death (1348 C.E.) were followed by shifting notions of the human body, biology, communicability, and ideology, which increasingly rendered public bathhouses either as shameful spaces or obsolete (Lopes de Barros 2005, 4). This may contrast with late medieval literature from other parts of Northern Europe which emphasized water both for its important functional and metaphorical significance in "cleansing" (Rothauser 2009). However, as Coudert (2009, 716–717) notes, these literary examples often embellish urban architecture rather than describe the sensory realities of urban pre- and early-modern European centers containing all manner of excrement and waste runoff from various homes and shops comingling into streams that ran along gutters of city thoroughfares. Coudert notes that early medieval centers likely did not have the same issues of wastage, (e.g., the emphasis on recycling excrement was not only shunned, but encouraged for fertilizer) likely speaking to increases in population and density in the later middle ages and early modern period (2009, 717).

Urban planning and water sources are thus important to consider in light of the bioarchaeological data. As stated above, Cunha and colleagues (2017) found paleoparasitological remains of geohelminth species (*A. lumbricoides* and *T. trichiura*) within a subsample of Islamic burial contexts at Largo Cândido dos Reis. These parasites are transmitted predominately via oral-fecal pathways following a period of maturation within soils (Cunha et al. 2017), and may shed light on some of the sanitation infrastructure during the period. Unfortunately, no archaeological evidence of latrines or baths have been found to date within Santarém, though Évora has demonstrated evidence of latrines and sewers from the 10th – 12th centuries C.E. (Filipe 2012), and Silves seems to have enjoyed improvements in sewage infrastructure after the 11th century such as the linkage of latrines with cesspools (Serra 2013). In Spain, the documentation of hydrological innovation and sanitation networks is much more robust and rich (Alba et al. 2008; Réklaityté 2019). Excavations of numerous towns throughout Spain have demonstrated the presence of latrines in almost every home, complex sewer networks, and latrine-cesspit connections, speaking to the role that Islamic authorities emphasized in maintaining wastage and sanitation (Réklaityté 2005). Given the material presence of parasitic eggs discovered from burials at Largo Cândido dos Reis (Cunha 2015; Cunha et al. 2017), it is possible that some of the indicators of non-specific stress reported above are indeed associated with parasitic load. However, as Cunha and colleagues are careful to point out, lack of presence does not inherently signal a lack of parasitic infection, especially given taphonomic and curational procedures which may reduce the likelihood of recovering paleoparasitological remains (Cunha et al. 2017, 125). Additionally, this work was conducted on a small subsample of Islamic burials and no Christian burials, limiting overall comparability. Future work analyzing the comparative presence and prevalence of helminths in Christian contexts is needed to further elucidate how shifting processes of urbanization following the Christian conquests may have downstream effects on intercommunicability of parasites.

Conclusion: Limitations and Future Directions

While this study found evidence of significant differences in stress indicators during growth and development between religious funerary groups, there are several limitations worth outlining. First, the osteological paradox (Wood et al. 1992) is necessary to consider, as lower observed prevalence of stress indicators may be the result of more rapid transition into the death assemblage. In this sense, the significantly lower odds of porotic hyperostosis and periostosis in Islamic individuals are a product of Islamic individuals dying before living long enough to sustain a skeletal response to stress. Conversely, Christian individuals may skeletally manifest more indicators of stress but only because they lived through the stress event. While the use of odds ratios helps to overcome some of the biases in crude prevalence and take into account underlying age structures (Klaus 2014), odds ratios in and of themselves do not fully address the issues of the paradox. As Wood and colleagues (1992, 344) succinctly put it: "This bias cannot be avoided simply by obtaining larger, more representative skeletal samples; it is built into the very nature of the data." Issues of preservation and sample size severely limited the potential to address the osteological paradox head on by examining patterns of stress indicators in a life course perspective (DeWitte et al. 2015; Wilson 2014b). Comparative analyses of stress will be more rigorous and informative should future age at death estimates on this sample be refined.

Additionally, theses samples are cross-sectional in that individuals with a given stress indicator may lack other indicators. While comparisons by stress indicator are routine in bioarchaeology (Klaus et al. 2009; Temple et al. 2012; Watts 2011) there is always a risk that aggregate crude prevalence may contain individuals with multiple intraskeletal indicators (inflating overall prevalence) whereas other individuals exhibit few indicators, or that the palimpsest nature of skeletal assemblages is more stochastic in stress prevalence. Finally, the temporal dimensions of cemeteries are also worth considering, (DeWitte et al. 2015; Novak 2017), and while the Islamic usage of the site is better understood, the Christian burial assemblages requires further chronological refinement.

Despite these limitations, I posit that these data and results are an important step in furthering previous comparative work within the site and Peninsula more broadly (Cunha 2015; Gonçalves 2010; Gooderham et al. 2019; Graça 2010; Matias 2008b; Neves 2019; Rodrigues 2013; Vicente 2015), especially in re-evaluating long historical claims that accompany the Christian conquests (‘Reconquista’) (A Vakil 2003). The results here seem to support an emerging body of scholarship that not only evaluates the biosocial consequences of the Christian conquests (Gooderham et al 2019; Toso et al. 2021), but problematizes and nuances the ways in which shifting periods of religious-political autonomy in the Iberian middle ages was local and variable.

Chapter 7: Lifeways — Cortical Bone Maintenance and Loss

Introduction

This chapter examines cortical bone quantity as a potential indicator of skeletal health, malnutrition, senescence, and physical activity. During homeostasis, bone maintains a roughly balanced modeled and remodeled equilibrium such that bone is removed and formed at approximately equal rates, although typically remodeling results in a net loss of bone (Parfitt 2003). Excessive bone loss is marked by uncoupled remodeling, such that resorption outpaces deposition of new bone, resulting in a net loss of bone, weaking the bone in the process and making it susceptible to later fracture (Riggs et al. 1991). Bone remodels in response to metabolic and mechanical demands, as well as physiological demands that accompany growth, development, and childbearing (pregnancy, lactation, etc.) (Frost 2003; Parfitt 2003). Additionally, there is considerable variation in remodeling both within and between differing bone surfaces (Farr et al. 2015; Szulc et al. 2009). The human skeleton is comprised of two major surfaces of bone — cortical and trabecular — with approximately 80% of the skeleton being cortical bone (Polig et al. 1987). In long bones (e.g., the femur) the distinct bone types are easily distinguished, where cortical bone comprises the outermost layer and trabecular bone is found in the inner-most portion of the diaphysis and epiphyses. Both cortical and trabecular bone are frequently analyzed in anthropological studies for both qualitative and quantitative purposes (Agarwal et al. 1996). Trabecular bone in particular is often analyzed for its quality, as it remodels faster than cortical bone, and trabecular struts and architecture are conducive to examining for strength (Agarwal 2008). Cortical bone has also been analyzed qualitatively for cross-sectional geometry and porosity measures (McCalden et al. 1993; Parfitt 1984). Yet, cortical bone is typically analyzed quantitatively, as approximately 70% of all age-related appendicular bone loss is within cortical bone (Zebaze et al. 2010). Cortical bone is lost through intracortical remodeling (Zebaze et al. 2015), whose tempo fluctuates as a result of both age- and hormonal-related factors (Parfitt 2003). As such, while trabecular bone is often the primary site for remodeling and early bone loss, cortical bone typically corresponds with bone loss in later life (Osterhoff et al. 2016).

Cortical bone plays a pivotal role in overall bone strength and biomechanical resistance, which is important as many osteoporotic fractures occur at cortical sites (Center 2010; Holzer et al. 2009; Zebaze et al. 2015), particularly the distal forearm and hip (Melton 2000). Osteoporosis is typically defined as extremely low bone mineral density (BMD; t-score < -2.5 standard deviations below the population mean) and/or the presence of fragility fractures, whereas osteopenia is defined as low BMD (t-score between -1.0 and -2.5 standard deviations below population mean) and an absence of fractures (Kanis 1990; Kanis 1994; Kanis et al. 1994). Osteoporosis and bone loss is a multi-billion dollar epidemic affecting millions of people worldwide (Ballane et al. 2017; Kanis et al. 2012; Reginster et al. 2006). However, most of this research (and our resulting understanding of osteoporotic patterning) is predominately focused on contemporary populations, with little diachronic outside of minor discussions of secular trends. Therefore, assessments of bone quality and quantity in skeletal assemblages from historical and archaeological populations continue to remain an exciting opportunity to elucidate osteoporosis with greater time-depth (Agarwal 2008; Brickley 2002; Brickley et al. 2010; Curate

2014; Curate et al. 2011; Umbelino et al. 2019). Archaeological cultures differ significantly in their diet, reproductive history, and physical activity from contemporary, Western, biomedical study groups, and as such can shed light on the heterogenous patterning of bone loss and maintenance in our species (Sabrina C. Agarwal et al. 2011). Bioarchaeological analyses of osteoporosis and bone quantity and quality in the past can thus help to characterize variability more thoroughly, as contemporary biomedical understandings are conducted with in a limited geographic and cultural scope. Additionally, while osteoporosis is often conceptualized as a sex-linked disease given its disproportionate patterning in contemporary Western females, anthropology can complicate and combat given its synthesis of scientific and humanistic approaches (Fausto-Sterling 2005). Bioarchaeological studies have employed quantitative assessments of cortical bone for information on childhood health, adult pathology, and age-related bone loss and/or osteoporosis to name only a few (Agarwal et al. 1996; Agarwal 2012; Beauchesne and Agarwal 2014; 2017; Brickley et al. 2005; Brickley et al. 2010; Gilmour et al. 2021; 2022; Glencross et al. 2011; Mays1996). Archaeological and historical samples have shown surprising variability in the patterning of bone loss (Mays 1996; Mays 2000; Mays et al. 2006; Turner-Walker et al. 2001), with some supporting contemporary patterns while others challenge and complicate such findings (Agarwal et al. 1996; 2009; Agarwal 2008; Beauchesne and Agarwal 2014; 2017; Glencross et al. 2011). From a contemporary perspective, bone loss and accompanying fragility fractures are often seen as hallmarks of older age, especially for females (Barger-Lux et al. 2005), but some assessments from skeletal samples have demonstrated marked bone loss in young adults for both males and females with low prevalence of fragility fractures (Agarwal et al. 2009; Beauchesne and Agarwal 2017; Ekenman et al. 1995; Holck 2007; Lees et al. 1993).

The continued research and reporting of osteoporotic fractures, paired with easy access of published studies and data sets, has allowed clinical researchers to conduct large meta-analyses with surprising geographic scope (Ballane et al. 2017; Cauley et al. 2014; Cheng et al. 2011; Kanis et al. 2012). While osteoporosis is known to be a multifactorial, polygenic disease, the relationship between environment and genetics requires far more research. Some studies have found that genes influencing variation in bone mineral density (BMD) are likely similar between sexes (Brown et al. 2004), while others suggest sex-specific genetic and environmental patterns influence peak bone mass (Orwoll et al. 2001; Mcguigan et al. 2002). Recent studies focusing on lipoprotein receptor-related protein 5 (*LRP5*) have demonstrated its importance in BMD phenotypes (Ferrari et al. 2005; Kiel et al. 2007; van Meurs et al. 2008; Estrada et al. 2012). Mutations in *LPR5* in humans has been observed to cause either abnormally high bone mass (HBM), upwards of four standard deviations in BMD above the population mean (Boyden et al. 2002), or osteoporosis-pseudoglioma (OPPG) syndrome – a rare type of osteoporosis characterized by bone thinning and eye-developments that result in vision loss (Gong et al. 2001; Little et al. 2002). The importance of *LRP5* in osteogenesis is thus articulated as likely crucial factor in influencing the attainment of peak bone mass and osteoporosis susceptibility (Kiel et al. 2007; van Meurs et al. 2008; Estrada et al. 2012). However, many studies have been done exclusively on women (Thakkinstian et al. 2004; Ferrari et al. 1999; Mann et al. 2001; Peacock et al. 2002; Ioannidis et al. 2004), with fewer studies focusing on the genetic susceptibility of osteoporotic fractures in men alone (Gennari et al. 2001; Van Pottelbergh et al. 2003).

While the genetic and genomic bases for osteoporosis are receiving increasing attention in clinical contexts, investigations into past communities still offers a unique opportunity to clarify patterning of osteoporosis with diachronic scope (Agarwal 2008). Although bioarchaeologists lack the resolution and preservation to conduct thorough genetic and epigenetic analyses, quantifying bone loss in the past has proven a fruitful, albeit challenging, endeavor as it provides chronological insight into biomedical understandings about bone health. This is especially due to the multifactorial etiology of bone loss beyond genetics, which can be influenced by factors such as diet, ethnicity, parity, physical activity, nutrition, and lactation (Frost 2003; Nelson et al. 2003; Sowers 1996; Wilsgaard et al. 2009) to name only a few. Nutrition for example plays a significant role in the maintaining homeostasis, especially when considering protein, vitamin D, and dietary calcium (Nelson et al. 2014). The human skeleton stores the majority of calcium reserves, which can be used by the body to maintain homeostasis (Heaney et al. 2005). However, when dietary calcium is insufficient, the body will begin to leech calcium from skeletal reservoirs, leading to bone loss. Vitamin D, which helps to mediate calcium absorption in the intestines, can also contribute to bone loss when intake is low (Dawson-Hughes 2003).

Bone maintenance and loss is also mediated by mechanical loading and physical activity, though the degree to which this is the case is not entirely clear. Much of our knowledge stems from how extreme lack of activity negatively affects bone, such as bed rest and microgravity in space resulting in extreme bone loss (Hargens et al. 2016; Stavnichuk et al. 2020; Turner 2000; Zerwekh et al. 1998). However, the positive effects of physical activity and loading on bone maintenance are less understood. Exercise does seem to play a key role in increasing both bone mineral density (BMD) and bone mass, but bone's response to mechanical strains seems to be greater in juveniles relative to adults (Pearson et al. 2004; Rittweger 2006). While bone morphology and mass can still be affected by activity in adults (Bergmann et al. 2010), the response seems to be less than that of adolescents (Pearson et al. 2004) underscoring a key ontogenetic phase of long-term bone health. However, as Ruff and colleagues (2006) caution: this should not be taken to the extreme position that adult morphology is a reflection of juvenile loading histories alone. The relationship is likely more variable and complex depending on the location, bone, and age of individual in question.

Finally, reproductive variables are also important to consider in their relation to bone maintenance and loss. Both pregnancy and lactation seem to accompany high turnover rates, and in rare cases, pregnancy- and lactation-induced osteoporosis (PLO) (Winter et al. 2020). Bone resorption seems to be partially mediated during pregnancy through increased estradiol levels (Winter et al. 2020). Early pregnancy and fetal development requires maternal calcium, which seem to be satisfied through increases in intestinal calcium absorption to buffer against excessive resorption (Kovacs et al. 2015). However, this trend can reverse in later pregnancy when calcium demands are higher, especially in women lacking sufficient dietary calcium (Kovacs et al. 2015). For lactation, clinical studies have found mixed results. Longitudinal studies have generally found breastfeeding women to exhibit increased cortical porosity and decreased BMD, cortical thickness (Bjørnerem et al. 2017; Brembeck et al. 2015). However, the short-term negative effects of lactation appear to be minimized or even reversed following lactation (e.g., weaning or post-weaning), such that bone mass experiences full recovery or even improvements in mass (Brembeck et al. 2015; Cooke-Hubley et al. 2017; Laskey et al. 1999; Polatti et al. 1999). The results of these longitudinal studies suggest that pregnancy and lactation can confer long-term increases in bone density and geometry even if the short-term effects of pregnancy and lactation appear to be negative (Salari et al. 2014).

In this study, I examine how cortical bone indices vary by age, sex, and religious funerary group in a medieval Portuguese sample. The necropoles of Largo Cândido dos Reis (S.LCR) and Avenida 5 de Outubro (S.Av5Out) in Santarém, Portugal offer a unique opportunity to examine how various biocultural indicators of health and disease vary along religious axes in the Middle Ages, as both cemeteries contain burials that chronologically vary according to differing religious occupations of the city – in this case, Islam and Christianity. In doing so I seek to characterize how temporal changes in politico-religious autonomies, and religious identity of the city's residents as inferred from their distinct funerary treatment, may co-vary with indicators of cortical bone quantity throughout the lifecourse. Finally, I aim to contextualize these results alongside other bioarchaeological studies of cortical bone quantity and loss. I quantify cortical bone through the analysis of tissue in two distinct skeletal locations: the cortical bone of second metacarpal using radiogrammetry and rib cortical bone as measured by cross-sectional area. While shape differences between cortical bone indices in differing tissues are worth careful consideration (Gilmour et al. 2022), rib cross-sectional area measurements can provide additional insight into cortical bone maintenance and bone loss given their highly trabecularized architecture. As such, I examine these two locations to supplement each other, as the rib is more metabolically active due to its location (Cho et al. 2003), while the metacarpal is biomechanically more loaded (Lazenby 2002a; 2002b), and sensitive to activity related changes such as osteoarthritis (Becker 2016; Becker 2019).

Previous analyses of bone mineral density (BMD) on a subsample of 20 females and 20 males at Largo Cândido dos Reis found significantly lower BMD neck and BMD total hip values in females compared to males (Vicente 2015). However, these analyses were conducted using densiometric (DXA) techniques, which can be complicated by taphonomic alteration of the mineralized tissue measurements (Agarwal 2008; Brickley et al. 2003). Osteoporotic fracture prevalence was found to be low, with only one case of Colles' fracture (distal radius) being recorded, but the author was careful to note this is likely due to the demographic structure of the sample being skewed relatively young. I hypothesize that increased cortical bone indices, regardless of tissue, will follow conventional trends such that older age groups (e.g., 50+ years) will exhibit larger medullary cavity indices (MW and En.Ar, respectively) and smaller cortical bone indices (CT; Ct.Ar; CI, CTI; respectively) than their younger age-group counterparts (Beauchesne and Agarwal 2014; Glencross et al. 2011; Mays 1996; Miller 2016). I hypothesize that age-related difference will be more severe for females than males, based on the earlier findings by Vicente (2015) regardless of funerary/religious typology. Finally, I expect intra-and inter-religious variability, with Islamic males and females exhibiting generally higher values than their Christian counterparts, under the premise that Santarém purportedly flourished under the 'Golden Age of Islam' whereas the later Christian medieval period exhibited higher population density, densification, and urbanization.

Materials

Details on the individuals, site, and larger context can be seen in Chapter 3. The sample distribution by site, age, sex, and funerary group can be seen in Table 7.1. Due to the underrepresentation of second metacarpals in Islamic burials at the site of Largo Cândido dos

Reis (see Chapter 9), Islamic metacarpals were pooled with those from the site of Avenida 5 de Outubro.

Table 7.1 - Sample distribution of metacarpals and ribs analyzed by sex, site, age, and funerary group.

			Islamic			Christian		
Bone	Sex	Age	Av5Out	LCR	Total	Av5Out	LCR	Total
Metacarpal	Females							
		18-29	3	1	4	-	5	5
		30-49	9	4	13	-	6	6
		50+	9	5	14	-	10	10
		Total	21	10	30	-	21	21
	Males							
		18-29	2	3	5	-	11	11
		30-49	4	3	7	-	23	23
		50+	4	11	15	-	9	9
		Total	10	17	27	-	43	43
Rib	Females							
		18-29	3	4	7	-	4	4
		30-49	6	2	8	-	4	4
		50+	7	3	10	-	11	11
		Total	16	9	25	-	19	19
	Males							
		18-29	2	5	7	-	9	9
		30-49	4	5	9	-	17	17
		50+	4	9	13	-	9	9
		Total	10	19	29	-	35	35

Methodology

Metacarpal Radiogrammetry

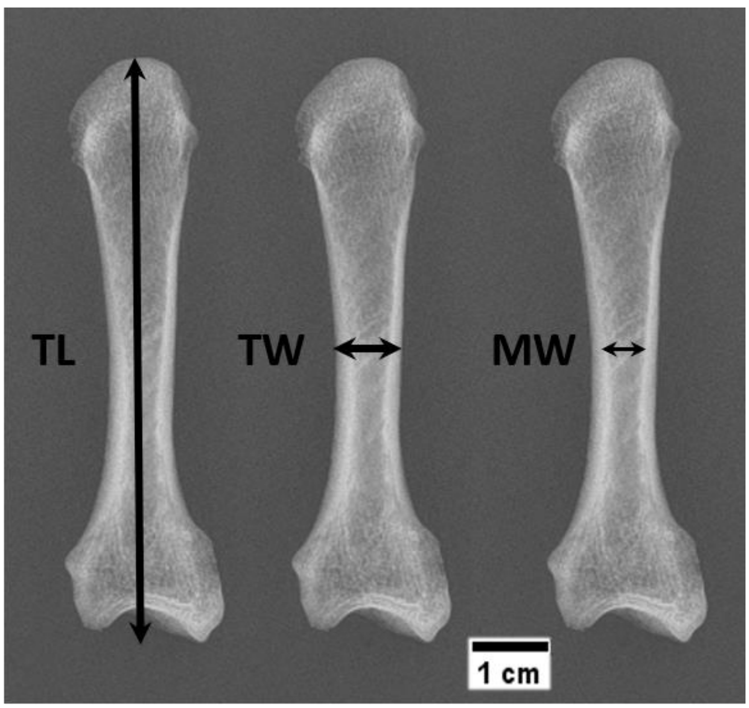
Beginning in the 1960s, metacarpal radiogrammetry was posited as a "New Approach" in screening individuals for susceptibility to excessive bone loss (osteopenia) and risk for osteoporosis through quantifying the amount the cortical bone present using x-rays of the metacarpals (Barnett et al. 1960). As a non-destructive and non-invasive means of assessing and quantifying cortical bone, it gained popularity in clinical studies, and was utilized in longer, longitudinal studies in order to assess sex and age corollaries with cortical bone (Garn 1970; Virtama et al. 1969). Soon after, archaeologists began adopting the method in order to assess cortical bone in past skeletal populations, beginning with Garn's (1970) proposed use of the second metacarpal for size, tubular geometry, and representativeness and preservation in archaeological contexts. Regarding representativeness, Waldron suggested that the second metacarpal often has a moderate survival rate, frequently present so long as some 54.6% of an individual's remains are recovered (Waldron 1987). In the case of Largo Cândido dos Reis, hands in general showed moderate representativeness, with 65.80% for Christian burials and 47.80% for Islamic burials. However, fragmentation, friability, erosion, and post-depositional damage were all factors that influenced the preservation and recovery of second metacarpals at the site. Thus, while second metacarpals may be *represented*, they are not necessarily able to be *analyzed* due to issues of fragmentation, breakage, or erosion. Recently, Gilmour and colleagues (2021) proposed a method of yielding cortical index measurements from fragmentary metacarpals by using a region of interest (ROI). However, the present study had already collected and scanned complete metacarpals prior to the publication, so only complete metacarpals are analyzed here. A total of 107 individuals represented by a complete second metacarpal were able to be analyzed in the present study.

Notably, some scholars reassessed Garn's claims that metacarpals exhibit semi-circular geometry, and caution that the positioning of the metacarpal for x-rays may well have an effect on the overall total-width measurements (Roy et al. 1994; Lazenby 1995). In a survey of fifteen studies examining radiogrammetry of the second metacarpal, Ives and Brickley (2004, 9) found inconsistencies in 1) which side the metacarpal came from (left or right), 2) the position of the metacarpal (antero-posterior; AP or postero-anterior; PA), and 3) the indices measured. They found that the position of the metacarpal can indeed have a significant effect on total width (TW), with the posterior (dorsal) aspect of metacarpals having a wider metric than the anterior (palmar) one. However, no other indices were affected, which likely suggests that outside of mean total width, the positioning of the metacarpal is not likely to affect results (Ives et al. 2004, 15). More recently, Gilmour and Plomp (2022) interrogated how traditional indices compare with newer developments in their attempts to capture metacarpal cortical 'shape.'

Another potential issue is the effect of handedness, or how hand dominance may lead to a side-bias in overall size of a metacarpal for a given individual. Metacarpal radiogrammetry studies have varied considerably in their sampling strategy for which side is analyzed. Occasionally, studies select a metacarpal at random (Mays 1996; Mays 2001; Mays 2000), while others preferentially select all from one side (Dequeker 1972; Dequeker 1976), which could produce conflicting results if there is bilateral asymmetry in cortical bone indices. Lazenby (Lazenby 2002b) for instance, suggested that the mechanical demands placed on hands varies with hand dominance, which probably results in differing cortical indices. Both Dequeker (1972; 1976) and Steele (2000) found evidence of bilateral asymmetry in mean cortical thickness between matched second metacarpals. However, Ives and Brickley (2004) conducted a comparison of matched 20 right and left metacarpals from the same individuals, and found no significant differences in any cortical bone indices, suggesting that handedness is a relatively minor concern. Lack of bilateral asymmetry in metacarpal bone indices was observed in other clinical (Derisquebourg et al. 1994) and bioarchaeological (Beauchesne and Agarwal 2014; Glencross et al. 2011; Brickley et al. 2005; Mays 2001) studies have found little evidence for handedness in affecting cortical bone indices. In the case of archaeological studies, preservation and representativeness often dictate which metacarpals are used (Mays 1996; 2000; 2001), and as such, random or preferential sampling, supplemented with a test for handedness for a subset of individuals that have both left and right metacarpals (Ives et al. 2004) is likely the most feasible option in most bioarchaeological studies.

Finally, the efficacy of metacarpal radiogrammetry in being a reliable index of cortical bone has been evaluated since at least the 1990s. Additionally, despite radiogrammetry's origins in clinical research, clinical studies today often employ other non-invasive methodologies (e.g., dual energy X-ray absorptiometry; DXA) to quantify cortical bone, though there are a few exceptions where radiogrammetry is still analyzed today (Franceschi et al. 2018; Magan et al. 2019). Numerous studies have examined the correspondence between cortical indices obtained from the metacarpal and osteoporotic fracture locations like the distal radius (Colles fracture) (Adami et al. 1996; Dey et al. 2000; Rosholm et al. 2001), proximal femur (hip fracture) (Adami et al. 1996; Boonen et al. 2005; Dey et al. 2000; Brickley et al. 2005), and lower lumbar (spine fracture) (Adami et al. 1996; Boonen et al. 2005; Meema et al. 1992; Wishart et al. 1993). In a thorough intra-skeletal and multi-method analysis, Beauchesne and Agarwal (2017) showed how quantitative cortical indices obtained from the metacarpal did not always reflect cortical bone levels in other portions of the skeleton, such as the lumbar vertebrae, or ribs. They caution that while low cortical bone indices in metacarpals may well correspond with common osteoporotic fractures, cortical bone in the metacarpal likely represents a specific, regional amount of cortical bone compared to other skeletal regions. As such, it is likely best to interpret the amount of cortical bone in metacarpals conservatively, and contextually, and not as a general proxy of cortical bone throughout the skeleton.

Figure 7.1 - Metacarpal Radiogrammetry measurements for total length (TL), total width (TW) and medullary width (MW) of the second left metacarpal from Ent. 476.



Measurements and corresponding indices for quantifying cortical bone in the second metacarpal are largely based on the works of Mays (Mays 1996; 2000; 2001) and refined by Ives and Brickley (2004). Following clinical protocols (e.g. Dequeker, 1976), Mays obtained radiographs of the second metacarpals in antero-posterior position, and conducted subsequent measurements directly on the radiograph film using digital hand calipers (Figure 7.1). The first measure taken is the total length (TL), which is defined as the distance "from the capitulum to the saddle of the basis" (Ives et al. 2004, 10). The TL is then divided by 2 in order to achieve the midpoint of the metacarpal, which is used as the landmark to obtain the total width (TW) of the metacarpal by measuring the periosteal ends of each side of the diaphysis. Medullary width (MW) is then obtained by measuring the endosteal boundaries of the medullary cavity. Cortical thickness (CT) is obtained by subtracting the medullary width (MW) from the total width (TW). Finally, the cortical index (CI) is calculated by:

$$Cortical\ Index\ (CI) = \frac{Total\ Width\ (TW) - Medullary\ Width\ (MW)}{Total\ Width\ (TW)} x\ 100$$

Notably, sexual dimorphism and body size can influence cortical index values, and subsequently bias interpretations between sexes in samples where sexual dimorphism is severe. As a result, Glencross and Agarwal (2011) developed a revised cortical index (also called cortical thickness index; CTI) which accounts for total length (TL) rather than total width (TW) to better account for size differences:

$$Revised\ Cortical\ Index\ (CTI) = \frac{Total\ Width\ (TW) - Medullary\ Width\ (MW)}{Total\ Length\ (TL)} x\ 100$$

Finally, they developed a similar index for the medullary canal in order to further account for allometric size differences:

$$Medullary\ Width\ Index\ (MWI) = \frac{Medullary\ Width\ (MW)}{Total\ Length\ (TL)} x\ 100$$

These latter indices should be used in cases where sexual dimorphism, as evidenced by Total Length (TL), differs significantly between sexes. However, since no significant differences in TL were observed between the sexes, the MWI was not employed in the current study.

Traditionally, metacarpal radiogrammetry was conducted by directly measuring the radiographs on a light box using digital calipers. The phasing out of many traditional radiographs and black-rooms across the U.S. in the 2010s, accompanied by the increasing adoption of digital x-ray technologies, has urged a change in the methodology to shift to digital means. Analyzing a sample of 75 individuals from pre-contact Colombia, Miller (2016, 95–96) was able to develop a digital protocol using digital x-rays accompanied by measurements using ImageJ software, which were shown to be comparable to those obtained using digital calipers on traditional radiographs.

In the present study, left metacarpals were preferentially selected, using rights only when lefts were absent, broken, or taphonomically altered. All metacarpals were analyzed at the University of California, Berkeley Student Health (Tang) Center, using a Phillips Diagnost 3.0 digital x-ray machine, set to 55kV 1.2mAs and 80ms. Metacarpals were placed in a foam block with parallel slits in order to nestle the metacarpals in antero-posterior position (AP). X-rays were formatted as DICOMs, which were then analyzed using ImageJ software (Miller 2016, 95–96). Scans in ImageJ were scaled according to a known object included in each x-ray scan (a

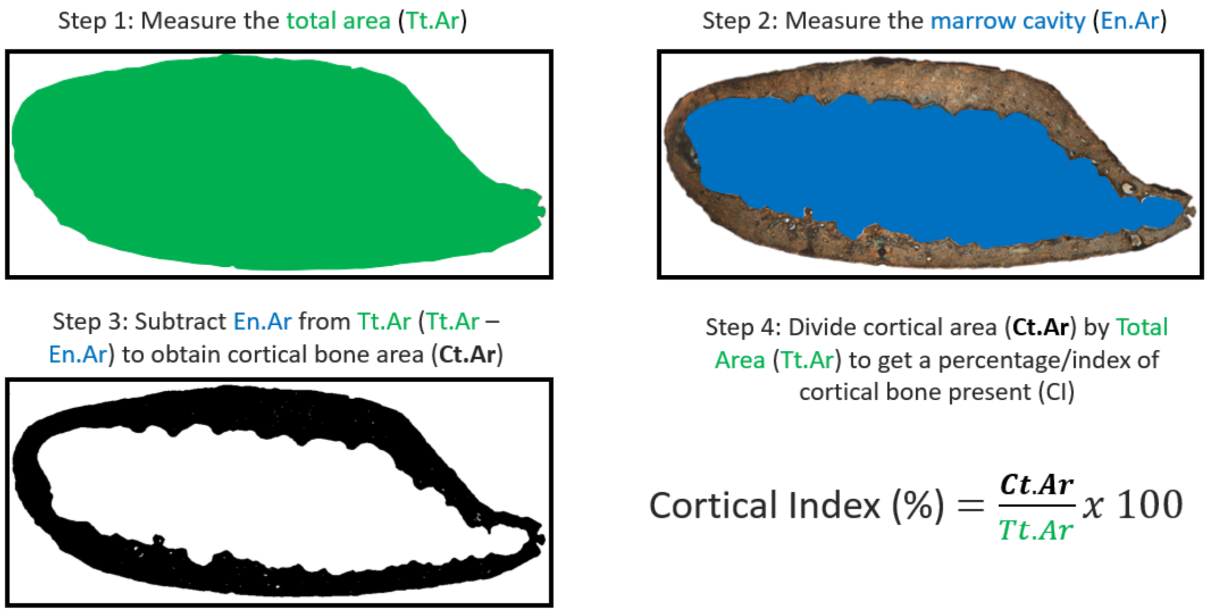
U.S. nickel with a diameter of 21.21mm) in order to account for potential variation in size due to x-ray distance from foam, minor fluctuations in the machine, etc.

Rib Cross-Sectional Area

In addition to cortical bone quantity measured from metacarpals, I also measured a sub-sample of cortical bone quantity in rib bones from histologically prepared cross sections. Rib thick sections were first cleaned using a soft brush, water, ethanol, and/or a sonicator as needed. Due to the friable nature of many rib samples, many were gently cleaned before sonication to allow proper cleaning in the inter-trabecular cavities. Approximately 1mm sections were taken from the middle shaft of mid-thoracic ribs (4-8) using a Buehler Isomet® slow-speed saw affixed with a 6" diamond-coated wafering blade set to a speed of 100-125 rpm and lubricated with a water and ethanol mixture. Traditionally the 6^{th} rib is preferred as many of the clinical histomorphometric calculations were developed on it. However, the preservation of the entire 6^{th} rib in many archaeological contexts is rare, and in many cases it is extremely difficult to identify exact rib number in more fragmented burials (Stout et al. 1995). Subsequent research has shown that while the 6^{th} rib is preferable, it is not necessary for histomorphometric analysis (Stout et al. 1976; S. D. Stout et al. 1995; Cho et al. 2003). Sections were allowed to dry for 24 hours before embedding in a resin medium. Many archaeological bone samples are highly fragile and friable, necessitating a durable medium to maintain structural integrity during thin-sectioning, grinding, and polishing (Beauchesne and Saunders 2006; Brönnimann et al. 2018; Morales et al. 2017; Stout et al. 1976). Samples were embedded with a two-part epoxy resin medium (Buehler's Epo-Thin 2) following the manufacture's protocol. Samples were subsequently vacuumed in a Buehler Cast N' Vac 1000 impregnation chamber to draw bubbles from the medullary cavity formed during the embedding process. This was done so in a ratcheting fashion in 10 mmHg intervals, to -25 mmHg pressure, and repeated for a total of two cycles, before allowing the samples to cure in the chamber for 24 hours. Blocks were then thin-sectioned using the Buelher Isomet® once again, for 1-1.5mm bottom-most portion as a 'blank' to ensure proper subsequent cross-sectional sampling, and a 1-1.5mm wafer was sectioned for mounting on PetroThin® geological slides using a 2 Ton® Clear Epoxy solution (Devcon2). Slide-mounted samples were then ground to desired thickness (~30 - 50 µm) for histotaphonomic analysis (See Chapter 10).

Samples were measured for cortical area using a Leica MZ6 microscope affixed with a Leica K3C digital camera attachment at 8.5x magnification. Cross-sectional area was calculated using ImageJ software following Cho and Stout (2003) as well as Beauchesne (2012, 92), whereby a polygon was traced along the outermost (periosteal) border, which then calculated the total area (Tt.Ar) for the rib cross section. A polygon was then traced along the endosteal border where the cortical and trabecular margins conjoined, which resulted with the endosteal area (En.Ar). Cortical area (Ct.Ar) was calculated by subtracting the endosteal area (En.Ar) from the total area (Tt.Ar; Fig. 7.2). The percentage of cortical area present was determined by dividing cortical area by total area and multiplying by 100 (Ct.Ar./Tt.Ar*100; abbreviated here as CI).

Figure 7.2 - Rib macro-cortical measurements for total area (Tt.Ar), endosteal area (En.Ar), cortical area (Ct.Ar) and calculation of cortical index (CI) of a rib sample from LCR 352.



Measurement error

Some degree of measurement error is present in nearly all anthropometric analyses. Variability in obtained anthropometric measurements can arise due to technical error, instrumentation and calibration variability, within-examiner variation (intra-observer error), and between (inter-observer error) variation.

In order to assess the possible confounding effects of measurement error in anthropometric measures, anthropologists frequently analyze results for both their 1) reliability and 2) variability. Reliability refers to the reproducibility of obtained results, often by analyzing the consistency of results across time with repeated measures or within and between differing observers. Validity refers to the extent to which the measurements actually capture what they are meant to. As a result, measurements may be reliable, (i.e. reproducible – consistent within and between researchers) but not necessarily valid if they fail to correctly measure what they are intended to. For example, using digital calipers to measure bone length may produce consistent results with repeated measures (reliable), but the calipers could be mis-calibrated to not measure the true length of the bone (invalid). On the other hand, results that are deemed valid are usually reliable, though not always. Using properly calibrated digital calipers may aid in obtaining both valid and consistent results for bone length, but variation within and between observers is still a potential confounding issue in anthropometric data collection.

Reliability

In order to assess reliability, all anthropometric measures were analyzed for inter- and intra-observer error with at least four weeks between data collection. Three analyses were conducted in order to assess reliability: 1) change in absolute mean, 2) Bland-Altman plots, and

3) intraclass correlation coefficient (ICC). Changes in absolute mean were analyzed using paired two-tailed t-tests with an $a = 0.05$ in order to assess possible variability in means between measures. Bland-Altman plots, also known as a Tukey mean-difference plot, compare agreement between two measurements. Building on the work of Eksborg (1981), Bland and Altman proposed in a series of papers a means of visually assessing reliability between repeated measures (Altman et al. 1983; Bland et al. 1995; Bland et al. 1999; Bland et al. 2010). Unlike correlation, which assesses the relationship *between* two variables, Bland-Altman plots assess the mean differences alongside limits of agreement — calculated using mean and standard deviation of the differences *between* the two measurements (Giavarina 2015). The result is an XY scatterplot which depicts the difference of the two paired measurements (e.g. measure 1 – measure 2) against the mean of the two measurements (measure 1 + measure 2 / 2). The limits are constructed as standard deviations, so that 95% of the data points should fall between ± 2*s* of the mean difference (Giavarina 2015). Notably, Bland-Altman does not evaluate whether the results are 'acceptable' or not — it merely depicts the measures graphically and gives a visual means of assessing measurement consistency, which differs by measure and circumstance (Giavarina 2015).

Finally, intraclass correlation coefficient (ICC) was used as a means of assessing reliability. Similar to interclass correlation coefficient (also known as Pearson correlation), the ICC assesses the strength of the relationship between two measurements, yielding a number between 0 and 1 where a coefficient closer to 1 indicates high similarity between values of the same group, and closer to 0 indicates dissimilarity between values of the same group (Jamaiyah et al. 2010). Coefficients are usually classified in their degree of reliability, where < 0.2 are deemed 'slightly reliable,' 0.2 - < 0.04 is deemed 'fairly reliable,' 0.4 - < 0.06 is 'moderately reliable,' 0.6 - < 0.08 is 'substantially reliable,' and 0.8 – 1.0 is 'near perfect reliability' (Goto et al. 2007; Jamaiyah et al. 2010).

One accuracy index used by anthropometrists is the Technical Error of Measurement (TEM). The TEM assesses both inter- and intra-observer error by assessing the standard deviations in repeated measurements to assess reliability (Ulijaszek 1998). Lower absolute TEM results in higher reliability. The formula for calculating absolute TEM is as follows:

$$TEM = \sqrt{\frac{\sum D^2}{2n}}$$

Where *D* refers to the difference between repeated measurements and *n* refers to the number of measures being compared. Relative TEM was calculated by using the following equation:

$$Relative\ TEM = \left(\frac{TEM}{VAV}\right) x\ 100$$

Where *VAV* refers to the Variable Average Value which is computed by averaging the total averages between repeated measures. Absolute TEM was used to then calculate the Coefficient of Reliability:

$$Coefficient\ of\ Reliability = 1 - \left(\frac{TEM^2}{SD^2}\right)$$

Where *SD* refers to the standard deviation from the total set of measurements. The Coefficient of Reliability gives a coefficient between 0 (unreliable) and 1 (completely reliable). Ulijaszek (1998) advocated for a coefficient of 0.95 or greater to be considered reliable for biometric methodologies.

Validity

Finally, the Coefficient of Variation (CV, also known as the relative standard deviation) was used to assess general precision. Comparing standard deviations as measures of variability between two samples can be difficult, especially if means, measurement scales, or units differ. The CV permits comparisons (without units) since it is merely the standard deviation *relative* to the respective mean. The Coefficient of Variation can help give a general "feeling" of the overall reliability, with CVs of 5% or less being recommended, and CVs of 10% or higher suggesting poor measurement performance (Jamaiyah et al. 2010, 132).

Intraobserver variance was first calculated by taking the squared difference between measures before dividing by two:

$$s2 = \frac{(m1 - m2)^2}{2}$$

Which was then divided by the mean of repeated measures (m):

$$m = \frac{m1 + m2}{2}$$

To yield the CV squared:

$$CV^2 = \frac{s2}{m^2}$$

Finally, the square root of the mean of CV^2 was calculated before multiplying by 100 to yield a percentage:

$$CV\ (\%) = \left(\sqrt{CV^2}\right) * 100$$

Metacarpal Radiogrammetry

In order to assess reliability, a subset of *n* = 40 metacarpals were measured for all parameters (Total Length, TL; Total Width, TW; Medullary Width, MW; Cortical Thickness, CT; Cortical Index, CI; and Cortical Thickness Index, CTI) at least 4 weeks after initial data collection. While it is not necessary to remeasure all data points, a sizeable subset is often recommended. Some scholars prefer to re-measure based on a specified subset (e.g. 10% of total *n*) but this can lead to issues in representation and normality depending on the overall sample size. As a result, a subset of *n* = 40 metacarpals were remeasured (35.7% of total sample) since *n* = 30 has been shown to decrease misclassification errors (Cheverko et al. 2017), possibly due in part to the central limit theorem (CLT). For both measures, normality was assessed graphically with normal quantile plots as well as Shapiro-Wilk tests.

Results for the reliability analysis are shown in Appendix 7.1. In the case of Intraobserver error, Bland-Altman plots showed that only MW did not meet the 95% threshold for deviations. All other measures (TL, TW, CT, CI, CTI) showcased at least 95% or greater of points that fell within 2*s*. Results of the Intraclass Correlation Coefficient (ICC – Model 2) analysis showcased near perfect reliability (0.99+) for each measure, with highly significant accompanying F-tests and p-values. The average difference between same-observer measures was usually minor, ranging from 0.2mm (TL) to 0.11mm (CT). When paired with differences in absolute mean, differences were also minor, ranging from 0.08mm – 0.03mm. Only TL showed a significant p-value for difference in absolute mean ($p = 0.04$). For Technical Error of Measurement (TEM), the absolute TEM results showed variation from 0.04 (TW) to 0.97 (CI), suggesting generally agreeable reliability between measures. Relative TEM ranged from 0.25 (TL) to 2.15 (CT), but all had a reliability coefficient of 0.99 or higher. Finally, Coefficient of Variation (CV, %) percentages were low, ranging from 0.25 (TL) to 2.29 (CT). All values were below 5%, which suggests a generally good performance and reliability (Jamaiyah et al. 2010, 132). Altogether, these metrics suggest that despite minor variability in some measurements, the overall metacarpal radiogrammetry anthropometric data is highly reliable within the same observer.

Analytical Procedures

Handedness

A sub-sample of 21 individuals with bilateral preservation of complete second metacarpals were tested for asymmetry (handedness). This was done in a similar manner to the reliability analysis mentioned above, as comparing left and right metacarpal dimensions can be likened to matched pairs analysis. Bland-Altman plots, as well as average difference and changes in absolute mean difference, and corresponding paired t-tests and associated p-values are listed in Appendix 7.2. While TL was the only metric to be lower than 95% for Bland-Altman plots, all other metrics were above the 95% threshold. Paired t-Tests show significant differences for TL, TW, CT, and CTI, but not CI, suggesting that while there are significant differences in asymmetry for some metrics, CI is not significantly affected.

Normality

Each metacarpal metric (TL, TW, MW, CT, CI and CTI) were separated by funerary group (Islamic or Christian), sex (Male or Female), and age (18-29, 30-49, 50+ years) and subsequently analyzed for normality. Normality was assessed visually by examining histogram distributions, box and whisker plots, and normal quantile plots before statistically testing the distributions for normality using a Shapiro-Wilk test with an $\alpha = 0.05$ (Appendix 7.3). All metrics showed approximately normal distributions, box and whisker plots, normal quantile plots, and Shapiro-Wilk tests except for total length (TL; $W = 0.66$, $p = 0.00$) in the Islamic males in the 18-29 age group, cortical thickness (CT; $W = 0.76$, $p = 0.02$) in the Christian female 30-49 age group, and cortical thickness in both the Christian male 18-29 age group ($W = 0.89$; $p = 0.02$, and the Christian male 30-49 age group ($W = 0.84$; $p = 0.03$). For these metrics a Kruskal-Wallis test was employed instead of an ANOVA.

Similar normality checks were conducted for rib cortical area values stratified by age, sex, and funerary group. All indices exhibited relatively tight normal quantile plots, semi-normal density plots, and no Shapiro-Wilk tests were statistically significant (Appendix 7.4).

Statistical comparisons within and between funerary groups were carried out largely using two-sided t-Tests with an $\alpha = 0.05$. In the case of multiple comparisons (e.g., 18-49 Islamic vs. 50+ Islamic, 18-49 Islamic vs. 18-49 Christian, etc.), a Bonferroni correct was used to adjust resulting p-values to reduce overall family-wise error rate (FWER).

Due to issues in sample size and reductions in statistical power, the younger (18-29 years) and middle (30-49 years) age groups were collapsed. While this sacrificed overall resolution of bone loss across various age groups, it should still capture key differences in reproductive years for female adults (18 – 49 years) and age-related bone loss in later life (50+ years).

Results

Metacarpal Radiogrammetry

Islamic females showed no significant age-related changes in any metric (Table 7.2). Notably, Islamic females showed a slight increase in medullary width (MW) in age groups, accompanied by a decrease in cortical thickness (CT), cortical index (CI) and cortical thickness index (CTI) values, but the differences were not significant. Islamic males showed no significant age-related changes in any metric except for medullary width, where the middle age group (30-49 years) showed a significantly smaller medullary width compared to younger males (18-29 years; $F = 3.64$, $p = 0.04$; Table 7.3).

Table 7.2 - Age-comparison of film-converted metacarpal radiogrammetry metrics in Islamic Females, pooled by site (Largo Cândido dos Reis and Avenida 5 de Outubro).

	18-29 (n = 4)	**30-49 (n = 13)**	**50+ (n = 14)**	**ANOVA/Kruskal-Wallis**
Metric	Mean (SD)	Mean (SD)	Mean (SD)	F/H (p)
TL	67.97 (3.25)	66.90 (2.93)	65.28 (2.92)	1.73 (0.196)
TW	7.10 (0.42)	7.67 (0.53)	7.58 (0.54)	1.85 (0.176)
MW	2.70 (1.13)	3.65 (0.79)	3.75 (0.60)	3.08 (0.061)
CT	4.39 (0.81)	4.02 (0.66)	3.84 (0.61)	1.16 (0.327)
CI	62.39 (13.48)	52.53 (8.78)	50.59 (7.27)	2.83 (0.076)
CTI	6.50 (1.32)	5.99 (0.88)	5.90 (1.02)	0.56 (0.576)

Table 7.3 - Age-comparison of film-converted metacarpal radiogrammetry metrics in Islamic Males, pooled by site (Largo Cândido dos Reis and Avenida 5 de Outubro).

	18-29 (n = 5)	**30-49 (n = 7)**	**50+ (n = 15)**	**ANOVA/Kruskal-Wallis**
Metric	Mean (SD)	Mean (SD)	Mean (SD)	F/H (p)
TL	71.63 (4.03)	73.48 (2.00)	70.25 (3.81)	2.06 (0.149)
TW	8.69 (0.26)	8.12 (0.22)	8.48 (0.15)	1.59 (0.22)
MW	4.25 (0.43)	3.38 (0.64)	4.03 (0.66)	3.64 (0.042)
CT	4.44 (0.30)	4.74 (0.49)	4.44 (0.54)	0.93 (0.408)
CI	51.08 (3.46)	58.53 (6.50)	52.53 (6.30)	3.06 (0.066)
CTI	6.20 (0.41)	6.46 (0.77)	6.34 (0.87)	0.16 (0.85)

Table 7.4 - Age-comparison of film-converted metacarpal radiogrammetry metrics in Christian Females, pooled by site (Largo Cândido dos Reis and Avenida 5 de Outubro).

	18-29 (n = 5)	**30-49 (n = 6)**	**50+ (n = 10)**	**ANOVA/Kruskal-Wallis**
Metric	Mean (SD)	Mean (SD)	Mean (SD)	F/H (p)
TL	67.82 (6.16)	65.50 (2.69)	65.59 (3.87)	0.54 (0.590)
TW	8.16 (0.59)	7.55 (0.48)	7.97 (0.42)	2.40 (0.119)
MW	3.96 (0.60)	3.69 (1.26)	3.74 (0.54)	0.17 (0.841)
CT	4.20 (0.84)	3.86 (0.94)	4.23 (0.52)	0.52 (0.602)
CI	51.26 (7.66)	51.58 (14.76)	53.12 (6.09)	0.08 (0.922)
CTI	6.27 (0.89)	5.87 (1.25)	6.46 (0.80)	0.72 (0.501)

Table 7.5 - Age-comparison of film-converted metacarpal radiogrammetry metrics in Christian Males, pooled by site (Largo Cândido dos Reis and Avenida 5 de Outubro).

	18-29 (n = 11)	**30-49 (n = 23)**	**50+ (n = 9)**	**ANOVA/Kruskal-Wallis**
Metric	Mean (SD)	Mean (SD)	Mean (SD)	F/H (p)
TL	65.58 (3.44)	67.82 (3.65)	70.00 (4.40)	3.44 (0.04)
TW	8.26 (0.87)	8.34 (0.94)	8.46 (0.84)	0.12 (0.90)
MW	3.99 (0.98)	3.98 (0.84)	3.94 (0.80)	0.01 (0.988)
CT	4.27 (0.68)	4.36 (0.37)	4.52 (0.57)	0.61 (0.547)
CI	52.03 (8.51)	52.66 (5.52)	53.70 (6.43)	0.16 (0.851)
CTI	6.50 (0.90)	6.43 (0.44)	6.48 (0.86)	0.06 (0.946)

Christian females showed no significant age-related changes in any metric across age groups (Table 7.4). Notably, Christian females showed relatively minor changes in medullary width (MW) across age groups, with medullary width being decreased in the middle age group (30-49 years) while higher in the older age group (50+ years). The same trend was observed for total width (TW) and cortical thickness (CT). Higher cortical index (CI) measures were found across age groups, which was surprising, and cortical thickness index (CTI) values were higher for younger (18-29 years) and older (50+ years) age groups, and lowest in the middle age group. Christian males showed no significant age-related changes in any metric across age groups except for TL (Table 7.5). Christian males showed a general increase in total width (TW), cortical thickness (CT), and cortical index (CI) across age groups, while showing a reduction in medullary width (MW) across age groups.

Table 7.6 - Age-comparison of 18-49 years vs. 50+ years of metacarpal radiogrammetry metrics by funerary group and sex at Largo Cândido dos Reis and Avenida 5 de Outubro.

Group	Metric	Mean (SD)	Mean (SD)	*t*	p
Islamic Female		***18-49 (n = 17)***	***50+ (n = 14)***		
	TL	67.15 (2.94)	65.28 (2.92)	-1.77	0.09
	TW	7.53 (0.55)	7.58 (0.54)	0.25	0.81
	MW	3.43 (0.94)	3.74 (0.60)	1.14	0.26
	CT	4.10 (0.69)	3.84 (0.61)	-1.15	0.26
	CI	54.85 (10.51)	50.59 (7.27)	-1.33	0.19
	CTI	6.11 (0.97)	5.90 (1.02)	-0.59	0.56
Islamic Male		***18-49 (n = 12)***	***50+ (n =15)***		
	TL	72.71 (3.00)	70.25 (3.81)	-1.88	0.07
	TW	8.36 (0.54)	8.48 (0.65)	0.53	0.60
	MW	3.74 (0.70)	4.03 (0.66)	1.10	0.28
	CT	4.61 (0.43)	4.44 (0.54)	-0.90	0.38
	CI	55.43 (6.49)	52.53 (6.30)	-1.17	0.25
	CTI	6.35 (0.63)	6.34 (0.87)	-0.03	0.98
Christian Female		***18-49 (n = 11)***	***50+ (n = 10)***		
	TL	66.56 (4.50)	65.59 (3.87)	-0.53	0.60
	TW	7.83 (0.60)	7.97 (0.42)	0.61	0.55
	MW	3.82 (0.98)	3.74 (0.54)	-0.24	0.82
	CT	4.01 (0.87)	4.23 (0.52)	0.70	0.49
	CI	51.43 (11.50)	53.11 (6.09)	0.43	0.68
	CTI	6.01 (1.06)	6.46 (0.80)	1.11	0.28
Christian Male		***18-49 (n = 34)***	***50+ (n = 9)***		
	TL	67.10 (3.69)	70.00 (4.40)	1.76	0.11
	TW	8.31 (0.90)	8.46 (0.84)	0.06	0.96
	MW	3.99 (0.87)	3.94 (0.80)	-0.22	0.83
	CT	4.33 (0.49)	4.52 (0.58)	0.45	0.66
	CI	52.45 (6.50)	53.70 (6.43)	0.35	0.74
	CTI	6.45 (0.61)	6.48 (0.86)	-0.48	0.65

When younger (18-29 years) and middle (30-49 years) age categories were collapsed, and compared to the older age category (50+), no significant differences were found for any group when separated by funerary group and sex (Table 7.6). No significant differences were observed except for the comparison of total length between Islamic and Christian younger males (18-49) where Islamic males exhibited significantly higher average total length measures than their Christian counterparts ($p < 0.01$; Table 7.7).

To further investigate the potential for individuals with low bone mass, the threshold developed by Meema and Meema (1987) was used, which identifies outliers whose cortical index (CI; %) values are 2 standard deviations or more below the group-specific mean (Table 7.12) Only two individuals were identified using this standard: one older (50+ years) female

Islamic individual (1/14; 7.14%) and one middle-aged (30-49 years) Christian male individual (1/23; 4.34%). The general lack of individuals with low bone mass, particularly in older age categories, could be a product of age, bone mass, and/or small sample sizes which impact the overall distribution and variance. Graphical depictions for funerary-specific metacarpal indices by age groups can be seen in Appendix 7.5 through 7.27.

Table 7.7 - Funerary comparison of metacarpal radiogrammetry metrics by age group and sex at Largo Cândido dos Reis and Avenida 5 de Outubro.

Group	Metric	Mean (SD)	Mean (SD)	*t*	p
Female 18-49		***Islamic (n = 17)***	***Christian (n = 11)***		
	TL	67.15 (2.94)	66.56 (4.50)	0.39	0.71
	TW	7.53 (0.55)	7.83 (0.60)	-1.33	0.20
	MW	3.43 (0.94)	3.82 (0.98)	-1.05	0.31
	CT	4.10 (0.69)	4.01 (0.87)	0.31	0.76
	CI	54.85 (10.51)	51.43 (11.50)	0.79	0.44
	CTI	6.11 (0.97)	6.01 (1.06)	0.26	0.80
Female 50+		***Islamic (n = 14)***	***Christian (n =10)***		
	TL	65.28 (2.92)	65.59 (3.87)	-0.22	0.83
	TW	7.58 (0.54)	7.97 (0.42)	-1.97	0.06
	MW	3.74 (0.60)	3.74 (0.54)	0.03	0.98
	CT	3.84 (0.61)	4.23 (0.52)	-1.71	0.10
	CI	50.59 (7.27)	53.11 (6.09)	-0.93	0.37
	CTI	5.90 (1.02)	6.46 (0.80)	-0.26	0.80
Male 18-49		***Islamic (n = 12)***	***Christian (n = 34)***		
	TL	72.71 (3.00)	67.10 (3.69)	5.23	<0.01*
	TW	8.36 (0.54)	8.31 (0.90)	0.19	0.85
	MW	3.74 (0.70)	3.99 (0.87)	-0.96	0.35
	CT	4.61 (0.43)	4.33 (0.49)	1.89	0.07
	CI	55.43 (6.49)	52.45 (6.50)	1.36	0.19
	CTI	6.35 (0.63)	6.45 (0.61)	-0.47	0.65
Male 50+		***Islamic (n = 15)***	***Christian (n = 9)***		
	TL	70.25 (3.81)	70.00 (4.40)	0.14	0.89
	TW	8.48 (0.65)	8.46 (0.84)	0.07	0.94
	MW	4.03 (0.66)	3.94 (0.80)	0.31	0.76
	CT	4.44 (0.54)	4.52 (0.58)	-0.32	0.75
	CI	52.53 (6.30)	53.70 (6.43)	-0.43	0.67
	CTI	6.34 (0.87)	6.48 (0.86)	-0.47	0.65

Table 7.8 - Number and proportion of individuals identified with low bone mass using the Meema and Meema (1987) standard, by age, sex, and funerary group.

Sex	Age	Islamic: CI < 2 SD of mean	Islamic: %	Christian: CI < 2 SD of mean	Christian: %
Females					
	18-29	0/4	0	0/5	0
	30-49	0/13	0	0/6	0
	50+	1/14	7.14	0/10	0
	Total	1/30	3.33	0/21	0
Males					
	18-29	0/5	0	0/11	0
	30-49	0/7	0	1/23	4.34
	50+	0/15	0	0/9	0
	Total	0/27	0	1/43	2.33

Rib Cross Sectional Area

Few significant differences were observed between age groups for rib cross sectional area measures (Table 7.9). Only Islamic females showed decreased mean CI values in the older age group (50+ years) compared to the younger age group (18-49 years; adjusted p = 0.04), and Christian older males had significantly lower Ct.Ar values than their younger counterparts (p = 0.02). All other comparisons were not significant. No significant differences were observed between same-sex and same-age funerary groups for any metric (Table 7.10). Graphical depictions for rib cross sectional indices can be seen in Appendix 7.28 through 7.35.

Table 7.9 - Age-comparison of 18-49 years vs. 50+ years of rib cross sectional area indices by funerary group and sex at Largo Cândido dos Reis and Avenida 5 de Outubro.

Group	Metric[a]	Mean (SD)	Mean (SD)	*t*	p	Adjusted p[b]
Islamic Female		***18-49 (n = 15)***	***50+ (n = 10)***			
	Tt.Ar	58.24 (12.64)	59.49 (10.33)	-0.27	0.79	0.99
	En.Ar	30.63 (9.23)	35.86 (8.18)	-1.50	0.15	0.30
	Ct.Ar	27.61 (7.71)	23.63 (3.17)	1.79	0.09	0.18
	CI	47.69 (9.44)	40.25 (4.81)	2.59	0.02*	0.04*
Islamic Male		***18-49 (n = 16)***	***50+ (n =13)***			
	Tt.Ar	69.43 (16.39)	72.22 (17.13)	-0.44	0.66	0.99
	En.Ar	40.06 (15.01)	43.97 (15.73)	-0.68	0.50	0.99
	Ct.Ar	29.37 (4.56)	28.25 (6.31)	0.53	0.60	0.99
	CI	44.08 (10.01)	40.30 (8.86)	1.08	0.29	0.58
Christian Female		***18-49 (n = 8)***	***50+ (n = 11)***			
	Tt.Ar	61.62 (16.88)	68.21 (16.13)	-0.86	0.41	0.82
	En.Ar	33.31 (13.8)	40.28 (13.43)	-1.1	0.29	0.58
	Ct.Ar	28.31 (4.26)	27.93 (6.62)	0.15	0.88	0.11
	CI	47.86 (8.91)	41.78 (8.46)	1.50	0.16	0.32
Christian Male		***18-49 (n = 26)***	***50+ (n = 9)***			
	Tt.Ar	66.92 (10.05)	67.97 (19.11)	-0.16	0.88	0.99
	En.Ar	36.02 (7.94)	41.56 (17.86)	-0.9	0.39	0.78
	Ct.Ar	30.89 (6.40)	26.4 (3.16)	2.74	0.01*	0.02*
	CI	46.43 (8.19)	41.51 (12.33)	1.12	0.29	0.52

[a] *Where Tt.Ar = Total Area, En.Ar = Endosteal Area, Ct.Ar = Cortical Area, and CI = Cortical Index, calculated as Ct.Ar/Tt.Ar*100*

[b] *P-value resulting from a Bonferroni correction*

Table 7.10 - Age-comparison of 18-49 years vs. 50+ years of rib cross sectional area indices by funerary group and sex at Largo Cândido dos Reis and Avenida 5 de Outubro.

Group	Metric[a]	Mean (SD)	Mean (SD)	*t*	p	Adjusted p[a]
Female 18-49		***Islamic (n = 15)***	***Christian (n = 8)***			
	Tt.Ar	58.24 (12.64)	61.62 (16.88)	-0.50	0.63	0.99
	En.Ar	30.63 (9.23)	33.31 (13.8)	-0.49	0.63	0.99
	Ct.Ar	27.61 (7.71)	28.31 (4.26)	-0.28	0.78	0.99
	CI	47.69 (9.44)	47.86 (8.91)	-0.05	0.97	0.99
Female 50+		***Islamic (n = 10)***	***Christian (n =11)***			
	Tt.Ar	59.49 (10.33)	68.21 (16.13)	-1.49	0.16	0.32
	En.Ar	35.86 (8.18)	40.28 (13.43)	-0.92	0.37	0.74
	Ct.Ar	23.63 (3.17)	27.93 (6.62)	-1.93	0.07	0.14
	CI	40.25 (4.81)	41.78 (8.46)	-0.51	0.62	0.99
Male 18-49		***Islamic (n = 16)***	***Christian (n = 26)***			
	Tt.Ar	69.43 (16.39)	66.92 (10.05)	0.55	0.57	0.99
	En.Ar	40.06 (15.01)	36.02 (7.94)	0.99	0.33	0.66
	Ct.Ar	29.37 (4.56)	30.89 (6.40)	-0.90	0.37	0.74
	CI	44.08 (10.01)	46.43 (8.19)	-0.79	0.44	0.88
Male 50+		***Islamic (n = 13)***	***Christian (n = 9)***			
	Tt.Ar	72.22 (17.13)	67.97 (19.11)	0.54	0.60	0.99
	En.Ar	43.97 (15.73)	41.56 (17.86)	0.33	0.75	0.99
	Ct.Ar	28.25 (6.31)	26.4 (3.16)	0.90	0.38	0.76
	CI	40.30 (8.86)	41.51 (12.33)	-0.25	0.81	0.99

[a] *Where Tt.Ar = Total Area, En.Ar = Endosteal Area, Ct.Ar = Cortical Area, and CI = Cortical Index*
[b] *P-value resulting from a Bonferroni correction*

Discussion

Some metrics for both metacarpals and ribs followed an expected trend: mean medullary measures (MW and En.Ar respectively) were larger in older age categories compared to younger ones, and cortical indices for each tissue were conversely lower in older age groups compared to younger ones. These follow the general observation for age-related bone loss in other bioarchaeological samples, such that even when comparing separate mortality samples cross-sectionally with different age parameters, and medullary cavities are larger (Agarwal et al. 1996; Agarwal 2008; 2012; Beauchesne and Agarwal 2014; Cho et al. 2003; Glencross et al. 2011). Mean total width (TW) values were found to be larger in the 50+ age groups compared to 18-49 groups, regardless of sex or funerary group. Some studies have found more periosteal apposition in females (Garn 1972), while others have found so in males (Virtama et al. 1969), and in the case of 18th- and 19th- century Britain, both sexes seemed to exhibit roughly equal rates of apposition (Mays 2000; 2001). The slight increase in TW, although not significant, could be a product periosteal deposition through manual labor, something observed in the metacarpal results at the Imperial Roman site of Velia (Beauchesne and Agarwal 2014). Indeed, some have posited total width as a reflection of periosteal apposition which aids in bone strength and bending (Mays 2001; Peck et al. 2007; Seeman 2008; Szulc et al. 2006). However, some other bioarchaeological studies have found a general lack of systematic increase in mean TW across age groups (Glencross et al. 2011; Miller 2016)

To further contextualize these results, peak bone mass was taken as the largest cross-sectional mean value for each funerary, sex, and age-specific group, following Mays (1996). Other group mean CI values were then divided by the maximum value to semi-quantify the percentage of cortical bone difference between cross-sectional groups. These results can be seen in Table 7.11, alongside other medieval European and/or Portuguese published studies (Curate et al. 2019; Mays 1996; 2000; 2015; Umbelino et al. 2019). While there are a number of other studies with published data (Beauchesne and Agarwal 2014; Glencross et al. 2011; Miller 2016; Virtama et al. 1969; Wesp et al. 2022), the geographic and/or temporal differences were significant enough to currently warrant their exclusion. The results from the raw CI values and percentage of cortical bone present were surprising in some cases. Average CI values were highest in the younger age category (18-29 years) only for Islamic females, whereas all other groups analyzed showed more variable and surprising patterns. Cortical Index values are typically expected to highest in younger age categories, through the attaining of peak bone mass (Böttcher et al. 2006). Islamic 18-29 year old males exhibited lower mean CI values (51.08) than their 30-49 (58.53) and 50+ (52.53) year old counterparts. Curiously, mean CI values were greater in each successive age-category for both Christian females and males, a similar finding from the Mesolithic male sub-sample in central Portugal (Umbelino et al. 2019). Islamic 18-29 females had slightly larger mean CI values than their male counterparts, which has been observed in other samples (Beauchesne and Agarwal 2014; Böttcher et al. 2006; Maggio et al. 1997; Szulc et al. 2006), and posited to be the result of females having increased endosteal deposition in anticipation for possible resorption later in life due to the metabolic demands of pregnancy and lactation (Martin 2003; Schoenau et al. 2001). A large analysis of CI values from contemporary Finland (Virtama et al. 1969) found peak bone mass achieved during the third decade of life, which would coincide with the middle (30-49) age group in this study. However, given that the Christian females did now show a similar trend, it is difficult to entertain this hypothesis fully with the current data. Additionally, the reproductive demands and timing of menses likely differs substantially between medieval women and contemporary industrialized women. Taken together, these surprising results in CI patterning are most certainly an artifact of sample size, which supports the rationale to collapse younger (18-29) and middle (30-49) age groups. Indeed, combining the younger and middle age groups not only resulted in patterns more typical of what is expected for CI values (progressive loss with aging throughout the life course), but also for other metrics as well. CI was found to be lower in the 50+ age group compared to the 18-49 age group, regardless of funerary group or sex.

Table 7.11 - Metacarpal percentage of peak cortical index values compared to other sites.

	Santarém - Islamic			**Santarém - Christian**			**Ancaster**[a]			**Coimbra**[b]			**Muge**[c]			**Spitalfields**[d]			**Wharram Percy**[e]		
	N	Mean	%	N	Mean	%	N	Mean	%	N	Mean	%	N	Mean	%	N	Mean	%	N	Mean	%
Males																					
18-29	5	51.08	87.3%	11	52.03	96.9%	14	50.9	100%	19	52.84	100%	5	49.81	96.0%	6	46.80	100%	10	42.90	94.5%
30-49	7	58.53	100%	23	52.66	98.1%	27	47.8	93.9%	54	51.47	97.4%	11	51.76	99.8%	21	46.30	98.9%	29	45.40	100%
50+	15	52.53	89.7%	9	53.70	100%	12	45.6	89.5%	75	50.66	95.9%	4	51.86	100%	64	42.00	89.7%	34	40.40	89.0%
Females																					
18-29	4	62.39	100%	5	51.26	96.5%	11	51.8	100%	22	52.16	97.7%	6	54.14	100%	-	-	-	15	49.50	100%
30-49	13	52.53	84.2%	6	51.58	97.1%	12	47.0	90.6%	49	53.39	100%	4	49.55	91.5%	20	49.20	-	27	44.40	89.7%
50+	14	50.59	81.1%	10	53.12	100%	16	34.0	65.6%	93	41.52	77.8%	4	48.33	89.3%	-	-	-	23	41.50	83.8%

Data retrieved from:

[a] Mays 2015

[b] Curate et al 2019

[c] Umbelino et al 2019

[d] Mays 2000, 2015

[e] Mays 1996

Table 7.12 – Percentage of peak cortical index values by funerary group, age, sex, and skeletal element.

	Metacarpal		**Rib**	
	18-49 Years	50+ Years	18-49 Years	50+ Years
Islamic Females	100%	92.23%	100%	84.40%
Islamic Males	100%	94.71%	100%	91.42%
Christian Females	96.84%	100%	100%	87.30%
Christian Males	97.67%	100%	100%	89.40%

Despite the utility in combining age groups for statistical purposes, it was intriguing to discover no significant differences for nearly any metric within and between funerary groups. As Samuel and colleagues state: “All individuals lose bone with advancing age” (2009, 72), and as such, the general lack of age-specific bone loss, even when stratified by funerary group and sex was unexpected, and may suggest a confluence of physical activity, dietary, reproductive, and/or sample size factors within the data. Sex differences in metacarpal cortical bone loss are often observed, and typically seen as a complex biocultural product of sex-specific hormones and biomechanics combined with culturally-mediated gendered variables such as activity, nutrition, parity, and breastfeeding, to name only a few (Ahlborg et al. 2003; Samuel et al. 2009; Seeman 2002; 2008). Some studies (Hewitt 1963; Martin et al. 2011) suggest that sex differences in metacarpal morphology begin as young as 2 years of age, due to sex-specific hormonal changes. In contemporary samples, males tend to exhibit larger bones resulting from a prolonged period of skeletal growth and development (Doyle et al. 2011; Seeman 2002; 2008), with pubertal androgen facilitating increases in periosteal bone formation (Seeman 2003). An analysis of 302 individuals from 19^{th} – 20^{th} century Portugal found significant endosteal bone (higher MW and lower CI values) loss in older females, but not in males (Curate et al. 2019). The authors interpreted this in light of possible peri- or post-menopausal hormonal fluctuations leading to the sex-specific age-related pattern in bone loss. In analyzing a Mesolithic population from central Portugal, Umbelino and colleagues found a 10.7% loss of cortical bone to be between younger and older female age groups (Umbelino et al. 2019), whereas mean CI values decreased by 20.2% for the contemporary 19^{th} – 20^{th} century female assemblage (Curate et al. 2019). The authors posit that while bone loss is still notable for females across the life course, Mesolithic females may have been comparatively buffered in the severity of bone loss due to physical activity, though the Mesolithic sample sizes are notably small (n = 14) and the data is cross-sectional, not longitudinal.

Biocultural Considerations for Physical Activity, Reproductive Histories, and Nutrition

Physical activity plays a crucial role in the maintenance of bone (Davison et al. 2005), as laid out in Wolff’s law (Frost 1987) long ago. Previous analyses of musculo-skeletal markers (MSMs), as well as degenerative change (e.g., Schmorl nodes, osteoarthritic changes, etc.) on sub-samples of individuals from Largo Cândido dos Reis (Graça 2010; Neves 2019; Rodrigues 2013; Tereso 2009) suggest a level of sustained physical activity throughout the life course. Rodrigues (2013) found evidence of more pronounced entheseal changes in upper limbs compared to lower ones, generally suggesting a demanding use of the upper body, but given their complex etiology, it is difficult to say precisely what such activities were practiced (Villotte et al. 2010; 2013).The metacarpal results may suggest significant physical activity of the upper limb and hand for both funerary groups that was practiced well into older age. Generally speaking, medieval labor in Iberia is typically conceptualized along gendered lines, such that Muslim and Christian women predominately practiced domestic activities, though there is significant variation (Guichard 1998; Jewell 2006; Macias 1998). For instance, Christian femora and tibiae were found to be robust in both sexes (Fernandes 2011; Gonçalves 2010; Graça 2010; Tereso 2009), whereas a subsample of Islamic femora and tibiae were found to be significantly less robust for females (Rodrigues 2013). Robusticity in these cases was assessed using the various bone-specific indices from Olivier and Demoulin (1984), which divides the midshaft circumference by the maximum length and multiplies by 100. Rodrigues also found higher prevalence of osteoarthritic (OA) changes in the vertebral column for males (74%) compared to females (21.7%), but OA was generally low in most of these studies (Fernandes 2011; Gonçalves 2010; Graça 2010; Tereso 2009), likely as a result of the younger demographic make-up of the sample. In the case of La Torrecilla, Spain significant sex differences in entheseal patterns were found for Islamic skeletons, and the sexual dimorphism was greater than the enthesis patterns observed in a comparative Christian sample from Villanueva de Soportilla (al-Oumaoui et al. 2004). Analyzing MSM and OA in a medieval Islamic sample from Cortijo de Coracho, Spain, Inskip (2013a) found that overall osteoarthritis prevalence was not significantly different between sexes, but significant entheseal changes between sexes and across time periods was observed, suggesting increasing differences in gender roles with time and the cementing presence of Islam. Notably, the OA results from Inskip's analysis (2013a, 84–85) suggested that males partook in less-physically demanding activities than their pre-Islamic male counterparts, possibly as a result of economic and linguistic access to less physical jobs or the employment of others such as Christian clients (Kennedy 1996). Both in La Torrecilla (al-Oumaoui et al. 2004) and Cortijo de Coracho (Inskip 2013a), Islamic females seemed to exhibit higher scores for forearm supination and pronation, which have been posited as a result of dexterous manual activities such as weaving and cottage industries (Hambly 1999; Shatzmiller 2021; Shatzmiller 1997). Altogether, these results may underscore the osteogenic benefits of physical and manual activities in maintaining bone throughout the life course, an observation marked in other archaeological samples as well (Beauchesne and Agarwal 2014; Umbelino et al. 2019).

Another biocultural factor to consider is reproductive history, as high parity and extended breast-feeding seem to have positive effects on bone maintenance, despite the temporary loss of bone observed in pregnancy and lactation (Cumming et al. 1993; Henderson et al. 2000; Hillier et al. 2003; Kojima et al. 2002; Lenora et al. 2009; Michaëlsson et al. 2001; Paton et al. 2003; Sowers 1996; Wiklund et al. 2012). However, the reproductive histories in past communities is difficult to consider closely due to a lack of ethnohistoric and associated evidence with particular skeletons. While there were some key legal, scriptural, and social differences between Islamic and Christian reproductive histories, the differences are not always easy to parse in light of biological data. Musallam (1983, 11) for example examined how Islamic sexual morality permitted polygyny, impermanence of marriage (due to legal feasibility of divorce), and sexual intercourse both with wives and concubines contrasts with that of Christian sexual repression, monogamy, and permanence (due to difficulties of attaining divorce). Generally, Abrahamic religions in the medieval period permitted the marriage of women at very young ages (Verskin 2020, 15). However, this does not mean that parturition necessarily occurred at young ages, as some years likely passed between marriage (following menarche) and first childbirth (Verskin 2020, 58). In the case of Islam, for example, menarche marked a legal transition from being a minor to entering adulthood (Yazbak 2002). Islamic scripture generally advocated for a breastfeeding period of up to two years,[13] and describes the total period of gestation and weaning

[13] Surah 2:233

as 30 months.[14] Juridical and medical texts generally advocated for the nursing by the biological mother, though wetnurses were permitted and encouraged in certain circumstances (Gil'adi 1999). Notably, the use of animal milk was outright rejected in these texts, under nutritional shortcomings (Gil'adi 1999). In the later Christian middle ages, nursing between the biological mother and child was considered best, as a means of strengthening the emotional bond and purification (Shahar 1990, 54). By the later 14th and 15th centuries, images of the Holy Mother nursing Jesus became more widespread, cementing the importance of nursing and likening breastfeeding to a religious experience (Shahar 1990, 56). Wetnurses increasingly became important figures, especially for social elites, but were likely not as available for the medieval laity. One possible difference between classical writers and Muslim physicians can be seen in the amount of breast feeding. Classical writers typically advocated for suckling when the infant cries, whereas Islamic physicians frequently prescribed breastfeeding one to three times a day in fear of overfeeding (Gil'adi 1992, 25). While this could contextualize general breastfeeding differences at a textual level, whether this would have been followed by the laity is much less likely. Rather, breastfeeding practices were most certainly local, variable, and individualistic. Fertility estimates from paleodemographic techniques such as D_{30+}/D_{5+} ratios (Buikstra et al. 1994) are unfortunately difficult to implement in a comparative manner, due to the underrepresentation of sub-adults at numerous medieval Islamic cemeteries, likely as a result of religious/cultural customs in burying children and adults separately (Petersen 2013). As such, reproductive histories likely played a major role in explaining the observed data, but with the given information we are unable to tease apart their potentials more precisely.

Nutrition also factors considerably in bone maintenance, loss, and fractures (Cashman 2007). Deficiencies in vitamin D (Cooper et al. 2005; Eriksen et al. 2002; Genaro et al. 1989; Harvey et al. 2004; Heaney 1999), calcium (Black et al. 2000; Cross et al. 1995; Dawson-Hughes 1991; Dawson-Hughes 2003; Feskanich et al. 1994; Hegstead 1986), and protein (Bonjour 2005) can all lead to increased risk of osteoporosis. The dietary and nutritional histories of these individuals are currently unknown, but preliminary dental evidence suggests possible carbohydrate and cereal consumption, especially for the Christian group compared to Islamic individuals (see Chapter 5). Archaeological and ethnohistoric sources suggest a general shift from legumes and mixed fauna during the Islamic period to the 'triad' of bread, wine, and terrestrial/fish meat after the Christian conquests (Marques 2021). However, applications of stable isotopes are beginning to both confirm and complicate previous historical notions of diet within the peninsula. Generally speaking, the emerging trend from these analyses both within Spain (Alexander et al. 2015; 2019; Dury et al. 2019; Guede et al. 2017; Jordana et al. 2019; López-Costas et al. 2019; Lubritto et al. 2017; MacKinnon et al. 2019; Pérez-Ramallo et al. 2022; Pickard et al. 2017; Salazar-García et al. 2016) and Portugal (Curto et al. 2019; Toso et al. 2019; Toso et al. 2021) suggest that Islamic diets appear to be reliant on terrestrial resources while Christian diets varied more considerably depending on geographic location and reliance on marine resources. Additionally, these studies have generally found a lack of significant sex differences in diet for both Islamic and Christian communities, or at least in what is revealed through bulk collagen analysis, though there were notable sex differences in Islamic individuals

[14] Surah 46:15

from urban Lisbon (Toso et al. 2019). Preliminary stable isotope analysis on bulk collagen ($\delta^{13}C$ and $\delta^{15}N$) are presented and discussed in Chapter 5, and suggest no sex differences for the Islamic individuals, though sample sizes are incredibly small (n = 5 females, n = 7 males) and as such, results should be interpreted with caution. Future research on phytoliths, faunal remains, and/or stable isotope analysis are desperately needed to help contextualize these results further. More importantly, stable isotope analysis on individuals with matched cortical bone values are needed to further contextualize these results (Miller 2016), as many analyses are conducted on differing sub-samples from a larger skeletal assemblage.

Similar to the metacarpal results, rib samples showed few significant differences in these analyses. Only Islamic females showed a significantly lower mean CI value in the 50+ year group compared to the younger age group (18-49 years). While this may signal post-menopausal differences between cohorts as has been observed in more recent populations (Beresheim et al. 2018), the differences may be more complicated than simply hormone-related changes with menopause. No significant differences were observed between older Christian females (41.78) and Islamic females (40.25), who retained similar values in terms of raw metrics. Notably, sample dispersion was much smaller in the Islamic group (4.81) than the Christian group (8.46), possibly as a result of a biased sub-sample of older Islamic individuals. In other words, older Christian females may be represented by individuals from a broader spectrum of ages over the age of 50 years, whereas the Islamic older females may be more tightly clustered around an older mean age-at-death. Additionally, in terms of percentage of peak bone mass, both older Christian females (87.30%) and Islamic females (84.40%) had roughly similar percentages, suggesting the difference between younger and older Islamic females is likely a product of peak bone mass and smaller total area compared to the other sub-groups. Indeed, older (50+ years) males also exhibited significantly lower average cortical thickness/area (Ct.Ar) values compared to their younger counterparts. The Imperial Roman sample from Velia, Italy showed similar trends where older males had significantly lower Ct.Ar values than younger males (Beauchesne and Agarwal 2017). Altogether, the rib data may suggest that differences in available total area and cortical area which compound into smaller mean cortical index values for older Islamic females.

The biomechanical demands of the metacarpal likely aid its retention of cortical bone across the life course compared to the rib, as can be seen in Table 7.16 where rib values exhibit lower percentages of peak bone mass (following Mays 2006) than their metacarpal counterparts. It is possible that the significant difference in rib CI values, but not metacarpal CI values, in Islamic females could be the product of different biomechanical loading histories (Peck et al. 2007). However, the data resulting from ribs and metacarpals above are not matched pairs (i.e., from the same individuals), so interpretations of their patterning should be met with caution. The data support the emerging pattern that bioanthropologists should remain cautious about any one skeletal element or tissue envelope as being reflective of bone mass for the remainder of the skeleton (Beauchesne and Agarwal 2017; Gosman et al. 2011; Peck et al. 2007). Heterogenous patterning in bone quantity and quality, especially within the same individual/skeleton, remains an exciting area of future research when preservation is outstanding.

Conclusion: Limitations and future directions

Several limitations are worth underscoring in this study. Issues of preservation continue to have cascading consequences on samples fit for analysis, final sample sizes or demographics (Jackes 2011b; Waldron 1987). The paucity of well-preserved metacarpals and/or individuals of estimable demography in this study resulted in a winnowing of potential candidates in all age groups for analysis. Only 107 of the 639 burials excavated from the site suggests the second metacarpal represents at most a mere 29% of the overall individuals at the site, far lower than Waldron's findings of 54.6% (Waldron 1987). Rib samples were taphonomically compromised at the microscopic level (see Chapter 10), rendering histomorphometric analyses impossible unlike other intraskeletal studies (Beauchesne and Agarwal 2017; Gosman et al. 2011; Peck et al. 2007). Additionally, intracortical porosity was not calculated, which can account for a substantial (upwards of 12%) percentage of cortical bone (Agnew et al. 2012). Sample sizes were admittedly small in this analysis, requiring the collapsing of various age groups (18-29 and 30-49 years) to maximize statistical power. However, in doing so, we lose out on finer grained shifts in bone maintenance throughout the life course. As mentioned above, the issue of intraskeletal variability is important to keep in mind as more robust intraskeletal analyses are beginning to elucidate the complex and dynamic nature of various tissue envelopes, even within the same skeletons (Agarwal 2021; Beauchesne and Agarwal 2017; Gosman et al. 2011; Peck et al. 2007). Issues of shape, and how to account for various tissue envelopes and morphologies across the skeleton also pose an challenging, but exciting, avenue of contemporary bioarchaeology (Gilmour et al. 2022). The inability to estimate age accurately and precisely past 50+ years of age remains a significant challenge to life course approaches, where fine-grained changes with senescence are untenable. While this study employed multiple lines of evidence and evaluated their effects in differing age cohorts, issues of selective mortality and frailty are still present (Wood et al. 1992), and I was unable to employ more fine-grained analyses such as hazards models to account for cortical bone throughout the life course (Wilson 2014b).

Finally, the lack of significant results could be an artifact of the data itself, or at least in the way we approach it as bioarchaeologists. There is a linguistic tendency in bioarchaeological research using metacarpal radiogrammetry to treat age groups in semi-longitudinal terms. Discrepancies (expected or otherwise) in cortical bone values between age groups are often treated as acquired characteristics throughout the life course — excessive bone between age groups is often treated as bone "gain" whereas deficits in older age groups are characterized as bone "loss." While the heterochronicity of the skeleton affords a theoretical opportunity to operationalize life course approaches in bioarchaeology (Agarwal 2012; 2016; Agarwal et al. 2011; Gowland 2015; Robb 2002; Sofaer 2006c; 2011; Watkins et al. 2015), and there is undoubted potential there, there is also risk in linguistically and conceptually treating cross-sectional palimpsests as longitudinal cohorts. Future research will benefit tremendously from subsequent analyses, such as stable isotope analysis, intraskeletal analyses, and fracture analysis to better characterize the complex dimensions and patterning of bone loss at Largo Cândido dos Reis.

Chapter 8: Deathways — *Post-hoc* Archaeothanatology

Introduction

This chapter seeks to explore how a post-hoc archaeothanatological approach may yield information on decomposition, necrodynamics, and possible shrouding at Largo Cândido dos Reis. Since the 1980s, germinal approaches arising from French anthropology have helped to synthesize osteological and anatomical knowledge of decomposition processes with archaeological field excavation methodologies (Duday et al. 1987). This *anthropologie de terrain*, or archaeothanatology, has helped immensely to better understand complex burial dynamics and funerary treatment. Archaeothanatology emphasizes knowledge of the decomposition process and encourages careful attention to anatomical connections(H. Duday et al. 2006, 152), particularly joint articulations, as they are indicative of decay and post-mortem movements. For instance, a comprehensive understanding of which connections are *persistent* — those that retain their anatomical articulation for longer, and resist decomposition for a longer duration versus *unstable*/*labile* — those that lose their anatomical connection more readily is critical in field recordings and reconstructing decay processes. Counterintuitively, persistent joints, though easiest to record due to their often direct articulation *in situ* (e.g. humero-ulnar articulation, lumbar vertebrae, atlanto-occipital, sacro-iliac), are less informative than their labile counterparts (e.g., phalanges of the hands and feet), which can reveal much more about decay and movement (Duday et al. 2006, 127). This is due to the biomechanical demands of certain bones that require either larger or more powerful ligaments, and as such, bones that are typically larger and preserve better reveal less about post-burial movements and decomposition than their more unstable counterparts (Duday 2006, 33–34). However, cadavers do not decompose uniformly and are subject to numerous variables (climate, temperature, humidity, soil, insect activity, etc.) and as such, even various portions of the same cadaver can be in differing stages of decomposition (Pinheiro 2006b). Thus a key goal of archaeothanatology is to chronologize and seriate decomposition of various elements in order to reconstruct the deposition of the body to distinguish between funerary rites and post-depositional factors. Presence of labile connections such as the hands and feet *in situ* is typically seen as a good indicator of a primary burial, as decomposition that took place elsewhere would have weakened or completely decomposed labile connections and made their transfer to a secondary burial in articulation less likely (Duday 2006; 2009; Duday et al. 2006). Attention to joint articulations outside of the anatomical relation – termed "necrodynamics" (Dirkmaat et al. 2015; Mickleburgh et al. 2018; Ortiz et al. 2013; Wilhelmson et al. 2015) — is crucial in reconstructing interment processes and further helps to demonstrate that the disarticulation of human remains does not necessarily preclude a secondary burial treatment, such as a primary burial upon an organic material platform that is also subject to decay.

One employment of this approach concerns the ability to reconstruct possible wrapping, or shrouding, of corpses prior to interment (Harris et al. 2012; Nilsson Stutz 2003; 2006; Roksandic 2002b). Broadly termed 'burial containers', these consist of the broad range of materials used to encapsulate the body for interment, such as veils, shrouds, clothing, or coffins . Despite their utility in 'protecting' the body, burial containers themselves are subject to poor preservation. This is especially the case with fabrics whose organic constituents (e.g. cellulose in the case of linen and cotton) make them highly absorbent and often susceptible to acidic burial environments (Cardamone et al. 1991), or microorganisms (Janaway 2002). As a result, both linen and cotton both degrade easily and seldom survive archaeologically except for anoxic or desiccated conditions (Janaway 2002; Ueland et al. 2015). Burial clothing and/or wrapping also appear to facilitate absorption and draining of bodily fluids during decomposition, such that bodies can actually become mummified (Bouquin et al. 2012; Dautartas 2009; Kelly 2006; Voss et al. 2011b). Secondary evidence of burial wrappings can occasionally preserve, such as sewing needles which likely pinned fabrics together, but if wrappings were tied or knotted together, there is often no direct trace evidence. Even wooden coffins can degrade with relative ease, leaving only trace evidence of their presence in the form of nails which held boards together, or wall effects (*effets de paroi*) that they left behind in the grave cut (Duday 2017; Duday et al. 1987; Harris et al. 2012).

The case of Medieval Portugal provides an interesting opportunity to explore this approach further, given the presence of differing religious communities accompanying funerary customs suggests the employment of burial containers. I present in this chapter an analysis focusing on the city of Santarém, Portugal which was under Islamic control through much of the central middle ages before transitioning to a Christian pilgrimage center in the later middle ages after the Christian conquests (twelfth century AD (Custódio et al. 1996b; Rodrigues 2019). While the site undoubtedly represents a palimpsest of differing temporalities, faith communities, and funerary customs, the presence of multiple-faith groups in the same space helps to furnish a comparative approach seen in other medieval Iberian contexts (Alexander et al. 2015; Toso et al. 2021). Following in this work, I use the term 'multi-faith' here not to denote the contemporaneous usage of the same cemetery by differing religious groups, but rather to signal the multi-temporal dimensions present in most archaeological cemeteries (DeWitte et al. 2015; Novak 2017; Waldron 1994; 2007). The shifting religious and political autonomy within the same geographic space offers an interesting opportunity to comparatively and diachronically analyze religiously motivated funerary customs practiced by the city's residents within relatively similar local and sedimentary conditions.

Islamic law throughout much of al-Andalus – the Islamic cultural domain within medieval Iberia – generally followed the writings of Malik ibn Anas (711-795 C.E.), who was instrumental in finding one of the four major schools of Sunni law. The Andalusian caliph al-Hakam I (d. 822) institutionalized Malikism as law by the ninth century (Payne 1973), which continued to garner support from caliphs such as Abd al-Rahman II (d. 961) and al-Hakam II (d. 976), and subsequently influenced the jurisprudence and religious funerary customs throughout much of al-Andalus (Chávet et al. 2006) and beyond (Fortier 2010). Generally, death was accompanied by a ritualized procession, involving the stripping and washing of the corpse (*ghusl*) followed by enshrouding of the body in "Yemeni cotton" (*kafan*) and occasionally, tethering of the mandible to the skull (Bianquis 2012; Buturovic 2017; Gatrad 1994; Petersen 2013; Tritton 2008, 441). In most cases, the shrouding of the body can vary by gender, with women being enshrouded in five pieces of cloth whereas men are enshrouded in three pieces. Interestingly, few individuals were allowed to be buried with their clothing, such as martyrs, victims of drowning, respiratory illness, internal ailments, fire, falling structures, and women who die in pregnancy (Buturovic 2017).

Burial width also appears to have received considerable attention and debate. Burial width was typically narrow to prevent post-depositional alteration of the body. The twelfth century "Treatise of Ibn ʻAbdun" from Seville attests to just how narrow tombs could be in prescription no. 149 (Garcia Gómez et al. 1998, 149):

> "Debe aumentarse un poco el largo y el ancho de los huecos de los sepulcros, porque yo he visto que a un cadáver hubo que sacarlo três veces de la tumba para arreglar el hueco convenientemente, y que outro cadáver hubo de ser metido a fuerza de apretar"
>
> ["The length and width of the graves must be increased a little, because I have seen that one corpse had to be removed three times from the tomb to fix the hole, and that another corpse had to be forcefully squeezed [into the grave]."]

Given the narrowness of Islamic graves, it is not surprising that variation has also been noted in the bodily position of Islamic graves within Spain (Casal 2003, 31) and France (Gleize 2022), with differing elements showcasing varying angles of flexion and extension. Lozano Cosano (2016, 100) notes this could be due to both "internal" (ritual positioning, shrouding), and "external" (grave limits, shape, covering) factors. In some cases, small stones, ceramic sherds, or even wood have been found as a means of supporting or propping certain anatomical articulations to facilitate bodily position and intactness (el Aswad 1987, 221; León Muñoz 2008, 43). Thus, ensuring minimal post-depositional disturbance and movement was fundamentally linked to tomb construction. Graves are intentionally dug to allow for the head to be turned right, in accordance with *qibla* — the direction of Mecca — southeast in the case of Iberia (López Quiroga 2010; Mazzoli-Guintard 1996).

The case of burial wrappings throughout medieval Christendom is more variable. The majority of funerary rituals throughout late medieval Christendom was likely simple and prescribed, with bodies interred in an extended, supine position and arms placed at the sides or occasionally crossed over the breast (O'Sullivan 2013b), though considerable vernacular variation existed (Gilchrist 2022, 124). Christian burial treatments seem to vary due to influences of various religious orders and changing religious and eschatological considerations for burial and the afterlife (Bynum 1995b; Mattoso 1996). Numerous religious orders, such as the influential Order of Cluny, the Cistercians, and mendicant orders such as Dominicans and Franciscans brought about religious reforms throughout Christendom, with cascading influences on funerary preparation in Portugal and beyond (Mattoso 1996). Ecumenical decrees, papal bulls, and theological discourse also impacted religious conceptions of death, burial, and the afterlife (Brown 1981; Bynum 1995b), with a particular focus on preparation for Resurrection (Gilchrist et al. 2005; O'Sullivan 2013b) and intercession on behalf of the soul in Purgatory (O'Sullivan 2013b, 274). Bodies were occasionally stripped of vestments and wrapped in linen shrouds, or winding sheets, in the case of late Medieval England (Daniell 1997) in addition to other "furnishings" (Litten 2007). Artistic depictions from Book of Hours occasionally depict a body wrapped in a shroud before being interred (Figure 8.1). Given the linen composition, it is not surprising that few shrouds have actually preserved archaeologically, though some shrouds have preserved such as fragments in St. Mary Spital in London as well as a complete shroud from St. Bees Priory in Cumberland (Gilchrist et al. 2005, 106). Other materials could be employed as well, such as lead sheets, cerecloth (wax-inundated shrouds), and hides, although evidence is less common (Gilchrist et al. 2005, 107–110). The presence of small needles encircling the corpse was observed in a few circumstances at the site of Largo Cândido dos Reis (Matias 2008b, 651–652) , suggesting the employment of burial shrouds where the fabric was pinned together rather than tied.

Figure 8.1 - Depictions of simple earthen inhumations with bodily wrapping in A) Fifteenth century (c. 1450) French Book of Hours (*Heures à l'usage de Paris*, Petit Palais, LDUT 0035, fol. 127[15]); and B) fifteenth century (c. 1460) Belgian Book of Hours (Walters Ms. W.197, fol. 175v[16]).

Given the ethnohistorical evidence and limited archaeological evidence of shrouds being employed for both funerary groups at the medieval site of Largo Cândido dos Reis explore whether archaeothanatological methods, recording procedures, and detailed photographs and drawings can be employed in a *post-hoc* manner (Green 2022; Harris et al. 2012; Nilsson Stutz 2006; Roksandic 2002b) to discern possible shrouding.

[15] Retrieved from: http://initiale.irht.cnrs.fr/en/decor/98979.
[16] Retrieved from: https://www.thedigitalwalters.org/Data/WaltersManuscripts/html/W197/description.html

Materials

Further details on the site materials can be seen in Chapter 3, but a brief revisiting will help frame the burial and cultural context in relation to archaeothanatology and possible shrouding. The site of Largo Cândido dos Reis (S.LCR, Municipal site nº 74) was situated just outside the Porta de Manços in Santarém, Portugal (39°14'01.8"N 8°41'10.1"W). Excavations began in July of 2004 in a salvage framework, as a result of discovering burials during a public works project to renovate sanitation networks. Excavations continued until September 2005, discovering a total of 639 burials spanning nearly 10,000 m^2 (Matias 2008b). The site comprised of two principal necropolis: one Islamic (n = 422 burials) and the other Christian (n = 217 burials), which were distinguished based on their funerary typological characteristics (Matias 2008b). Islamic burials were characterized by relatively simple, narrow and shallow graves that were rectangular or ovular in shape (*darih*) with no accompanying niches (*lahd*, and/or *saqq*) (Chávet et al. 2006). The majority of burials were excavated directly into the marly limestone substrate (350; 83%), with a small portion constructed in clayey substrates (72; 17%; Matias 2008b). Bodies were interred on their right side facing southeast towards Mecca, with no commingling (Figure 2). Christian burials were characterized by comparatively deeper graves, occasionally anthropomorphic in shape (confirming to the outline of the body, with a head niche), with the body positioned in an extended supine position (Figure 3). Arms were occasionally crossed over the breast, and the presence of additional individuals such as ossuaries accounted for approximately 62% of Christian graves. Similar to the Islamic tombs, the majority of graves were constructed through direct relief of marly limestone substrates (184; 86%) with a subset of collective pits (33; 14%) excavated from clayey substrates. A number of master's theses (Fernandes 2011; Gonçalves 2010; Graça 2010; A. P. H. Neves 2019; Rodrigues 2013; Tereso 2009) and subsequent publications (Rodrigues et al. 2021) analyzing sub-samples of individuals from Largo Cândido dos Reis have helped to characterize the underlying demographies (e.g., age, sex), taphonomic, and skeletal health/pathologies present in the sample excavated from the site. The present study seeks to build upon this scholarship and further analyze the potential for bioarchaeological analyses within the site by employing a comparative approach between the two principal funerary groups.

While this has undoubtedly yielded one of the larger medieval, and specifically Islamic, cemeteries in Portugal to date, it likely represents a smaller portion of the total cemetery, currently obstructed by modern urban development. Initial assessments based on funerary typology and associated materials (e.g. ceramics) suggested these burials were medieval, with the Islamic cemetery ('*maqabara'*) likely dating to the ninth or tenth centuries, prior to the Christian conquests in the middle of the twelfth century (1147 C.E.), and the later Christian cemetery being established in tandem with the thirteenth century hermitage of Santa Maria Madalena (A. Matias, 2008a, 2008b). Recent results of AMS ^{14}C dating from a pilot project (Chapter 4) suggest a number of Islamic burials ranged between 992 and 1158 C.E., while a Christian burial was dated to approximately 1179-1264 C.E. (405 Oss.; 830 ± 15 BP, cal C.E. 1179-1264 (2σ)). These preliminary findings seem to confirm initial chronological assessments for both the Islamic and Christian phases of the cemetery.

Figure 8.2 - Photograph, burial drawing, and tomb architecture of Islamic burial Ent. 402, estimated to be an adult male (Rodrigues 2013). Photos courtesy of Câmara Municipal de Santarém. Photos and drawings conducted in the field by A. Matias, and subsequent digital drawings by T. Trombley.

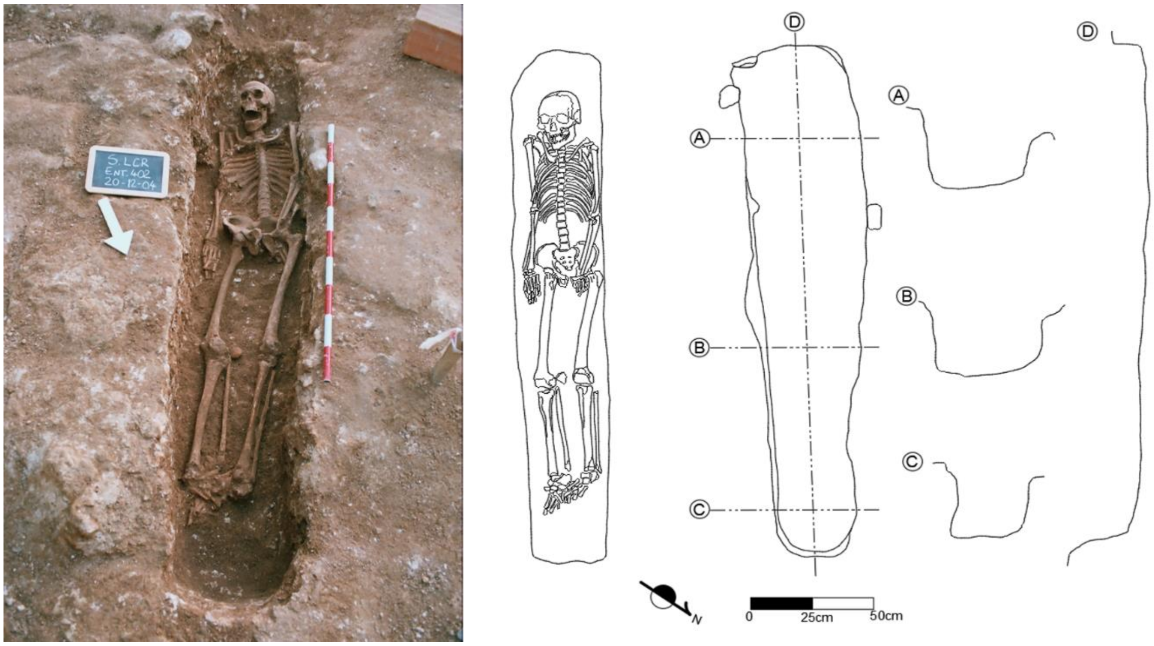
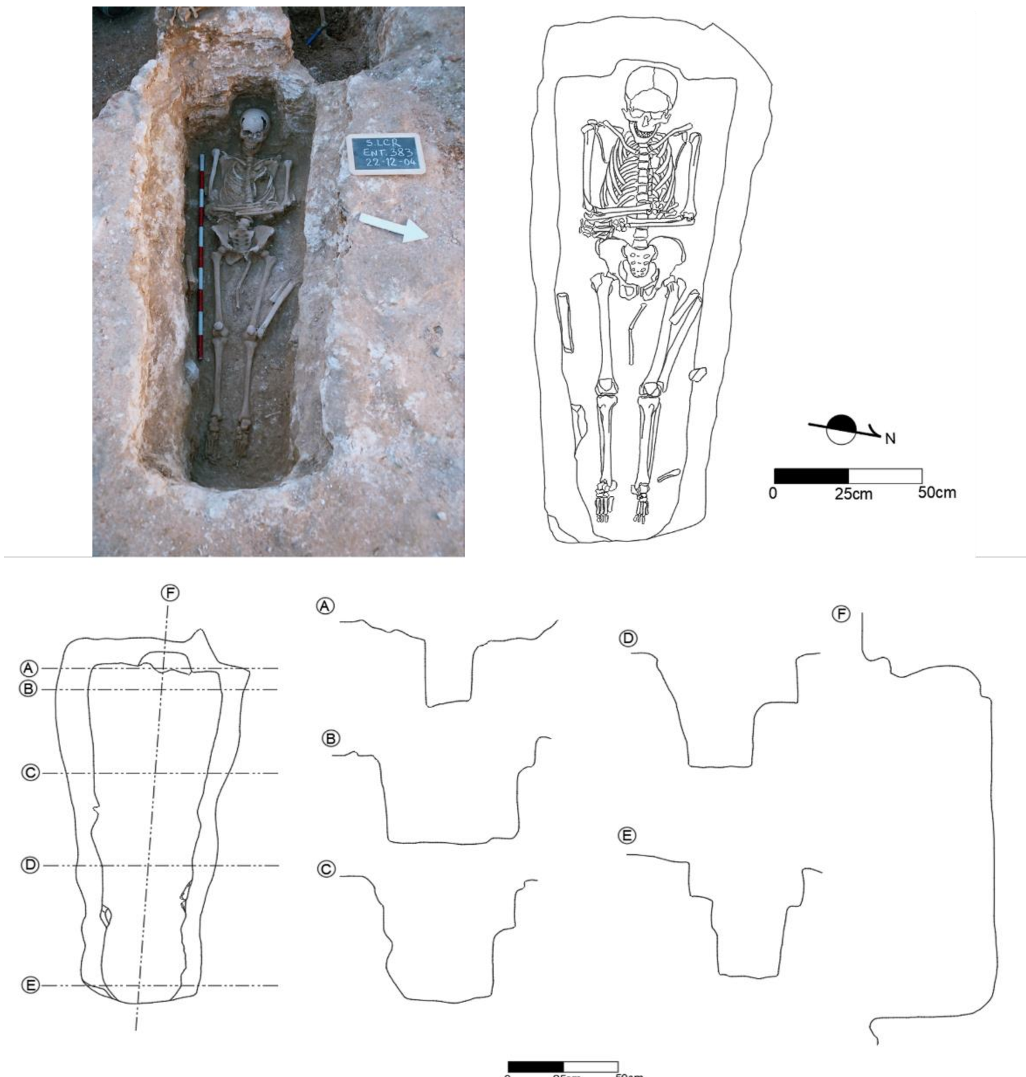


Figure 8.3 - Photograph, burial drawing, and tomb architecture of Christian burial Ent. 383, an adult female approximately 30-49 years of age (Vicente 2015). Photos courtesy of Câmara Municipal de Santarém. Photos and drawings conducted in the field by A. Matias, and subsequent digital drawings by T. Trombley.



Only primary graves were examined here, along with burials that showed sufficient skeletal preservation for discerning possible constrictions, which limited overall sample sizes severely. Only adults were examined here, as children in medieval Islamic cemeteries are frequently separated from adult spheres of the cemetery (Petersen 2013), and given the underrepresentation of non-adults in the cemetery (~16% of total sample), it's indeed possible Islamic children were buried elsewhere, or not discovered within the confines of the excavation. I examine here a total of 119 individuals — 70 Islamic and 49 Christian — for archaeothanatological evidence of burial containers. The demographic distribution can be seen in Table 8.1. Sex was estimated predominately on dimorphic features of the pelvis (when present), with a particular emphasis on the sub-pubic concavity, ischio-pubic constriction, ventral arc, sub-pubic angle, and greater sciatic notch (Ascàdi et al. 1970; Brothwell 1981; Buikstra et al. 1994; Phenice 1969).

Table 8.1 — Sample demographics in present study.

Sex	Islamic	Christian	Total
Male	43	32	75
Female	23	14	37
indeterminate	4	3	7
Total	**70**	**49**	**119**

Methodology

Detailed archaeothanatological note-taking, photos, drawings, and burial metrics were conducted in the field for each burial utilizing forms put forth by Santos et al. (1991), and subsequent analyses were carried out in a *post-hoc* archaeothanatological manner following Harris and Tayles (2012), Nilsson Stutz (2003; 2006) Roksandic (2002b), and Green (2022). Skeletal elements *in situ* were analyzed for their bodily position, degree of constriction, relation to overall grave cut, and necrodynamic activity. Archaeothanatology has proven an important methodological and interpretive tool within bioarchaeological contexts in Portugal, given the range of funerary treatments observed temporally and spatially throughout the country (Neves 2019; Neves et al. 2012). A fundamental principle of archaeothanatology and movement of the body is understanding decomposition in relation to burial 'space.' As the body decomposes and soft tissue progressively disappears, bones subsequently become "precariously balanced" (Nilsson 1998, 7), and the space within and outside the body in tandem with burial containers and soil porosity can often dictate where such skeletal elements end up as a result of gravity. Space is often characterized according to three definitions: external, internal, or secondary external (Duday 2006; Harris et al. 2012), though more recent refinements have built upon these conceptions (Green 2022, 439). Internal space refers to the space within the bodily confines (i.e., skin), often facilitated by delayed infilling of surrounding soils due to the soils being nonporous or the presence of a burial container. In supine burials, this is often marked by articulation of the pelvis, patellae, and collapsing of the ribs into the thoracic cavity where viscera were once present (Neves et al. 2012, 33). External space refers to the zone outside of the bodily confines resulting from delayed infilling of soils outside of the body. Due to this delayed infilling outside of the body, external space often suggests the employment of a burial container such as a coffin, which acted as a barrier to soils from replacing decomposing soft tissue (Duday 2006; Green 2022; Harris et al. 2012). Skeletally, this often manifests in disarticulation and a falling of skeletal elements outside of their bodily confines.

For instance, in extended supine burials within empty space such as a coffin, the pelvis flattens with decomposition, with pubic symphyses dis-articulating resulting in the lateral rotation of the femora, and the external (lateral) deposition of the patellae (Duday et al. 2006; Duday 2006). In burials where the individual is on their side, bones that are not on the floor of the grave such as the scapula or *os coxa* often fall posteriorly (Duday et al. 2006), whereas the ribs will often sag, though progressive infilling by sediment where tissue once was as well as confined burials can prevent such displacement (Neves et al. 2012, 34). Finally, secondary external space refers to the movement of skeletal elements outside of the bodily confines, but not as a result of external space such as a coffin. In this case, decomposition itself, specifically putrefaction, results in the production of gases and bloating of the body as gut bacteria activity facilitates gaseous buildup as a result of consuming cellular proteins (Duday et al. 2006; Hyde et al. 2013). As such, this bloating can cause an expansion of the bodily confines and facilitate alterations in the burial environment, bodily movement, and soil infilling. This results in skeletal elements that are precariously positioned (unstable) from decomposition to move according to gravity, where newly formed voids outside of the body (Duday et al. 2006, 138; Green 2022). Additionally, liquefaction of the internal organs and subsequent seeping of bodily fluids into the burial environment can attract invertebrates (e.g. worms, snails, slugs) and other necrophagous organisms, which themselves can attract additional predators (e.g., insectivores), all of which can facilitate bioturbation in and around the body (Duday 2006, 34; Nilsson 1998, 7). Finally, in cases where the body is in direct contact with porous/fluid soils that can readily replace soft tissue during decomposition, the burial is often characterized as exhibiting no space whatsoever. Labile joints found in direct articulation with interstitial sediment often suggests lack of space and the progressive filling of sediment that replaces voids created by decomposition, such that the thoracic cavity experiences no collapsing, there's little evidence of bodily movement, and even the hyoid may still be in articulation. Thus, the positioning of certain articulations, such as the patellae, scapulae, hyoid, and *os coxae,* are crucial indicators of whether burials were surrounded with earthen fill, or contained empty space (Duday et al. 2006).

An adaptation of the flow-chart methodology developed by Harris and Tayles (2012, 232) was employed, resulting in the following 'codes' for later tabulation:

Table 8.2 - Burial container codes and descriptions
(following Harris and Tayles 2012, 232-233).

Code	Category	Description
1	Wide Coffin	Internal space accompanied by lack of constriction, disarticulation of os coxae, femora, and fall of patella outside of bodily confines
2	Loose non-durable wrapping, *or* no wrapping *or* wide grave with soft sediment	No evidence of constriction, or constriction was possibly influenced by narrow grave cut, accompanied by internal space or lack of space.
3	Tight durable wrapping	General lack of external space, with accompanied constriction, medial fall of patellae, and wall effect that conforms to outline of the body
4	Tight durable wrapping, *or* narrow coffin/grave	Similar to tight durable wrapping, but with constriction being difficult to discern between 'box' shape and conforming to the body
5	Narrow grave	Evidence of constriction with medial fall of patellae, but constriction does not conform to the body. Wall effect(s) is/are with grave cut only.
6	Tight non-durable wrapping	Evidence of constriction, with internal space, only, with patellae not falling within confines of body
7	Loose non-durable wrapping *or* tight non-durable wrapping	Similar to code 6 above, but with inability to discern if constriction is due to grave cut
8	Tight non-durable wrapping *or* tight durable wrapping *or* narrow coffin/grave.	Similar to code 4 above, but no fall of patellae within lower limb confines.
9	Loose non-durable wrapping *or* tight non-durable wrapping *or* tight durable wrapping *or* narrow coffin/grave	Constriction is evident, but inability to distinguish if constriction is due to wrapping or a narrow grave cut (i.e., indeterminate).

Additionally, when possible, burial metrics (length, depth, and width) were measured for each burial in the field and later analyzed by funerary group to elucidate possible trends in tomb construction. Normality was assessed visually using histograms and normal quantile plots followed by Shapro-Wilk tests with an $\alpha = 0.05$. While all burial metric sub-groups had fair sample sizes (> 30), only Islamic depth and Christian depth were found to be non-significant according to Shapiro-Wilk tests, whereas all other burial metrics were non-normally distributed ($p < 0.05$). As such, a two-sided Wilcox rank sum test was used with an $\alpha = 0.05$. Effect size was subsequently calculated using the `rstatix` package in R.Studio v 4.2.2 (RStudio Team 2020)

Results

The distribution of potential burial containers is shown in Table 8.3 and Figure 8.4. No graves for either funerary group showcased evidence of coffins, nor decomposing in open space. A small subset of graves showcased signs of loose non-durable wrapping, or no wrapping whatsoever (Christian = 18.37%, Islamic = 10.00%). A small subset of Christian individuals (22.45%) similarly showed signs of tight durable wrapping, evidenced by skeletal constriction in wider graves (Figure 8.5). Only one Islamic individual showed signs that would be consistent with tight durable wrapping, Ent. 355.

Table 8.3 – Counts and percentages of burial container scores at Largo Cândido dos Reis by funerary group. Where: 1 = Wide Coffin, 2 = Loose non-durable wrapping or no wrapping/wide grave with soft sediment, 3 = Tight durable wrapping, 4 = Tight durable wrapping or narrow coffin/grave, 5 = Narrow grave, 6 = Tight non-durable wrapping, 7 = Loose non-durable wrapping or tight non-durable wrapping, 8 = Tight non-durable wrapping or tight durable wrapping or narrow coffin, 9 = Loose non-durable wrapping or tight non-durable wrapping or tight durable wrapping or narrow coffin.

	Christian		**Islamic**		**Total**	
Code	N	%	N	%	N	%
1	0	0.00	0	0.00	0	0.00
2	9	18.37	7	10.00	16	13.45
3	11	22.45	1	1.43	12	10.08
4	0	0.00	0	0.00	0	0.00
5	0	0.00	0	0.00	0	0.00
6	0	0.00	0	0.00	0	0.00
7	16	32.65	0	0.00	16	13.45
8	7	14.29	12	17.14	19	15.97
9	6	12.24	50	71.43	56	47.06
Total	49	100	70	100	119	100

Figure 8.4 – Distribution (%) of burial container scores at Largo Cândido dos Reis by funerary group.

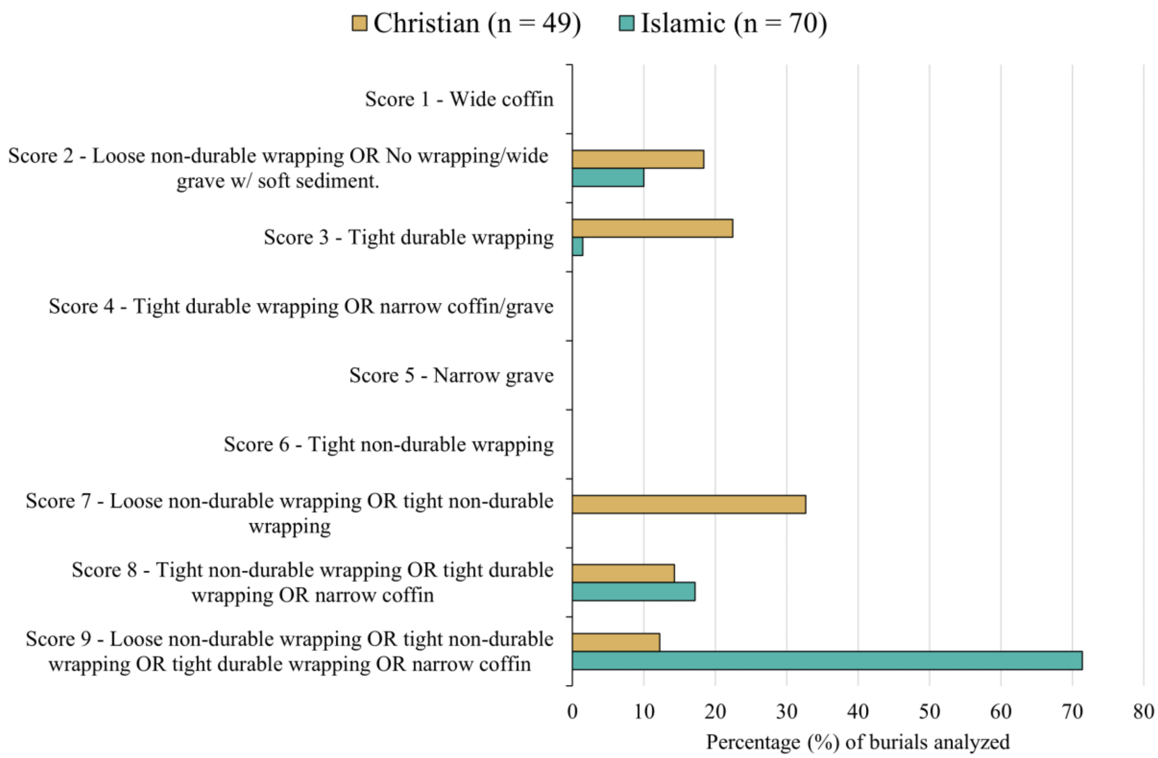
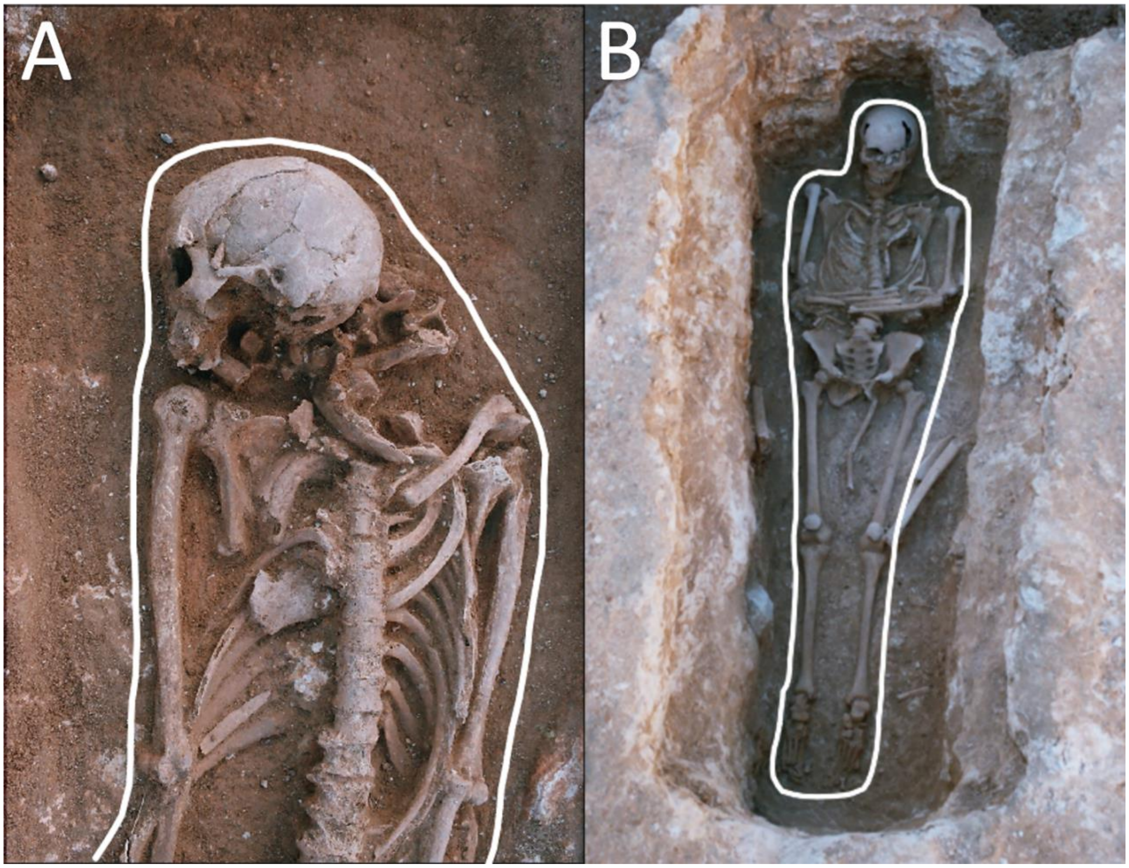


Figure 8.5 - A) Ent. 355 an Islamic adult male (Rodrigues 2013) showing signs of likely shrouding (white outline) given constriction within grave cut. B) Ent. 383, a Christian adult Female (Vicente 2015) showing signs of likely shrouding (white outline). Photos courtesy of Câmara Municipal de Santarém.



The majority of burials could not be identified without the addition of one or more criteria. A cumulative 59.18% of Christian graves and 88.57% of Islamic graves showcased indeterminate evidence of either the employment of some form of burial container, narrow tomb morphology, or both.

Both burial depth and width were found to be statistically significant, with Islamic graves being shallower and narrower than their Christian counterparts (Table 8.4). Although Christian graves appeared slightly longer than Islamic graves, burial length was not significantly different between funerary groups.

Table 8.4 – Metric comparison of mean burial dimensions (in cm) by funerary group at Largo Cândido dos Reis.

	Christian		Islamic				
Category	*N*	$\bar{x}$ (s)	N	$\bar{x}$ *(s)*	*W*	*p*-value	Effect size
Burial Length	39	193.54 (15.91)	66	190.74 (17.35)	1455	0.27	0.11
Burial Width	64	58.88 (13.43)	150	39.29 (6.30)	8939	< 0.01*	0.68
Burial Depth	40	49.03 (16.09)	72	32.08 (12.76)	2297	< 0.01*	0.49

Discussion

The majority of graves regardless of funerary group (76.48%) showcased signs of either burial containers, narrow graves, or both. Burials from Largo Cândido dos Reis showed no evidence of coffin burials, or decomposing in completely open space (Matias 2008b). Necrodynamic movements facilitated by space were likely due to either internal space or secondary external space, likely as a result of putrefaction where bodies experienced bloating during the excretion of gasses. Molecular techniques continue to refine our understanding of the thanatomicrobiome and epinecrotic communities (Heimesaat et al. 2012; Javan et al. 2016), and underscore the importance of bacteria in facilitating anaerobic respiration, producing gases such as hydrogen sulfide, methane, cadaverine, and putrescine (Hyde et al. 2013). The buildup of these gases causes the characteristic ‘bloat’ stage, but as a result can facilitate necrodynamic movements, such as the movement of forearms clasped over the abdomen (Duday et al. 2006; Williams 2022, 315). Indeed, experimental work with cadaver donors suggests substantial movements can take place during the bloat stage (Mickleburgh et al. 2018; 2022; Schotsmans et al. 2022; Wilson et al. 2020).

One Christian burial in particular, Ent. 417, an adult male (Vicente 2015), shows likely signs of this phenomenon (Fig 8.6). The burial was constructed in an anthropomorphic shape, and the body shows articulation throughout most of the skeleton, with lateralization of the femora and the right patella in an unstable articulation likely propped to the *effet de paroi* of the southeast burial wall. Unfortunately, a post-hole bisected the left distal femur, proximal tibia, and patella so we cannot see the position of where the left patella is, but it likely would have fallen laterally given the rotation of the femur. The flaring of the rib cage accompanied by the wide positioning of the humerii from the thoracic cavity suggest that the upper arms and elbows maintained a sizeable distance from the thoracic cavity due to skin, muscle, and fat tissue. Some soil infilling preserved the overall shape of the thoracic cavity, with upper ribs (1-5) falling into the thoracic cavity and lower ribs (6-12) flaring outwards. The position of the hands is disarticulated from their respective forearms, with the right arm crossed above the mid chest, and the left arm crossed above the right ilium. The joints of the hands, being labile, disarticulated from the forearms first, before further movement of the forearms occurred. In the case of the right hand, this resulted in the hand bones being positioned atop the stomach, which explains their disarticulated/jumbled positioning within the thoracic cavity as they fell with gravity, whereas the left hand being positioned above the lower lumbar and left ilium explains their comparatively better state of articulation. Each forearm has moved some 5-7 cm inferiorly after the disarticulation of the hand as the body continued to decompose and gravity facilitated further movements. Altogether, burial 417 exemplifies much of the necrodynamic movements observed at Largo Cândido dos Reis, whereby movements took place within the bodily confines (internal space) or as a result of putrefactive bloat (secondary-external space) (Mickleburgh et al. 2018; 2022; Schotsmans et al. 2022; Wilson et al. 2020).

Necrodynamics and post-depositional movements were observed in every Islamic grave, with most individuals exhibiting a dorsal ‘fall’ towards the north-west wall of the grave. In numerous cases, individuals were found to exhibit an *effet de paroi* directly against the north-west wall. Given the relatively standard burial width ($\bar{x}$ = 39.29 cm, s = 6.30 cm; see also: Table 3) for Islamic graves at the site, it appears that the distance from the north-west grave wall directly corresponds to whether the individual fell completely dorsally or experienced an *effet de paroi*. In cases where the body was situated closer to the south-east grave wall with accompanying sufficient space, the body fell dorsally such that the right leg (femur, tibia, and fibula) retained a right decubitus position while the left leg appeared in dorsal position (Figure 7). One Islamic burial (SP7089) in Nîmes, France showed signs of wrapping due to the position of the patella *in situ*, despite decomposing in empty space (Gleize et al. 2016). The individual was situated far enough from the southeast wall such that the patella was not held in place via an *effet de paroi*, suggesting it had remained *in situ* via a shroud.

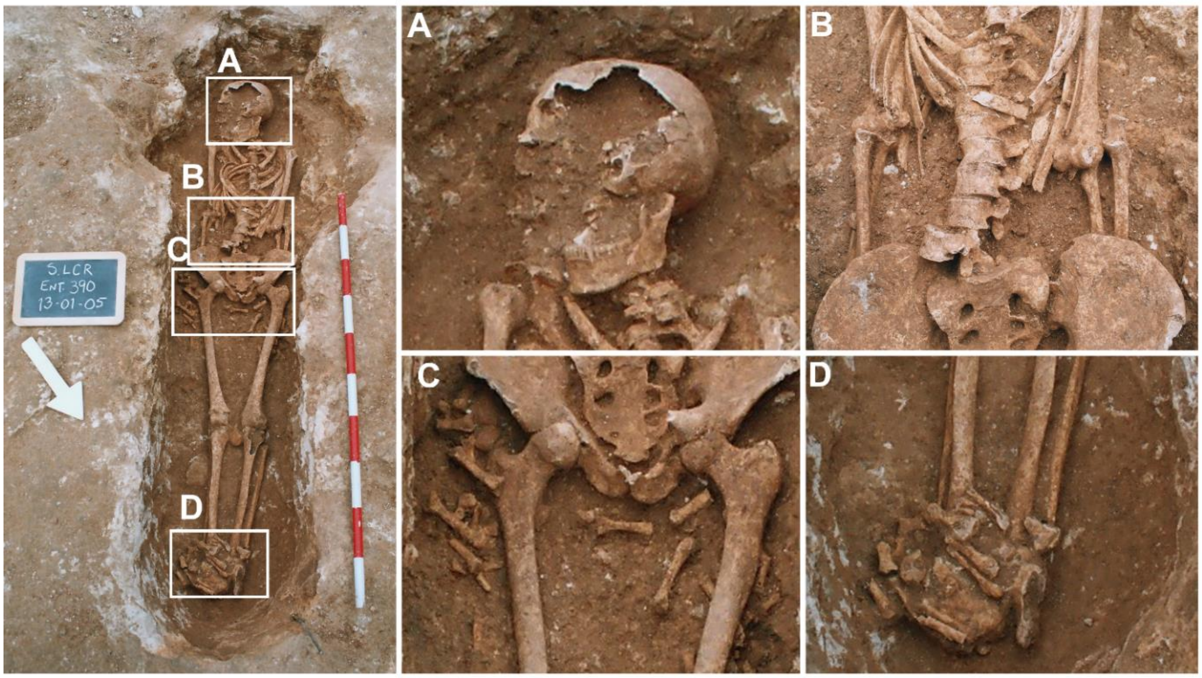
Figure 8.6 - Ent. 417, a Christian adult male (Vicente 2015). Note the flaring of the rib cage, distance of the humerii from the thoracic cavity, and inferior position of the forearms in relation to the respective hands (approximately 5-7 cm), all suggesting a possibly obese individual experiencing internal space and necrodynamic movements during putrefaction and bloat. Photo courtesy of Câmara Municipal de Santarém.

Only one Islamic individual showcased evidence of what might be consistent with tight durable wrapping: Ent. 355 (Figure 5). The individual showcases signs of clavicular verticalization, and overall skeletal constriction that conforms to most of the post-crania, situated within a wider grave cut (48cm). Notably, the cranium, cervical vertebrae, and mandible are in a state of disarray and disarticulation, possibly from secondary external space resulting from decomposition and delayed soil infilling, such that soft tissues are not immediately nor progressively replaced by surrounding sediment (Williams 2022, 321). Alternatively, decomposition may have taken place *in situ* but within the confines of a burial container, such that cranial and cervical elements did not fall outside the confines of a durable wrapping. Given the Islamic funerary tradition of interring the individual on their right side, Ent. 355 showcases dorsal falling but remained remarkably constricted throughout the entirety of the dorsal fall. While this suggests tight wrapping, Ent. 355 also showcases signs of possible Diffuse Idiopathic Skeletal Hyperostosis (DISH), with L1-L4 showing contiguous ossifications along the anatomical right side of the vertebrae (Matias, 2008a, 671–672). These ossifications were hypertrophic, and distinctly patterned along the right side, likely as a result of the descending aorta in the left side (Ortner 2003, 559–560). It is thus possible that limited bodily movement can be explained by the employment of a burial container or limited post-depositional movement and torsion in the thorax due to the presence of vertebral pathology, or a combination of the two. Notably, Ent. 355 experienced secondary disturbance in the lower appendicular skeleton as a result of a subsequent Christian grave cut (Ent. 392), which further limits the potential to discern constriction, necrodynamics, and possible shrouding.

Another burial, Ent. 166 (and adult male of indeterminate age), shows potential evidence of tight, durable shrouding given the position of the upper extremities (Figure 8.7). Ent. 166 appears to have experienced a dorsal fall, but rather than the arms being situated on the sides of the body, actually fell backwards behind the back prior to the fall. The metacarpals, phalanges, and wrists appear to have decomposed *in situ* behind each of the respective *os coxae*. It is therefore possible the body was interred in a way that the right arm and hand were situated just posterior to the right hip, with the left arm and hand balancing precariously atop the posterior aspect of the left abdomen and femur. The left arm subsequently fell posteriorly during decomposition but may have been held tightly together by shrouding material before the rest of the body fell atop it, thus situating the hands behind the *os coxae.* However, the general state of preservation was poor for Ent. 166, possibly due to an interaction of clayey soils and post-depositional disturbances resulting from construction, further limiting our potential. Ent. 390 (Figure 8.8) similarly showed evidence of arms positioned dorsal to the *os coxae*, again, likely as a result of the original positioning and subsequent dorsal fall. Interestingly, L5 can still be seen in right decubitus position, but L4-L1 sequentially exhibit torsion with the dorsal fall. Unlike Ent. 166, the hand bones (and foot bones) appear in a state of disarray, possibly resulting from differential decomposition, necrodynamics, voids ,or bioturbation as suggested by the presence of malacofaunal remains (terrestrial snail shells) within the burial. The posterior fall of the *os coxae* may have been the result of an original external void, whereas the left ulna displaced from the trochlea posteriorly, possibly as a result of secondary internal void following gravity (Green 2022). The position of the mandible atop the lower cervical vertebrae in a semi-decubitus position while the cranium is situated in right decubitus position may suggest the individual fell dorsally before the temporo-mandibular articulation weakened, dislodging the mandible from the cranium in decubitus position. As mentioned briefly above, there do appear to be some prescriptions which advocated for the tethering of the mandible to the skull (Gatrad 1994; Petersen 2013; Tritton 2008), which could possibly factor into this sequence, though the material used is not known. Subsequently, the cranium may have fallen back into right decubitus position at a later stage. These movements suggest some degree of original external space, either facilitated by a burial container such as a shroud which 'suspended' labile decomposing materials, or possibly even the effect of bioturbation and ground-water fluids that caused minor bones to 'float' in grave floor (Duday 2006, 41).

Figure 8.7 - Islamic burial Ent. 166, an adult male exhibiting possible signs of shrouding/tight wrapping. Note how the right and left forearms and hands are positioned posterior/dorsally to their respective ossa coxae, suggesting the arms were positioned behind the back prior to the dorsal fall. Note the right decubitus position of the right femur, while the left femur is in supine position. Photo courtesy of Câmara Municipal de Santarém.

Figure 8.8 - Islamic burial Ent. 390, an adult male (Rodrigues 2013). White boxes and accompanying letters correspond to zoomed-in photos. A) Note the lateral decubitus position of the cranium compared to the mandible; B) Vertebral torsion throughout the lumbar vertebrae and left trochlear joint of the ulna being disarticulated; C) positioning of the hands behind the respective *ossa coxae*, in a state of disarray; D) note the position of the tibiae and fibulae compared to the feet, which are in a greater state of disarray. Photos courtesy of Câmara Municipal de Santarém.



Christian burials were easier to discern possible burial containers, given: 1) their extended supine position, which archeothanatological literature has predominately focused on (Green 2022; Harris et al. 2012), 2) skeletal constriction, when observed, did not appear the product of narrow tomb architecture, unlike Islamic burials. These were often marked by the articulation of patellae, lack of external space, and a degree of constriction often confining to the body itself. Some individuals showed little movement whatsoever, with labile articulations and their associated skeletal elements (e.g., hand bones) decomposing *in situ* with minimal gravitational movement, possibly as a result of more porous soils and progressive infilling. While evidence of employment for shrouds in some Christian burials is noteworthy, it likely showcases the variable nature by which individuals were interred throughout the latter Christian Middle Ages. The discernment of burial containers from archaeothanatological evidence alone continues to be a challenging (Duday 2009), but exciting area of inquiry. Direct evidence of textiles in Islamic funerary contexts is rare, typically involving outstanding preservation in arid contexts (Gayraud et al. 1995; Gleize 2022; Lombard 1978; Sokoly 1997). Similarly, in medieval Christendom, there are few instances of burial shrouds preserving, such as those of the aforementioned St. Bees Priory in Cumberland, St. Mary Spital in London (Gilchrist et al. 2005, 106). To complicate matters further, some prescriptions advocate for the loosening of the shroud after interment (Buturovic, 2017; el Aswad, 1987), though the degree to which shrouds would have been loosed is currently difficult to know via archaeothanatological evidence alone. This is compounded with the issue of textile composition, as *kafan* is traditionally made from 'Yemeni cotton' (Andrew Petersen 2013), but to our knowledge, cotton was not grown locally within Santarém during the medieval period (Sequeira 2014, 38, 45). By the later Christian Middle Ages (15th – 16th c. C.E.), wool and linen were produced in far greater quantities than cotton or silk, largely due to available raw materials (Sequeira 2014, 35). Given the observations in Islamic burials, I posit that burial shrouds, if employed at all, were likely non-durable and generally loose-fitting, though some burials show archaeothanatological evidence of more tight wrapping (e.g., Ent. 166). Conversely, Christian burials appeared to have employed higher instances (22.47%) of possible tight wrappings (Score 3), given the skeletal constriction (lateralization of the clavicles, medial rotation of the humerii) and minimal post-depositional movements accompanied by the grave cut extending beyond the constriction of the body.

A cumulative 88.57% of Islamic burials analyzed showed signs of possible shrouding and/or narrow grave cuts (Scores 8 and 9), while the Christian sub-sample was more variable in its distribution of possible burial container typologies (Table 4). Much of our inability to confidently discern the employment of burial containers in Islamic graves stems from 1) an underrepresentation of archaeothanatological literature in Islamic contexts, and 2) the impact of narrow tomb dimensions in facilitating skeletal evidence of constriction. Christian graves were variable in burial width dimensions, ranging from 26 – 99 cm with 95% of the variation falling between 33 – 83 cm. Islamic graves were comparatively much narrower in variation, ranging between 25 – 68 cm with 95% of the variation falling between 24.5 and 52.5 cm. Not only were Islamic graves significantly narrower than their Christian counterparts, but the sample dispersion for Islamic burials was also significantly smaller, with a standard deviation of 6.30 cm compared to the Christian standard deviation of 13.43 cm (Levene's test: $F = 26.91$, $p < 0.001$). Therefore, archaeothanatological evidence of constriction — often one of the prerequisites for burial containers — in Islamic burials was difficult to discern as being the product of burial containers, narrow grave construction facilitating constrictive burial dimensions, or a combination of the two. From an ethnohistorical and legal standpoint, burial width appears to have been debated, though typically advocating for narrow tombs in accordance with Maliki jurisprudence in order to avoid post-depositional movements of the body and maintain the body in right decubitus position facing Mecca (Chávet et al. 2006; Garcia Gómez et al. 1998, 149; Halevi 2007). Indeed, the majority of Islamic cemeteries that have been excavated both in Iberia and in the Near East generally conform to these prescriptions (Chávet et al. 2006; Carballa et al. 2007; Gleize 2022; Gonzaga 2018b; Murillo Fragero et al. 2009Ruiz Taboada 2015; Simpson 1995), sometimes no more than 60 cm wide (Gleize 2022, 382). In fact, there is both ethnohistorical and archaeological evidence for the employment of mud bricks, sherds, and rocks beneath the cranium in order to maintain right decubitus position and/or give the appearance of the individual sleeping (el Aswad 1987, 221; León Muñoz 2008). In some cases, Islamic burials at Largo Cândido dos Reis seem to have employed similar props beneath the cranium such as limestone blocks (Matias 2008b, 647). In many instances, it's likely that the grave was constructed just outside the confines of the cadaver, while the final positioning of skeletal elements represents movements within the internal space of the bodily confines. Altogether, the observed variance and lack of sample dispersion in burial width and depth suggest Islamic burials were in fact highly prescribed and normative (Gleize 2022) compared to their more variable Christian counterparts. Burial construction appears more regulated in these Islamic burials, which altered the contours of archaeothanatological potentials, whereas Christian burial construction, the raw materials used for burial containers, and the degree of constriction (e.g., tight or loose) of those burial containers appear more variable based on both the burial metric and archaeothanatological evidence.

Conclusion

The application of archaeothanatology continues to experience burgeoning scholarship, revealing crucial funerary rituals, burial architecture, and decomposition sequences. While the scholarship on archaeothanatological approaches to right decubitus burials in Islamic contexts is emerging (Gleize 2022; Gleize et al. 2016), the majority of archaeothanatological investigations on burial containers have focused on extended supine burials or sitting burials, and further work is needed on lateral decubitus burials given their differential positioning and necrodynamic potential. While there is likely evidence of burial containers and shrouds employed at Largo Cândido dos Reis, tomb architecture and construction, likely in accordance with Islamic jurisprudence and funerary rites of the time, severely limited the confidence in discerning burial containers. Many burials were indeterminate in their employment of shrouds based on available *post-hoc* archaeothanatological evidence. *Post-hoc* archaeothanatological approaches are not without their shortcomings, and are heavily subjected to original documentation and photographs/drawings during excavation. However, the increasing incorporation of archeothanatology in burial contexts (Knüsel et al. 2022), paired with experimental and detailed understandings of decomposition (Dent et al. 2004; Mickleburgh et al. 2018; Pinheiro 2006b; Wilson et al. 2020) have helped to document the emerging patterns of funerary rites and their consequences on human skeletal remains. The burgeoning corpus of this scholarship aids *post-hoc* approaches in providing more examples and variability of human decomposition, and the potential for *post-hoc* approaches in re-analyzing previously excavated material or even challenging previous funerary archaeological hypotheses which may have lacked biological anthropologists and/or detailed archaeothanatological understandings of decomposition (Green 2022; Nilsson Stutz 2006, 218).

Chapter 9: Deathways — Macrotaphonomy

Introduction

Taphonomic variables are present at nearly every archaeological site. Yet despite their ubiquity, taphonomic variables are often conceptualized as part of routine reporting or careful differentiation from other phenomena rather than a worthwhile means of anthropological inquiry. Traditionally, taphonomic variables have been seen as distortive and reductive rather than informative and additive, something many paleoanthropologists, archaeologists, bioarchaeologists, and forensic anthropologists have long attempted to challenge (Ringrose 1993; Lyman 2010; Behrensmeyer et al. 1985; Haglund et al. 1997). Knüsel and Robb eloquently address how modern Western deathways have often framed all manners of taphonomic variables in relation to human skeletal remains (cut marks, cremation, exposure, excarnation, etc.) as "…deviations rather than potentially part of the normative process" (2016, 655).

Efremov (1940) famously coined taphonomy as "the transition from the biosphere to the lithosphere," by conjoining "biostratinomy" — the stage between an organism's death and final burial — with "diagenesis" — the stage corresponding to post-burial processes that affect an organism's remains (Lyman 2010, 3). This tethering ultimately protracted the temporal sequence of preservation, to help include death events (necrology) with post-mortem factors. While taphonomy became adopted in anthropology via paleontology and paleoanthropology (Behrensmeyer 1975; 1978) and forensic anthropology (Haglund et al. 1997) rather seamlessly, archaeologists deliberated on site-formation processes and the potential for archaeologists to adopt taphonomic analogies. The pioneering work of Michael Schiffer heuristically attempted to separate cultural transformations (or C-transforms) from natural ones (or N-transforms) (Schiffer, 1983, 1985, 1988) in their production of the archaeological record. In doing so, 'natural' (i.e., taphonomic) factors that distort the archaeological record can be accounted for in order to get at the original 'cultural' deposition. Indeed, it was common practice for many archaeologists to articulate taphonomy precisely as the "non-cultural processes" (i.e. N-transforms) (e.g. White, 1979; Whitlam, 1982; Dibble et al., 1997). Even when taphonomy has been expanded to include cultural (i.e. C-transforms) and other non-natural formation processes, archaeologists have tended to still view taphonomy with in a distortive, entropic framework, a debate that reached its zenith in the famous Pompeii Premise (Binford 1981b; Schiffer 1985b).

While archaeologists struggled to address cultural and natural processes in their formation of archaeological assemblages in the latter part of the 20th century (see Chapter 2 and Lyman 2010 for what he terms the 'co-option' of taphonomy by archaeologists), bioarchaeology was beginning to emerge with an explicit emphasis on biocultural approaches. Schiffer's (1972) own flow model for how artifacts transition from their "systematic context" to the "archaeological context" offers a theoretical alternative to taphonomy, but explicitly considers abiotic artifacts. While 'refuse' can certainly be considered the final transitional stage from systematic to archaeological context for many artifacts, human remains, and many other materials for that matter, are not often casually discarded — they are often intentionally disposed of, and indeed interred, in a deliberate and cultural manner (Sprague 2005). Bioarchaeologists then occupy a theoretical gray area between paleontologists and archaeologists in their conceptualization of taphonomy. On the one hand, bioarchaeologists that specialize in human skeletal remains represent a biological 'template' with which to analyze preservation, missingness, or representation (Lyman 2010). This harkens closer to paleontologists who use known species and skeletal systems to measure degrees of completeness in given samples in order to quantify and qualify taphonomic filters. However, unlike paleontological remains, human remains (and many other organisms frankly) are not merely biotic organisms that exclusively occupy the biosphere we are fundamentally biocultural beings (Dressler 2005; Alan H Goodman & Thomas Leatherman 1998; Ingold et al. 2013; Sobo 2012). As such, the transition itself from Efremov's biosphere to the lithosphere is bioculturally mediated — human remains are inextricably linked and imbued with social and cultural values, meanings, and treatments after death that are likely to impact later taphonomic outcomes.

The separation between cultural and natural factors in the preservation of human remains is theoretically challenging. There is undoubted utility in distinguishing between diagenetic events and culturally-sanctioned funerary rites, as the exhaustive work of Duday (Duday 1978; 2006; 2009; Duday et al. 1987; 1990; 2006) among others (Schotsmans et al. 2017; Knüsel et al. 2022) has demonstrated. Here, careful attention to decompositional sequences, necrodynamics, and tomb construction can help discriminate taphonomic variables such as rodent tunneling, scavenging, or water intrusion, from deliberate funerary gestures. Duday's development of archaeothantology helped to provide both a theoretical and methodological means of stripping away the 'natural' factors that distorted the body from its culturally-deposited origin (Duday 2006, 33). This is not unlike forensic anthropologists and paleopathologists who carefully coined 'pseudopathologies' to help describe taphonomic influences that could mimic pathological conditions or fractures (Haglund et al. 1997; Ortner 2003; Schotsmans et al. 2017; Wells 1967). Distinguishing between 'natural'/taphonomic variables from those produced through human action (funerary rites, interpersonal violence, pathology, etc.) is of crucial importance, and as a result often requires a separation of natural and cultural filters.

Yet despite the utility in distinguishing between 'natural' and 'cultural' factors, the separation itself strikes at the very philosophical foundations of bioarchaeology and taphonomy (Lyman 2010; Knüsel et al. 2016, 656). As biocultural beings, some may see the utility in parsing biological from cultural variables in their co-production of bodies, while others emphasize the inextricable linkage between biology and culture as an "emergent" phenomenon (Sobo 2012). Bioarchaeologists have long appreciated the plastic and dynamic nature of bones and teeth, such that the human skeletal system is truly seen as a bioculturally modified organ (Agarwal et al. 2011; Burnett et al. 2017; Goodman 1998; Sofaer 2006c). But while bioarchaeologists have done well to champion biocultural approaches in framing the human skeleton during life, biocultural approaches to death and taphonomy are far less common, in large part due to their frequent heuristic separation as discussed above.

This chapter seeks to inquire whether biocultural approaches can be extended beyond the life/death divide and provide similar utility in funerary taphonomy. By employing a biocultural perspective, I seek to problematize the separation of 'natural' and 'cultural' processes, and elucidate how they can be inextricably linked and in some cases, difficult to parse, especially when it comes to human remains deposited and curated in culturally-mediated contexts. I do so by examining macrotaphonomic indicators of bone representation, preservation, erosion, weathering, as well as tomb typologies, architectural features, and invertebrate activity in a comparative manner between two distinct funerary groups within the same cemetery. The presence of distinct funerary treatments, both with an emphasis on inhumation and resurrection, within the same geological and geographical space offers a unique opportunity to examine how culturally-mediated burial practices may affect taphonomic outcomes while semi-controlling for local sedimentary and geographical factors.

Materials

The background on the region, site, and materials can be seen in Chapter 3. The list of individuals analyzed for preservation can be seen in Table 9.2 and Figure 9.1. Other sample distributions by macrotaphonomic indicator are listed below in their respective sections.

Methodology

Tomb typology and burial metrics

In order to facilitate a funerary taphonomic approach, burials were first characterized in a descriptive and quantitative manner. Funerary taphonomy and archaeothanatological approaches must not exclusively consider the human remains, but also associated architecture, funerary items, or intrusive features (Blaizot 2022). Burials were first characterized for local soil/sediment based on field observations (Matias 2008a). A subset of Islamic burials (*n* = 234) with discernible shape were analyzed following the typological categorization of Iberian Islamic tomb styles outlined by Fernández Guirado (1995, 44–51), Peral Bejarano (1995, 26–31), and further expanded upon by Gonzaga (2018, pp. 16–19; see also Appendix 9.1 - 9.16). Unfortunately, numerous Islamic graves were excluded due to inability to discern the shape of the tomb (*n* = 188). Christian tombs were similarly characterized based on their shape and morphology. Burial dimensions (length, width, depth) were analyzed in the field using measuring tapes to the nearest centimeter. Sums were then analyzed *post-hoc* using metrics recorded on the field forms for each grave that yielded discernable metrics. Normality was assessed via histograms, normal quantile plots, and Shapiro-Wilk tests with an $\alpha = 0.05$. Despite ample sample sizes, only burial depth was found to be approximately normal, with all other metrics by funerary group having non-normal distributions ($p < 0.05$). As such, burial metrics were compared using a Wilcox rank sum test rather than a *t*-test. Effect sizes were subsequently calculated using the `rstatix` package in R.Studio v 4.2.2 (RStudio Team 2020).

Preservation

In order to assess variability in bone preservation, skeletal remains were analyzed using a modification of the preservation index developed by Dutour (1989) and expanded upon by Garcia (2006) and Bello and colleagues (Bello & Andrews 2006; Bello et al. 2006). Dutour originally divided each skeleton into 44 zones, whereby each zone was noted as present or absent, and if present, was scored according to the percentage of completion using four categories (0-25%, 25-50%, 50-75%, 75-100%). The sum of the yielded scores can then be divided by the total number of anatomical parts and multiplied by 100 to yield the Anatomical Conservation Index (ACI) (also referred here as the Anatomical Preservation Index, API):

$$Anatomical\ Conservation\ Index\ (ACI) = 100\ x \sum \left(\frac{scores\ attributed}{total\ number\ of\ anatomical\ parts}\right)$$

The product of which can then be sorted in 10% increments ranging from Bad preservation (0-10%) to Excellent preservation (81-100%) for any given skeleton. Well-Preserved Bones (WPB) are those elements with at least 50% of their bone present, while Well-Preserved Skeletons (WPS) refers to individuals with more than 50% of their elements well preserved (Bello & Andrews 2006; Bello et al. 2006). Additionally, the Bone Representation Index (BRI) originally developed by Dodson and Wexlar (1979) and refined for bioarchaeology by Bello and Andrews (2006) was also employed. This examines the proportion between the number of bones excavated ($N_{observed}$) and the number of bones that should be present according to the MNI ($N_{theoretical}$.):

$$Bone\ Representation\ Index\ (BRI) = 100\ x\ \sum \left(\frac{N_{observed}}{N_{theoretical}}\right)$$

Similar to the ACI, the BRI can be used to examine which bones are well-represented (WRB) by having at least 50% presence, and which skeletons are well-represented (WRS) as those having at least 50% of their bones present. Thus while the ACI assesses the *quantity* of osseous material in a sample, the BRI assesses the *frequency* of each bone in a sample (Bello & Andrews 2006). For example, a skeleton can be considered well-represented (more than 50% of elements present) but not necessarily well-preserved (at least 50% of bones well-preserved). The use of these indices together can therefore help to obtain a better picture of preservation and representation of osseous remains at a given site (Table 9.1).

Table 9.1 - Definitions of indices used (following Bello and Andrews 2006).

Index	***Definition***
Well-preserved bones (WPB)	Bones having at least 50% of their elements present
Well-preserved skeletons (WPS)	Skeletons having at least 50% of their bones well-preserved
Well-represented bones (WRB)	Bones being represented with at least 50% frequency
Well-represented skeletons (WRS)	Skeletons with at least 50% of their bones represented

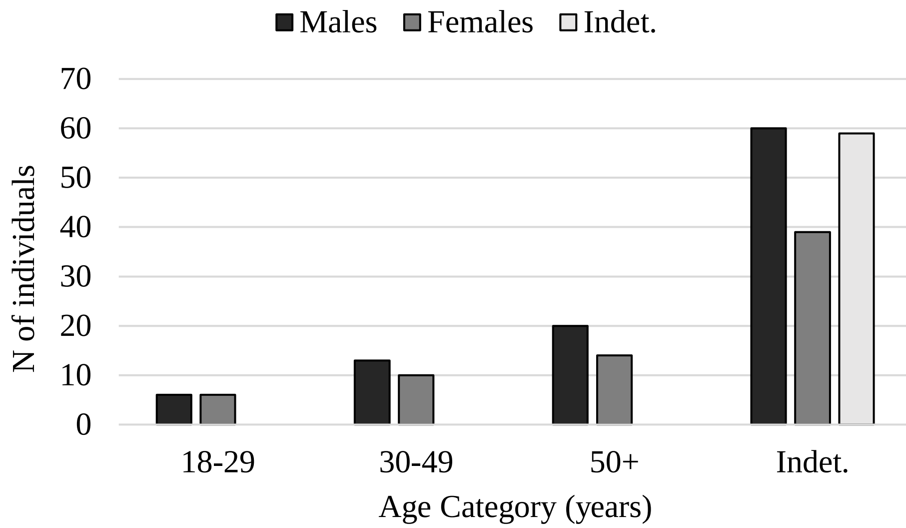
In addition to the above indices, Andrews and Bello (2006, 18) have developed the Taphonomic Index which aggregates differing taphonomic filters into one ordinal index. Ranging in scores from 1 to 10, the Taphonomic Index analyzes 1) skeletal completeness, 2) breakage of bones, 3) disarticulation, and 4) surface modification, to yield a total score between 4 (an incomplete skeleton with heavy breakage, in total disarticulation and heavy surface modification) and 40 (a nearly complete skeleton with little-to-no breakage, in articulation with minimal to no surface modification) for any given individual. The authors applied this index to their study of 92 burials at Çatalhöyük in order to aggregate differing taphonomic agents and evaluate their spatial, demographic, and funerary corollaries (Andrews & Bello 2006).

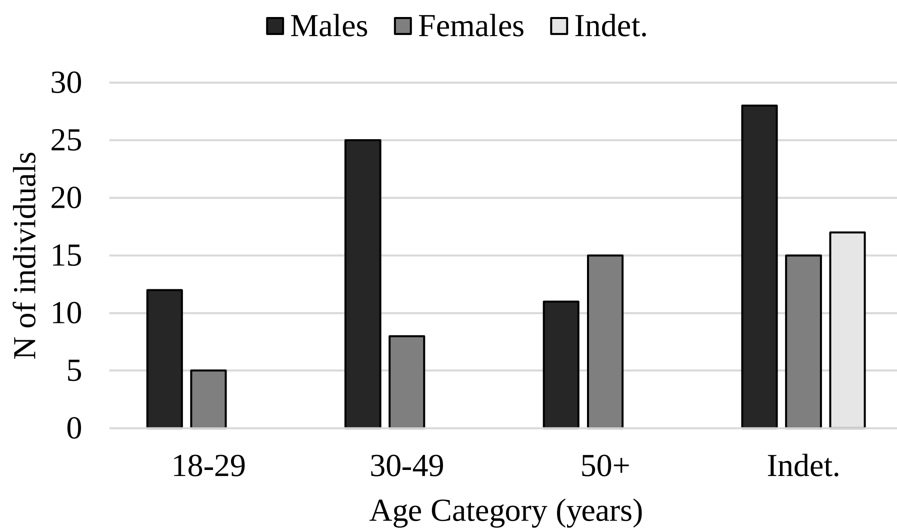
While the Taphonomic Index gives a good numeric indication of preservation for any given individual, it does aggregate differing taphonomic filters and factors that may be better left to separate, more nuanced analyses and scoring. The authors note that the last factor in particular, surface modification, was employed primarily to examine black fungal staining at Çatalhöyük, but could also include carnivorous gnaw-marks, weathering, cut marks, trampling, root marks, and erosion (Andrews et al. 2006, 18). Thus, aggregating weathering and erosion, or gnaw-marks and cut marks as part of the same numeric score could swamp out meaningful differences and nuance within bone surface taphonomies. Given the differences in erosion profiles, root marking, and weathering observed at Largo Cândido dos Reis, surface modifications were scored separately, and the Taphonomic Index was not employed in the present study in order to permit more detailed scoring of the various taphonomic filters at play. The distribution of individuals by funerary group, age, and sex can be seen in table 9.2 and figure 9.1.

Table 9.2 - Distribution of individuals analyzed for preservation at Largo Cândido dos Reis.

Funerary group	*Sex*	*18-29 yrs*	*30-49 yrs*	*50+ yrs*	*Indet.*	**Total**
Islamic	M	6	13	20	60	**99**
	F	6	10	14	39	**69**
	Indet.	-	-	-	59	**59**
Christian	M	12	25	11	28	**76**
	F	5	8	15	15	**43**
	Indet.	-	-	-	17	**17**
Total		**29**	**56**	**60**	**218**	**363**

Figure 9.1 - Distribution of Islamic (top) and Christian (bottom) individuals analyzed for preservation by age and sex at Largo Cândido dos Reis.





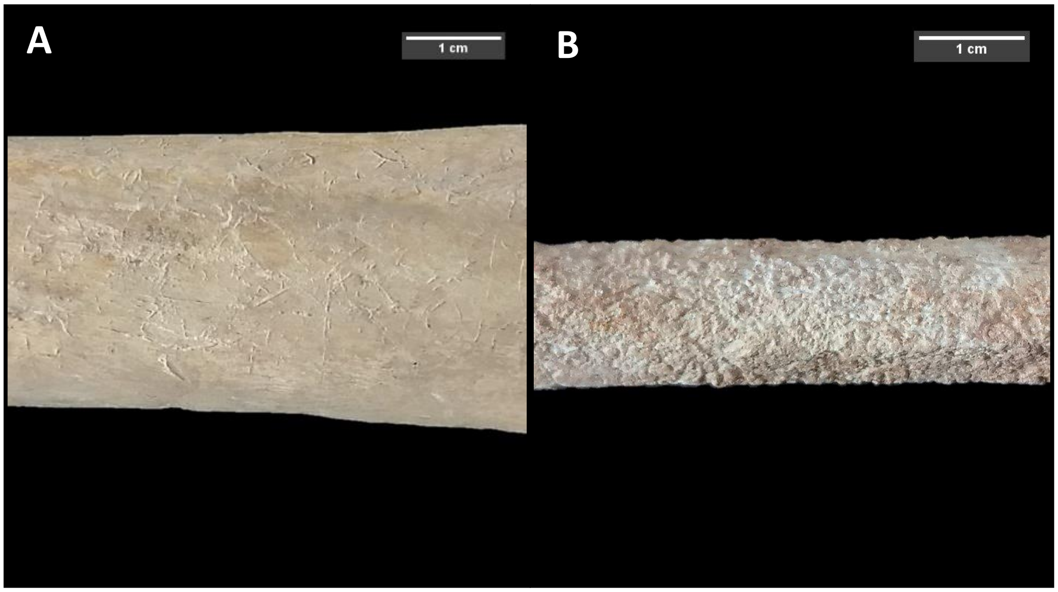
Surface Changes: Weathering and Erosion

Numerous factors can affect the surfaces of bone after burial, ranging from thermal alteration to plant roots, invertebrate activity, scavenging, human interaction, or local soil/sedimentary factors to name only a few (Buikstra et al. 1994, 97). Scholars have long recognized the importance of distinguishing "pseudopathologies" — surface modifications that occur taphonomically — from actual pathological indicators (Wells 1967; Buikstra et al. 1993; Ortner 2003). Following the pioneering work of Behrensmeyer's (1978), assessments of weathering have a deep history in bioarchaeological analyses, given its characteristic modification of periosteal surfaces. Weathering here refers to the exposure of bone to thermal alteration, such that superficial cracking and splintering is observed (Figure 9.2). Bones were scored for weathering following the ordinal scale by Buikstra and Ubelaker (1994, 98). While represented bones for each individual were analyzed for weathering, individual scores were derived from averaging weathering scores for the long bones and cranium. Weathering was scored in 228 Islamic and 132 Christian individuals.

Figure 9.2 - Weathering in tibia of Ent. 123.

Erosion comprises one of the other more common forms of surface changes observed in skeletal remains, but is occasionally collapsed alongside assessments of weathering (Buikstra et al. 1994, 97). Later developments in the UK found that acidic or alkaline burial environments as well as root/fungal activity produced surface modifications distinct from typical weathering such as flaking and cracking, with bones instead exhibiting dendritic and patchy modification of periosteal surfaces (Brickley et al. 2004, 15). Given that similar modifications were observed at Largo Cândido dos Reis (Appendix 9.17-9.19), erosion was scored according to the ordinal scale by Brickley and McKinely (2004: 15-16). Similar to weathering, erosion was scored in represented bones and subsequently averaged between long bones and cranium. Erosion was scored in 228 Islamic and 131 Christian individuals.

Figure 9.3 - Examples of erosion at Largo Cândido dos Reis. A) Incipient erosion (score 1) in Ent. 384 and B) heavy erosion (score 5+) in Ent. 437.

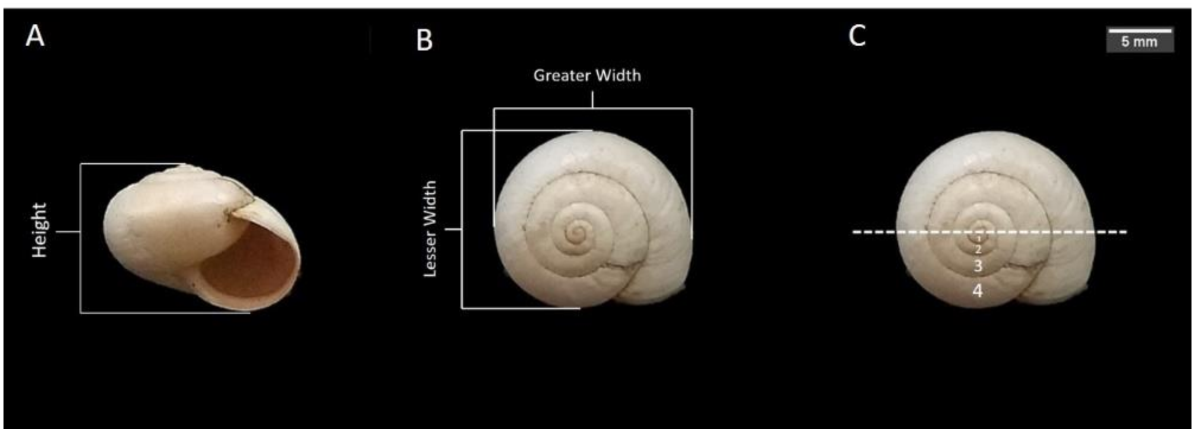


Invertebrate Activity and Archaeomalacology

The site of Largo Cândido dos Reis is interesting in that numerous graves were found to have dense assemblages of malacofaunal remains – specifically, snail shells from terrestrial gastropods (Matias 2008a) (Appendix 9.24-9.30). From an ecological standpoint, decomposing human bodies can become dense loci for biodiversity (Anderson et al. 2002; Ferreira 2012; Voss et al. 2011b). While buried cadavers can prove difficult in assessing biodiversity in both forensic and archaeological settings due to soils acting as a physical barrier to many scavengers (Rodriguez 1997; Bourel et al. 2004), putrefaction resulting in the seeping of organic fluids into the neighboring soil and grave floor can attract necrophagous insects, worms, and terrestrial gastropods (Duday et al. 2006, 128–129). While many forensic studies have focused on the role of invertebrates in interacting with decomposing human corpses (Haskell et al. 1997; Anderson et al. 2002; Morton et al. 2006; Ururahy-Rodrigues et al. 2008), the role of malacofauna has received comparatively little attention. Marine molluscs have received minor attention in forensic settings (Sorg et al. 1997), but their terrestrial counterparts have received almost no attention (Fernández-López de Pablo et al. 2011). Identification of malacofauna in archaeological contexts can be incredibly informative for consumptive, ecological, or even chronometric purposes (Allen 2017). Galvão and colleagues (2015) claim to have published the first evidence of terrestrial gastropods in 'natural' contact with human remains, discovering n = 20 shells belonging to *Allopeas micra* located *in situ* throughout medullary cavities in the femora and humerii from forensic burial. Given that most of the shells were of similar size (~2mm) and no long bones showed evidence of openings, the authors suggest that the snails likely burrowed and entered the medullary cavities through nutrient foramina, possibly for consumptive purposes or aestivation. Given differing sizes, ages, and species present, the gastropod recovered at Largo Cândido dos Reis likely represents a death assemblage (thanatocoenoses event). Furthermore, this assemblage is likely not the byproduct of human consumption, as human consumption middens are often marked by dense assemblages consisting of predominately adults, and typically show evidence of heat alteration or proximity to archaeological features such as hearths (Fernández-López de Pablo et al. 2011).

A biometric approach was carried out in the current study, following the pioneering work of Pilsbry (1939) and expanded upon by Kerney and Cameron (1979). Shells were first distinguished by their 1) height, 2) lesser width, and 3) greater width. Height refers to the dimensions from the shell lip extending to the apex of the shell (Figure 9.4), whereas greater and lesser widths refer to the maximum and minimum diameters of the shell, respectively (Kerney et al. 1979, 14) (Figure 9.4 - B). Finally, due to the spiraled growth pattern of gastropod shells, the number of whorls (coiled spirals from the apex radiating towards the mouth) can also be occasionally informative in gastropod identification. Whorls were counted by drawing an imaginary midline across the apex, and counting successive radiations originating from the apex, outwards (Figure 9.4 - C; see also Kerney and Cameron 1979, p. 13). These metrics were carried out on a sub-sample of *n* = 1,014 archaeomalacological shells using Paleotech Mitutoyo Absolute dental calipers to the nearest 0.01mm. Only shells only with known burial contexts and were complete enough to carry out all 4 metrics were analyzed. Archaeological specimens were compared with ongoing reference collections housed at the Museu Municipal de Santarém, but primarily through digital photographic comparison through established taxonomic guides (Kerney et al. 1979) or the online data base: iberus shells (iberus-shells.com).

Figure 9.4 - Biometric data collected for each complete snail shell in present study.



Analytical procedures

Bayesian Analysis

All statistical and graphical analyses were carried out in R.Studio (RStudio Team 2020) with the help of ggplot2 (Wickham 2016). For comparisons of preservation scores and well-preserved skeletons/well-represented skeletons between funerary groups, Bayesian analysis was employed. While a complete coverage of Bayesian analysis is beyond the scope of this section, I encourage readers to consult the work of Kruschke (2013; 2015; 2018; 2021; Kruschke et al. 2018) among others (Western et al. 1994; Albert 2009; Lambert 2018) who clearly explain Bayesian analysis, especially in relation to software such as R. Analyses were carried out in R.Studio v 4.2.2 (RStudio Team 2020) in tandem with the JAGS software package, which stands for Just Another Gibbs Sampler, and can facilitate Markov chain Monte Carlo (MCMC) methods either via Gibbs sampling or by employing the Metropolis-Hastings algorithm (Metropolis et al.

1953). This facilitates a probabilistic approximation of the posterior distribution given the observed data.

All MCMC simulations were ran with a burn-in period of 1,000 steps to allow for convergence (Appendix 9.37-9.43). Diagnostics on all parameters (mean, standard deviation, and degrees of freedom) exhibited dense superimposed trace plots with no orphaned chains (Kruschke 2015, 179–180). Density plots for all parameters similarly exhibited overlap after the burn-in period and reaching convergence. Gelman-Rubin statistics for all parameters exhibited low shrink factors (~1.0) with no chain variance exceeding 1.1 (Brooks et al. 1998; Gelman et al. 1992). Finally, to evaluate potential for autocorrelation, the effective sample size (EES) proposed in Kass et al (1998, 99). Kruschke (2015, 184) advocates an ESS of approximately 10,000 for accurate estimates of the posterior 95% highest density interval (HDI). Given that all of the EES values well exceeded this threshold, and are all unimodal, all diagnostics suggest that the MCMC are representative of posterior distributions of interest.

For the proportion of well-preserved skeletons (WPS), I constructed a broad, conservative prior from the Beta family, with $\alpha = 5$, $\beta = 3$. My justification of this prior choice stems from previous research within European sites reporting the proportion of WPS for each site (Bello et al. 2006, 6), which found the proportion of WPS to range between 24.1% and 98.4%, with a mean around 75%. While this Beta family prior does not perfectly align with the data, my choice of $\alpha = 5$, $\beta = 3$ should still reflect a central tendency of 75% with lower likelihoods at 100% or 0%. A similar rationale was applied to the anatomical conservation index (ACI) prior, following results from Bello and Andrews (Bello et al. 2006). In this case, a beta family prior distribution with $\alpha = 0.75$, $\beta = 0.4$ was chosen, based on ACI values for adults following an approximate U-shape, skewed towards 1. Once again, this prior is intentionally broad and conservative in order to facilitate initial assessments. To facilitate comparisons between funerary groups, a region of practical equivalence (ROPE) was used, following Krushke (Kruschke 2013; 2015; 2018). Default values for differences in scales (-0.5, 0.5) and effect size (-0.1, 0.1) were used, but a larger ROPE for difference in means was used (-5.0, 5.0). This larger ROPE was chosen as this is a preliminary Bayesian analysis, and a larger, more conservative ROPE should be idea for early studies whereas later studies with more robust/specific priors can facilitate narrower ROPE parameters (Kruschke 2018).

Frequentist analysis

To further compare the distribution of ACI values between funerary groups, original sampling distributions were compared to bootstrapped ones with 95% confidence intervals. Bootstrapping, or sampling with replacement, can help to approximate the sample mean even when the sample distribution is limited (Ismay et al. 2019). Sampling with replacement was done 1,000 times on funerary-specific ACI mean values, followed by 95% (percentile-based) confidence intervals.

The majority of statistical comparisons were carried out in a frequentist manner, employing two-proportion Z tests and t-tests with an $\alpha = 0.05$. Hypothesis tests were only carried out in this manner if datasets were shown to be normally distributed with normal quantile plots and Shapiro-Wilk tests. Binomial logistic regression and ANOVAs were employed for further remodeling and comparison of preservation indices. In cases of missing data (i.e., lack of demographic indicators such as age or sex for a given skeleton), tests and logistic regression models were run with and without indeterminate individuals separately.

Given the prevalence of missingness (Appendix 9.44-9.48) indeterminate individuals were also imputed in a step-wise, single imputation manner and subsequently using multiple imputation via the MICE (Multiple Imputation by Chained Equations) package in R (Van Buuren et al. 2011). Sex was imputed using a logistic regression function (logreg) while Age was imputed using a polytomous regression (polyreg).

Finally, a principal component analysis (PCA) was carried out on malacofaunal biometric data in order to help elucidate possible species candidates using the factomine and factoextra packages (Lê et al. 2008).

Results

Tomb typology and burial metrics

The majority of Islamic graves (*n* = 350; 82.94%) were constructed through direct relief of the marly limestone substrate, while the remainder (*n* = 72; 17.06%) were constructed in clay soils (Matias 2008b). Islamic graves were predominately modest in length, often not extending far beyond the reaches of the body ($\bar{x}$ = 190.74cm, *s* = 17.35cm, *n* = 66). Graves were however relatively narrow ($\bar{x}$ = 39.29cm, *s* = 6.30cm, *n* = 150) and shallow ($\bar{x}$ = 32.08cm, *s* = 12.76cm, *n* = 72). Islamic tombs at Largo Cândido dos Reis were predominately simple earthen inhumations, with over 98% showcasing semi-rectangular pits with no other materials used in tomb construction (Appendix 9.16). While one grave (Ent. 485) did showcase an anthropomorphic tomb structure (J1.2), the tomb walls and floor were not covered in clay, which is typically considered a prerequisite for this typology. Two graves, Ent.183 and Ent.190, showcased encircling of rocks around the tomb's outline (H16). Finally, only one grave, Ent. 577, showed evidence of being covered in ceramic roof tiles (*telhas*; Appendix 9.7-9.8). While some graves showed evidence of small ceramic sherds, the occurrence was relatively minor (*n* = 13). Only one individual, Ent. 173, showed clear evidence of grave goods, with a ceramic vessel placed between the femora (Appendix 9.5-9.6).

The majority of Christian graves were created through direct relief of marly limestone substrates (n = 184, 84.79%) while the remainder were discovered in 33 collective pits created through direct relief of sandier substrates (Matias 2008b). Most graves were found in decubitus dorsal position (*n* = 210; 96.77%), while *n* = 5 individuals were found in on their left side and *n* = 2 individuals were found decubitus ventral position (Matias 2008b). Christian graves extended slightly beyond the reaches of the body ($\bar{x}$ = 193.54 cm, *s* = 15.91 cm, *n* = 39), but were of notable width ($\bar{x}$ = 58.88 cm, *s* = 13.43 cm, *n* = 64) and depth ($\bar{x}$ = 49.03 cm, *s* = 16.09 cm, *n* = 40). Christian graves were variable in burial width dimensions, ranging from 26 – 99 cm with 95% of the variation falling between 33 – 83 cm. Islamic graves were comparatively much narrower in variation, ranging between 25 – 68 cm with 95% of the variation falling between 24.5 and 52.5 cm. Finally, in terms of burial depth, Christians exhibited significantly deeper burials with more variation compared to the shallower Islamic graves. Islamic graves were significantly narrower ($p < 0.01$, effect size = 0.68) and shallower (p < 0.01, effect size = 0.49) than their Christian counterparts (Table 9.3).

Table 9.3 - Comparison of mean burial metrics (in cm) by funerary group at Largo Cândido dos Reis.

	Christian		Islamic					
Category	*N*	$\bar{x}$ (s)	N	$\bar{x}$ *(s)*	*t*	*p*-value	Effect size	Magnitude
Burial Length	39	193.54 (15.91)	66	190.74 (17.35)	1455	0.27	0.11	Small
Burial Width	64	58.88 (13.43)	150	39.29 (6.30)	8939	< 0.01*	0.68	Large
Burial Depth	40	49.03 (16.09)	72	32.08 (12.76)	2297	< 0.01*	0.49	Medium

Preservation – Bayesian

The output from the Bayesian estimation analysis for anatomical conservation index (ACI) values can be seen in Figure 9.5 and Table 9.4. Christian distribution for ACI exhibited a 95% highest density interval between 39.2 and 48, with a mode of 44, whereas Islamic proportion of well-preserved skeletons was found to be between 28.5 and 34.3 with a mode of 31.5. Difference of means was found to be well below zero, with a mode of -12.4 and 95% HDI of -17.5 to -6.96. Finally, effect size was found to be well below zero as well, ranging with an 95% HDI of -0.75 and -0.293. Altogether, these latter two group comparisons fell well outside their respective regions of practical equivalence (ROPE), suggesting a significant difference between the average proportion of preserved bone between funerary groups.

Additionally, the Bayesian analysis for the proportion of well-preserved skeletons (WPS) between funerary groups can be seen in Figure 9.6 and Table 9.5. The modelled proportion of Christian well-preserved skeletons had a 95% HDI between 36.4% and 52.5% with a mode of 44.2%. Conversely, the Islamic distribution had a 95% HDI between 15.8% and 26.1% with a mode of 20.4%. Difference of means (Christian minus Islamic) resulted in 100% of the differential distribution above 0, with a 95% HDI ranging from 14.1% to 33.2% and a mode of 23.6%. Given the positive correlation between Islamic (theta[2]) and Christian values (theta[1]), its not surprising that the difference of means is significant.

Figure 9.5 - Output of Bayesian estimation analysis for average anatomical conservation index (ACI) values between funerary groups.

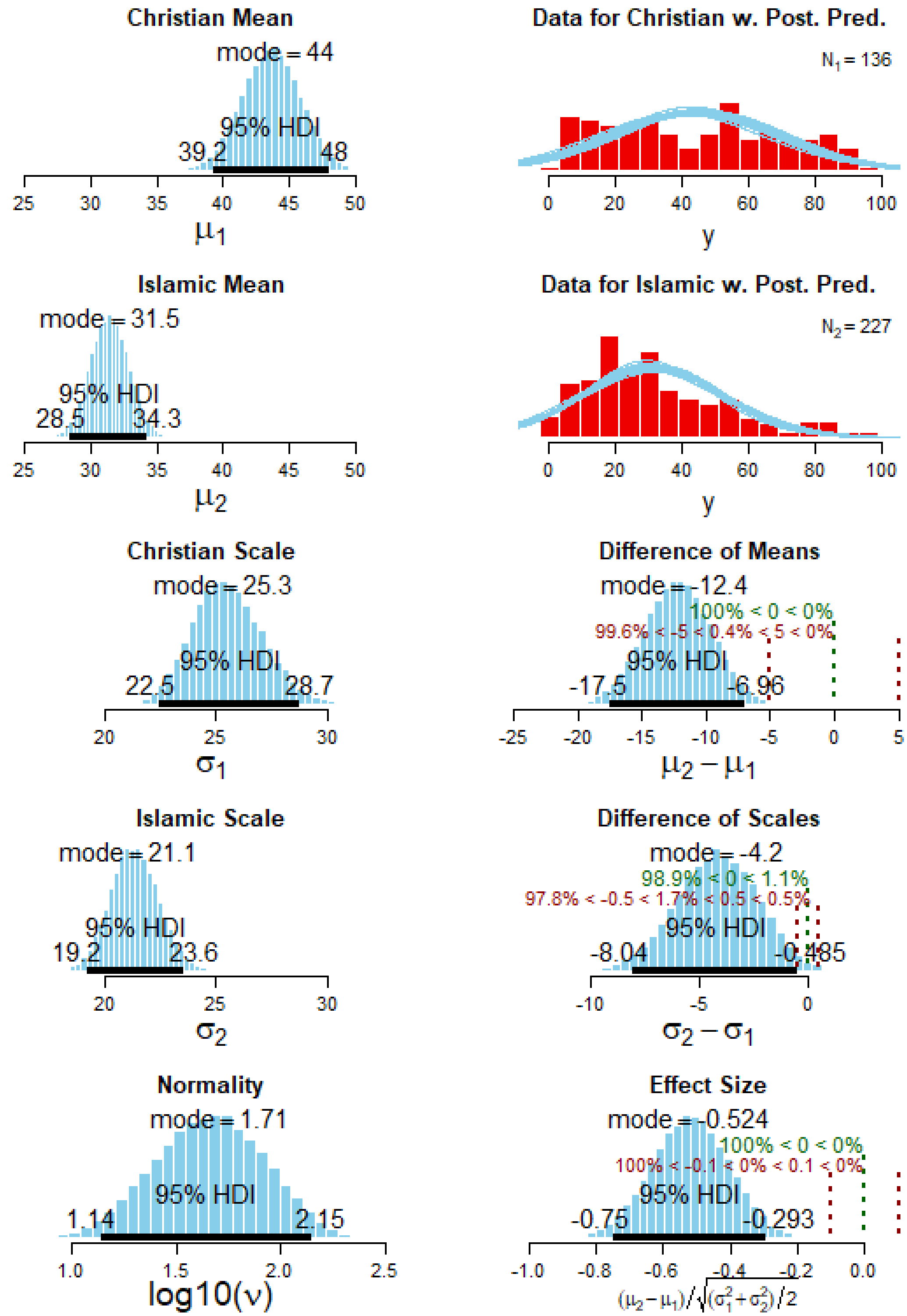


Table 9.4 - Bayesian output summary for MCMC modeled comparison of ACI scores between funerary groups.

	Mean	Median	Mode	ESS	HDIlow	HDIhigh	CompVal	PcntGtCompVal	ROPElow	ROPEhigh	PcntLtROPE	PcntInROPE	PcntGtROPE
MU[1]	43.65	43.66	43.99	30043.6	39.24	48.01	—	—	—	—	—	—	—
MU[2]	31.44	31.44	31.49	27329.6	28.52	34.31	—	—	—	—	—	—	—
MUDIFF	-12.21	-12.20	-12.42	27943.8	-17.47	-6.96	0	0	-5	5	99.63	0.37	0
SIGMA[1]	25.54	25.45	25.32	27733.5	22.47	28.74	—	—	—	—	—	—	—
SIGMA[2]	21.32	21.30	21.07	21591.6	19.17	23.56	—	—	—	—	—	—	—
SIGMADIFF	-4.21	-4.18	-4.20	28106.8	-8.04	-0.49	0	1.14	-0.5	0.5	97.78	1.70	0.52
NU	54.72	46.13	30.70	11758.2	9.21	124.02	—	—	—	—	—	—	—
LOG10(NU)	1.66	1.66	1.71	14902.4	1.14	2.15	—	—	—	—	—	—	—
EFFSZ	-0.52	-0.52	-0.52	27276	-0.75	-0.29	0	0	-0.1	0.1	99.98	0.02	0

Figure 9.6 - Comparison of proportion of well-preserved Christian skeletons (theta[1]; θ) vs. proportion of well-preserved Islamic skeletons (theta[2]; θ). Note the 95% HDI does not overlap 0.0 whatsoever when distributions are subtracted from one another.

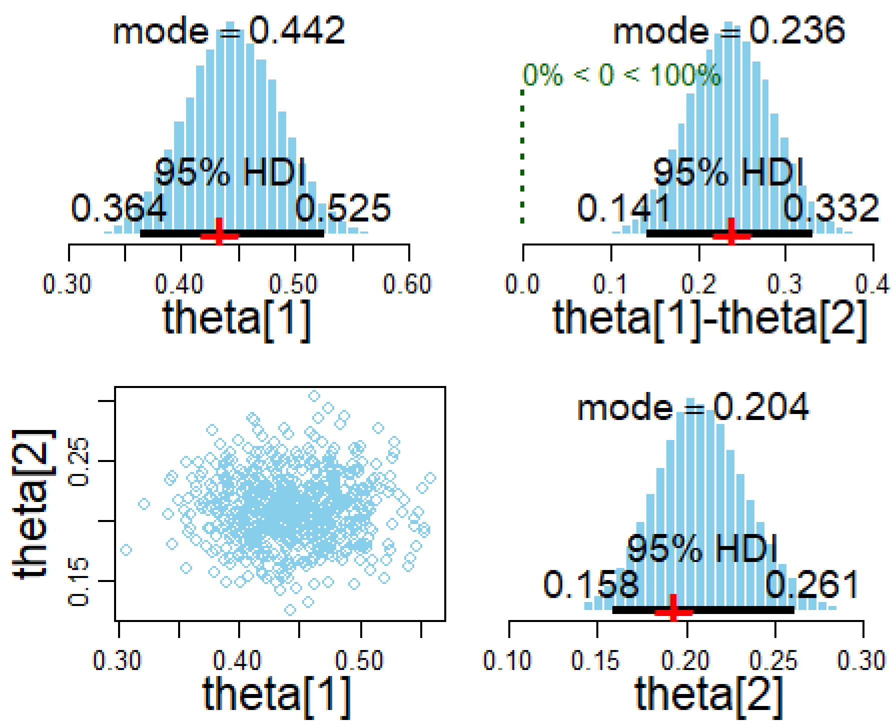


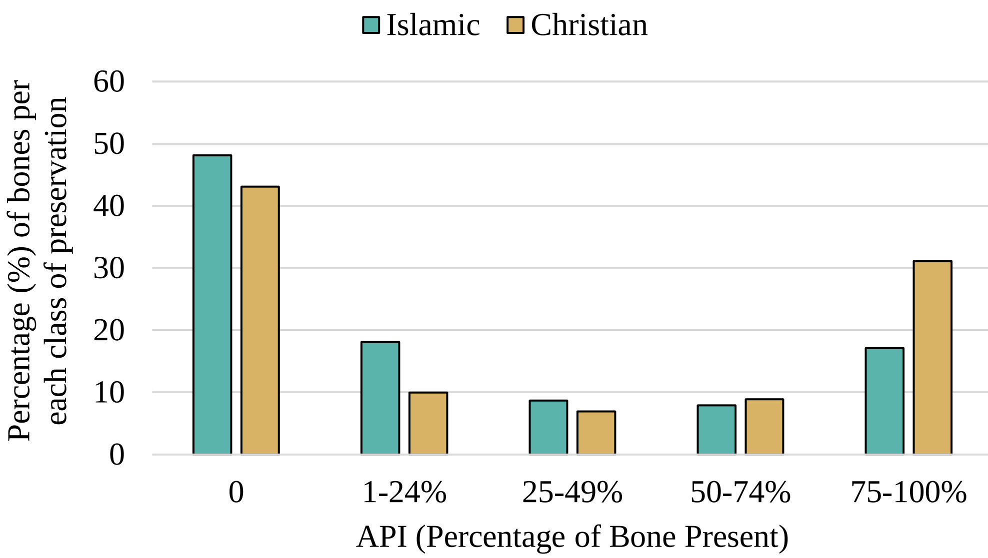
Table 9.5 - Bayesian output summary for MCMC modeled comparison of well-preserved skeletons (WPS) proportions between Christian (theta[1]) and Islamic (theta[2]) funerary groups.

	Mean	Median	Mode	ESS	HDIlow	HDIhigh	CompVal	PcntGtCompVal
THETA[1]	0.44	0.44	0.45	49066	0.3665	0.5279	—	—
THETA[2]	0.21	0.21	0.20	50000	0.1556	0.2590	—	—
THETA[1]-THETA[2]	0.24	0.24	0.24	50000	0.1422	0.3338	0	100

Preservation - Frequentist

The percentage of bones for each class of preservation by funerary group can be seen in Figure 9.7. Islamic elements showed overall increased frequencies of bones with 0-50% preservation, while Christian elements showed a higher prevalence of 50-100% preservation. The original and resulting bootstrapped distribution with shaded confidence intervals can be seen in Figure 9.8 and Table 9.6.

Figure 9.7 - Percentage of bones per each class of preservation by mortuary group at Largo Cândido dos Reis.



Bone Representation Index (BRI) values for each element by funerary group are presented Table 9.7. No significant differences in BRI values were observed when compared by side for either mortuary group (Appendix 9.53). Notably, Christian BRI values by side were equivocal, while Islamic values trended towards higher prevalence in the right side of the skeleton for every element. Given the lack of significant differences between sides, elements were pooled by side for subsequent comparison between funerary groups. BRI values were significantly higher in Islamic mandibulae and dentition compared to their Christian counterparts, while sterna, hands, femora, patellae, tibiae, fibulae, and feet were significantly higher in the Christian funerary group (Table 9.7).

Christian individuals showed a significantly higher prevalence (43.38%) of well-preserved skeletons (WPS) compared to their Islamic counterparts (19.38%, z = 4.91, $p < 0.01$) Table 9.8). A higher proportion of well-represented skeletons (WRS) was also observed in Christian individuals, though the difference was not significant. In order to further compare general anatomical preservation between the two funerary groups, Anatomical Preservation Index (API) scores were aggregated as the sum of observed scores divided by the total possible number of scores for all elements. Aggregated API values were significantly higher in Christian elements (43.74%) than Islamic ones (31.93%, z = 15.02, $p < 0.01$).

Figure 9.8 - Original distribution of Anatomical Conservation Index (ACI) scores (left) for Christian (top, yellow) and Islamic (blue, bottom) vs. Bootstrapped distribution (right, gray) and confidence intervals (shaded rectangles). Note the lack of overlap in 95% confidence intervals between Christian (top right, yellow) and Islamic (bottom right, blue) ACI values.

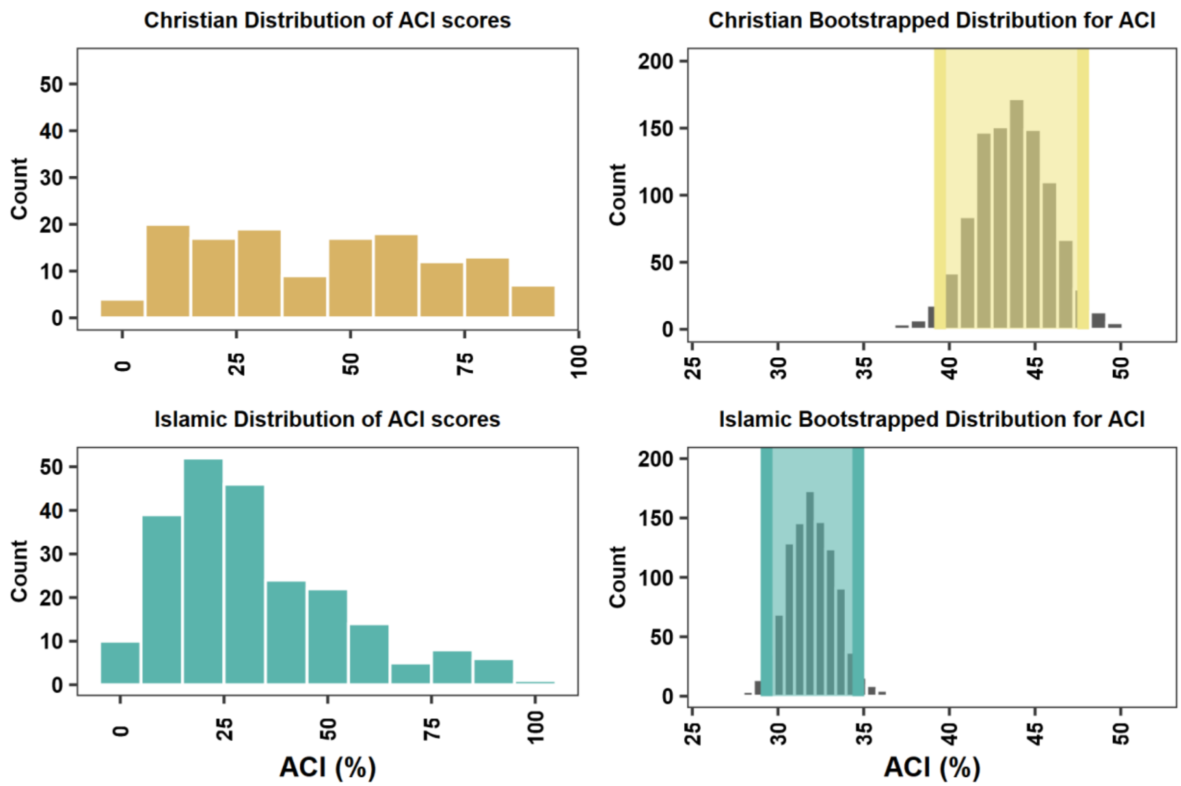


Table 9.6 - Results of Original and Bootstrapped distributions.

	Original			Bootstrapped		
Funerary group	Mean	Lower 95%	Upper 95%	Mean	Lower 95%	Upper 95%
Christian	43.7	39.4	48.0	43.7	39.5	47.8
Islamic	31.9	29.1	34.8	31.9	29.2	34.9

Figure 9.9 - Anatomical Conservation Index (ACI) aggregate values by funerary group at Largo Cândido dos Reis.

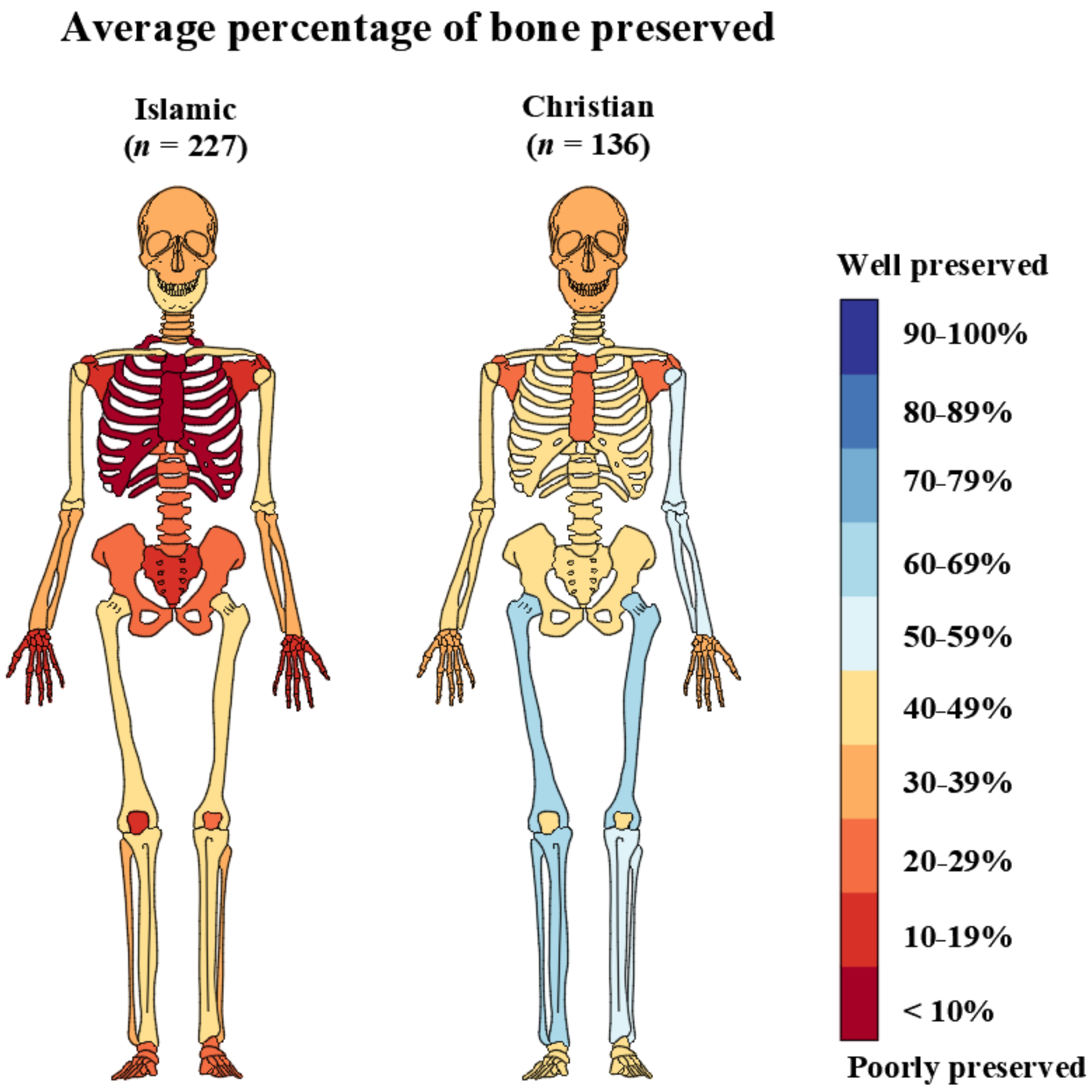


Figure 9.10 - Aggregate Bone Representation Values (BRI) by funerary group at Largo Cândido dos Reis.

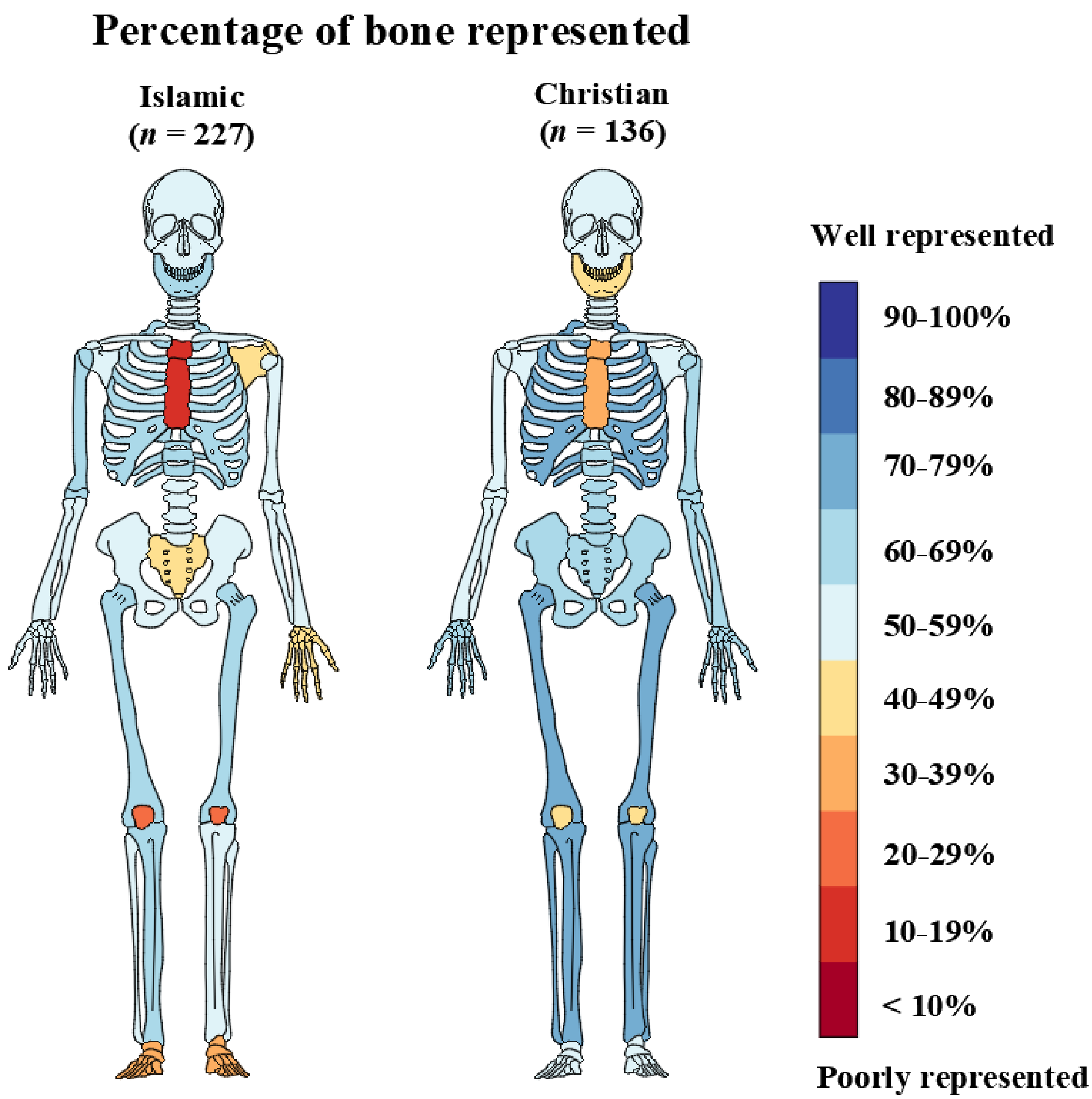


Table 9.7 - Distribution of Bone Representation Index (BRI) values by element and religious group, sides pooled.

Element	Christian	Islamic	*z*	*p*-value
Crania	56.34	55.34	0.53	0.60
Mandibulae	46.32	61.67	-2.85	0.01*
Teeth	49.26	61.67	-2.31	0.02*
Cervical vertebrae	52.94	59.91	-1.30	0.19
Thoracic vertebrae	66.18	64.32	0.36	0.72
Lumbar vertebrae	62.50	52.86	1.79	0.07
Sterna	39.71	16.74	4.87	0.01*
Ribs	73.53	68.72	0.97	0.33
Sacrum	62.50	49.34	2.44	0.10
Ossa Coxae	63.24	55.95	1.93	0.05
Claviculae	51.84	55.07	-0.85	0.40
Scapulae	53.68	50.88	0.73	0.47
Humerii	59.93	63.44	-0.94	0.35
Radii	61.40	54.41	1.84	0.07
Ulnae	61.03	54.85	1.63	0.10
Hands	65.80	47.80	4.72	0.01*
Femora	72.43	63.88	2.37	0.02*
Patellae	47.06	23.79	6.48	0.01*
Tibiae	72.43	60.57	3.24	0.01*
Fibulae	71.32	58.37	3.50	0.01*
Feet	56.86	37.52	8.79	0.01*

Table 9.8 - Frequency of preservation and representation indices by funerary group at Largo Cândido dos Reis.

	Christian			Islamic				
Index	*N*	Total	%	*N*	Total	%	Z	*p*-value
ACI[a]	2617	5983	43.74	3189	9987	31.93	15.02	0.01*
WPS[b]	59	136	43.38	44	227	19.38	4.91	0.01*
WRS[c]	79	136	58.09	112	227	49.34	1.62	0.11

[a] Anatomical Conservation Index (ACI) aggregate, where *N* refers to the sum of observed preservation scores for all elements and *Total* refers the sum of total possible preservation scores.
[b] Well-Preserved Skeletons (WPS), where *N* refers to the number of individuals with more than 50% of their elements well-preserved and *Total* refers to total number of individuals analyzed.
[c] Well-Represented Skeletons (WRS), where *N* refers to the number of individuals with more than 50% of their skeleton represented and *Total* refers to total number of individuals analyzed.

Age and Sex

Results of the binary logistic regression with individuals of indeterminate age included are presented in Tables 9.9. The model test resulted in a χ^2 = 63.31 with an accompanying p-value < 0.001, while the Lack of Fit test resulted in a -LogLikelihood of 7.69, a $\chi^2 = 15.37$, and a p-value of 0.16. The misclassification rate was 27.27% and the Receiver Operating Characteristic (ROC) resulted in an area under the curve (AUC) of 0.76.

Effect Likelihood Ratio tests (Appendix 9.55) showcase that both Funerary Group ($\chi^2 = 11.16$, $p < 0.01$) and Age ($\chi^2 = 27.07$, $p < 0.01$) are significant predictors for being well-preserved, while sex was not a significant predictor ($\chi^2 = 1.35$, $p = 0.51$). Odds ratios showed that Christian skeletal remains showed a 240% increase in odds of being well-preserved compared to their Islamic counterparts ($p < 0.01$; Table 9.9). No significant differences were observed between sexes nor either sex versus indeterminates. For individuals where age could be estimated, there were no significant differences in WPS outcome and age category, though notably skeletons in the older age category (50+ years) had a 20% higher odds of being well-preserved compared to the younger age category (18-29 years). All age categories showed significantly higher odds of being well preserved compared to indeterminate individuals.

Table 9.9 - Odds Ratio results for logistic regression of predictors on Well-Preserved Skeletons (WPS) at Largo Cândido dos Reis, indeterminates included.

Predictor	Comparison	OR point estimate	*p*-value (> χ^2)	OR 95% CI
Funerary group				
	Christian vs. Islamic	2.39	< 0.01*	1.43-3.99
Sex				
	F vs. M	0.92	0.76	0.53-1.59
	F vs. Indet.	1.53	0.37	0.60-3.89
	M vs. Indet	1.67	0.26	0.69-4.05
Age				
	18-29 vs. 30-49	1.01	0.98	0.40-2.53
	18-29 vs. 50+	0.80	0.64	0.32-2.00
	30-49 vs. 50+	0.80	0.55	0.37-1.69
	18-29 vs. Indet.	3.77	< 0.01*	1.57-9.01
	30-49 vs. Indet.	3.73	< 0.01*	1.84-7.53
	50+ vs. Indet.	4.69	< 0.01*	2.36-9.30

To further examine the relationship between funerary category and age, a two-way (factorial) ANOVA using funerary group (Christian vs. Islamic) and age category (18-29 years, 30-49 years, 50+ years, Indet.) on API was performed. Results showcase that significant differences are observed only in relation to indeterminate individuals (Table 9.10).

Table 9.10 - Two-way ANOVA results for age and funerary group on Anatomical Conservation Index (ACI) score at Largo Cândido dos Reis.

Christian, 18-29 yrs	***Christian, 30-49 yrs***	***Christian, 50+ yrs***	***Christian, Indet.***	***Islamic, 18-29 yrs***	***Islamic, 30-49 yrs***	***Islamic, 50+ yrs***	***Islamic, Indet.***
Christian, 18-29 yrs	-5.36[a] (6.21)[b] -17.56, 6.85[c] 0.39[d]	-8.84 (6.48) -21.59, 3.91 0.17	10.91 (5.71) -0.33, 22.14 0.06	-12.21 (7.84) -27.62, 3.20 0.12	-0.05 (6.65) -13.12, 13.03 0.99	-4.34 (6.17) -16.45, 7.80 0.48	21.45 (5.31) 11.02, 31.88 < 0.01*
	Christian, 30-49 yrs	-3.45 (5.45) -14.2, 7.24 0.52	16.27 (4.50) 7.40, 25.12 < 0.01*	-6.85 (7.01) -20.63, 6.93 0.33	5.31 (5.65) -5.78, 16.41 0.35	1.01 (5.08) -8.98, 11.00 0.84	26.81 (3.98) 18.98, 34.63 < 0.01*
		Christian, 50+ yrs	19.74 (4.88) 10.14, 29.34 < 0.01*	-3.37 (7.25) -17.64, 10.89 0.64	8.79 (5.95) -2.91, 20.49 0.14	4.49 (5.41) -6.16, 15.14 0.41	30.29 (4.40) 21.64, 38.94 < 0.01*
			Christian, Indet.	-23.12 (6.57) -36.04, -10.19 < 0.01*	-10.95 (5.10) -20.98, -0.93 0.03*	-15.25 (4.46) -24.03, -6.47 < 0.01*	10.55 (3.15) 4.35, 16.74 < 0.01*
				Islamic, 18-29 yrs	12.16 (7.40) -2.40, 26.72 0.10	7.87 (6.98) -5.86, 21.59 0.26	33.66 (6.22) 21.42, 45.90 < 0.01*
					Islamic, 30-49 yrs	-4.30 (5.61) -15.33, 6.74 0.44	21.50 (4.64) 12.37, 30.62 < 0.01*
						Islamic, 50+ yrs	25.80 (3.93) 18.07, 33.52 < 0.01*

[a] $\bar{x}_i$-$\bar{x}_j$
[b] Std. error of difference
[c] Lower Confidence Level, Upper Confidence Level
[d] *p*-Value
[*] Statistically significant at the α = 0.05 level

Table 9.11 - Odds Ratio results for logistic regression of predictors on Well-Preserved Skeletons (WPS) at Largo Cândido dos Reis, indeterminates excluded.

Predictor	Comparison	OR point estimate	*p*-value (> χ^2)	OR 95% CI
Funerary group				
	Christian vs. Islamic	1.38	0.34	0.71-2.69
Sex				
	F vs. M	0.96	0.90	0.49-1.88
Age				
	18-29 vs. 30-49	1.01	0.99	0.41-2.48
	18-29 vs. 50+	0.88	0.79	0.36-2.17
	30-49 vs. 50+	0.88	0.73	0.42-1.85

In order to evaluate these relationships without indeterminate individuals, subsequent tests were re-run excluding all individuals with indeterminate Sex or Age (n = 218). Logistic regression with indeterminates excluded showed no significant result for the Whole Model test (χ^2 = 1.00, p = 0.91), and an ROC-AUC value of 0.545. No significant effect was observed for Effect Likelihood Ratio tests (Appendix 9.56) nor Odds Ratios (Table 9.11). Funerary groups showed a significant difference in mean API values when indeterminates were included (*t* = -4.49, p < 0.01), but not when indeterminates were excluded (*t* = -0.27, p = 0.79; Table 9.12).

Table 9.12 - Comparison of mean Anatomical Preservation Index (API) values by funerary group with indeterminates included and excluded at Largo Cândido dos Reis.

	Christian		Islamic			
Category	*N*	$\bar{x}$ (s)	N	$\bar{x}$ (s)	*t*	*p*
indeterminates included	136	43.73 (25.59)	227	31.93 (21.82)	-4.49	0.01*
indeterminates excluded	76	40.90 (24.74)	69	49.84 (23.56)	-0.27	0.79

Similarly, indeterminates showed a significantly lower mean API value when compared to their Male and Female counterparts (*F* = 20.08, p < 0.01), but no significant difference was observed between sexes when indeterminates were included or excluded (Table 9.13). Finally, a comparison of mean ACI values by age categories using a one-way ANOVA showed a significant difference when indeterminates were included (*F* = 36.85, p < 0.01), while no age difference was observed between groups where age could be estimated (Table 9.14).

Table 9.13 - Comparison of mean Anatomical Preservation Index (API) values by Sex with indeterminates included and excluded at Largo Cândido dos Reis.

	Females		Males		Indet.			
Category	N	$\bar{x}$ (s.d.)	N	$\bar{x}$ (s.d.)	N	$\bar{x}$ (s.d.)	*F/t*	*p*
indeterminates included	112	38.95 (22.54)	175	41.04 (25.22)	76	21.73 (16.31)	20.08	< 0.01*
indeterminates excluded	58	46.83 (23.16)	87	52.78 (24.56)	-	-	1.48	0.14

Table 9.14 - Comparison of mean Anatomical Preservation Index (API) values by Age category with indeterminates included and excluded at Largo Cândido dos Reis.

	18-29 years		30-49 years		50+ years		Indet.			
Category	*N*	$\bar{x}$ (s.d.)	N	$\bar{x}$ (s.d.)	N	$\bar{x}$ (s.d.)	N	$\bar{x}$ (s.d.)	*F*	*p*
indeterminates included	29	50.61 (27.25)	56	48.73 (23.82)	60	51.85 (23.07)	218	27.01 (18.78)	36.85	< 0.01*
indeterminates excluded	29	50.61 (27.25)	56	48.73 (23.82)	60	51.85 (23.07)	-	-	0.24	0.79

Given the relation of indeterminate individuals and mortuary group, binary logistic regression was conducted where the response variable was an individual of indeterminate Age, and predictors were entered as Funerary group (Christian vs. Islamic), Ossa Coxae ACI (%), Skull ACI (%), Total ACI (%), Teeth ACI (%), WRS (Yes or No), and WPS (Yes or No). Results showcase that Mortuary Group and Ossa Coxae were significant predictors of whether an individual was of indeterminate Age. Odds ratios showcase that Islamic individuals were more than 300% higher odds of being an individual of indeterminate Age compared to their Christian counterparts. Lower Ossa Coxae ACI was significantly associated with higher likelihood of being and individual of indeterminate Age (Odds point estimate = 7.65, 95% CI = 2.11-27.63).

To further investigate the relationship between missing sex/age categories and its effect on preservation, missing parameters were systematically imputed (using single imputation) in a stepwise fashion, where indeterminate sex was imputed as Female, and Age as 18-29 years, then 30-49 years, and so on (Appendix 9.57). Results of the binomial logistic regression show that regardless of imputation, funerary group is a significant predictor, with Christians exhibiting between 262 – 299% increased odds of having a well-preserved skeleton compared to their Islamic counterparts. Sex was not found to be a significant predictor of preservation, even when imputed, across any comparison. When age categories were imputed, significant differences were observed for each comparison against other age cohorts. Results of the Effect Likelihood Ratio tests also confirm that while age was a significant predictor, significance was only reached when comparing the imputed age category to other age cohorts (Appendix 9.58). To put another way, age was not a significant predictor of preservation *except* for in cases where the age category was imputed, where it was found to have an inverse relationship with preservation. Finally, the results from the multiple imputation can be seen in Table 9.15, which illustrate that only funerary group was a significant predictor of being a well-preserved skeleton.

Table 9.15 – Pooled results of binomial logistic regression on well-preserved skeleton (WPS), using multiple imputation datasets.

Term	Estimate	Std. Error	Statistic	df	*p*-value
Intercept	-0.36	0.35	-1.00	150.78	0.32
Sex (M)	0.09	0.27	0.35	172.44	0.73
Age (30-49)	-0.01	0.39	-0.03	52.02	0.98
Age (50+)	0.10	0.38	0.27	60.69	0.79
Mortuary (Islamic)	-1.17	0.24	-4.77	355.10	< 0.01*

Surface changers: weathering and erosion

The majority of individuals analyzed (n = 280, 77.78%) from Largo Cândido dos Reis showed no signs of weathering (Table 9.16). What weathering scores were present were relatively minor, with the majority showcasing signs of minor surface cracking. Given issues in sample size and therefore expected counts in ordinal severity scores for weathering, weathering scores were pooled by religious group to examine inter-funerary trends. Weathering was significantly more prevalent in Christian individuals (n = 42, 31.82%) than Islamic ones (n = 38, 16.67%). Notably, only one Islamic individual exhibited a score other than 1, while n = 4 Christian individuals showed scores of increased weathering.

Table 9.16 - Distribution of weathering scores by funerary group at Largo Cândido dos Reis (using Yates correction).

Category	*Islamic* N (%)	*Christian* N (%)	X^2	*p*
No weathering	190 (83.33)	90 (68.18)	-	-
Weathering (total)	38 (16.67)	42 (31.82)	10.25	0.00*
1	37 (16.23)	38 (28.79)	-	-
2	1 (0.44)	3 (2.27)	-	-
3	0 (0.00)	1 (0.76)	-	-

Erosion was highly prevalent at Largo Cândido dos Reis, with 96% of individuals analyzed (*n* = 345) showcasing some degree of erosion (Table _ - Distribution of erosion scores by funerary group). Islamic individuals showcased overall higher prevalence of pooled erosion scores than their Christian counterparts. Distribution of Christian erosion scores was skewed towards lower scores while Islamic erosion scores were skewed higher (Figure _ - Distribution of erosion scores by funerary group). Notably, no Christian individuals showcased signs of extreme erosion (5^{+}).

Table 9.17 - Distribution of erosion scores by funerary group at Largo Cândido dos Reis (using Yates correction).

Category	*Islamic* N (%)	*Christian* N (%)	X^2	*p*-value
No erosion	3 (1.32)	11 (8.40)	-	-
Erosion (total)	225 (98.68)	120 (91.6)	9.32	0.00*
1	23 (10.09)	43 (32.82)	27.17	0.00*
2	36 (15.79)	34 (25.95)	4.85	0.03*
3	62 (27.19)	27 (20.61)	1.60	0.21
4	65 (28.51)	11 (8.40)	18.98	0.00*
5	31 (13.60)	5 (3.82)	7.77	0.00*
5^{+}	8 (3.51)	0 (0.00)	-	0.03*

Invertebrate activity and archaeomalacology

Snail shells were significantly more prevalent in Islamic graves (n = 100; 32.79%) than Christian (n = 32; 14.95%) ones (z = -4.59, p < 0.01). Shell size index was also significantly larger in Islamic graves than Christian ones (Table 9.18; Figure 9.11). Results from the principal component analysis and morphological comparison suggest a minimum of seven species present in the burial assemblage (Figure 9.12-9.13; Table 9.19; Appendix 9.66-9.70).

Table 9.18 - Mean shell size by funerary group.

	Islamic		Christian			
	N	Mean (sd)	N	Mean (sd)	*t*	p
Shell H*GW/100	833	1.20 (0.71)	181	0.71 (0.73)	8.18	< 0.01

Figure 9.11 - Box and whisker plot of shell specimens (scatter points) and size index and funerary group.

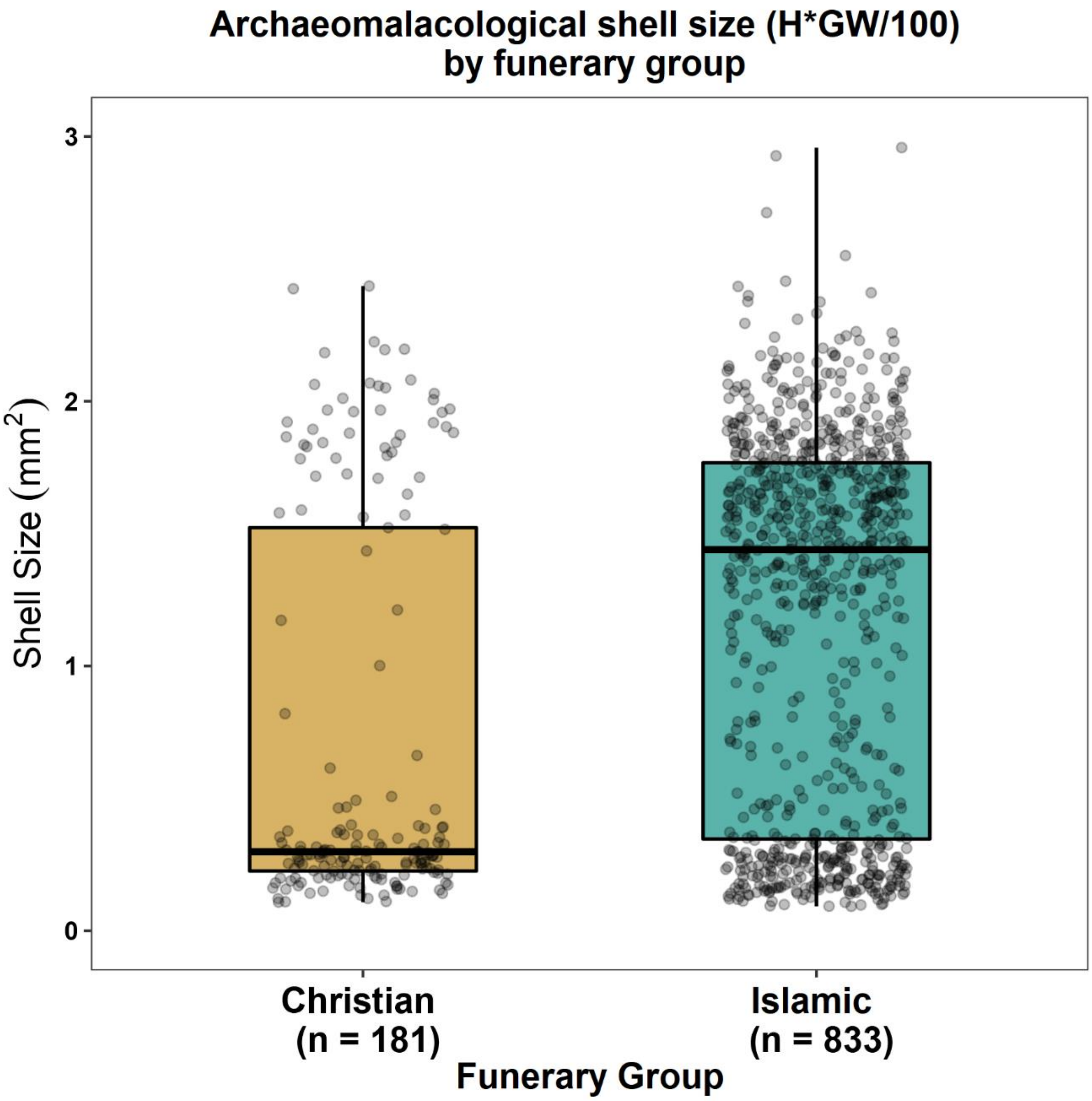


Figure 9.12 - Biplot of shell height and width by sample individual and funerary group for snail shells from Largo Cândido dos Reis.

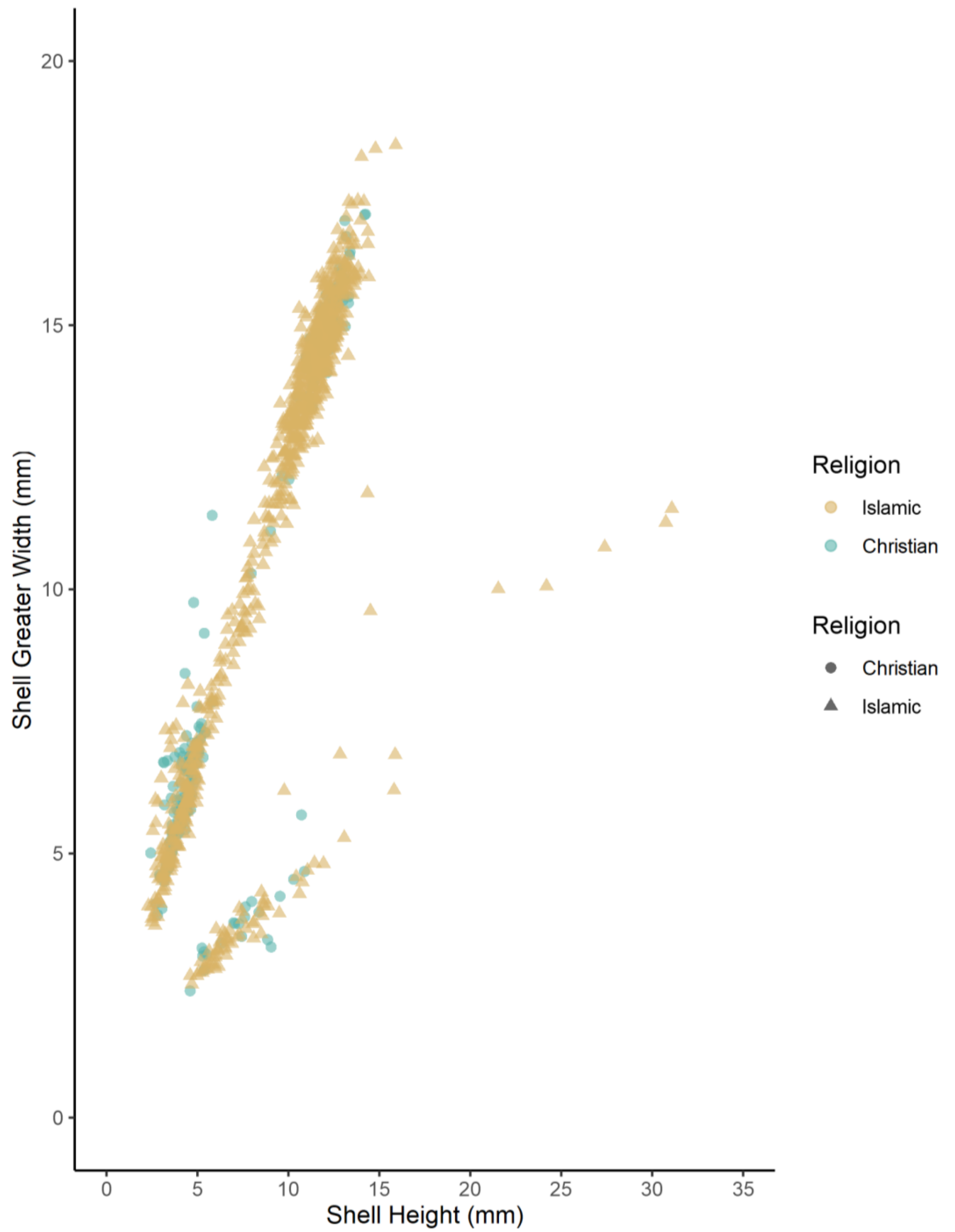


Figure 9.13 - PCA biplot of biometric variables by sample individual for snail shells from Largo Cândido dos Reis.

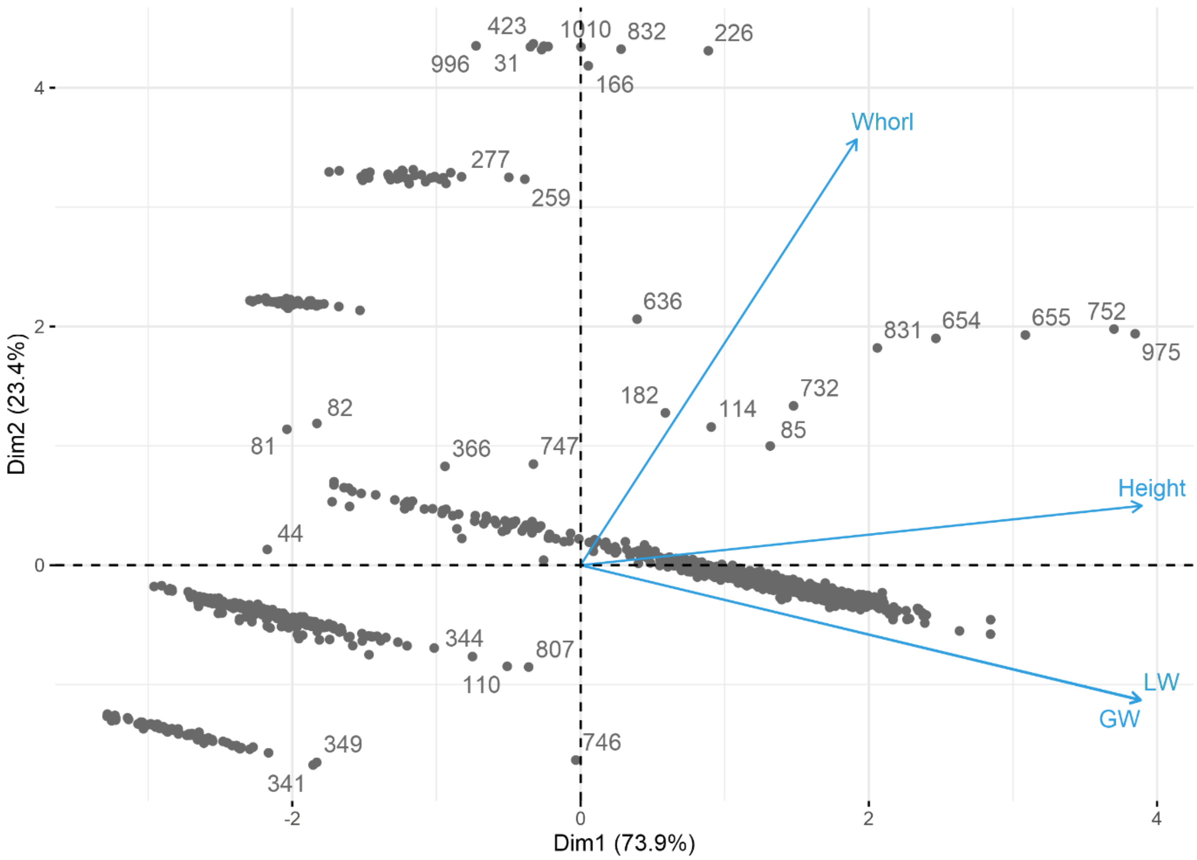


Table 9.19 - Proposed list of possible genera and species of archaeomalacological remains from Largo Cândido dos Reis.

Genus	Species	Habitat	Reference
Theba	*pisana*	Dry, exposed sites, usually near the sea, and frequently on dunes (almost exclusively so at the N. of range). Sits out on plant stems in dry weather.	Kerney and Cameron 1994, 202-203
Cepea	*nemoralis*	In woods, usually in herbaceous vegetation of lower strata, in gardens and sometimes under rocks.	iberus shells database
Candidula	*intersecta*	Dry and open sites, especially dunes and grassland. Buries in fine weather, when hard to find.	Kerney and Cameron 1994, 177
Oxychilus	*cellarius*	Moist, shaded places of all kinds: woods, rocks, gardens, under rubbish; frequently in caves.	Kerney and Cameron 1994, 124
Ferussacia	*folliculus*	Generally found under rocks where it is more humid, preferably in calcareous terrain and in litoral zones	iberus shells database
Ceciliodes	*acicula*	Subterranean, living well below the surface among plant roots or in the crevices of rocks, mostly on calcareous soils; more commonly found dead in flood rubbish, or in ant hills.	Kerney and Cameron 1994, 149
Rumina	*decollata*	Dry open places: waste ground, scrub, grassy screes; mostly on calcareous soils	Kerney and Cameron 1994, 151

Discussion

Mortuary Archaeology

Lack of any *lahd* and *šaqq* graves is interesting, though not entirely unsurprising. All Islamic graves at Largo Cândido dos Reis, and indeed in Santarém conform to a *darih* typology of a simple pit with no side-step or niches. While *Maliki* jurisprudence emphasized *lahd* and *šaqq* burial rites, it's clear that in Santarém, just as in the major metropolis of Córdoba (Lozano Cosano 2016, 109), *darih*-style tombs were preferentially constructed and emphasized. Islamic graves were considerably narrow and shallow, as has been observed in other Iberian *maqabir* (Chávet et al. 2006; Ruiz Taboada 2015).

The only burial that showed indisputable evidence of a covering was Ent. 577, with the outline of the grave encircled by ceramic *telhas* (Appendix 9.7-9.8). While this tomb style has been observed in numerous other portions of Iberia (Chávet et al. 2006; Fernández Guirado 1995; Gonzaga 2018a; Peral Bejarano 1995), it is curious that only one case is observed at the site. Similar tomb typologies have been uncovered at the site of Capelo Ivens and Travessa do Froes (S. CI90), but was discovered exclusively in sub-adult burials. In the case of Largo Cândido dos Reis, it's possible that landscaping and grading of this site has removed many other tile-covered burials (Matias 2008b), but it is difficult to confirm this. The relation between burial fill and coverings in Islamic contexts is a strong one, as grave fill usually includes materials employed in coverings (Lozano Cosano 2016, 103). Given the general paucity of artifacts (n = 1), ceramic sherds (n = 13), or cobbles found in Islamic graves, it is likely that nearly all graves lacked any covering. What few ceramic sherds and stones have been found in Islamic graves were likely included for purposes of propping or supporting the body (León Muñoz 2008, 43; Matias 2008b) rather than remnants of a covering. This is further supported by the fact that these sherds lack the characteristic undulations, color, texture, and cross-section of *telhas*, suggesting that they likely weren't remnants of coverings. Another possibility is that tile coverings were re-used by subsequent inhabitants of the city rather than removed through landscaping. The presence of Islamic graves with coverings of reused Roman *tegulae* has been observed both within Andalusia (Fernández Guirado 1995; Peral Bejarano 1995), and the Portuguese sites of Conímbriga, Condeixa-a-velha (Alarcão et al. 1977; Farinha 2012), Rossio do Carmo, Mértola (Candón Morales 2001; Torres et al. 1996) and Cerro da vila, Loulé (Matos 1971; Teichner 2006). Given the apparent reuse of construction materials for funerary purposes, it is not impossible that the tiles could be reused once again for construction materials. Given the absence of *telha* sherds in Islamic burial contexts at the site, this could suggest that once-present *telhas* were deliberately removed rather than destroyed. However, similar to the aforementioned landscaping hypothesis, it is difficult to confirm this with the present data.

The lack of grave goods in Islamic burials is not surprising given the long tradition of simple inhumations in order to level hierarchies in death (Halevi 2007; López Quiroga 2010). While grave goods have been found throughout Islamic graves in medieval Spain (Casal 2003, 31–33), the case of Ent. 173 with a pot found between the femora is interesting (Appendix 9.5-9.6). It's possible that the inclusion of a vessel such as a pot serves as a symbolic object for containing water (Lozano Cosano 2016, 105). Issues of thirst and parching are occasionally referenced in Islamic funerary rites (Abdesselem 2008; Leisten 1990), and given the additional importance of hydration and water networks in proximity to *maqabir* (León Muñoz 2008; Lozano Cosano 2016; Olcina Doménech et al. 2008; Serrano Peña et al. 2000), the inclusion of water to combat thirst is one possible explanation. Another possible explanation is that of eschatological passage from the world of the living to the afterlife. Peral (1995, 24) suggests that the inclusion of grave goods may have helped bring individuals closer to God and afterlife, particularly those who may have faced difficulty in entering paradise. Others have similarly suggested the symbolic purpose of grave goods in Islamic contexts, possibly in almsgiving (Fierro 2000, 181–183; León Muñoz 2008, 45).

Christian burials appeared more varied in their tomb construction but adhered to general churchyard construction of anthropomorphic tombs. Similarly, a distinct lack of grave goods was observed, which could support the notion that the medieval laity simply did not emphasize the importance of grave goods (O'Sullivan 2013b). The superficial relief observed in some burials (e.g., Ent. 383; Appendix 9.9-9.10) suggests a lid covering was employed, either stone, wood, or some other material. Given the position of the head within an anthropomorphic niche, paired with the distinct lack of decomposition in open space (Duday et al. 2006) suggests that coffins were not employed at the site, or at least, not a significant number of those buried and recovered from the excavation.

Distributions of burial metrics both within and between funerary groups are noteworthy. Lack of significant differences in burial length between Christian and Islamic graves is not entirely surprising, as grave length dimensions are primarily an effect of individual height. Graves were constructed long enough to accommodate the individual in an extended position, with additional space (~10 cm on average) on either side of the head and feet. Burial width distributions differed significantly between the two funerary groups. Christian graves were variable in burial width dimensions, ranging from 26 – 99 cm with 95% of the variation falling between 33 – 83 cm. Islamic graves were comparatively much narrower in variation, ranging between 25 – 68 cm with 96% of the variation falling between 24.5 and 52.5 cm. Finally, in terms of burial depth, Christians exhibited significantly deeper burials with more variation compared to the shallower Islamic graves. Maliki jurisprudence did appear to advocate for burial depths sufficient enough to protect from scavengers (Chalmeta Gendrón, 1968; Fierro 200, p. 117), but shallow enough to hear the call to prayer (Insoll, 1999) or cemetery-goers (Fortier 1997, 2010, p. 308). Yet, there are some other sources such as the *Fiqh us-Sunnah* which advocates for digging a grave "equal to the height of an average man",[17] though this notably comes from hadith relating to the battle of Uhud (625 C.E.) with numerous dead (Saabiq 1991). Burial width appears to have been debated, typically advocating for narrow tombs in order to avoid post-depositional movements of the body, and maintain the body in right decubitus position facing Mecca (Garcia Gómez & Lévi-Provençal 1998, p. 149). Altogether, the observed variation and spread of the burial metrics suggest Islamic burials, at least in terms of width and depth, were in fact highly prescribed.

Preservation

Age and Sex Considerations

Lack of significant age-related differences in mean Anatomical Preservation Index (API) values suggest that the relationship between age-at-death and conservation index does not have a straightforward relationship. The inclusion of indeterminates subsequently showed significant higher mean API values in all estimated age-at-death groups (18-29, 30-40, 50+ years) compared to the indeterminates. It is possible that many of the indeterminate individuals were of an older age category, whose lower bone mass could ostensibly result in higher fragility and friability and lower API values. However, the extensive number of individuals (n = 218) would suggest, from a demographic standpoint, that age alone is likely not responsible for an individual's preservation values. Surprisingly, the older age category (50+ years) was associated with an increased odds (20%) of being well-preserved compared to the youngest age category (18-29 years), and while the difference was not significant, it further suggests that increased age alone is not a significant predictor of lower preservation. Comparisons of mean API values showed similar results when compared by sex, whereby individuals whose sex could be estimated exhibited markedly higher API values compared to indeterminate individuals. Yet, when indeterminates were excluded and mean API values were compared by sex, no significant differences were found.

Unsurprisingly, these results taken together suggest that the link between demographic indicators, as estimated by skeletal morphological indicators (e.g. pelvic girdle), and preservation is a strong one, to where individuals that are poorly preserved are more likely to be indeterminate due to issues in assessing age and sex. To put another way, demographic indicators were observed only in cases where the skeletal elements from which these indicators are estimated are well preserved. In the case of Largo Cândido dos Reis, sex was missing in 20.90% (76/363) and

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age was missing in 60.05% (218/363) of individuals analyzed. The pattern is likely monotone, in that individuals whose sex could not be estimated could not have their age estimated as well. This is likely due to the varying skeletal tissues employed that could help discern sex, such as the talus or various cranial features (Matias 2008a), which have larger densities of cortical bone, whereas age-discerning features such as the pelvic girdle had relatively little cortical bone and were often highly fragmentary. The result is individuals who could be assigned a sex, but not an age category. These results seem to hold true in the case of the binomial logistic regression where being an individual of indeterminate age was coded as the response variable, as well as the one-way, two-way, and three-way factorial ANOVA tests. Mortuary group (Islamic) and lower Ossa Coxae Anatomical Conservation Index (ACI) values were the only significant predictors, with Islamic individuals showcasing a 300% increased odds of being indeterminate compared to their Christian counterparts, and lower Ossa Coxae ACI values associated with increased likelihood (765%) of being an individual of indeterminate age. In the latter case, it once again suggests that preservation of the ossa coxae has a significant effect on whether an individual's estimable demography. Jackes (2000) illustrates how pubic symphyses were observable in only 50% of individuals with known age-at-death individuals from Spitalfields. Additionally, she notes how excavation techniques likely affect the recovery bias for pubic symphyses, highlighting the Portuguese site of Cabeço da Arruda where only one pubic symphysis was recovered from a total of 70 individuals. While the relationship between preservation, taphonomy, and estimable demography is not surprising, these results suggest that from a funerary taphonomic perspective, funerary treatment, in this case the Islamic funerary tradition, certainly can have an impact on the bioarchaeological assessment of paleodemographic variables.

From a statistical standpoint, the data would likely best be considered as missing not at random (MNAR), where missingness (in this case, demographic indicators) is built into the data (Little et al. 1987; Rubin 1976). If data is demonstrated to be missing due to random chance, either by missing completely at random (MCAR) or missing at random (MAR) and represents a relatively minor proportion of the entire dataset (e.g. less than 5%), then missingness may be able to be ignored (Little et al. 2002, 119). When missingness is more rampant (e.g. when 40% of the data is missing), results can be heavily biased (Cole 2008), though notably there is no global missing value rate (Vach 1994, 113). Traditionally, bioarchaeologists employ a complete-case analysis approach, whereby missing values (e.g. Sex, Age) are treated with either pairwise or listwise deletion. However, Little and colleagues (2012, 1358) caution against complete-case analysis, as it is often unrealistic. Stuart *et al* (2009) illustrate how looking at cases with only complete data can result in more issues than solutions, such as contradictory findings due to biasing as well as reduction in statistical power. In a more extreme stance, Enders (2010, 39) argues complete case analysis causes far more harm than good, such that both listwise deletion and pairwise should only be employed when the number of cases with missing data is a small percentage of the overall sample (< 2-5%) and when the data is demonstrated to not be MAR.

A complete-case analysis approach whereby data is pairwise or listwise deleted is likely not the best option of interpretation in the present study, given the high rates of missingness and the missingness being built directly into the data (Graham 2009). Effectively, the missingness is not "ignorable" (Allison 2001; Graham 2009; Graham 2012). This is likely bolstered by the fact that there were no significant differences in preservation between estimable age-groups or between sexes, which otherwise could be seen as lurking variables in influencing preservation indices. Indeed, tests run including and excluding indeterminates, regardless of funerary group, showcased differing results, whereby no significant differences are observed between funerary groups when indeterminates were excluded, but the opposite was true when indeterminates were included. Given the relationship between Islamic funerary treatment and indeterminacy in sex or age, excluding indeterminates not only biases the results and interpretations, but from a funerary taphonomic perspective, also excludes individuals of a certain funerary group by virtue of the way they buried their dead.

Results of the single imputation of demographic variables for indeterminates seem to support this conclusion. The observation that imputed age categories were a significant predictor of preservation makes intuitive sense, as indeterminate individuals tend to be more poorly preserved, and when imputed with an age category, decrease the overall likelihood of being better preserved for that imputed age category. These support previous findings that age was a significant predictor ($\chi^2 = 27.07$, $p < 0.01$) of preservation, but only in cases where indeterminates were included and where individuals of indeterminate age were compared with estimable age cohorts. The lack of sex differences in the binomial logistic regression when indeterminates were excluded ($\chi^2 = 0.02$, $p = 0.80$), included ($\chi^2 = 1.35$, $p = 0.51$), or imputed ($p > 0.05$ in all six cases) altogether suggests sex was not a significant predictor of preservation at Largo Cândido dos Reis. Finally, funerary group was found to be significant predictor of preservation regardless of whether indeterminates were excluded (Table 9.9), included (9.11), or imputed, with Christians showing higher likelihood of being better preserved than their Islamic counterparts in every comparison. Altogether, this suggests that, at least in the case of Largo Cândido dos Reis, funerary treatment of the body likely even more so than age, is highly linked with preservation outcomes.

Inter- and Intra-Funerary Comparisons

While there were no significant differences in BRI values by side for either mortuary group, it is curious that Islamic individuals exhibited a clear lateralization bias with higher BRI values for all right elements. Given that Islamic individuals were buried on their right side and in relatively shallow graves (mean = 32.08 cm depth), it is possible that the left side experienced higher rates of fragmentation, friability, or intrusive destruction as a result of construction, landscaping, root inundation, and urban development, since the left side was typically closer to the surface. Additionally, given the relatively narrow burial spaces for many of the Islamic graves (mean = 39.29 cm), decomposition and necrodynamics of Islamic skeletal remains may have well resulted in difficulty in recovery. Overall, the lack of lateralization in BRI values suggests that skeletal elements can be pooled across the midline.

Significantly higher aggregate Anatomical Conservation Index (ACI) values in the Christian funerary group is noteworthy, especially when paired with the result that Christian funerary group showed a significantly higher prevalence of well-preserved skeletons (WPS), with more than double the prevalence (43.48%) of well-preserved skeletons compared to the Islamic funerary group (19.38%). This taken together with the lack of significant difference in well-represented skeletons (WRS) between the funerary groups suggests that while Islamic and Christian skeletons may have experienced relatively similar rates of representation when aggregated by individuals, Christian skeletons were significantly better preserved both in terms of elements and within individuals. The percentage of each class of API values also showcases Islamic skeletal elements skewed towards 0-50% preservation while Christians experienced a higher representation of 50-100% preservation, which further suggests Christian bones were better preserved than Islamic ones. The results from the Bayesian analysis bolster the frequentist results, suggesting the average percentage of Christian bone falls between 39.2 - 48.0% whereas Islamic bones fall between 28.5 – 34.3%. The resulting distribution from the difference of group means not only fell well below zero (95% HDI -17.5% to -6.96%) but additionally fell outside of the region of practical equivalence (ROPE) of -5.0 to 5.0. While this may suggest a limited ROPE parameter, differences were significant for both difference of scales and effect size using default ROPE values (Kruschke 2018), and likely signal a significant difference in ACI scores between funerary groups. These results are further supported by the Bayesian modelling of the proportion of well-preserved skeletons. The proportion of well-preserved skeletons is estimated to be between 35.4% and 52.5% for Christian burials, and 15.8% and 26.1% for Islamic burials, with a difference in distributions well outside of zero (Figure 9.6; Table 9.5). Altogether, both the frequentist and Bayesian analyses strongly suggest significant differences in preservation between funerary groups, despite being buried in the same cemetery.

Largo Cândido dos Reis vs. Other Sites

Compared to other documented sites (Bello et al. 2006), the percentage of well-preserved skeletons (WPS) was comparatively lower at Largo Cândido dos Reis (Table 9.20). The percentage of WPS for the Islamic funerary group at Largo Cândido dos Reis was the lowest of all observed values (19.38%), followed by Hauture (24.10%) and the Christian funerary group (43.38%). When funerary groups were pooled, Largo Cândido dos Reis had the second-lowest percentage of WPS (28.37%). Similarly, Largo Cândido dos Reis showed a comparatively lower percentage of well-represented skeletons (WRS), where the Islamic funerary group (49.34%) was higher only than Hauture (37.90%), and the Christian percentage (58.09%) and pooled percentage (52.62%) was slightly higher than Spitalfields (51.40%) but lower than all other sites. Altogether, these suggest that Largo Cândido dos Reis fair comparatively poorly to other documented European sites, and suggests that traditional bioarchaeological approaches that require good preservation and estimable demographics is far more limited in this context.

In comparison with other documented sites (S. Bello et al. 2006), both Christian, Islamic, and Total BRI values from Largo Cândido dos Reis (LCR) were comparatively lower than those of St. Maximin, St. Estève, Fédons, Observance and Spitalfields (Tables 9.21). Only the site of Hauture showed markedly lower BRI values than Largo Cândido dos Reis, particularly evidenced by the lower thoracic region of the axial skeleton, as well as the lower legs. Generally, sterna and patellae were found to be in low representation across all sites. The low bone density in the sterna has been proposed as a possible explanation for its low representation, often represented only by the manubrium (Bello et al. 2006, 4; Waldron 1987), while the low representation of patellae could be the result of recovery bias and the disarticulation of patellae during decomposition (Bello et al. 2006, 4). Ossa coxae at Largo Cândido dos Reis experienced some of the lowest rates of observed representation across sites, with only the site of Hauture experiencing lower rates of representation. While Christian ossa coxae experienced markedly higher BRI values (63.24) than Islamic ossa coxae (55.95) , all were considerably lower than the next lowest site of St. Maximin (69.70).

Table 9.20 - Percentage of well-preserved skeletons (WPS) and well-represented skeletons (WRS) at Largo Cândido dos Reis (LCR) and six other sites from Bello and Andrews (2006: 6). Adults only.

	LCR - Christian	LCR - Islamic	LCR - Total	St. Maximin	St. Estève	Hauture	Fédons	Observance	Spitalfields
WPS (%)	43.38	19.38	28.37	47.70	75.00	24.10	98.40	75.00	76.60
WRS (%)	58.09	49.34	52.62	63.60	96.20	37.90	100.00	87.50	51.40

Table 9.21 - Bone Representation Index (BRI) values by site from Bello and Andrews (2006: 3-4). LCR = Largo Cândido dos Reis.

	LCR - Christian	LCR - Islamic	LCR - Total	St. Maximin	St. Estève	Hauture	Fédons	Observance	Spitalfields
Crania	56.34	55.34	55.71	78.80	91.70	73.20	88.80	86.60	95.40
Mandibulae	46.32	61.67	55.92	59.10	90.50	57.10		82.70	85.60
Sterna	39.71	16.74	25.34	34.20	35.70	25.90	60.90	44.10	62.90
Sacra	62.50	49.34	54.27	33.30	64.30	46.40	52.60	73.70	74.30
Ossa Coxae	63.24	55.95	58.68	69.70	79.20	46.40	78.90	84.60	91.60
Claviculae	51.84	55.07	53.86	60.60	78.60	45.00	88.70	75.70	67.90
Scapulae	53.68	50.88	51.92	62.10	69.00	44.60	80.10	80.70	75.30
Humerii	59.93	63.44	62.12	74.20	85.70	62.10	92.90	86.90	82.20
Radii	61.40	54.41	57.02	67.40	81.50	55.40	85.70	81.80	78.60
Ulnae	61.03	54.85	57.16	69.70	79.80	55.40	83.80	81.60	76.40
Femora	72.43	63.88	67.08	65.90	88.10	61.20	88.70	85.80	90.00
Patellae	47.06	23.79	32.41	16.70	33.30	10.70	45.10	39.90	48.90
Tibiae	72.43	60.57	64.01	62.10	83.30	45.50	82.70	84.40	87.80
Fibulae	71.32	58.37	63.22	52.30	72.00	42.00	69.50	78.20	73.20

Percentage (%) of bones represented:

	< 10%	10-19%	20-29%	30-39%	40-49%	50-59%	60-69%	70-79%	80-89%	90-100%	
Poorly represented											**Well represented**

Surface modifications – weathering and erosion

While the majority of both Islamic and Christian individuals showed no signs of weathering, higher prevalence of pooled weathering scores in the Christian funerary group. Given that individuals were interred in earthen graves and covered with subsequent soil fill, it's not surprising that rates of bleaching, cracking, and exposure were relatively minor.

Erosion scores were particularly high at Largo Cândido dos Reis, affecting more than 96% of individuals analyzed. Erosion by root inundation and/or soil has also been observed in Loulé, suggesting that it is not uncommon for skeletal remains throughout medieval Portugal (Cunha et al. 2001). Erosion at Largo Cândido dos Reis is likely a product of both soil and root erosion, as many erosive lesions retained a tubular, cylindrical appearance. Root activity and exudates are related to soil environment, landscape, and top-soil (Cantó et al. 2020), and given the general aridity of the region, the plateau on which the historic center sits, and limestone bedrock, there is relatively minimal top soil depth. Roots were found inundating entire burials (Matias 2008a), while in other cases root tunneling was observed (Appendix 9.20). Plant roots can cause exudation of organic acids in their formation of the rhizosphere, altering chemical and physical properties of the surrounding soil (Cantó et al. 2020; Rekha et al. 2018). Beginning in the 19th century, the city of Santarém began planting mulberry trees (*Morus sp*.) outside of the historic city center (Matias 2008b). Some species such as the white mulberry (*Morus alba*) and black mulberry (*Morus nigra*) can exhibit extensive — if not sometimes aggressive — root systems, with horizontal roots sometimes extending some 7m, and lateral penetration some 2m deep in silty loam soils (Czarapata 2005, 215; Sprackling et al. 1979, 71). This, in addition to municipally sponsored landscaping and urban gardening in the 20th century (Appendix 9.61-9.63) may have facilitated various levels of flora and accompanying root systems superimposed above the cemetery.

Soils at Largo Cândido dos Reis varied in texture, color, and sorting, but nearly all soils sampled were alkaline in pH (8.4-8.7). This is not surprising given the limestone plateau substrate upon which the historic city center sits (see Chapter 3). While it is generally thought that limestone is conducive to better preservation (Shipman 1993), it is possible that the interaction between bodily fluids and burial microenvironment alters this. For instance, the release of fluids during putrefaction can interact with the soils along the burial floor (Duday et al. 2006), which may result in more corrosive burial microenvironment. Bones and bone surfaces in direct contact with soils often show increased decay than bones/surfaces not in contact with soils (Miccozzi 1997). Indeed, at least one Islamic individual, Ent. 39, showcased increased erosion along the right side of the cranium due to its direct contact with the burial floor (Appendix 9.64). This suggests that while averaging erosion scores throughout the skeleton helps to give an *overall* estimate of total skeletal erosion, intra-bone variation is still a potential issue. In several cases, erosion affected and even completely obliterated dental remains (Appendix 9.65). Enamel is able to withstand corrosion to a pH of 5.5, which suggests that the acids produced either during decomposition or through root activity and exudates was relatively acidic.

While nearly all individuals analyzed from the site showcased some degree of erosion, higher prevalence and increasing severity in erosion scores for Islamic burials is particularly noteworthy. This could be due to the relatively shallow and narrow character of Islamic burials, which may have facilitated easier access for root activity than their Christian counterparts. Additionally, burial containers may also have played role in buffering root inundation in Christian burials. Previous archaeothanatological research (See Chapter 8) discovered that Islamic graves showed no evidence of being interred with vestments and showcased little evidence for the use of durable wrapping. Canonically, Islamic burials adhering to Maliki jurisprudence are stripped of clothing and shrouded in a *kafan* made of "Yemeni cotton" (Buturovic 2017; Gatrad 1994; Petersen 2013; Tritton 2008, 441). While linen consists of less cellulose (68.6%) than cotton (95%+) (Florian 1987), both are highly absorbent and begin to take on water within acidic environments which results in overall degradation of cellulose chains and fibers (Cardamone et al. 1991). Even without acidic environments, both linen and cotton are easily degraded by microorganisms (Janaway 2002). Thus while linen is slightly more resilient in acidic burial environments compared to cotton, both degrade easily and seldom survive archaeologically except for anoxic or desiccated conditions (Janaway 2002). Assuming Islamic funerary congregations employed cotton or linen as *kafan*, it is possible that the lack of vestments and degradable shrouds facilitated root inundation and therefore erosion more easily. Conversely, presence of items of personal adornment such as belt-buckles in Christian burials likely index that numerous Christian individuals were interred with vestments. In a thorough analysis of various forensic burials throughout Portugal, Ferreira (2012) found that both coffin construction and funerary vestments had tremendous impacts on decomposition rates. She discusses how due to environmentalist concerns and issues in overcrowding of Portuguese cemeteries, "green burial" practices that employed biodegradable vestments to prevent the formation of adipocere and accelerate decomposition (Ferreira 2012, 142). Vestments in medieval Portugal were commonly made of *estamene*, a coarse, low-quality wool produced throughout much of Iberia, while silk was reserved for members of the nobility or aristocracy (Oliveira Marques 1971). Even low quality wool has the potential to resist most acidic environments (above a pH of 2) due to the disulfide links which help maintain structural integrity (Janaway 2002). Additionally, some religious burials throughout medieval Christendom employed sackcloth – a rugged fabric often consisting of animal hair – or cerecloth – fabrics inundated in a form of wax, often beeswax – as funerary vestments or as a substrate between the body and the grave floor (Korpiola et al. 2015, 22–23). In acidic burial environments, protein-based fibers such as wool, animal hair, and silk preserve relatively well while materials consisting of cellulose such as cotton and linen degrade much more rapidly (Janaway 2002). Altogether, the use of animal-based fibers in funerary vestments and substrates in the Christian funerary tradition, paired with skeletal evidence for possible durable wrapping may suggest possible buffering from erosive agents compared to their Islamic counterparts which employed plant-based burial containers.

Invertebrate Presence

I posit that increased prevalence of burials with malacofaunal remains, paired with increased density and average larger size in Islamic graves may be the result of being more superficial and proximate to the surface, where snails could gain more ready access. The higher prevalence and larger species observed in Islamic graves is likely due to their shallow constitution, which facilitated easier access for larger species that cannot burrow as deep. The presence, density, and diversity of malacofaunal remains observed in Largo Cândido dos Reis likely speak to the bioturbation present, as well as some of the ecological history of the cemetery area prior to modern urbanization. Most of the species candidates recovered within burial contexts have been observed today to inhabit dry exposed sites, moist/shaded areas, as well as calcareous soils and burying. Given the presence of predatorial species (e.g., *Rumina decollata*), paired with the direct presence of some species within osteological features that would otherwise be difficult to place intentionally (Appendix 9.24 – 9.30), it is highly likely that many of the specimens recovered were present in burial contexts specifically for consumptive and/or aestivation purposes. While most snails are generalists, they typically eat (in order of importance): plant material, fungi, animals, and soil, though there is tremendous environmental variation (Speiser 2001, 263–264).

As it stands here, this archaeomalacological work is very preliminary. Terrestrial gastropods within Portugal are traditionally difficulty to identify to the species level on shell alone, often requiring dissection of reproductive features (Callapez et al. 2016; Holyoak et al. 2016; Holyoak et al. 2015). While the biometric and identification helped to reveal initial taxonomic classification, future work will look to identify the number and percentages of each species. Additionally, both future radiogenic and stable isotopic sampling of shells may prove insightful, as dating shells may help to situate their chronology of intrusion, their potential overlap with burials that have been previously dated (see Chapter 4), as well as their potential consumption of decomposing material within grave features.

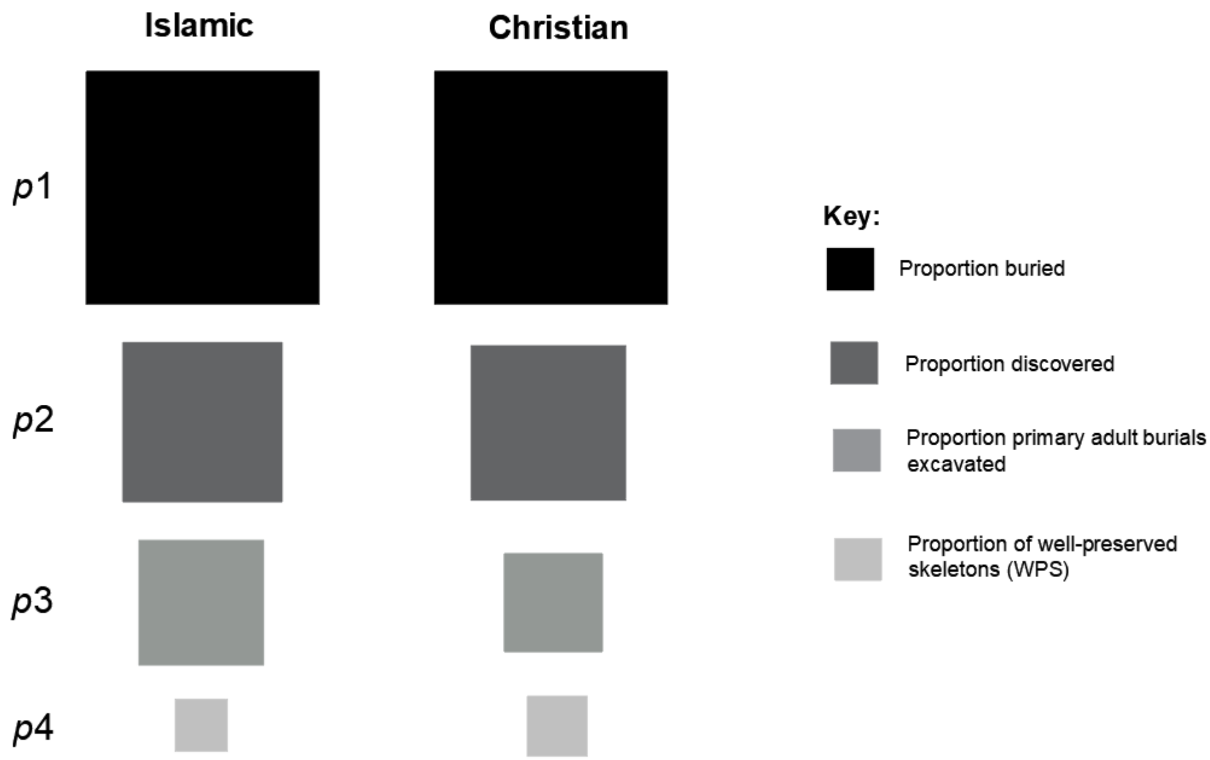
Bio(cultural)stratinomy – Biocultural and Urbanistic Considerations for Taphonomy

As stated above, there is a long history in Islamic funerary rites of intentionally burying the decedent in a shallow grave, in order to hear the call to prayer and continued prayers in death (Fortier 1997; 2010; Insoll 1999). The statistical comparisons above strongly suggest a significant difference in burial depth between funerary groups, such that Islamic graves were indeed shallower on average than their Christian counterparts, either due to intentional construction or subsequent terraforming, landscaping and grading. Burial depth has been observed to influence rates of decomposition, whereby deeper burials produced slower rates of decomposition and shallower graves exhibit accelerated decomposition (Garland et al. 1989; Janaway 1996; Janssen 1984; Micozzi 1991; Rodriguez et al. 1985; Schotsmans et al. 2011). Deeper burials tend to correspond to better preservation, as shallow graves are more susceptible to insects, carnivores, and temperature fluctuations (Carter et al. 2008; Janaway 1996; Janaway et al. 2009; Mant 1987; Schotsmans et al. 2011). The increased prevalence and severity of erosion observed in Islamic remains, in conjunction with increased prevalence, average size, and counts of malacofaunal remains all support the notion that Islamic remains were indeed shallower and situated closer to the surface where malacological communities and rhizosphere activity could take place. Consequently, Islamic remains were likely more susceptible to perturbations and taphonomic filters originating from the surface or sub-surface, such as bioturbation, insect activity, exposure to the rhizosphere of surface plants, and urban development.

The observed statistical differences between including and excluding individuals of estimable demographics suggest the strong relationship between taphonomy, preservation, and demography (Waldron 1987; 1994; 2007). It was not possible to estimate the proportion those buried at the site ($p1$) for either funerary group at Largo Cândido dos Reis (Figure 9.14), which is unsurprising as such death assemblages only occur in cases of catastrophic and rapid deposition of the entire population (Waldron 2007, 28). While it is highly unlikely that both funerary groups interred the exact same number of individuals, given the salvage nature and temporal/financial constraints of the excavation (i.e., excavating only areas that would be impacted), an equal proportion of those buried ($p1$) is depicted as a basic assumption. The proportion of those with potential to be discovered ($p2$), those (adults) actually recovered ($p3$), and those (adults) that were actually well-preserved (WPS; $p4$) are depicted as squares with areas comprising their corresponding proportion. The results show how, even if we assumed the proportion of individuals buried (*p*1) at Largo Cândido dos Reis was equal between funerary groups, stark differences arise in the filtering from *p*3 to *p*4, such that a smaller proportion of Christians burials were discovered (*p*2), but a higher proportion was well-preserved (*p*4) compared to Islamic burials and skeletons. These results bolster the statistical comparisons in including and excluding individuals with missing demographic data. If analyses on preservation were done in a complete-case basis, as is typically done in bioarchaeology, we not only risk issues of statistical power and inference, but more broadly we exclude and minimize the representation of certain communities by virtue of the way they buried their dead. If we hold to the notion that sex, age, or other estimable demographics are necessary variables impossible of excluding, we risk omitting peoples of the past with differing deathways and funerary rites that may obfuscate such estimable potentials. We, in effect, assume that Western scientific and experimentally-derived co-variates supersede the importance of past funerary rites their taphonomic consequences. The results suggest that imputation is undoubtedly an exciting area for future research for archaeologists and bioarchaeologists alike.

Finally, the importance of urbanism in impacting preservation outcomes at Largo Cândido dos Reis cannot be overstated. In the case of Spain, Ruiz Taboada (2015, 57) suggests "Muslim cemeteries ceased to be a part of Spain's historical landscape centuries ago due both to the purposeful destruction of funerary markers by the Catholic Monarchs who were anxious to eradicate any funerary remains of non-Christian communities, and to urban development." This suggests that we would expect marked increase in post-depositional damage if not outright destruction and desecration of Islamic graves after the Christian conquests. This is similar to De León's concept of necroviolence: "violence performed and produced through specific treatment of corpses that is perceived to be offensive, sacrilegious, or inhumane by the perpetrator, the victim, or both" (De León et al. 2015, 69).

Figure 9.14 - “Waldron” squares, following Waldron (2007:29), showcasing the progressive loss of discovered, well-preserved skeletal material. Square areas correspond to proportions at Largo Cândido dos Reis. Note the substantial differences in square area for Islamic burials between *P3* and *P4.*



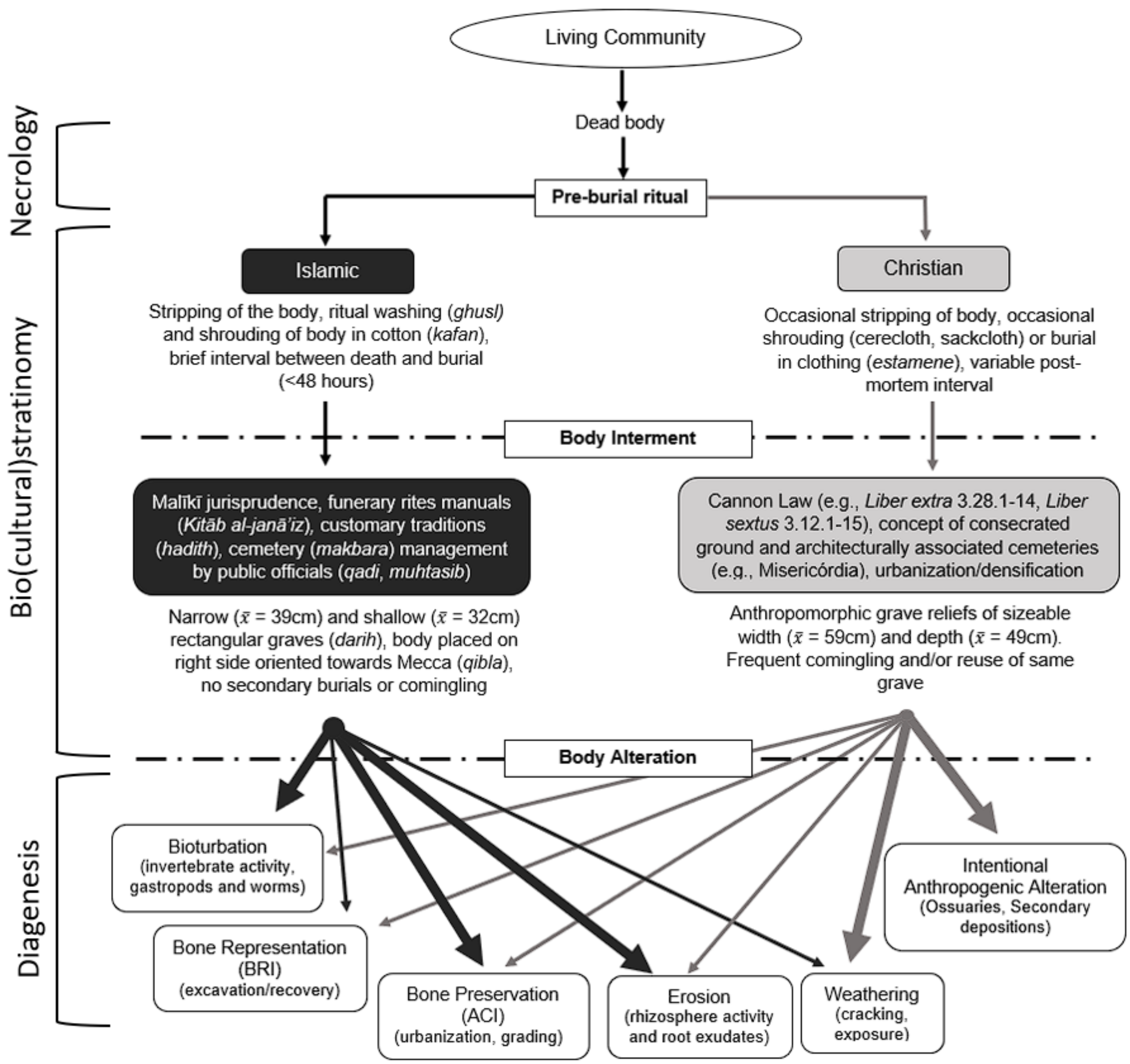
Reductions of previous Islamic graves by posterior Christian ones is worth considering further. The reduction of Islamic graves by posterior Christian ones at Largo Cândido dos Reis was a relatively minor occurrence, (n = 21; 6.93%), but noteworthy in regards to ideas of desecration. Primary Islamic burials that transitioned to secondary burials with later Christian funerary practices certainly showed marked reduction in elements represented, but in no cases were there signs of ‘intentional’ post-depositional damage. Rather, in all cases Christian funerary processions seemed to have bisected Islamic graves by chance, and displaced only the remains that were within the confines of Christian tomb construction parameters. Thus, while there was a general paucity of these inter-faith tomb reductions, there was no evidence suggesting any necroviolence or post-humous desecration was practiced on behalf of Christian funerary processions towards Islamic burials. Given the higher prevalence of interment-based reductions in Christian graves, and the fact that all 56 interment-based reductions were caused by the later deposition of an individual in the Christian funerary tradition, reductions were likely a product of “space saturation” (Ruiz Taboada 2015, 65), whereby older tombs are re-open or destroyed to permit space for newer individuals rather than necroviolence. Put another way, more Christian graves were impacted by subsequent Christian reductions than Islamic ones, which suggests that if reductions are considered evidence of necroviolence, Christians ‘destroyed’ their own graves more than Islamic ones. This suggests that issues of churchyard cemetery space likely became more pressing with time, with an increase in re-use and super-positioning of later Christian burials on previous ones, whether Islamic or Christian. This may be bolstered by the eschatological importance of space in medieval Christian funerary rites, particularly consecrated ground (Gilchrist et al. 2005). Asides from the situating of Iberian Islamic cemeteries outside of city walls, Islamic cemeteries were seldom associated with religious architectural features. This contrasts with later medieval Christian cemeteries, which were often formally associated with Christian architectural spaces (Gilchrist et al. 2005).

As discussed in Chapter 4, much of the Islamic period likely followed a dispersed form of urbanization, such that the city developed in disparate nuclei maintaining peri-urban orchards, gardens, and cemeteries (Navarro Palazón et al. 2007). However, according to Trinidade (2007b, 31), many Islamic urban centers throughout Portugal were "a dense and saturated fabric of close knit domestic structures mostly only accessed by a *cul-de-sac* or blind alley." In the case of large Spanish cities such as Valencia, fourteenth century chroniclers, such as the 1393 Council of Valencia blamed Islamic city planners for their "narrow and wretched" design (Trinidade 2007b, 35). Urban development during the Christian middle ages often resulted in the building over of previous Islamic cemeteries, such as the case in 15th century Lisbon where population growth and expansion built over an Islamic cemetery situated on the Santa Maria da Graça slope (Trinidade 2007b, 40). In the case of Santarém, the Christian conquests in 1147 fundamentally transformed the cityscape, altering it from an Islamic military and cultural domain into an important Christian pilgrimage center under the Portuguese crown (Freitas Leal 2007). Indeed, the transition between Islam and Christianity also followed a change in less privatization, where Muslim urban mesh was largely privatized in individual homes with central courtyards, the very same land was aggregated and transferred into members of the post-conquests aristocracy, who leased the lands to Christian tenants (Trinidade 2007b). Thus, Christian conquests transformed urban spaces to be more rigid and uniform, where the residential areas were much more fluid. As such, the dense urban meshwork, labyrinthian avenues, and two-story structures seen today throughout the historical city center are likely the result of the Visigothic and Islamic city planning later altered during Christian medieval period where shops were situated on the first floor and familiar residences on the second story (Freitas Leal 2007). Beginning in the latter half of the twelfth century, numerous religious orders such as Hospitallers, Templars, friars of Santiago de Uclés, and the order of Calatrava all helped to establish Santarém's importance as a religious center (Custódio et al. 1996b). This was subsequently bolstered by the arrival of mendicant orders, especially Dominicans, Franciscans, and the various mendicant friars of Bernardo of Morlans, Saint Anthony of Santarém, and Gil of Santarém, who established numerous monasteries throughout the city and region. Mendicant orders also helped to establish Santarém as an important pilgrimage city for medical treatment (McCleery 2005, 198), likely as a product of the numerous holy miracles such as the Santo Milagre of 1266 C.E. (Custódio et al. 1996b) paired with the healing powers of physician saints such as Gil of Santarém (McCleery 2005; Resende et al. 2000). By the fourteenth century, the city cemented itself as an important religious center, with more than fifteen parishes, numerous monasteries, convents, courts, and lodging/treatment centers such as misericordias and hostels (*albergias*) due to its location along pilgrimage route to Santiago de Compostella. It's no surprise then that Santarém was one of the most urbanized cities within the Portuguese kingdom in the later Christian middle ages (Freitas Leal 2007), and hosted the Portuguese royal court for nearly two centuries (Braga et al. 2007). The increasing densification and urbanization of Santarém, both during the latter Middle Ages and into today, seems to have disproportionately affected — and continues to affect — Muslim graves more so than Christian ones. Rather than posthumous desecration, it seems indeed that

Ruiz Taboada's latter claim of urban development may well explain the significantly poor preservation observed in Islamic remains, a result observed elsewhere in Islamic burial contexts (Gleize 2022, 378, 390; Pradines et al. 2009).

The stark differences in bone preservation between funerary groups in the same cemetery of Largo Cândido dos Reis suggest that taphonomy, insofar as it concerns human skeletal remains, indeed should be conceptualized in both a protracted and ontological manner (Knüsel et al. 2016, 656). Pereira (2013) among others (Carton et al. 2022; Zemour 2016) have encouraged scholars to consider 'funerary time' ("*temps funéraire*") as a temporal sequence worth reconstructing. Carton and Zemour (2022, 427) build on this concept and outline specific intervals such as "corpse time", "processing time", and "bone time" which correspond to the treatment, transportation, exhibition, and deposition of the corpse, respectively. The diachronic dimensions afforded by this approach allow bioarchaeologists to situate remains within a socio-temporal sequence, and further underscores the importance of both necrology and biostratinomy that paleontologists and taphonomists have long championed. Altogether, the results suggest that taphonomic filters are best considered in a temporal manner that extends beyond just post-depositional processes, as cultural and religious funerary customs preparing the dead body and the grave itself ("corpse time") altered the very contours of taphonomic influences. I posit here that biostratinomy can include a cultural component—"bio(cultural)stratinomy" — because unlike paleontological depositional histories, human burials often include intentional deposition, and as such, cultural funerary customs undoubtedly influence the deposition of human remains, and therefore their taphonomic trajectories. These distinct funerary gestures and construction of tombs, informed by religious considerations for the afterlife, influenced the diagenetic destinies of these remains (Figure 9.15). Medieval cultural, religious, and ontological conceptions of death, funerary preparation, and burial are inextricably linked with taphonomic consequences and observed outcomes.

Figure 9.15 - Taphonomic flowchart for Largo Cândido dos Reis. Larger arrows correspond to statistically significant results for that funerary group.



Conclusion

A recent volume edited by Betsinger and DeWitte (2020) effectively showed how urbanization and city-dwelling can have demonstrable consequences on the biological, demographic, and social fabric of past communities. Using a suite of traditional and newer methodologies, the chapters underscore the myriad of ways in which urbanization can cascade into embodied experiences within bioarchaeology. While some chapters focus on the impact of urbanization on morbidity, mortality, and mortuary rituals (Robbins Schug 2020), the bioarchaeological consequences of urbanization post-mortem receive comparatively little attention. Again, the biocultural dimensions of bioarchaeology are well defined for embodied experiences during life, but much less so during death, burial, and prior to excavation — the precise interval of taphonomic inquiry. The results presented in this chapter strongly suggest that urbanism can continue to have drastic consequences post-mortem, and indeed circumscribes the very assemblages and representation of various communities in the past. Bioarchaeologists have only recently begun to explicitly confront the issues of missing data and the possibilities of imputation head on (Stojanowski & Johnson 2015; Wissler 2021), though the future shows promise (Buikstra et al. 2022, 29).

The site of Largo Cândido dos Reis is exciting in that it contains burials from two distinct funerary traditions in the same cemetery space, but both with the same general purpose of bodily inhumation and preservation for resurrection. The resulting differences underscore how taphonomy, at least in these human skeletal remains, are best understood in an eschatological manner, attentive to the ways in which culturally- and religiously-informed funerary rites in preparation for the afterlife can be considered part of the larger taphonomic sequence (necrology, biostratinomy, diagenesis). Crucially, these results problematize the neat separation of Cultural and Natural factors/transforms, as culturally-mediated gestures seem to have altered the very contours of diagenetic outcomes.

Chapter 10: Deathways — Histotaphonomy

Introduction*:* Funerary Histotaphonomy

This chapter analyzes microscopic indicators of preservation through histotaphonomy (Bell 2012). As seen in the previous chapter, statistically significant differences in macrotaphonomic indicators were observed between funerary groups, and this chapter seeks to further this investigation by focusing on preservation and bioerosion at the microscopic level.

According to Smith and colleagues (Nielsen-Marsh et al. 2007; Smith et al. 2007), there are four major diagenetic pathways: 1) bioerosion, 2) dissolution, 3) fossilization, and 4) accelerated collagen hydrolysis. Although diagenesis was originally coined in respect to the conversion of sediment into sedimentary rocks, and by extension the replacement of organic matter with sediments, it has more recently been adopted by archaeologists and taphonomists to characterize changes in skeletal tissues within burial environments (Turner-Walker 2008, 4). Microscopic analyses of diagenesis, here termed 'histotaphonomy', date back to at least the 19th century with the pioneering work of Wedl (1864) who was one of the first to document bioerosion of bones and teeth using light microscopy. Roux (1887) and Schaffer (1895) also documented bioerosion in paleontological specimens, suggesting that fungi may have inundated the remains by virtue of their coloration and filament appearance, which Roux termed *Mycelites ossifragus*. The germinal work of Hackett (1981) borrowed much from Wedl's work, distinguishing fungal *miscroscopical focal destruction* (*mfd*) as Wedl tunneling, and bacterial attack as non-Wedl *mfd*. Hedges and colleagues (Hedges et al. 1995) helped to create the Oxford Histological Index (OHI; Table 1), an ordinal scoring system for semi-quantifying the degree of bioerosion present in histological samples. Diagenetic signatures of bioerosion tend to exhibit decreased OHI scores, increased medium/microbial porosity ('m' porosity), low cracking and low small porosity ('s' porosity) (Smith et al. 2007, 1488). Microbial attack increases porosity (1-10 µm in diameter) and typically accompanies a decrease in collagen, typically originating from the vascular canals (Haversian canals) and subsequently inundates osteons, obscuring the original microstructure (Hackett 1981).

Despite histotaphonomy's long history of research (Roux 1887; Wedl 1864), it has only relatively recently been applied to elucidating possible funerary gestures in the past (Bell 2012; Booth 2017; Hollund et al. 2018). This is unsurprising, given the way taphonomy, and diagenesis in particular, are often considered degradative processes. Early views of taphonomy characterized taphonomic processes as the progressive loss or *removal* of biotic material and information and failed to recognize the *additive* information that could also be gleaned, such as gnaw-marks, cracking, and weathering. A crucial hallmark of later taphonomy studies was the acknowledgement that taphonomic processes are not unidirectional in loss of information, but also *contribute* information (Behrensmeyer 1975; Behrensmeyer et al. 1985; Lyman 2010; Olsen 1980; Ringrose 1993). The relatively recent articulation of 'funerary taphonomy' (Knüsel et al. 2016) provides a framework for addressing taphonomy in a more contributive manner, elucidating the ways in which funerary gestures and taphonomic consequences become intertwined. This is especially important in the case of human burials and skeletal remains, as the body is often prepared and interred in a deliberate, culturally-informed manner.

Diagenesis in histological samples of bone has undergone a similar shift. Histological analysis of human bone has often focused on anthropological assessments such as histomorphometry in order to characterize remodeling, porosity, or age-related changes in bone quantity and quality (Agnew et al. 2012; Beauchesne and Agarwal 2017; Cho et al. 2003; 2011; Martin et al. 1985; Mulhern 2000; Richman et al. 1979; Stout 1989; Stout et al. 1976; 1995;).

Unfortunately, much of histomorphometric analysis can be rendered impossible from even minor diagenesis due to obfuscation of the microstructure, and as such are typically excluded from analysis. Given the pervasiveness of diagenesis in most histological samples from archaeological burials (Jans 2008, 409; Jans et al. 2004; Turner-Walker 2008), it follows that many, if not most, archaeological sites and burials are simply unable to provide utility for histomorphometric analysis. Much of the recent shift centers on the interpretation of microscopic destruction and diagenetic alteration in light of funerary rites, depositional history, and burial context rather than simply a 'lost cause' for histomorphometry. A study by Hollund and colleagues (2012) documented taphonomic agents present in histological microstructure of bone, but importantly, they interpreted such data in light of putrefaction and post-mortem processing. Perimortem interment seems to protect the body from invertebrate access (Campobasso et al. 2001; Simmons et al. 2010), rapid skeletonization, and prolongs putrefaction (Breitmeier et al. 2005; Mann et al. 1990; Rodriguez et al. 1983; Rodriguez et al. 1985; Zhou et al. 2011). Together, this is taken to suggest that rapid burial after death would result in retarded skeletonization and a higher likelihood of transmigration of autolytic gut bacteria into skeletal tissues during putrefaction, whereas more delayed or excarnated burials would show signs of less bacterial attack due to more rapid skeletonization and minimized putrefaction. Histotaphonomic analyses of mummified remains suggest that mummification can arrest putrefaction, likely explaining immaculate preservation of microstructure in most mummified remains (Hess et al. 1998; Parker Pearson et al. 2005; Booth et al. 2015). Booth (2016) conducted a relatively large study analyzing thin sections from 301 individuals across 25 European sites to test whether funerary treatment of the body may predict bioerosion. Booth compared historic sites with documented evidence of rapid burial (and therefore prolonged stages of putrefaction), with earlier sites containing delayed inhumation (and therefore reduced levels of putrefaction). His results suggest that histological parameters of diagenesis and bioerosion correlated with degree of putrefaction, such that rapid post-mortem burial corresponded with elevated quantities of bioerosion compared to their more variable prehistoric counterparts. A comparative study by Brönniman and colleagues (2018, 55) similarly suggested that histotaphonomy can potentially aid in the reconstruction of various mortuary practices, such as excarnation or multi-stage burial practices. Recently, Goren et al. (2021) examined histotaphonomic patterning at Çatalhöyük, a site with archaeological evidence of post-mortem processing, dismemberment, decapitation, and post-burial movement of skeletal remains. The authors found a distinct increase in bioerosion in subadults when compared with adults, with sub-adults (0-20 years old) showing increased prevalence of OHI scores of 0, a finding they interpret in light of rib mineralization but also funerary processing that may have differed in terms of age-at-death, such that adults received differential funerary treatment than their sub-adult counterparts. Histology can undoubtedly document taphonomic events, but must be done in a careful, contextualized manner using various lines of evidence due to issues of equifinality (Hollund et al. 2012, 546). Histotaphonomy thus comprises an important means of not only documenting degradation mechanisms, but facilitating informed decisions about heritage management such as monitoring such mechanisms and groundwater levels (Van Heeringen et al. 2004; Lee-Thorp et al. 2008; Collins et al. 2004).

Bioerosion, or 'microbially attacked bone', refers to the process of biological agents, principally fungi (Marchiafava et al. 1974; Wedl 1864), bacteria (Hackett 1981; Jackes et al. 2001), and/or aquatic microorganisms (Bell et al. 1996; 2008; Davis 1997; Pesquero et al. 2010; Turner-Walker 2012), and is the most common diagenetic pathway (Hedges 2002; Jans et al. 2004; Turner-Walker & Syversen 2002). While much of the early work on microscopic diagenesis focused on fungal attack (Roux 1887; Schaffer 1895; Wedl 1864), research throughout the later 20th century suggests fungi likely comprise a comparatively minor component of bioerosion. This is in part due to the fact that saprophytic fungi such as those identified by Marchiafava and colleagues (1974) as *Mucor* sp. are aerobic, and thus require the presence of oxygen. Fungal attack is therefore a good proxy for oxygen-rich burial environments at the time of degradation (Jans 2013). However, the experimental design by Marchiafava et al. complicates interpretations, as they autoclaved bone samples at such excessive temperatures (200ºC for 20 minutes) that it likely rendered collagen into a gelatinized mass, conducive for numerous microorganisms (including fungi) to inundate and take advantage of (Kendall et al. 2018, 27; Turner-Walker 2008, 16). Later work by Piepenbrink (1986) and Grupe (Grupe et al. 1993; Grupe et al. 1989) sought to experiment with fungal degradation, but found little evidence of tunneling even with inoculating bone samples with fungi. Wedl *mfd* (i.e., fungal) bioerosion appears to be spatially situated near periosteal surfaces. A review of Wedl's (1864) pioneering work and proposition of fungal attack has recently been questioned, as his specimens seem to have been from marine environments which may have facilitated cyanobacteria and chlorophytes to tunnel within bone rather than fungi (Kendall et al. 2018; Turner-Walker 2019).

By the 1990s, the shift from fungi to bacteria as responsible for the majority of microbial attack took place. According to Turner-Walker (2008, 17), two broad classes of bacteria are considered: cyanobacteria in marine environments (Turner-Walker 2019), and aerobic bacteria, likely from archaeological soils (Turner-Walker et al. 2002; Turner-Walker & Syversen 2002), though the origins of non-marine bacteria is debated considerably (see below). Bacterial microscopical focal destruction (*mfd*), or 'non-Wedl MFD', is often characterized in three types: *linear longitudinal*, *budded*, and *lamellate*, following the classification by Hackett (1981). With low-powered light microscopy, *mfd* can be seen as porous areas accompanied by hypermineralized 'cuffs' ranging from 10 – 60 µm in diameter (Jans 2013, 22). This is thought to be the result of the redistribution of bioapatite minerals, as bacteria solubilize minerals for later movement, while digesting collagen via collagenases (Hackett 1981; Jans 2004, 87; Turner-Walker, Nielsen-Marsh, et al. 2002). Conversely, bioerosion by fungal attack is thought to consume both collagen and bioapatite simultaneously (Marchiafava et al. 1974). The timing of bacterial alteration is not well known. Most of the literature conservatively estimates that bacterial alteration within the first decades postmortem, (Hedges et al. 1995; Jans et al. 2004; Jans 2013; Yoshino et al. 1991), likely during the putrefactive stage (Child 1995; Jans et al. 2004).

Bacterial Attack: Endogenous or Exogenous Origins?

The timing of bioerosion in terrestrial burials is certainly an important question, but an even more elusive question remains: where does the bacteria come from? Currently, the debate largely focuses on the juxtaposition of exogenous soil (i.e., environmental) bacteria that tunnel into skeletal tissues, from endogenous (also termed 'enteric') bacteria that disperse throughout the body from the intestinal microbiome. The former suggests that bacterial decomposition is primarily the product of soil bacteria and other micro-organisms in the burial/soil environment (Grine et al. 2015; Grupe & Dreses-Werringloer 1993; Grupe, Dreses-Werringloer, et al. 1993; Grupe, Dreses-Werringloer, et al. 1993; Grupe et al. 1989; Grupe 1995; Kendall et al. 2018; Morales et al. 2017; Turner-Walker 2008; Turner-Walker 2012). The latter posits that putrefaction results in a transmigration of gut bacteria, which consequently inundate Haversian systems and surrounding skeletal tissues (Bell et al. 1996; Child 1995; Booth et al. 2015; Jans

2013; White et al. 2014; Jans et al. 2004; Nielsen-Marsh et al. 2007; Guarino et al. 2006; Hollund et al. 2012).

Much of the exogenous model centers on soil bacteria that are capable of producing collagenase to exploit bone protein, which seem to be present in most soil types (Vraný et al. 1988). For instance, experimental work conducted in Wales by Fernández-Jalvo and colleagues (2010) found that destructive foci were irregularly dispersed, and did not seem to originate from vascular networks within the medial cortical layer, concentrating instead on endosteal and periosteal layers. This is taken to mean that bacterial attack in the medial cortical layer would be expected in the case of the endogenous model. Three samples in particular (ND16 — tibia; ND17 — vertebra, and ND18 — vertebra) originated from the same animal (sheep), but were differentially exposed, such that ND16 and ND17 were buried while ND18 was exposed on the surface. Bacterial attack was observed in the buried samples, but no such bacterial attack was observed the exposed element (ND18), which instead showed periosteal signs of fungal tunneling. Altogether, the spatial patterning of bacterial attack paired with the differential intensity of attack between exposed and buried remains led the authors to suggest that bacterial attack was likely the result soil bacteria.

Conversely, the endogenous model prioritizes putrefaction as the main factor in bacterial inundation. Human cadavers undoubtedly are sources of dense colonies of microorganisms (Clark et al. 1997; Hill 1995; Noble 1982; Wilson 2005), and it is thought that death and the accompanying cessation of immune-mucosal membranes permit the transmigration of gut bacteria from the intestinal tract into the blood supply, usually within the first few days post mortem (Bell et al. 1996; Gill-King 1997b; Guarino et al. 2006; Hollund et al. 2012; Janaway 1996; Melvin et al. 1984; Trueman et al. 2002; White et al. 2014). This is often seen visually in the cadaver during putrefaction as the "marbling" or "posthumous circulation" stage, whereby enteric intestinal bacterial break down hemoglobin into sulfohemoglobin, resulting in colored pigments which become apparent throughout the abdomen and upper thorax (Pinheiro 2006b, 90–91). Prolonged putrefaction, resulting in the transmigration of bacteria that secrete collagenase, is thought to result in the increased observed bioerosion in histological bone samples. This stems from the notion that the rate of decomposition is generally slower in burials than on the surface, sometimes by a factor of eight (Fiedler et al. 2003; Mann et al. 1990; Rodriguez 1997), which overall results in extended putrefaction and decreased rate of skeletonization.

The lack of observed bioerosion in neonates (e.g., Booth, 2016) is cited in support of this model, and is the result of underdeveloped gut microbiomes, which develop at or soon after birth and require enough time to yield the presence of osteolytic bacteria (Mackie et al. 1999; White et al. 2014). Essentially, if adults consistently show high incidences of bioerosion compared to neonates, especially at the same site, then it suggests that exogenous bacteria are likely not the cause of bioerosion, but rather the result of mature colonies of osteolytic bacteria within the gut of adults. This line of thinking is further supported by the fact that neonatal bones are comparatively cartilaginous and undermineralized, which would suggest *increased* bioerosion values if soil bacteria were present (Hackett 1981).

Further evidence for endogenous provenience of gut bacteria is supported by observations of human bone bioerosion compared to faunal samples, especially at the same archaeological site. Brönnimann et al (2018) compared faunal and human samples, and found stark differences, with human bones exhibiting severe bacterial degradation (96%) and faunal remains exhibiting relatively minor bacterial degradation (23%). Furthermore, the authors found no significant difference when bacterial degradation values were compared by soil type, which suggests soil bacteria alone are unlikely to explain the variation in bioerosion values. Finally, the authors note that faunal remains that were sampled were sourced from varying degrees of preservation, likely as a result of butchering practices. Animal remains tend to be butchered and eviscerated soon after slaughter, so the lack of bioerosion in faunal remains could be the result of evisceration which removes the intestinal microbiome prior to putrefaction, and osteolytic bacteria are therefore unable to transmigrate into the blood supply and bone after death (Jans et al. 2004). To date, there have been two major experimental studies histologically examining pig (*Sus scrofa*) carcasses, which have yet to pinpoint the source of bacterial attack (Kontopoulos et al. 2016; White et al. 2014). White and Booth (2014) advocate for an endogenous model based on observed values in their experiment, where Kontopolous et al. (2016) suggests soils may still play a role in bioerosion. As Turner-Walker (2019, 30) has recently pointed out, neither of these studies employed high powered microscopy nor SEM/BSEM imaging, so the degree of bioerosion and tunneling could be superficial. Differences in which type of microscopy is used (low-powered light microscopy vs. higher powered SEM/BSEM) seems to explain much of the differences in the suspected origins of bacterial attack.

Proponents of the exogenous model (e.g., Turner-Walker 2008; Turner-Walker 2012) often cite the observed variability in bacterial inundation between human and non-human specimens in relation to porosity and Haversian bone dimensions. Here, the observed lack of bacterial attack in fauna compared to humans is explained by the fact that animals are typically slaughtered and eviscerated shortly after reaching sexual maturity, such that they retain a high degree of primary lamellar bone and comparatively less Haversian bone than their human counterparts. However, as Brönniman and colleagues point out (2018, 55), this logic would suggest that increased bacterial inundation should be observed in older, adult human skeletal remains compared to younger adult individuals due to increasing porosity throughout the life course, a finding Booth (2016) did not observe. Furthermore, large-bodied domesticates (e.g., bovids, ovicaprids, etc.), particularly those from articulated skeletons, have been observed with extensive bacterial attack despite being intrinsically less porous than their human counterparts. Undoubtedly, variation in bacterial attack and bioerosion throughout the life course is still an exciting avenue of future research. Bacterial degradation is likely the product of both endemic and exogenous factors working simultaneously. Indeed, some early scholars suggested that initial decomposition is predominately the result of microbial flora, and that only later stages of decomposition are the product of soil micro-organisms (Carter et al. 2003; Janaway 1985; Janaway et al. 2009, 315), whereas the experimental study by Kontopoulos et al (2016) suggested that bioerosion may be facilitated endosteally via endogenous gut bacteria and periosteally via exogenous soil microorganisms. Jans (2008) posits that bacterial attack corresponds with early post-mortem taphonomy and body processing (endogenous), whereas cyanobacterial and fungal attack reflect burial environment (exogenous). Damann and colleagues (2015), conducting high-throughput sequencing methods on bacterial community diversity in the ribs of 12 experimental cadavers, found that initial stages of decomposition and skeletonization were characterized by bacteria communities more similar to the gut, whereas later skeletonization was characterized by a bacterial community profile more similar to neighboring soils. Partially skeletonized remains with more recent PMIs exhibited large percentages of Firmicutes and Bacteriodetes, phyla typically associated with the human gut, whereas skeletonized and dry remains showed increasing abundance of soil phyla such as Actinobacteria and Acidobacteria (Damann et al. 2015, 847). The authors posit that bone may well be favorable to oligotrophic bacteria — those adapted to nutrient-poor environments and which favor slower growth blooms — due to inorganic bioapatite's buffering role in physically protecting bone nutrients. Future research is desperately needed to elucidate the origins of bioerosion further as well as their differential potential in various environments.

This chapter examines patterning of histotaphonomic indicators alongside religiously-informed funerary traditions. Samples were originally gathered and prepared for histomorphometric analysis, until preliminary samples showed extreme signatures of bioerosion. Thus, while samples were compromised in terms of histomorphometry due to bioerosion, I seek to examine how patterning of bacterial attack, alongside other histotaphonomic indicators of Wedl tunneling (suspected fungal attack), cracking, and collagen preservation, may vary along funerary, age- and sex-specific groups in a medieval, multi-faith cemetery from central Portugal.

Funerary Background

Like many other regions of medieval Iberia, the city of Santarém, Portugal, situated some 75 km northeast of Lisbon, experienced shifting religious-political autonomy throughout the middle ages, with Visigothic, Islamic, and Christian administrations controlling the city at differing times over a thousand-year period. Constant religious-political flux was accompanied by changing funerary and mortuary customs informed by religious practices of the city's residents. Distinct funerary treatments of the body, informed by religious concerns of the soul and body after death (eschatology), has allowed funerary archaeologists at the site to discern religious identity, at least in death, with relative ease (Matias 2008b). Islamic graves in the city are found in extended, right decubitus position in relatively shallow, earthen inhumations with a general lack of grave goods and oriented towards the southeast, facing Mecca. Conversely, later medieval Christian graves are often identified by extended supine position in anthropomorphic tomb structures, with occasional co-mingling and the presence of ossuaries. The presence of two distinct, religious funerary traditions within the same geological and geographical space offers an opportunity to examine the relationships between religiously-informed funerary rites and taphonomic outcomes at both macro- and microscopic scales.

Islamic funerary traditions in the region seem to follow a mix of Sunni jurisprudence following the works of Malik ibn Anas (711-795 C.E.), as well as local hadith and vernacular customs. Chávet and colleagues consider ritual funerary interment in medieval Islam as a "frontier between two worlds" ("zona fronteriza entre los dos mundos") for its simultaneous public exhibition and sacred exclusivity (Chávet et al., 2006). This frontier can also be seen in the eschatological and metaphysical act of dying in Islam, whereby the death brings a departure from the physical world (*dunya*) into the afterlife (*al-akhîra*) (Casal 2003, 23–37). Thus, the soul is believed to leave the body at death, which requires rapid burial within the following 24 hours (Petersen 2013). Indeed, one prophetic speech insists: "Bury him in the same night!" (Bukhârî 1977, 404; Fortier 2010, 304). Generally, death was accompanied by a ritualized procession, involving the stripping and washing of the corpse (*ghusl*) followed by enshrouding of the body in "Yemeni cotton" (*kafan*) and occasionally, tethering of the mandible to the skull (Bianquis 2012; Buturovic 2017; Gatrad 1994; Petersen 2013; Tritton 2008, 441). In most cases, the shrouding of the body can vary by gender, with women being enshrouded in five pieces of cloth whereas men are enshrouded in three pieces. Burials typically adhered to basic prescriptions such as: the situating of the body directly with the floor of the grave (Khalîl 1995, 107), the exclusion of grave goods in order to preserve uniformity (Halevi 2007; López Quiroga 2010), the individuality of a grave so that each grave only contain one individual (Insoll 1999), and the separation of adults and children (Petersen 2013), though considerable variation exists (Sadan 2000, 183). Casal (2003, 33–34) for instance outlines the numerous grave goods that have been found within medieval Islamic cemeteries in Spain. It is generally forbidden to cremate, artificially treat, or interfere with the corpse, as it meant to be intact for resurrection and "decompose naturally" (Insoll 1999; Buturovic 2017, 102).

Generally speaking, late medieval Christian funerary customs for the majority of people were typically simple and prescribed. The body was frequently stripped, washed, and extended in an East-West orientation, with head facing West towards the rising sun and arms typically placed at the side or crossed over the breast (O'Sullivan 2013a). The use of "furnishings" (Litten 2007) has been noted in both burial and embalming practices throughout the middle ages, as evidenced by the employment of cerecloth (fabrics inundated with wax, often beeswax) or numerous monastic burials laid atop or dressed in sackcloth – a coarse-fibered material often made of animal hair (Korpiola et al. 2015, 22–23). Post-mortem/interment intervals could vary considerably, as the Church generally advocated for burials within five days (Korpiola et al. 2015, 22), while members of the aristocracy would occasionally be embalmed, protracting the post-mortem/interment interval (Gittings 1984; Weiss-Krejci 2008). These acts often accompany a transition of spaces and locations, often from the home, to the church, to the cemetery (Long 2009; Rowell 1977). While intra-mural church burials and proximity to sacred objects may have been a concern for social elites, the majority of commoner burials took place outside in associated cemeteries. Similar to English churchyard cemeteries, the shift from church cemeteries to public ones in Portugal did not formally take place until the eighteenth century (Laqueur 2015). Beyond the theological concerns of caring for the dead voiced in the twelfth and thirteenth centuries, cemeteries also became a service increasingly attached with other church-supported public service institutions in Portugal, such as *albergias*, *Misericórdias*, and hospitals (Sá 1995a).

As seen in chapter 9 above, statistically significant differences in macrotaphonomic indicators (erosion, weathering), bone preservation, and bone representation were observed between Christian and Islamic skeletal material within the city, such that Islamic bones were significantly more eroded, and less conserved than their Christian counterparts. The multi-faith nature of the cemeteries within the city provides a unique opportunity to examine how post-death, pre-burial funerary rites (biostratinomy) might carry taphonomic (diagenetic) consequences at both macro and microscopic scales. Our research questions are as follows:

1. Are there detectable histotaphonomic differences between funerary groups?
2. Are there detectable histotaphonomic differences between sex groups, regardless of age or funerary group?
3. Are there detectable histotaphonomic differences between age groups, regardless of funerary group?

I hypothesize that 1) Islamic samples will show significantly increased levels of bioerosion as a result of more rapid burial preparation and/or textile composition; 2) there will be no sex differences between males and females; both when funerary groups are pooled and separated, due to similarities in gendered burial treatment; and 3) bioerosion will increase with age categories, due to age-related changes in cortical bone loss and increased porosity.

Materials

Historical context and site details can be seen in Chapter 3. The samples analyzed in the present study consisted of *n* = 147 individuals represented by mid thoracic (6-8) ribs, taken at the mid-section of the rib when possible. The majority of histotaphonomic studies have focused on long bone sections (e.g., femora) and/or fragments of cortical bone. However a recent study has shown ribs to be an effective means of documenting bioerosion and microbial attack (Goren et al. 2021). One advantage gained by utilizing ribs is their ubiquity, as skeletons are likely to have at least some portion of ribs preserved, represented in 73.53% and 68.72% of Christian and Islamic individuals analyzed from Largo Cândido dos Reis, respectively. While ribs contain substantially less cortical bone than their long-bone counterparts, sampling ribs was minimally invasive as individuals have numerous ribs, and many were already broken from depositional factors, a consideration that was extremely important in our collaboration with our Portuguese partners to minimize destructive sampling, especially of long bones. Another advantage afforded by ribs is the relative simplicity of consistently sampling the same region (abdominal cavity), as opposed to various appendicular elements. Finally, sections of ribs provide a relatively unique opportunity in that they are a 'bounded' area that can be analyzed entirely in one microscopic slide. In essence, an entire rib's cortical cross-sectional area can be analyzed for OHI, and even compared to cortical cross-sectional area measurements (mm^2) (Agnew et al. 2012). Interestingly, Kontopolous et al. (2016) found that proximity to the abdominal region (where the intestinal microbiome is located) did not have an effect on microscopic bioerosion, and given the stochastic nature of bioerosion observed intra-skeletally, suggests that intra-skeletal variability may well be a factor in assessing degrees of bioerosion and diagenesis. Indeed, Turner-Walker (2019) recently suggested this is likely an important new area for bioerosion studies.

Age and sex were estimated using standard morphoscopic features (Buikstra et al. 1994), with special attention given to the post-crania and the pelvis for its functionally related morphology and dimorphism. Age was estimated using multiple indicators of degenerative changes within the pubic symphysis and auricular surface (Brooks et al. 1990; Lovejoy et al. 1985). I employ conservative age categories here (18-29 years, 30-49 years, and 50+ years) to help maximize confidence at the cost of precision. Sex was estimated using standard methods focusing on the pubic bone complex (Ascàdi et al. 1970; Brothwell 1981; Buikstra et al. 1994; Phenice 1969). The total sample distribution can be seen in Table 10.1.

Table 10.1 – Sample demographics (*n* = 147 total).

Parameter		n
Site	Avenida 5 de Outubro	43
	Largo Cândido dos Reis	104
Funerary group	Islamic	62
	Christian	68
	indeterminate	17
Sex	Female	58
	Male	85
	indeterminate	4
Age	18-29 years	32
	30-49 years	41
	50+ years	46
	indeterminate	28

Methodology

Sample Preparation

When possible, ribs were cleaned carefully of surface dirt and matrix using a dental scaler as well as small amounts of water and/or ethanol, when needed. Samples with excessive matrix were sonicated in water for approximately 90 seconds. Many of the ribs were highly fragile and/or friable, to the extent that sonication and/or scrupulous cleaning of dirt, matrix, or clays could not be fully carried out without compromising the integrity of the rib samples. In these cases, samples were gently cleaned with small amounts of water and/or ethanol and a Kimtech Kimwipe. All ribs cleaned this way were dried before sectioning.

Approximately 1-2cm sections were taken from the midshaft of dry rib samples using a Buehler Isomet® slow-speed saw with a 6" diamond-coated wafering blade, with a speed of 100 rpm to avoid excessive grinding and polishing of microstructure. Samples were set out to dry for at least 24 hrs to dry completely prior to embedding. Due to the fragility and friability of archaeological bone samples, embedding samples within a durable medium helps the samples to retain structural integrity for subsequent thin-sectioning, grinding, and polishing (Beauchesne and Agarwal 2006; Brönnimann et al. 2018; Morales et al. 2017; Stout et al. 1976). Samples were embedded using Buehler's Epo-Thin® 2 two-part epoxy resin medium, following the protocol outlined by the manufacturer. Samples were then carefully placed in a Buehler Cast N' Vac 1000 vacuum impregnation chamber and vacuumed in a ratcheting fashion (to -25 mmHg pressure) to draw out bubbles from the medullary cavity. The cycle was repeated once more before samples were left to harden and cure within the chamber for at least 24 hours before thin-sectioning.

Blocks were then sectioned using Buehler Isomet® at 100rpm for 1-1.5mm to remove the bottom-most portion of the black as a 'blank' to ensure that subsequent wafers were even in the event that ribs became slightly off-balance in the Peel-A-Way™ mold. A subsequent 1-1.5mm wafer was removed for mounting and allowed to dry for at least 24 hours. Wafers were mounted frosted slides using a 2 Ton® Clear Epoxy solution (Devcon2). Samples were left to harden for at least 24 hours before grinding. Slides were then ground to desired thickness using a Buehler PetroThin® grinding system affixed with a vacuum mounting chamber, which facilitated careful grinding of excess wafer with an attached micrometer for precision grinding. Thickness was assessed using a digital micrometer and microscope to ensure proper visualization of microstructure. Average (mean) thickness for all thin-sections was found to be 39.79 µm (± 10.92 µm). Brönniman and colleagues (2018) advocate for a thickness of 30 µm for histotaphonomic analysis, to permit distinguishing differing microbial structures from overlapping and complicating diagnosis. However, 30 µm can be difficult to achieve across the entirety of a rib thin section without risking some areas become ground more significantly than others. In the event of uneven grinding, slides were ground on the PetroThin® to approximately 50 µm, and then further ground and polished in a progressive manner using 600-, 800-, and 1100-grit sandpaper and a small drop of water. Slides were finished by placing 1-2 drops of Permount® mounting medium atop the thin-section, and subsequently cover-slipped, ensuring care to avoid air bubbles.

Microscopy and Imaging

Samples were analyzed using a Leica DM-2500 in plane-polarized and cross-polarized light using a lambda (λ/2) plate filter for birefringence scoring (Schultz 2001; Bromage et al. 2003). Images were taken using an attached Leica K3C camera and the Leica Application Suite X (LAS X) software platform. Approximately 20-50 images at 50x encompassing the cortical bone were taken per sample in both plane-polarized and cross-polarized light, then stitched together using the Stitching plugin developed by Preibisch et al (2009) in Fiji (**F**iji **i**s **j**ust **I**mageJ: https://imagej.net/software/fiji/). This allowed for composite images (Figures 10.1-10.2) to be analyzed and scored, with further magnification as needed in particular intracortical regions.

Figure 10.1 - Comparison of well-preserved (A) and poorly-preserved (B) samples from Largo Cândido dos Reis.

Rib samples from Largo Cândido dos Reis. Both samples are composite (stitched) images of ~30 micrographs taken at 50x in plane-polarized light. Endosteal and periosteal margins were then traced and created the bounded image to remove trabeculae. **A**) Rib sample from LCR 352, a Christian male aged 30-49 years from a primary inhumation. Overall, the bone is well-preserved (OHI = 4) but minor foci of bioerosion, mainly budded *mfd* and Wedl tunneling (BAI = 4, WTI = 4), as well as cracking (CRI = 3). **B**) Rib sample from LCR 10, an Islamic male aged 50+ years from a primary inhumation. Overall, the bone is heavily inundated with bioerosion, with virtually no microstructure visible other than Haversian canals, save for a small few areas in the medial cortical portion (overall, < 5% visible microstructure; OHI = 0).

Figure 10.2 - Comparison of birefringent (A) and poorly-preserved (B) samples.

Rib samples from Largo Cândido dos Reis. Both samples are composite (stitched) images of ~30 micrographs taken at 50x in cross-polarized light using a lambda (λ/2) plate filter. Endosteal and periosteal margins were then traced and created the bounded image to remove trabeculae. **A**) Rib sample from Av5Out 3049, a female aged 50+ years with indeterminate funerary treatment (COI = 5). Specimen exhibits high birefringence with fluorescing regions throughout the entire cortical structure, indicative of collagen fibers. **B**) Rib sample from LCR 239_B, a Christian female aged 18-29 years from a co-mingled deposit. Overall, the bone is heavily inundated with bioerosion, and virtually no accompanying birefringence (COI = 1).

Analysis and Scoring

Samples were assessed using both the Oxford Histological Index (OHI; Table 10.2) developed by Hedges et al (1995) and Millard (2001), and further refined histotaphonomic indices by Brönniman and colleagues (2018) (Table 10.3). Scores of 0 correspond to almost no microstructure (< ~5%) visible, whereas scores of 5 refer to near-perfect preservation of microstructure (> ~95%), based on the presence of *mfd* defined by Hackett (1981) (Figure 2). The OHI facilitates comparison with other studies and gives a general sense of preservation, but comes with the disadvantage of aggregating various forms of microbial effects (Hollund et al. 2012, 541). Wedl tunneling was differentiated from bacterial attack based on the former's dendritic morphology (Brönnimann et al. 2018). Wedl tunnels are typically described as being 8-10 μm in diameter (Bell et al. 1996; Hackett 1981; Jans et al. 2002; Millard 2001), but some literature (Fernández-Jalvo et al. 2016, 276) suggest that lab-cultured fungi tunnel diameters (e.g., *Chaetomium*) consistent with Wedl scoring can in fact be narrower. When possible, Wedl tunneling was distinguished between it's more pervasive tunneling (Type I) and enlarged canaliculi (Type II) (Jans 2008; Trueman et al. 2002). Collagen and cracking were analyzed visually based on collagen birefringence (1 = minor amounts of collagen present, 5 = near perfect preservation; Figure 3) and the amount of cracking present (0 = major amounts of cracking, 5 = minor amounts; Figure 4) following Brönniman et al (2018). While Jans (Jans et al. 2002; Jans 2004) advocates for counting the number of cracked versus non-cracked osteons to estimate percentage of cracked microstructure, bioerosion often obfuscated microstructure and therefore complicated this calculation. Cracking was instead estimated based on overall general percentage affected, when scoreable (Brönnimann et al. 2018). Numerous studies have employed histotaphonomic analyses of heat/thermal alteration by examining both coloration in tandem with collagen fiber orientation and mineral organization (Squires et al. 2011; Fernández Castillo et al. 2013; Fernández Castillo et al. 2013; Brönnimann et al. 2018). However, given that no bones showed any signs of thermal alteration or burning, the Heat Index was not included in the present study. Finally, Cyanobacteria, typically characterized by larger diameter than *mfd*, were also analyzed but were not observed in the present samples. While I employed the Cyanobacterial Attack Index (CAI), no samples showed any signs of cyanobacterial attack (all scores = 5), which is unsurprising given that all samples were likely not in contact with water given their elevated positioning atop the city's limestone plateau. As such, they are omitted from these visual and statistical results.

In order to obtain cross-sectional area measurements, microscopic slides were placed under a Leica MZ6 microscope with a Leica K3C digital camera attachment. Cross-sectional area was calculated using ImageJ software, whereby a polygon was traced along the outermost (periosteal) border, which then calculated the total area (Tt.Ar) for the rib cross section. A polygon was then traced along the endosteal border where the cortical and trabecular margins conjoined, which resulted with the endosteal area (En.Ar). Cortical area (Ct.Ar) was calculated by subtracting the endosteal area (En.Ar) from the total area (Tt.Ar; Fig. 10.3D). The percentage of cortical area present was determined by dividing cortical area by total area and multiplying by 100 (Ct.Ar./Tt.Ar*100; abbreviated here as CI).

I employed multiple correspondence analysis (MCA) here as a multivariate means of assessing inter-relationships between categorical variables (indices, age, sex, mortuary treatment, and site) and supplementary cortical area measurements (Tt.Ar, En.Ar, Ct.Ar, CI). Multiple correspondence analysis is part of a larger family of correspondence analysis, which assesses associations between categorical variables (Abdi et al. 2007; Abdi et al. 2013; Sourial et al. 2010). Analyses were carried out in R.Studio (RStudio Team 2020) using the factomine package (Lê et al. 2008). The histotaphonomic indices OHI (0-5), BAI (0-5), WTI (0-5) and COI (1-5) were treated as active variables. Cracking index (CRI) was omitted due to the quantity of unobservable samples. Demographic variables of Age (18-29, 30-49, 50+), Sex (Male or Female), Mortuary treatment (Islamic or Christian), and Site (Av5Out or LCR) were treated as categorical supplementary variables. Finally, rib cortical bone cross sectional data, Total Area (Tt.Ar), Endosteal Area (En.Ar), Cortical Area (Ct.Ar), and Cortical Index (Ct.Ar/Tt.Ar*100; abbreviated here as CI) were treated as numeric supplementary variables in the MCA. Individuals with any missing or indeterminate data were omitted from the MCA in a row-wise manner, such that the MCA was carried out on a complete case analysis (n = 106). Given the minor prevalence in some scores (e.g., WTI = 5), a secondary MCA was performed, but with indices collapsed in a binary manner, such that scores 0-2 (< 50% microstructure visible) were treated as "poorly preserved", and scores 3-5 (>50% microstructure visible) were treated as "well-preserved." Collagen Index (COI) scores were collapsed as 1-2 (poorly-preserved) and 3-5 (well-preserved). This aided in reducing dimensionality while sacrificing granularity score differences.

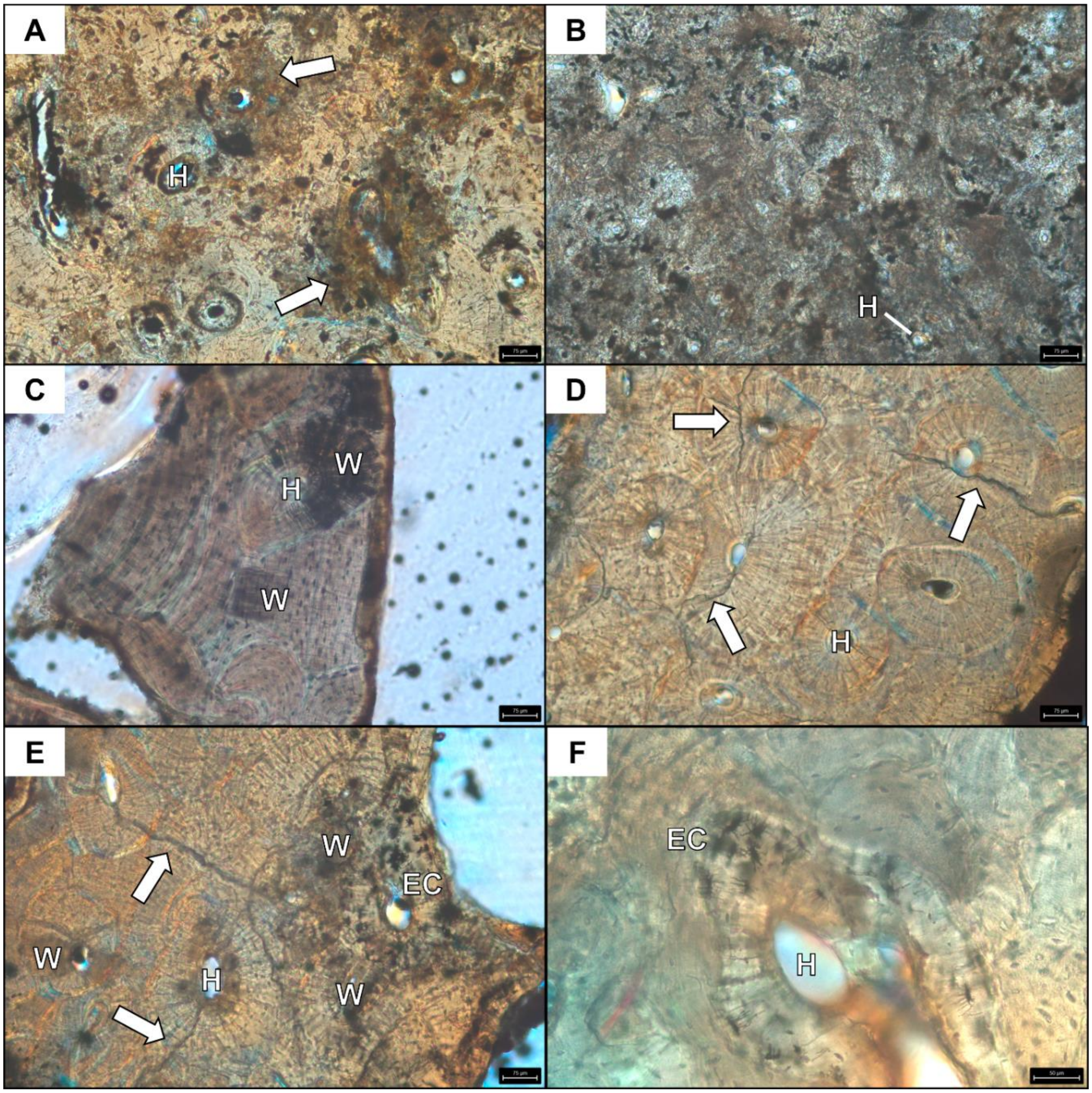
Table 10.2 – Oxford Histological Index (OHI) by Hedges et al (1995, 203).

Score	Approximate percentage of microstructure preserved	Description
5	> 95%	Very well preserved, virtually indistinguishable from fresh bone
4	> 85%	Only minor amounts of destructive foci, otherwise, generally well preserved
3	> 50%	Clear preservation of some osteocyte lacunae
2	< 50%	Clear lamellate structure preserved between destructive foci
1	< 15%	Small areas of well-preserved bone present, or some lamellar structure preserved by pattern of destructive foci
0	< 5%	No original features identifiable, other than Haversian canals

Table 10.3 – Histotaphonomic indices, following Brönniman et al 2018, 48. Each of the scales follow the general premise of the OHI (scores of 0 = completely destroyed microstructure; scores of 5 = perfect preservation).

Index	Scale	Description
Bacterial Attack Index (BAI)	0-5	Intensity of bacterial attack (*budded mfd, linear longitudinal mfd, lamellate mfd*)
Wedl-Tunnel Index (WTI)	0-5	Intensity of Wedl-tunnels (suspected fungal attack)
Cracking Index (CRI)	0-5	Intensity of crack formation
Collagen Index (COI)	1-5	Preservation of collagen based on intensity of birefringence using cross-polarized filters
Cyanobacterial Attack Index (CAI)	0-5	Intensity of cyanobacterial attack

Figure 10.3 - Examples of microscopical focal destruction (*mfd*) analyzed in present study.



Rib samples from Largo Cândido dos Reis. All images are taken in plane-polarized light and at 150x magnification unless otherwise specified. **A**) LCR 147 showcasing patchy distribution of microbial attack *mfd* (white arrows). Some lamellar features and Haversian canals (H) still visible). **B**) LCR 130, showing signs of heavy microbial attack and bioerosion such that Haversian canals (H) are the only visible microstructural feature. Note the differing colors and superimposition of some microbial attack over other features. **C**) LCR 228 with generally well-preserved microstructure, with visible osteons, concentric and interstitial lamellae, and Haversian canals (H) but incipient signs of Wedl tunneling. Note the patterning along the periosteal and concentric lamellae. **D**) LCR 352 with generally well-preserved microstructure other than sings of cracking (arrows); however another micrograph taken elsewhere in the rib cortical structure (**E**) similarly shows signs of cracking (white arrows) and Wedl tunneling, both type 1 (W) and type 2 in the form of enlarged canaliculi (EC). **F**) Micrograph of LCR 367 taken at 200x magnification to show the presence of enlarged canaliculi situated circumferentially to a Haversian canal (H). Note the size difference between the enlarged canaliculi and neighboring lacunae.

Results

The majority of samples analyzed had little microstructure preserved and were heavily inundated with bioerosion. A total of 59.8% (88/147) of samples analyzed showcased signs of heavy microbial attack (BAI score = 0) and 59.18% (87/147) had virtually no microstructure visible according to the more general OHI. Wedl tunneling (WTI) was not as prevalent as bacterial attack, affecting only 46.94% of samples (scores < 5), and substantially less inundation (9.52%) compared to bacterial attack. Only one individual (Av5Out 612) seemed to exhibit signs of intense Wedl attack that inundated nearly the entire microstructure. Collagen was generally poor, with 78.91% of overall samples (116/147) showing scores < 3.

Table 10.4 - Histotaphonomic indices by Funerary Group (*n* = 62 Islamic, *n* = 68 Christian).

	OHI		**BAI**		**WTI**		**COI**		**CRI**	
Score	Islamic N (%)	Christian N (%)	Islamic N (%)	Christian N (%)	Islamic N (%)	Christian N (%)	Islamic N (%)	Christian N (%)	Islamic N (%)	Christian N (%)
5	0 (0.00)	1 (1.47)	3 (4.84)	1 (1.47)	30 (48.38)	41 (60.29)	3 (4.84)	2 (2.94)	13 (20.97)	18 (26.47)
4	5 (5.72)	7 (10.29)	5 (8.06)	7 (10.29)	12 (19.35)	20 (29.41)	8 (12.90)	4 (5.88)	11 (17.74)	4 (5.88)
3	10 (11.66)	6 (8.82)	4 (6.45)	5 (7.35)	10 (16.13)	4 (5.88)	4 (6.45)	6 (8.82)	0 (0.00)	2 (2.94)
2	4 (4.70)	2 (2.94)	8 (12.90)	3 (4.41)	7 (11.29)	3 (4.41)	12 (19.35)	12 (17.65)	3 (4.84)	1 (1.47)
1	8 (9.59)	11 (16.18)	7 (11.29)	10 (14.71)	2 (3.23)	0 (0.00)	35 (56.45)	44 (64.71)	1 (1.61)	2 (2.94)
0	35 (56.45)	41 (60.29)	35 (56.45)	42 (61.76)	1 (1.61)	0 (0.00)	—	—	0 (0.00)	1 (1.47)
Indet.	—	—	—	—	—	—	—	—	34 (54.84)	40 (64.42)

Table 10.5 - Histotaphonomic indices by Sex (*n* = 58 females, *n* = 85 males).

	OHI		**BAI**		**WTI**		**COI**		**CRI**	
Score	Female N (%)	Male N (%)	Female N (%)	Male N (%)	Female N (%)	Male N (%)	Female N (%)	Male N (%)	Female N (%)	Male N (%)
5	1 (1.72)	0 (0.00)	3 (5.17)	1 (1.18)	29 (50.00)	48 (56.47)	3 (5.17)	3 (3.53)	13 (22.41)	21 (24.71)
4	7 (12.07)	8 (9.41)	6 (10.34)	8 (9.41)	18 (31.03)	19 (22.35)	6 (10.34)	8 (9.41)	7 (12.07)	9 (10.59)
3	5 (8.62)	9 (10.59)	3 (5.17)	5 (5.88)	5 (8.62)	11 (12.94)	2 (3.45)	7 (8.24)	0 (0.00)	1 (1.18)
2	3 (5.17)	4 (4.71)	5 (8.62)	7 (8.24)	4 (6.90)	6 (7.06)	10 (17.24)	15 (17.65)	2 (3.45)	2 (2.35)
1	7 (12.07)	13 (15.29)	6 (10.34)	12 (14.12)	2 (3.45)	0 (0.00)	52 (63.79)	52 (61.18)	1 (1.72)	2 (2.35)
0	35 (60.34)	51 (60.00)	35 (60.34)	52 (61.18)	0 (0.00)	1 (1.18)	—	—	0 (0.00)	1 (1.18)
Indet.	—	—	—	—	—	—	—	—	35 (60.34)	49 (57.65)

Table 10.6 - Histotaphonomic indices by Age
(n = 32 18-29 years, n = 41 30-49 years, n = 46 50+ years, n = 28 indeterminate age).

	OHI				**BAI**				**WTI**			
	18-29	30-49	50+	Indet.	18-29	30-49	50+	Indet.	18-29	30-49	50+	Indet.
Score	N (%)	N (%)	N (%)	N (%)	N (%)	N (%)	N (%)	N (%)	N (%)	N (%)	N (%)	N (%)
5	0 (1.7)	1 (2.4)	0 (0.0)	0 (0.0)	1 (3.1)	1 (2.4)	2 (4.4)	1 (3.6)	13 (40.6)	23 (56.1)	26 (56.5)	16 (57.1)
4	4 (12.5)	3 (7.3)	5 (10.9)	3 (10.7)	3 (9.4)	3 (7.3)	4 (8.7)	5 (17.9)	11 (34.4)	11 (26.8)	13 (28.3)	3 (10.7)
3	2 (6.3)	2 (4.9)	4 (8.7)	9 (32.1)	3 (9.4)	2 (4.9)	1 (2.2)	3 (10.7)	5 (15.6)	4 (9.8)	3 (6.5)	5 (17.9)
2	3 (9.4)	1 (2.4)	2 (4.4)	1 (3.6)	3 (9.4)	1 (2.4)	4 (8.7)	4 (14.3)	3 (9.4)	3 (7.3)	3 (6.5)	2 (7.1)
1	5 (15.6)	8 (19.5)	5 (10.9)	2 (7.1)	3 (9.4)	8 (19.5)	5 (10.9)	2 (7.1)	0 (0.0)	0 (0.0)	1 (2.2)	1 (3.6)
0	18 (56.3)	26 (63.4)	30 (65.2)	13 (46.4)	19 (59.4)	26 (63.4)	30 (65.2)	13 (46.4)	0 (0.0)	0 (0.0)	0 (0.0)	1 (3.6)
Indet.	—	—	—	—	—	—	—	—	—	—	—	—

	COI				**CRI**			
	18-29	30-49	50+	Indet.	18-29	30-49	50+	Indet.
Score	N (%)	N (%)	N (%)	N (%)	N (%)	N (%)	N (%)	N (%)
5	1 (3.1)	1 (2.4)	3 (6.5)	1 (3.6)	8 (25.0)	10 (24.4)	8 (17.4)	10 (35.7)
4	3 (9.34)	4 (9.8)	2 (4.4)	5 (17.9)	5 (15.6)	4 (9.8)	5 (10.9)	2 (7.1)
3	2 (6.3)	3 (7.3)	3 (6.5)	3 (10.7)	0 (0.0)	1 (2.4)	0 (0.0)	1 (3.6)
2	5 (15.3)	8 (19.5)	9 (19.6)	5 (17.9)	1 (3.1)	0 (0.0)	2 (4.4)	1 (3.6)
1	21 (65.6)	25 (61.0)	29 (63.0)	14 (50.0)	1 (3.1)	1 (2.6)	1 (2.2)	0 (0.0)
0	—	—	—	—	0 (0.0)	0 (0.0)	0 (0.0)	1 (3.6)
Indet.	—	—	—	—	17 (53.1)	25 (61.0)	30 (65.2)	13 (46.4)

Table 10.7 - Output of ordered (0-5) and binomial (0/1) logistic regression, with OHI as outcome variable.

	Value	St. Error	t/z-value	p-value	95% CI	OR	95% CI
Ordinal							
Mortuary	0.07	0.39	0.18	0.86	-0.70 – 0.83	1.07	0.50 – 2.31
Age (linear)	-0.21	0.34	-0.62	0.54	-0.88 – 0.46	0.81	0.41 – 1.59
Age (quadratic)	0.07	0.34	0.20	0.84	-0.59 – 0.74	1.06	0.56 – 2.09
Sex	-0.17	0.40	-0.42	0.67	-0.95 – 0.62	0.84	0.39 – 1.85
Binomial							
Intercept	-1.47	0.49	-3.01	< 0.01	-2.42 – -0.51	0.23	0.08 – 0.57
Mortuary	-0.10	0.51	-0.19	0.85	-1.10 – 0.90	0.91	0.33 – 2.49
Age (linear)	0.02	0.45	0.05	0.96	-0.86 – 0.90	1.02	0.43 – 2.58
Age (quadratic)	0.15	0.45	0.33	0.74	-0.73 – 1.04	1.16	0.49 – 2.96
Sex	-0.02	0.52	-0.03	0.98	-1.04 – 1.01	0.98	0.35 – 2.82

Figure 10.4 - Comparison of histotaphonomic indices by funerary group (n = 62 Islamic, n = 68 Christian).

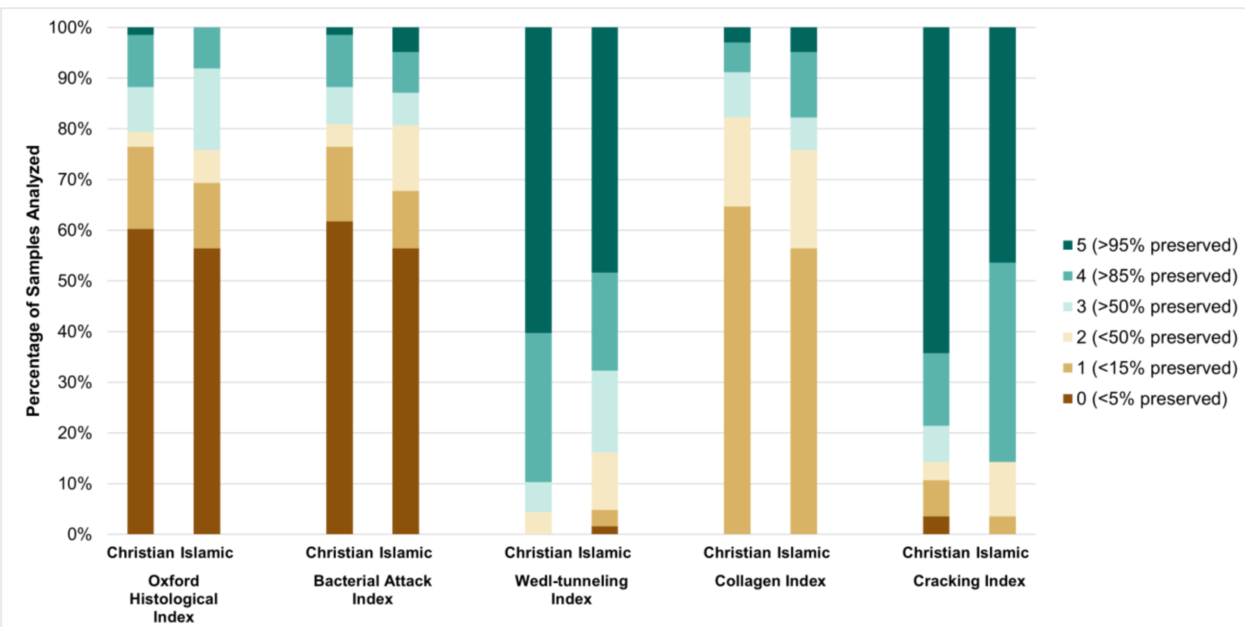


Figure 10.5 - Comparison of histotaphonomic indices by sex (n = 58 females, n = 85 males).

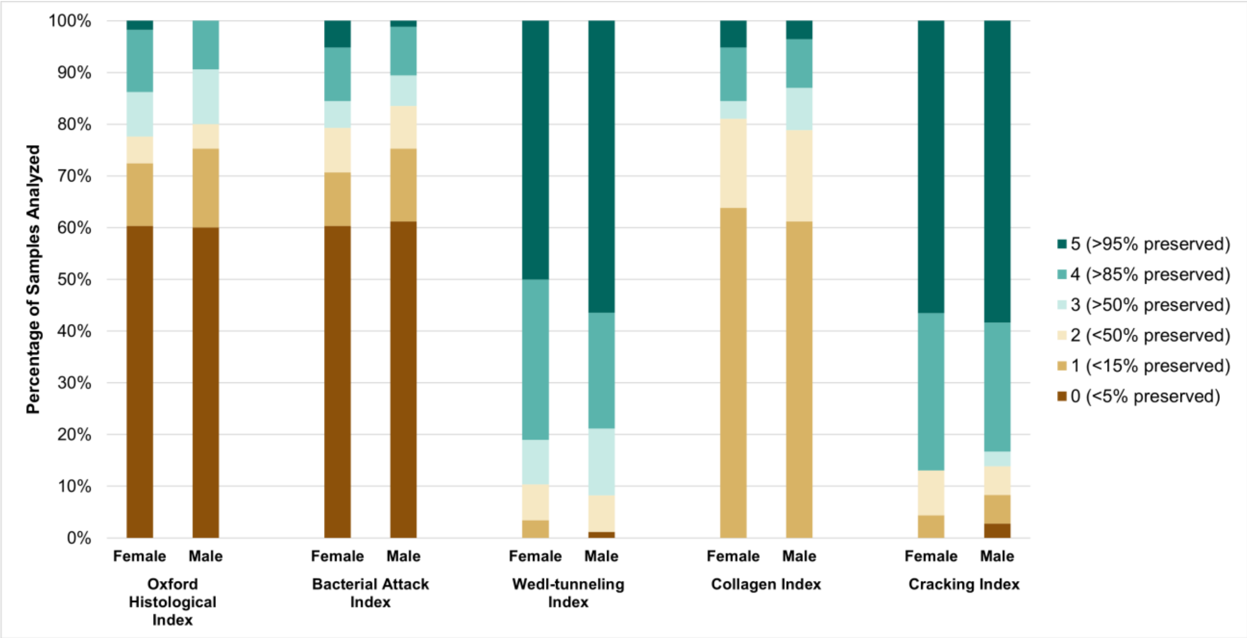
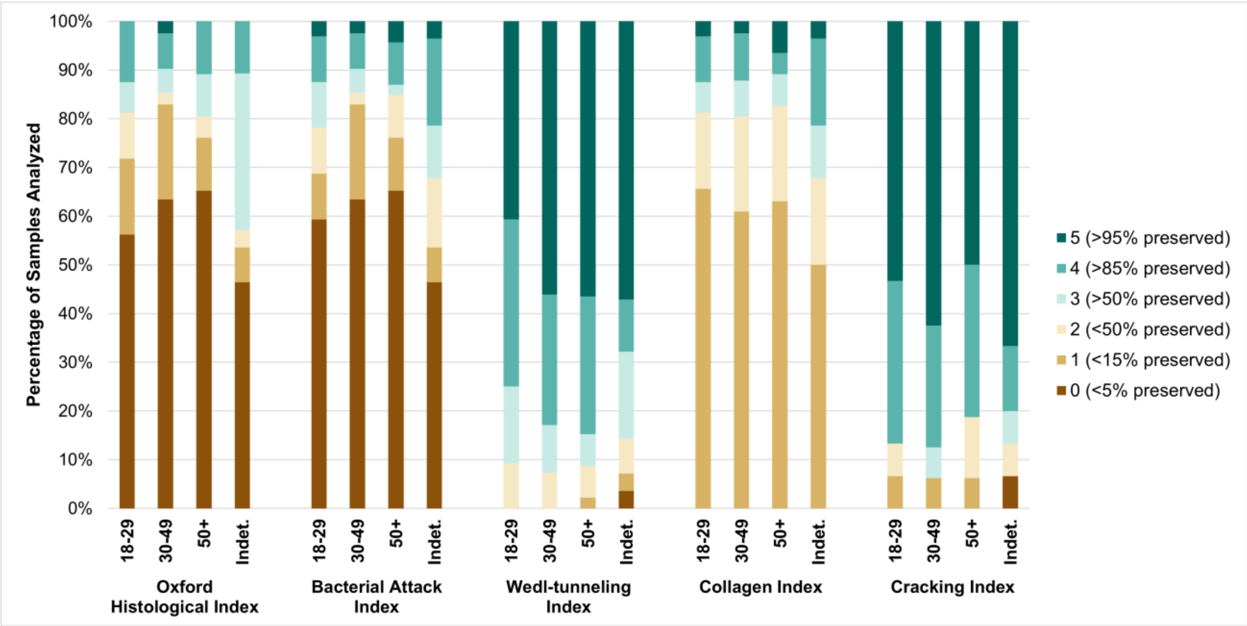


Figure 10.6 - Comparison of histotaphonomic indices by age group
(18-29 years n = 32, 30-49 years n = 41, 50+ years n = 46, indeterminate age n = 28).



The counts and percentage of scores for each histotaphonomic index by funerary group can be seen in Table 4, and visually depicted in Figure 5. A cumulative 79.41% of Christian samples and 75.81% of Islamic samples showed OHI scores of < 3, with more than 50% of the microstructure being unobservable due to bioerosion. When analyzed by sex, no major differences were observed in histotaphonomic indices (Table 10.5, Figure 10.5). Slight differences in age categories were observed between OHI and BAI scores of 0 between younger (OHI = 56.25%; BAI = 59.38%) and older (OHI = 65.22%; BAI = 65.22%) age categories (Table 10.6, Figure 10.6).

Multiple correspondence analysis (MCA) on the ordinal histotaphonomic indices provided 5 significant dimensions, containing 68.62% of the cumulative variance (Appendix 10.2). Contributions to Dimension 1 were seen primarily from poorly preserved indexes for microbial attack (OHI = 0), bacterial attack (BAI = 0), and lack of collagen (COI = 1). Overall, demographic indicators (Age, Sex, Site, Mortuary treatment) and rib cross-sectional area measurements (Total Area, Endosteal Area, Cortical Area, and Cortical Index) contributed little to the overall variation in histotaphonomic indices. Results of the ordinal MCA provided substantially less dimensions (4) with 91.59% of the cumulative variance found in the first two dimensions (Appendix 10.3). Wedl-tunneling was observed as semi-separated, while other indices (OHI, COI, and BAI) clustered together. Similar to the results from the ordinal MCA, all supplementary variables (Age, Sex, Mortuary, Site, and rib cortical cross-sectional area measurements) clustered near the origin. Contributions to Dimension 1 were predominately from well-preserved BAI, OHI, and COI indices, whereas Dimension 2 was sourced mainly from poor preservation as a result of Wedl-tunneling.

Discussion

Cracking was not observed in the majority of samples (85/147; 57.82%), which is unsurprising given the intensity of microbial attack obfuscating microstructure. The cracking we do observe does not seem to originate from thermal alteration. Given that collagen was poorly preserved (78.91% exhibited Collagen Index scores < 3), I suggest that cracking in this sample was likely the result of alternate wetting-drying cycles which causes expansion and contraction of microstructure, or alkaline-mediated collagen loss (Collins et al. 1995; Jans 2013; Nielsen-Marsh et al. 2007; Smith et al. 2002).

If fungi are indeed responsible for Wedl tunneling and are the result of saprophytic fungi as Marchiafava et al. (1974) once suggested, then it follows that Wedl tunneling indicates the presence of oxygen at the time of Wedl attack as saprophytic fungi are aerobic (Jans 2013, 23). Given the fact that all remains were skeletonized and the additional presence of archaeomalacological remains of pulmonary gastropods (Matias, personal communication), it is indeed likely that all burials observed were aerobic in nature. While some have not observed Wedl tunneling in calcareous sediments (Huisman et al. 2017), others have (Brönnimann et al. 2018). Most burials, especially those at Largo Cândido dos Reis, were interred in predominately calcareous soils or direct relief of limestone (82.94% - 84.79%), with occasional burials (15.21% - 17.06%) showing additional inclusions of clay horizons (Matias 2008a). At least three soil samples taken from various burial contexts exhibited basic pH levels (8.4 - 8.7), minimal organic material (0.4% - 1.3%), and high calcareous concentrations (47% - 79%). Some suggest that enlarged canaliculi (Wedl Type II) are the product of acids entering the bone (Jans 2008; Trueman et al. 2002), but the relationship still remains unclear. Duday and Guillon (2006) posit that the release of fluids during putrefaction can interact with the soils along the burial floor, which may result in more corrosive burial microenvironment, but whether this would be substantial enough to facilitate Wedl Type II *mfd* is not known. Bacterial and fungal attack appeared to rarely co-occur, such that bones heavily inundated with bacterial attack (BAI = 0) seldom showed signs of heavy Wedl tunneling. This can be seen clearly in results of both of the MCA biplots (Appendix 10.3 and 10.5). This finding is similar to what Jans et al (2004) found, and although the mechanism is not currently well understood, it may possibly be the result of competition between bacterial and fungal organisms such that preliminary colonizers may outcompete the other.

Bacterial attack index (BAI) and the Oxford Histological Index (OHI) clustered closely in both the ordinal and binomial MCA, which is unsurprising considering they both effectively measure the intensity of microbial attack, with the former simply distinguishing from Wedl tunneling. Collagen preservation (COI) was similarly close to BAI and OHI values, which was expected as bacterial attack is thought to directly result in the digestion of collagen via secretion of collagenases (Hackett 1981; Jans 2004, 87; Turner-Walker et al. 2002).

Bioerosion by Funerary Groups

Relatively equal distributions of OHI and BAI values between funerary groups was not expected and may suggest that both funerary groups practiced rapid burial. I hypothesized that Islamic funerary rites may have encouraged more rapid burial contra to their Christian counterparts, stemming from ethnohistorical manuals and Maliki jurisprudential rites (Bukhârî 1977; Fortier 2010; Petersen 2013). Under the endogenous model of bioerosion, perimortem burial would subject the body to prolonged periods of putrefaction and subsequently, bacterial attack (Bell et al. 1996; Booth 2016; 2017; Hollund et al. 2012; Hollund et al. 2018; Jans et al. 2004; Parker Pearson et al. 2005; White et al. 2014). With this in mind, the results suggest that Christian and Islamic burials were likely interred at relatively similar perimortem intervals, such that no differences in putrefaction was experienced between funerary groups. What delay, if any, Christian cadavers received between death and burial may not have been enough to alter putrefactive trajectories for bacterial attack. Alternatively, under the exogenous model, relatively similar values between funerary groups is likely a product of local soil bacteria, such that the general lack of variation by any demographic indicator is parsimoniously explained by the shared experience of local bacteria. However, as some have pointed out (Balzer et al. 1997; Booth 2016), whether collagenase-producing bacteria found within soils (Vraný et al. 1988) are capable of producing *mfd* is still not well understood, possibly due to their inability to produce collagenase in burial environments (Child 1995). Further research, preferably experimental studies using human cadavers, are desperately needed to better elucidate microbial and bacterial origins.

Funerary Textiles

While I hypothesized Islamic samples would exhibit increased signs of bioerosion compared to their Christian counterparts due to rapid burial, the relationship of bioerosion with textiles is worth further consideration. There is archival, art-historical, and archaeothanatological evidence for the employment of burial shrouds in both medieval Christian and Islamic funerary rites (Bianquis 2012; Buturovic 2017; Daniell 1997; Gatrad 1994; Korpiola et al. 2015; Litten 2007; O'Sullivan 2013a; Petersen 2013; Tritton 2008), despite the fact that shrouds seldom survive archaeologically (Janaway 2002; Ueland et al. 2015). Burial clothing and/or wrapping appear to facilitate absorption and draining of bodily fluids during decomposition (Bouquin et al.

2012; Dautartas 2009; Kelly 2006; Voss et al. 2011b). In an experimental study using pig models, Kontopoulos et al (2016) found differential preservation according to the textile composition in which the bone was wrapped. Thin-sections from the mid-diaphysis of three left humeri covered in different materials — one in 100% cotton blanket, another in 79% cotton, 20% nylon, 1% elastane socks, and the final in 100% nylon carpet — exhibited differential preservation, such that the samples covered in cotton materials (blanket and socks) exhibited minor bacterial activity in the periosteal/sub-periosteal and endosteal surfaces, while the sample covered in carpet demonstrated poor preservation and generalized destruction. Both wool and cotton are particularly susceptible to bacterial and fungal attack and subsequent degradation, often not surviving more than a few months outside of specific environmental conditions (Janaway 2002). The authors posit that cotton, being comprised of cellulose, may be preferentially utilized by soil microorganisms, while more resistant textiles such as nylon may facilitate increased bacterial and fungal inundation in bone due to microorganisms secreting chemical compounds (Kontopoulos et al. 2016, 326).

It was surprising to see such intensity of both generalized destruction and bacterial attack in both funerary groups, given the hypothesis that Islamic funerary rites employed shrouds more systematically than their Christian counterparts. However, in numerous cases, the presence of belt buckles and/or small needles encircling the corpse was observed (Matias, personal communication), suggesting the cadaver was in some cases buried with vestments, or shrouded such that the fabric was pinned together. This likely differed from Islamic *kafan* which traditionally emphasized knots and tying to pins, but how widespread this practice was is not fully understood. Additionally, at least 55.10% of Christian burials analyzed showed likely signs of burial containers in the form of tight durable, loose durable, or tight non-durable wrapping (Trombley et al in review). Therefore, while both funerary groups may have employed burial containers in the form of shrouds, increase in Wedl tunneling intensity (scores < 3) Islamic samples (10/62; 16.13%) compared to Christian samples (3/68; 4.41%) could be the result of increased susceptibility due to cotton shrouds, whereas Christians possibly employed more durable material. At present, the relationship between burial textiles and histotaphonomic indices are difficult to illuminate, given: 1) the fact that textiles do not preserve, 2) archaeothanatological evidence of their employment can be complicated by narrow tomb dimensions, something observed in Islamic tombs at both Avenida 5 de Outubro and Largo Cândido dos Reis, and 3) further knowledge needed on textile production and constitution in the region during the Islamic period.

Traditionally in Muslim funerary rites, *kafan* refers to "Yemeni cotton", the composition of which, if truly cotton, would likely degrade relatively rapidly due to their absorbent properties (Janaway 2002). At least for the later Christian middle ages (15^{th} – 16^{th} c. BCE), wool and linen were produced in far greater quantities than silk or cotton, largely due to available raw materials (Sequeira 2014, 35). Santarém, in particular, seems to have produced predominately linen and wool but not cotton or silk, at least based on available sources (Sequeira 2014, 38, 45). Vestments in medieval Portugal were commonly made of a coarse, low-quality wool produced throughout much of Iberia, while silk was reserved for members of the nobility or aristocracy (Oliveira Marques 1971). Even low quality wool has the potential to resist most acidic environments (above a pH of 2) due to the disulfide links which help maintain structural integrity (Janaway 2002). Additionally, some religious burials throughout medieval Christendom employed sackcloth — a rugged fabric often consisting of animal hair — or cerecloth — fabrics inundated in a form of wax, often beeswax — as funerary vestments or as a substrate between the body and the grave floor (Korpiola et al. 2015, 22–23). In acidic burial environments, protein-based fibers such as wool, animal hair, and silk preserve relatively well while materials consisting of cellulose such as cotton and linen degrade much more rapidly (Janaway 2002). Altogether, the use of animal-based fibers in funerary vestments and substrates in the Christian funerary tradition, paired with skeletal evidence for possible durable wrapping may suggest possible buffering from erosive agents compared to their Islamic counterparts which employed plant-based burial containers. However, as Danielle (1997) has observed in the case of late medieval England, simple linen or cotton shrouds were likely employed. Additionally, given the limited data on raw material cotton production in central Portugal (Sequeira 2014), it's difficult to discern if *kafan* would have truly been made with local and/or imported cotton, or some other local material altogether (e.g., linen). It is speculative, but plausible, that both funerary groups employed similar funerary textiles in wrapping the dead based on local available materials.

Age and Sex Considerations

While observed OHI and BAI values increased in intensity between estimable age groups, age was not found to contribute to the overall variation in a significant manner. This is despite decreases in cortical area (Ct.Ar), increases in medullary area (En.Ar), and overall decrease in cortical index (Ct.Ar/Tt.Ar*100; CI) across age groups. In essence, the intensity of bioerosion is not so much dependent on the amount cortical bone itself so much as that bone's intracortical *porosity* (Agnew et al. 2012; Boskey et al. 2010; Jowsey 1966; Nielsen-Marsh et al. 2007; Sharpe 1979; Smith et al. 2007; Turner-Walker et al. 2002). While I was unable to collect intracortical porosity data in the present study due to issues of infilling for measuring manually (Agnew et al. 2012) and inability to threshold for semi-automated pore extraction due to adjacent color gradients between pores and cortical bone (Cole 2014), porosity measurements will likely prove an crucial avenue for further research. Booth (2016) found no age-related increases in bioerosion once neonates were removed, which showed significantly less bioerosion than their post-neonatal counterparts. Booth (2016, 492) articulates these results in contrast of Turner-Walker's (2008, 9–15) hypothesis that increased bacterial bioerosion is a result of increasing porosity; however, given that all post-neonates were lumped together in Booth's study, it is indeed difficult to assess whether more granular age-separations, especially in adults whose porosity quality and quantity alter throughout the life course, would not have yielded significant results.

General lack of sex differences support the hypothesis and may indicate similar funerary treatment for both males and females, regardless of religious funerary group. Even when separated by funerary group, sexes still showed only minor differences in histotaphonomic indices (Appendix 10.1). This may indicate that both males and females, regardless of religious funerary group, received relatively similar funerary preparation, or at least insofar as it did not affect putrefaction, a finding similar to what was found by Goren et al (2021) at Çatalhöyük, though sample sizes were admittedly small.

As Turner-Walker (2008, 20) states, bacterial attack "…is almost ubiquitous and can be found in bones from almost all ages, from decades to millions of years. Only in bones recovered form contexts representing rapid burial in anoxic sediments or those from very cold climatic regions are these features absent." Most bacterial *mfd* is fairly uniform in morphology regardless of geographic or temporal factors (Kars et al. 2002), suggesting a consistent potential for bacterial bioerosion in osteological remains. Altogether, the pervasiveness and intensity of bacterial attack observed in the present study, regardless of age, sex, site, or funerary group, may bolster Jans's (2008, 409) claim that the majority of archaeological bone, especially human bones inhumed as complete bodies, are likely destined to heavy bioerosion and diagenetic alteration by microbial attack (Jans et al. 2004).

Conclusion

The results of this chapter suggest that mortuary treatment, despite the potential to severely affect macrotaphonomic outcomes, appears not to have had a significantly observable effect on the microstructure of bone in this sample. Numerous scholars (Hanson et al. 1987, 553; Fernández-Jalvo et al. 2010, 76) have pointed out that taphonomic alterations and preservation at the macroscopic level in bone seldom correspond in a predictable manner to preservation observed histologically. What constitutes "well-preserved" bone varies by scale of analysis, posing both a challenge and an exciting opportunity for tacking between taphonomic variables at both macro and microscopic levels in the same individuals and/or for scholars interested in expanding our knowledge of intra-skeletal variability.

Furthermore, despite the prevalence of bioerosive attack and little microstructural preservation, I argue that there is indeed utility in analyzing diagenetically altered bones. Following a long line of paleontologists, archaeologists, and other taphonomists: taphonomy and diagenesis are not simply reductive processes, but also *additive* ones (Behrensmeyer 1975; Behrensmeyer et al. 1985; Knüsel et al. 2016; Lyman 2010; Olsen 1980; Ringrose 1993). The removal of and destruction of biological tissues may well cause irreversible sample loss, but the processes of such destruction can still be informative when properly contextualized. What was once seen as a major impediment for histological assessment has since blossomed into a full-fledged area of research. Our results, among numerous other studies (Booth 2016; Booth et al. 2015; Brönnimann et al. 2018; Goren et al. 2021; Hollund et al. 2012; Hollund et al. 2018; Parker Pearson et al. 2005), suggest the exciting potential histotaphonomy has to offer in teasing apart funerary rites and diagenetic pathways in the past.

Chapter 11 - Conclusion

This dissertation sought to interrogate how religious identity, at least as reflected in burial/funerary treatment, may explain the variation observed in lifeways and deathways during the Portuguese Middle Ages. The presence of a multi-faith cemeteries in Iberia, palimpsest and multi-temporal as they may be, offer the unique opportunity to furnish a comparative approach while quasi-controlling for geography. The results suggest that religious funerary treatment explains much of the variation in deathways but comparatively less of the variation in lifeways. Put another way, few differences between funerary groups were observed in traditional bioarchaeological indicators of lived experience (dental indicators, cortical bone indices, indicators of stress), despite highly significant differences in taphonomy and preservation. This would appear to suggest that deathways are highly variable and lifeways are stable, but the relationship may paradoxically be the opposite. Consider how lifeways, and our ability to reconstruct them in bioarchaeology, are susceptible to numerous variables and signals: individual variation, the choice of which skeletal indicators are analyzed, equifinality, temporalities, and the numerous factors outlined in the osteological paradox (Wood et al. 1992).

The general lack of differences observed in lifeways may indeed suggest that religious identity did not factor majorly in the observed biological outcomes throughout the life course. At a most basic level, these data would suggest that life was not all that different between Muslims and Christians in this city. But such a statement should be met with extreme caution. The temporal dimensions of lifeways are complicated and entangled such that some skeletal manifestations may reflect episodic events whereas others are more aggregate and protracted in nature (Agarwal 2016; Gowland 2015). The heterochronicity of the skeleton is both incredibly powerful and problematic, depending on the resolution and perspective of the investigation. Here, the general lack of significant differences within and between funerary groups may be an issue of resolution and aggregation, such that meaningful differences become swamped out in what Hosek and Robb coined the "tyranny of the average" (Hosek et al. 2019). Issues of scale, whether intra-skeletally, individually, or within/between communities continue to pose a challenging but exciting area of bioarchaeological inquiry and potential. This dissertation largely focused on aggregate statistical analyses, but the lack of statistical differences at the aggregate level does not inherently preclude that meaningful biological and social differences were felt, experienced, and lived. Future approaches will benefit from tacking between varying scales to move from the community to the individual and back, and help elucidate differences in terms of *people* and *experience* rather than just *assemblages* (Boutin 2011; Hosek et al. 2019; Robb et al. 2018). What differences were observed tend to suggest that the Christian subgroup exhibited increased prevalence and odds of compromised growth and development from the indicators of non-specific stress, and possibly lower dietary quality as evidence by the dental evidence. Together, these may well suggest that the Christian conquest(s) ("Reconquista") may have facilitated a tumultuous restructuring of the city that accompanied changes in agriculture, food systems, sanitation networks, and urbanization (Gooderham et al. 2019; Lopes de Barros 2004; Lopes de Barros 2005; Oliveira 2015; Trinidade 2007a; Trinidade 2015; Vakil 2003). While the reconsideration of historical narratives from osteological data alone is not advisable (Novak et al. 2020), these data are exciting in their potential to synthesize with other comparative studies in evaluating the biosocial consequences of the Christian conquests and shifting religious-political autonomies (Gooderham et al. 2019; Toso et al. 2021). However, it is worth considering precisely *who* partook in the Christian settlement of central and southern Iberia following the

Islamic period. Future work examining regional mobility, such as employing radiogenic Strontium $^{87}Sr/^{86}Sr$ may help to elucidate the relative mobility of Christians within the city, and whether they moved because of economic necessity. Christians who migrated into Santarém following the Christian conquests may well have been economically impoverished, and the observed indicators of non-specific stress may be a result of intergenerational inertia (Gowland 2015; Kuzawa 2008). Additionally, the Christian valorization of poverty as a means of reverence and embodied practice of Christ's suffering complicate notions of suffering and stress as solely outside (environment/structure) affecting the within (body).

One of the major caveats of this dissertation is the focus on a limited cross-section of skeletal indicators of lifeways, with most corresponding to skeletal and/or oral health. As Temple and Goodman (2014b) pointed out, health is far more than simply the absence of a skeletal stress indicator or pathological lesion, and encompasses far more variables (psychological, social) than skeletons will ever fully record. Yet, bioarchaeologists have struggled to frame much of the discourse around health in non-materialist terms. Building on this, just as health is far more than skeletal indicators, life and lifeways encompass far more than just health, skeletal or otherwise. This dissertation examined lifeways, but in a highly limited capacity. Future research will benefit greatly from examining other aspects of lifeways not directly tethered with notions of health and pathology. Theoretically these could encompass identity, embodiment, and practice-based approaches which can be operationalized bioarchaeologically through the analysis of activity via musculo-skeletal markers (Inskip 2013b; 2016), diet via stable isotope analysis (Miller et al. 2018; 2020; Torres-Rouff et al. 2015), and body modification (Blom 2005; Burnett et al. 2017; Torres-Rouff 2002; Torres-Rouff 2012) to name only a few.

Bioarchaeological notions of lifeways are also highly influenced by issues of equifinality and complex temporalities. Novak (2017) deftly problematizes how bioarchaeological conceptions of cemeteries and their chronological dimensions are often far more protracted and nebulous than we tend to view them. By examining a historical cemetery associated with the Spring Street Presbyterian Church in Manhattan, New York, she notes how the cemetery "is actually a catchment zone of mingled and mangled temporalities" (Novak 2017, 239). While questioning the representativeness of cemeteries and resulting bioarchaeological data is certainly not new (Bocquet-Appel et al. 1982; DeWitte et al. 2015; Waldron 2007; Wood et al. 1992), Novak's novel contribution encourages us to reflect on the temporal dimensions of lives, cemeteries, and urban spaces even further, and how such linguistic reflections may better situate our data and results. Considering the data above, it is entirely possible that the lack of 'expected' differences in bone indices and indicators of non-specific stress is an artifact of differing "mingled and mangled" cohorts and generational sub-samples rather than an 'expected' loss or maintenance throughout the life course.

Stemming from these issues of representativeness, the osteological paradox was a common theme discussed throughout this dissertation, and continues to pose a significant theoretical problem for bioarchaeology. Wood and colleagues (1992) outlined three major pitfalls of bioarchaeological analysis: 1) demographic nonstationarity, 2) selective mortality, and 3) hidden heterogeneity. The samples analyzed in this dissertation are certainly not static — they are, as mentioned above, a complex palimpsest of "mingled and mangled temporalities" (Novak 2017, 239). Selective mortality and hidden heterogeneity have been particularly challenging for bioarchaeologists to address, as the issues are "built into the very nature of the data" (1992, 344). While this dissertation attempted to address some of these issues by implementing specific statistical procedures rather than comparing raw frequencies (e.g., Odds Ratios, see Klaus 2014), many of the more rigorous means of addressing these latter pitfalls require refined age-at-death estimations (DeWitte et al. 2015; Wilson 2014b), which was not possible in this study given the issues of preservation and intraskeletal availability. Future research will benefit greatly from refining age estimates on the current sample.

Altogether, despite the shortcomings in these data, the results from this dissertation suggest that lifeways in this sample, despite exhibiting little variation between funerary groups, are counterintuitively *more* susceptible to noise and signals that ultimately constrain the observable bioarchaeological data. Conversely, the highly distinct differences between funerary groups are precisely due to their relatively *stability* in reflecting the eschatological, ontological, and funerary treatment of their respective communities. Tackling both lifeways and deathways can help transcend the theoretical and methodological tendency to treat the living as vibrant and the dead as inert. This is especially important in the context of the Middle Ages, as many scholars working throughout the medieval period have demonstrated just how integral the dead were to daily life (Bassett 1992; Binski 1996; Geary 1994; Gordon et al. 2000; Tracy 2009). As Geary (1994, 2) eloquently stated:

> "Death marked a transition, a change in status, but not an end…The dead were present among the living through liturgical commemoration, in dreams and visions, and in their physical remains, especially the tombs and relics of the saints. Omnipresent, they were drawn into every aspect of life. They played vital roles in social, economic, political, and cultural spheres."

He goes on to assert (1994, 36): "The dead constituted an age class that continued to have a role and to exercise rights in society." Schmitt (1998, 183) noted how space played heavily into the interaction between the living and the dead in medieval society, underscoring how the medieval parish cemetery "…played a mediating role: the living had to go through it constantly, not only when they went to church or returned from church but also when they went from one end of the village to the other or, in town, from one quarter to another." The dead could also be incorporated into architecture such as the famed chapels throughout Europe as the Sedlec Ossuary in Kutna Hora, Czech Republic, the Capuchin Crypt of Rome, Italy, or the Capella dos Ossos of Évora, Portugal, cementing their relationship with space, place, built environment (Tracy 2009).

The dead factored greatly into the daily life of medieval communities, but also play a significant role in the descendant and living communities of those regions today. The integration of biocultural approaches with both lifeways and deathways helps to underscore the plurality of ways in which bioarchaeologists can contribute to heritage management, urbanization, and anthropological discourse. As Armelagos (2003) asserted: bioarchaeology *is* anthropology, and the burgeoning bioarchaeological scholarship and growing number of public and student interest (Buikstra et al. 2022; Stojanowski & Duncan 2015) attest to bioarchaeology's theoretical potential (Cheverko et al. 2020). Ethics are at the forefront of contemporary bioarchaeological discourse (Buikstra et al. 2022), especially in relation to excavation, preservation, and consent of descendant communities and stakeholders.

The pressing issue of urbanization and construction unearthing the buried remains of the city's past inhabitants is an increasing phenomenon, and one where the wishes of the dead and the wishes of the living come to a head and require nothing short of careful consideration and community deliberation. It is here where the dialogue between the political economic desires of the living needs to be weighed with the eschatological desires of the denizens of the past.

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Appendix – Chapter 3

Appendix 3.1 - Chronology of Santarém in relation to al-Andalus and larger events within the Iberian Peninsula. Adapted from Amado and Mata (2004, 135–142).

Global religious context	Date C.E. (Gregorian)	Date C.E. (Hijri)	Al-Andalus	Santarém
Birth of Muhammad in Mecca	570	-		
Siege of Constantinople	673-678	54-59		
	711	92	Tariq invades Iberia	
	712	93	Conquest of Toledo	
	714-716	95-97	Islamization of the Western Peninsula. Abd al-Aziz, son of Mus ibn Nusayr, becomes governor	Abd al-Aziz conquers Santarém from the visigoths. Negotiations and pacts between autochthonous Santarém community and Abd al-Aziz's forces prevents the city being sacked
Battle of Covadonga	718-722	99-103		
Abbasid dynasty is established with its capital in Baghdad	750	132		
	755	137	‘Abd al-Rahmān escapes to al-Andalus after the massacre of Umayyads in Damascus	
	756-788	138-169	‘Abd al-Rahmān I becomes first Umayyad emir of Córdoba	‘Abd al-Rahmān I visits Santarém in 784 and sanctions the construction of the aljama mosque in the medina

	763-764	145-157	Yahsudī revolts, originating in Beja, later extending throughout the entire southern portion of the Peninsula	
	868	254	Start of the *muladi* revolt against Umayyads. Muladi leader Ibn Marwān al-Jilīqī establishes an independent principality in Badajoz	Santarém shifts from being linked with the emirate in Córdoba to support Ibn Marwān al-Jilīqī
	888-912	274-300	Emirate ‘Abd Allah ibn Mamad, emir of Córdoba	
	889-890	275-276	Death of Ibn Marwān al-Jilīqī	
	897	283		The son of the emir of Córdoba subjugates Santarém within the emirate’s fold
	912-961	299-350	Caliphate of ‘Abd al-Rahmān III	

	929	316	‘Abd al-Rahmān III proclaims himself as caliph of al-Andalus, unifying the territory under the aegis of Córdoba	‘Abd al-Rahmān III takes control of Santarém, Mérida, and Beja
	938	326		*Wali* revolt in Santarém. Umayya ibn Isaq al-Quarasim moves against the caliph of Córdoba, who killed his brother, the vizier Ahmen ben Isaq. The revolt was promptly quelled by the caliph’s army. The *wali* of Santarém offers his services to the king of Oviedo, Ramiro II
Sacking of Lisbon by Ordonho III	955	343	Death of historian Ahman al-Rāzī	Possible conquest of Santarém, by Ordonho III
	970	51		First cartographical representation of Santarém in Ibn Hawqal’s *Map of the World (Kitāb sūrat al*-*Ard)*
	976-1009	366-399	Caliphate of Hisham II, caliph of Córdoba. Disagregation of Arabic power within Spain	

	1013	403	Emergence of the Taifa kings	
	1022-1094	412-486	Aftasid dynasty is established, with its capital in Badajoz and strong influence in Lisbon	Santarém becomes incorporated into the taifal king of Badajoz, becoming one of its most important cities
	1023-1090	413-482	Abbadid dynasty established, which governed the southwest of al-Andalus with its capital in Seville. Height of hispano-arab settlements in al-Andalus	
	1031	422	End of the Umayyad Caliphate in al-Andalus	
Almoravid Dynasty	1036-1147	427-541		
	1048	439	Last taifa king in Silves	

	1061-1106	452-499	Almoravid reign of Yūsuf Ibn Tāshufīn, sovereign of Marrakesh	
Pope Alexander II preaches 1st crusade in the Iberian Peninsula. Conquest of Coimbra	1063-1064	454-456		
D. Pedro is elected bishop of Braga	1070	462	Start of the Almoravid expansion throughout the Iberian Peninsula	A plowman from Santarém offers to the king of Seville, Mahammad ibn ‘Abbad al-M’tamid, an enormous melon cultivated within the region
	1086	478	Almoravid victory in Zalaca, against Afonso VI	
	1090-1092	482-484	Yūsuf ibn Tāshufīn surrounds Toledo	
Governor of the kingdom of Burgundy enters the territory between Minho and Mondego	1093-1095	485-488	End of the taifa of Badajoz at the hands of the Almoravids, who also successfully conquered Lisbon	D. Afonso VI de Leão conquers Santarém after besieging the city. Ibn Bassām, poet of Santarém, abandons the city and seeks refuge in Córdoba. First charter of Santarém, granted by Afonso VI

Wedding between Teresa and count Henry of Burgundy. Constitution of the Portucalense country is drafted, granting Henry governorship of the lands south of Minho.	1096			Santarém briefly becomes incorporated into the Portucalense Country
	1107	500	Almoravid victory in Uclés, commanded by Ali Ibn Yusuf	
Charter of Coimbra is granted	1111	504	Almoravid dominion over Badajoz, Évora, Lisbon, and Santarém, and Islamic influence/dominion reaches as far north as Porto	Almoravid forces commanded by Seyr Ibn Abi Beker reconquer Santarém, forcing count Henry to retreat as far as Coimbra
Death of count Henry.	1112	505		“Abzecri” is named governor of Santarém
Muhammad Ibn Tumart al-Mahdi establishes Almohad dynasty in Morocco	1121-1128	514-522		Death of the poet Ibn Sāra in Santarém

Victory for Christian forces in S. Mamede lead by D. Afonso Henriques	1127-1128	520-522		
	1128-1163	522-558	‘Abd al-Mūmin becomes the Almohad Caliph	
Afonso Henriques is named king during the conference of Zamora	1143-1145	537-539	Death of Tāhfīīn ibn ‘Ali, the last Almoravid. Revolts against almoravids lead by Ibn Qasī (Mértola), Ibn Wazīr (Évora), and Ibn al-Mundhir (Silves). Second taifa period in al-Andalus	Arab forces, many from Santarém, surround and conquer the castle of Leiria and the village of Soure, taking Christian prisoners back to Santarém (among them, the vicar of Soure, Deus Martinho). Santarém becomes independent, and Abzecri is disposed by Labide ibn Abdallah
	1147	541	Almoravid forces invade Spain, conquering Seville	Afonso Henriques conquers Santarém. Part of the Muslim community fleas and seeks refuge in Lisbon. Death of Ibn Bassām in Córdoba. Santarém is granted (through ecclesiastical donation) to Templar knights, who would go on to be the first seat of Christian power in Portugal

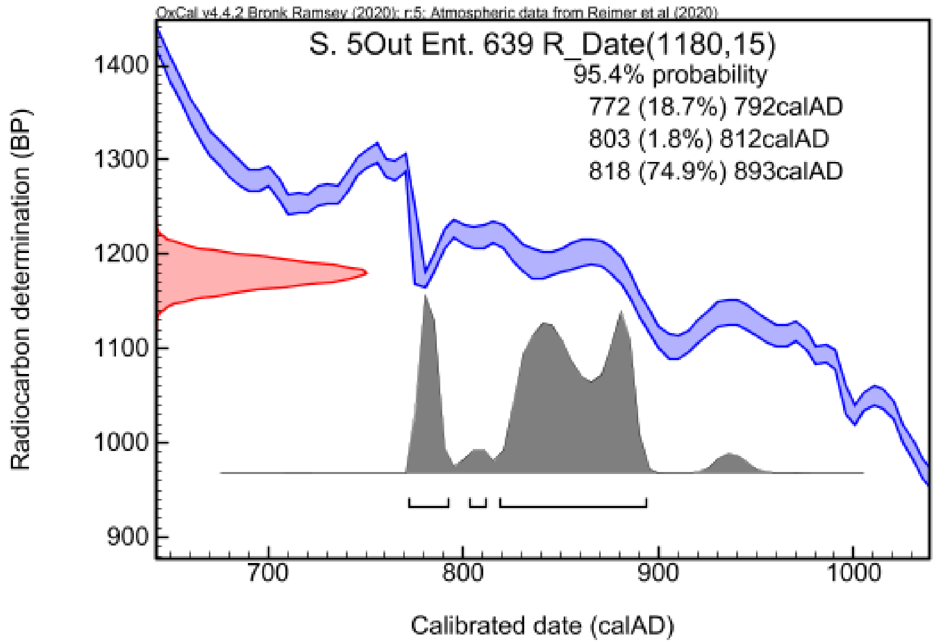
Likely failed attempt of conquering Alcácer do Sal.	1151	545	Accords reached between Afonso Henriquyes and Ibn Qasī	Christian forces from Alcácer do Sal become integrated into Santarém community
Founding of the Monastery of Alcobaça	1153-1154	547-548	Conclusion of the geographic works of al-Idrīsī	Founding of the church and monastery of Santa Maria da Alcáçova by the Templars, under the governorship of Master Hugo Martins
	1163-1184	558-579	Reign of Almohad Caliph Abū Ya'qūb Yūsuf	
D. Afonso Henriques is captured and made prisoner in Badajoz	1169-564			
Pope Alexander III formally recognizes Portugal's independence	1179	574	Muslim fleet attacks Lisbon	D. Afonso Henriques grants charter to Santarém
Death of Afonso Henriques, succeeded by Sancho I	1184	579	Almohad forces attack southern portion of al-Andalus and recapture a majority of the regions south of the Tagus river.	Siege of Santarém by Abū Ya'qūb Yūsuf, who dies in the siege. D. Afonso Henrique (before his death) helps young Sancho defend the city, despite being ill. Two river-side parishes are destroyed, as well as numerous houses in

				the suburban portions of the city
	1184-1199	579-596	Reign of Ya’kūb al-Mansūr	
	1190-1191	585-586	Almohad forces, commanded by the son of Abū Ya’qūb Yūsuf, advance on Silves, Torres Novas, Tomar, Almada, Alcácer and Palmela in response to his father’s death	In response to D. Sancho refusing to give up Silves, Almohad forces plan to encircle and lay siege to Santarém, but the emir becomes ill and the expedition is abandoned. Sancho solicits aid from English knights that were in Lisbon as a result of travelling for the Second Crusades
Saint Anthony is born in Lisbon	1195	591	Almohad victory in Alarcos lead by al- Mansūr	
Battle of Navas de Tolosa (Battle of Uqab)	1212	608	Abu Abdallah Muhammad (al-Nasir) is defeated, marking the end of Almohad rule in al-Andalus	

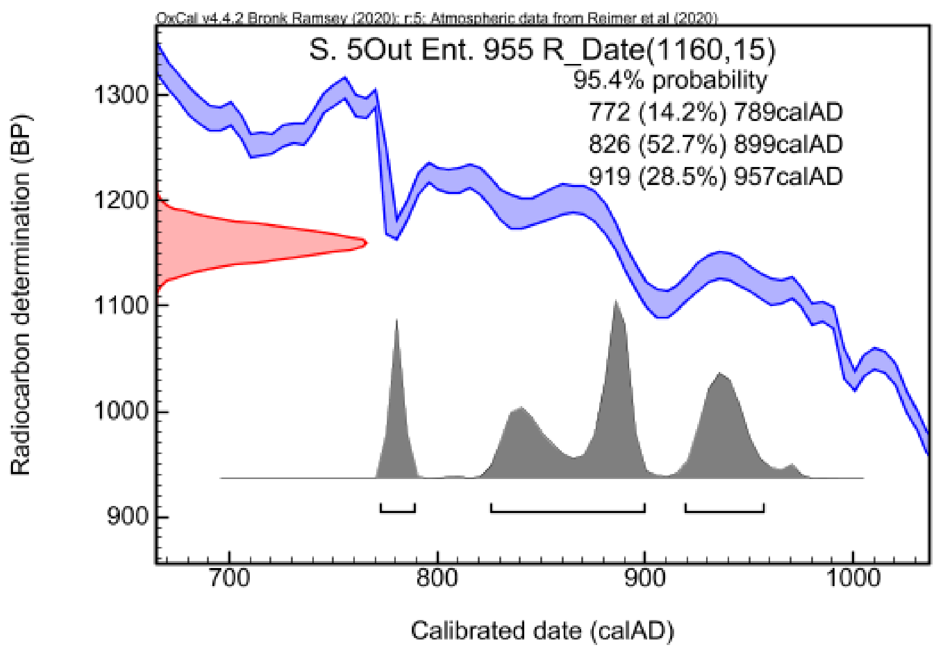
Fernando III, the saint and king of Castela, conquers Córdoba	1236-1237	633-634	Muhammad b. Yūsuf al-Ahmar establishes Granada as the capital of the emirate and the last Islamic stronghold in the Peninsula
Afonso III conquers Faro	1248	645	End of Islamic rule in the south of al-Andalus.

Appendix – Chapter 4

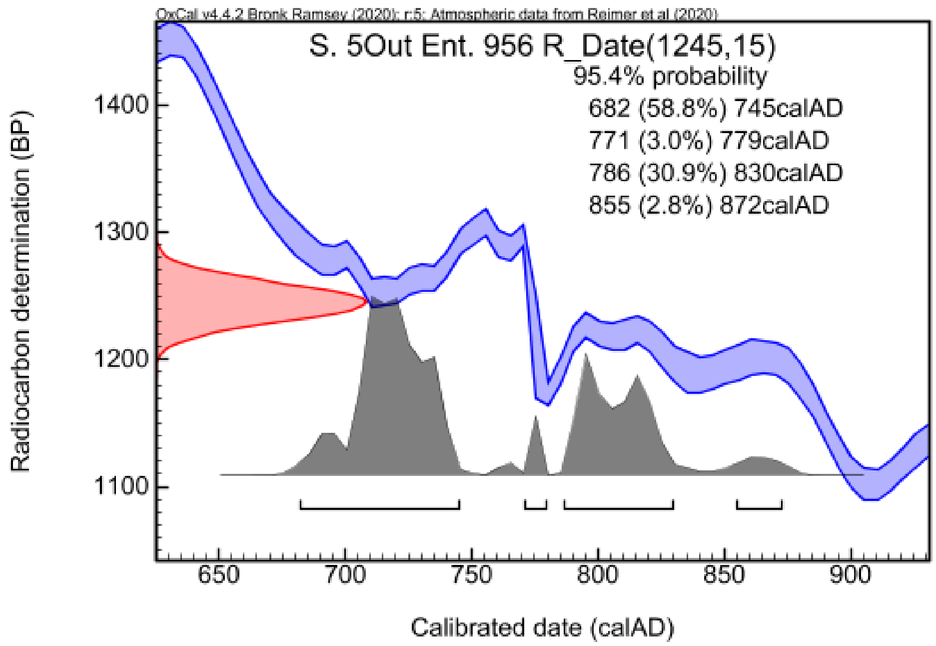
Appendix 4.1 - Avenida 5 de Outubro 639 calibration.



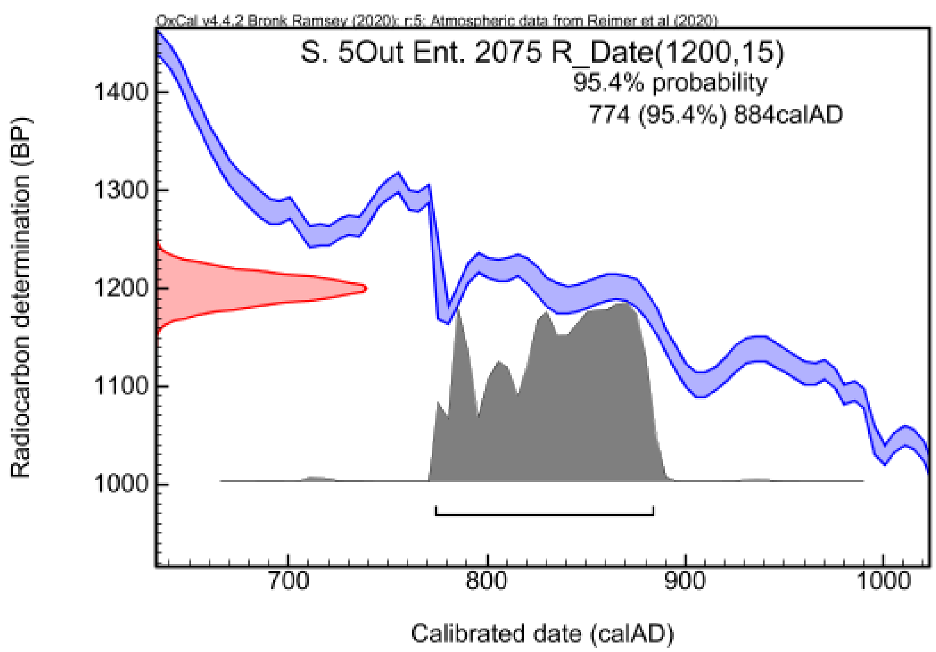
Appendix 4.2 - Avenida 5 de Outubro 955 calibration.



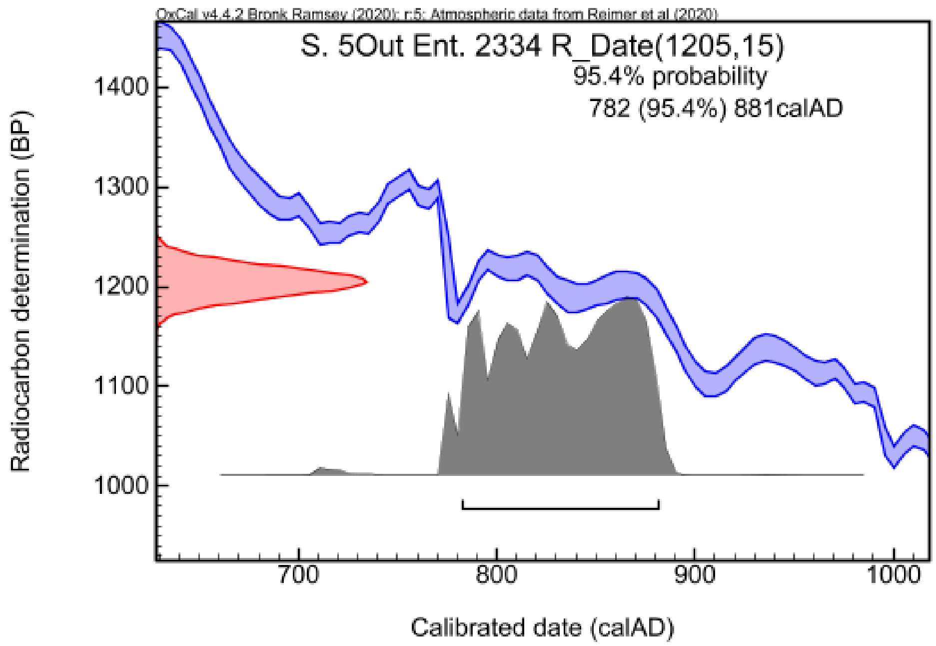
Appendix 4.3 - Avenida 5 de Outubro 956 calibration.



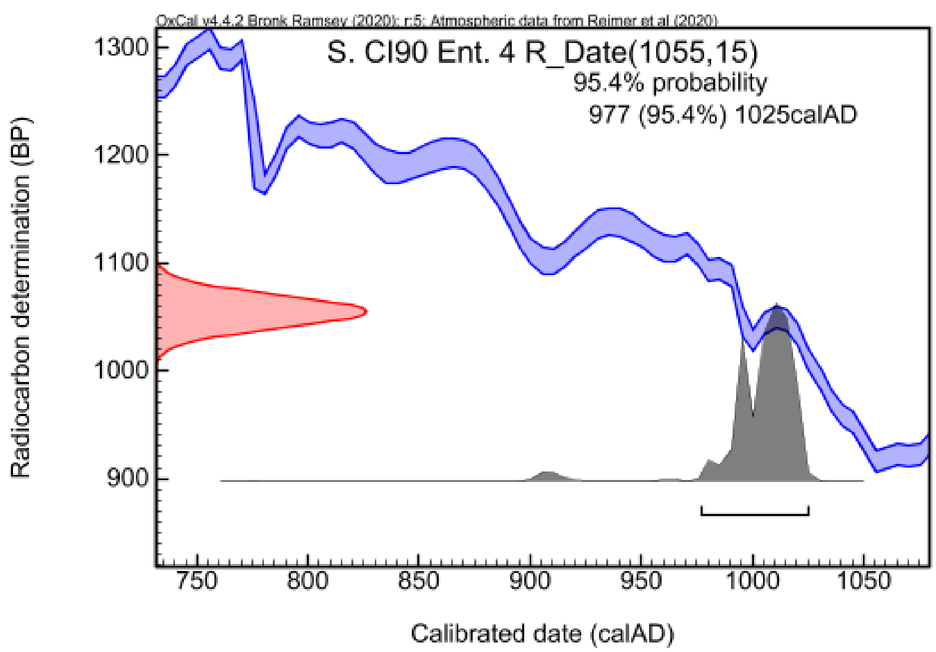
Appendix 4.4 - Avenida 5 de Outubro Ent. 2075 calibration.



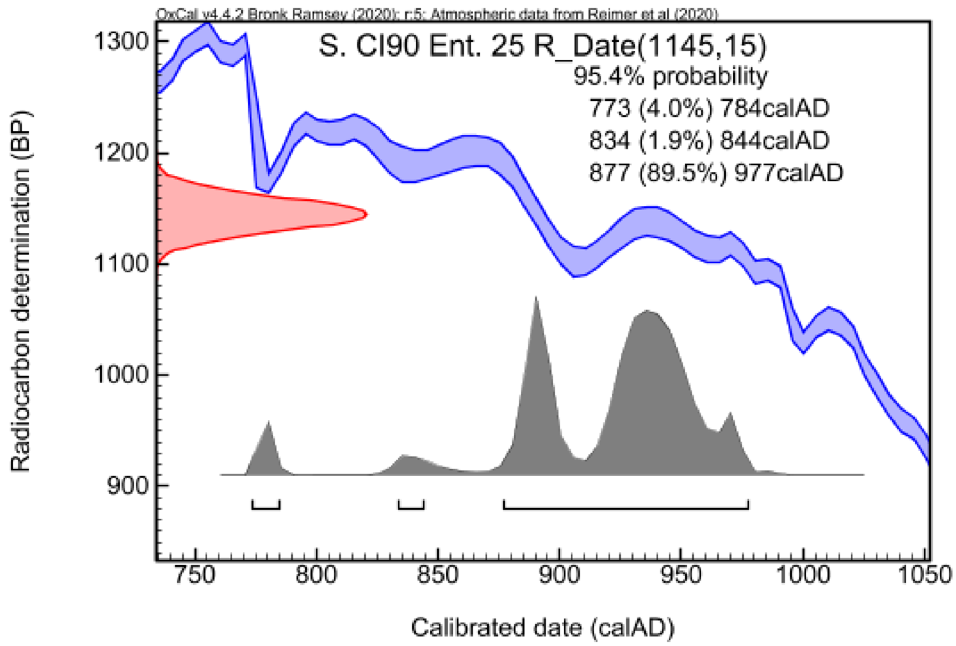
Appendix 4.5 - Avenida 5 de Outubro Ent. 2334 calibration.



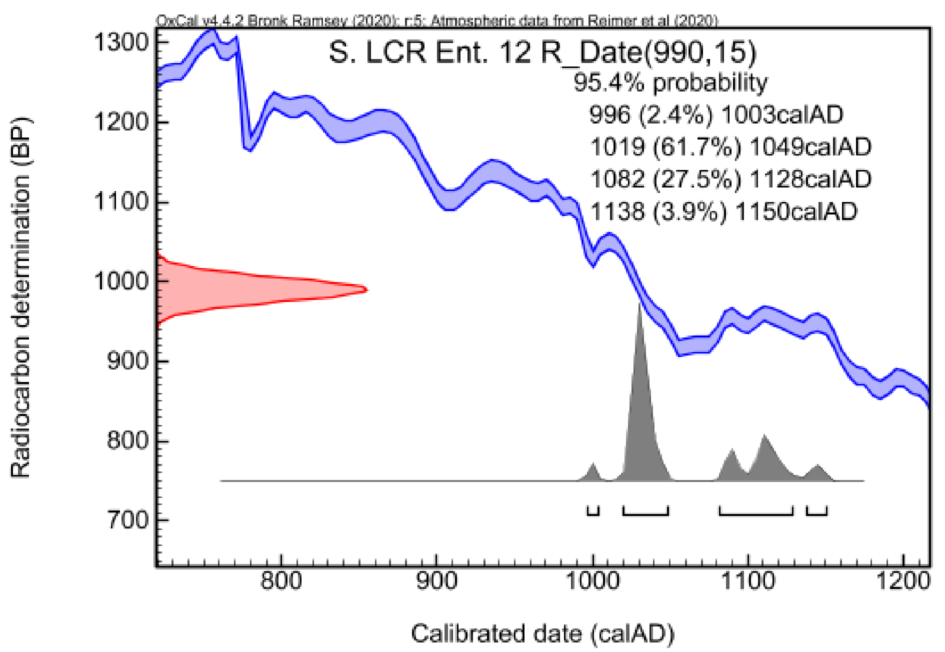
Appendix 4.6 - Capello Ivens 90 Ent. 4 calibration.



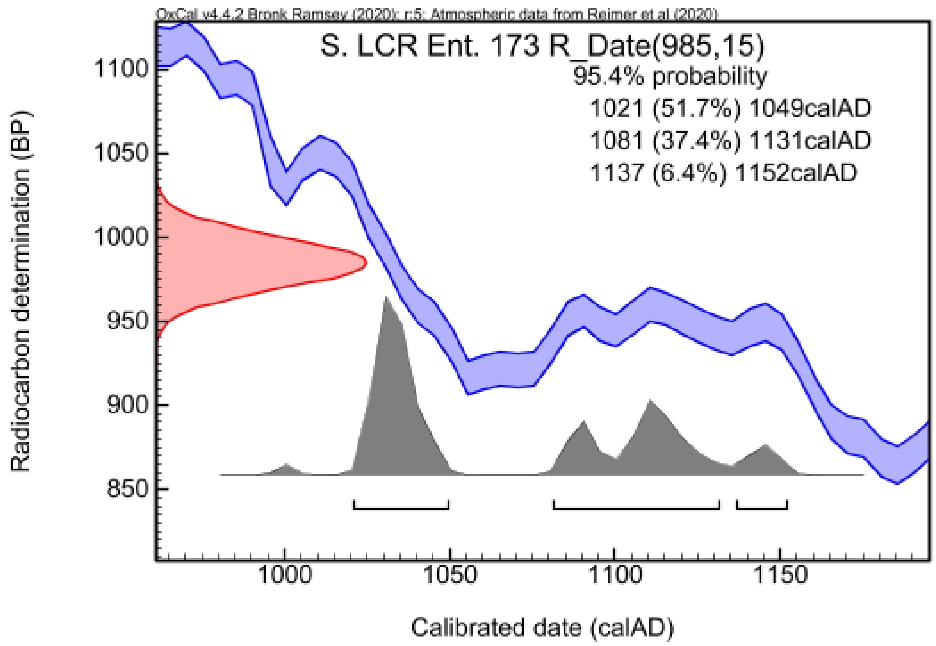
Appendix 4.7 - Capello Ivens 90 Ent. 25 calibration.



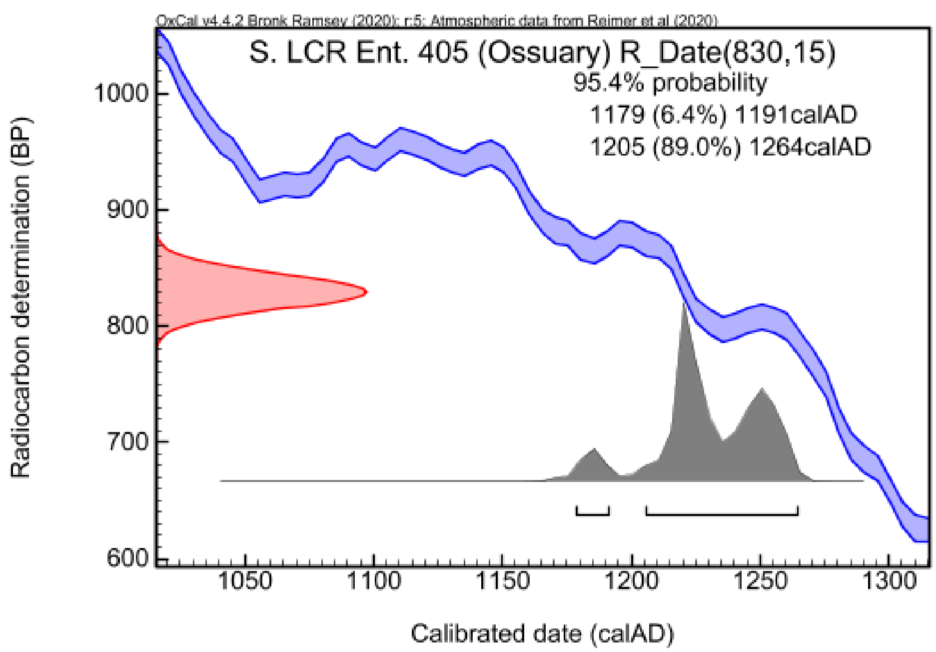
Appendix 4.8 - Largo Cândido dos Reis Ent. 12 calibration



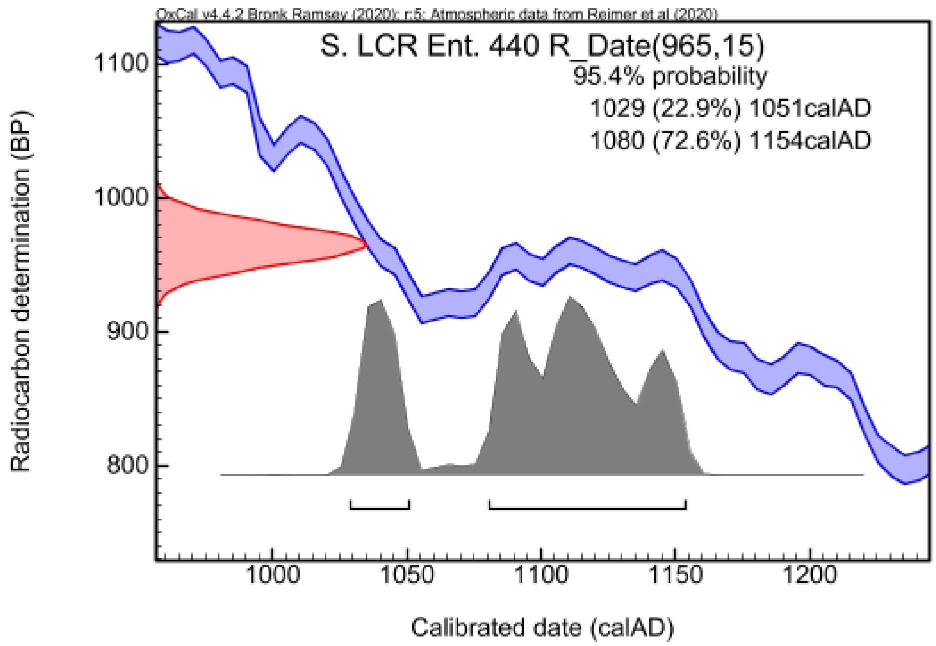
Appendix 4.9 - Largo Cândido dos Reis Ent. 173 calibration



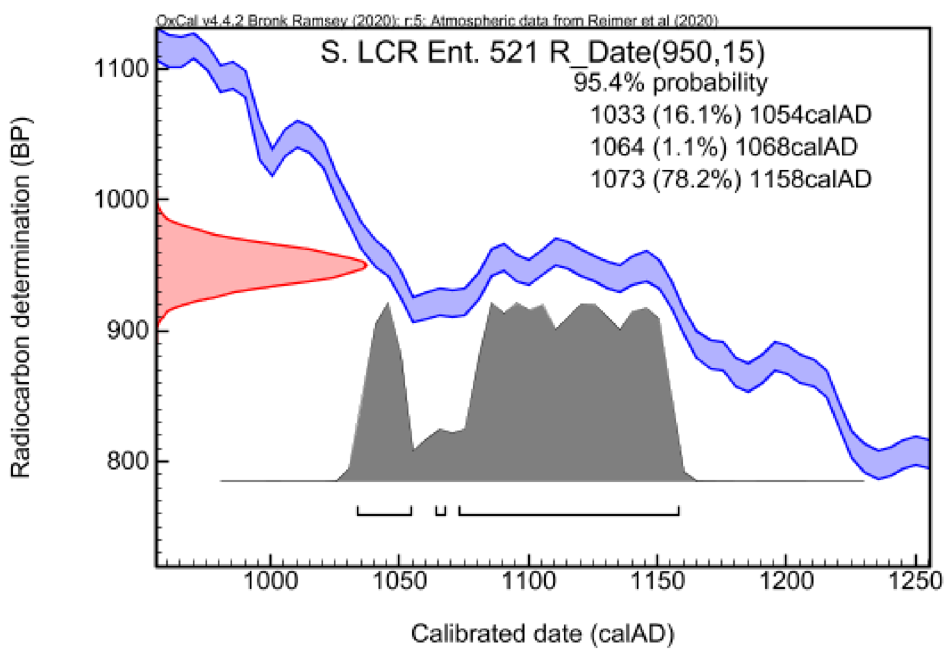
Appendix _4.10 - Largo Cândido dos Reis Ent. 405 (Oss.) calibration



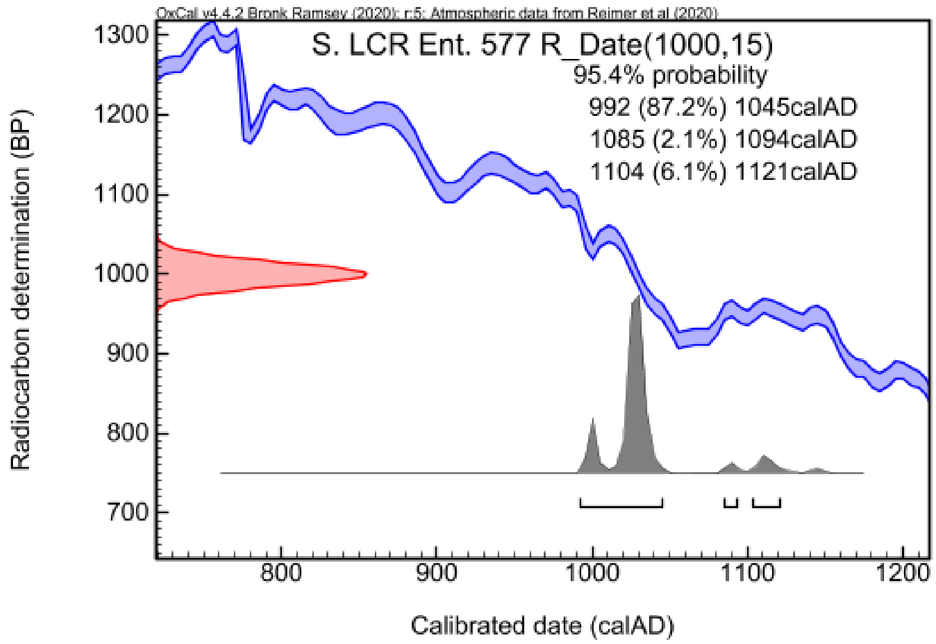
Appendix 4.11 - Largo Cândido dos Reis Ent. 440 calibration.



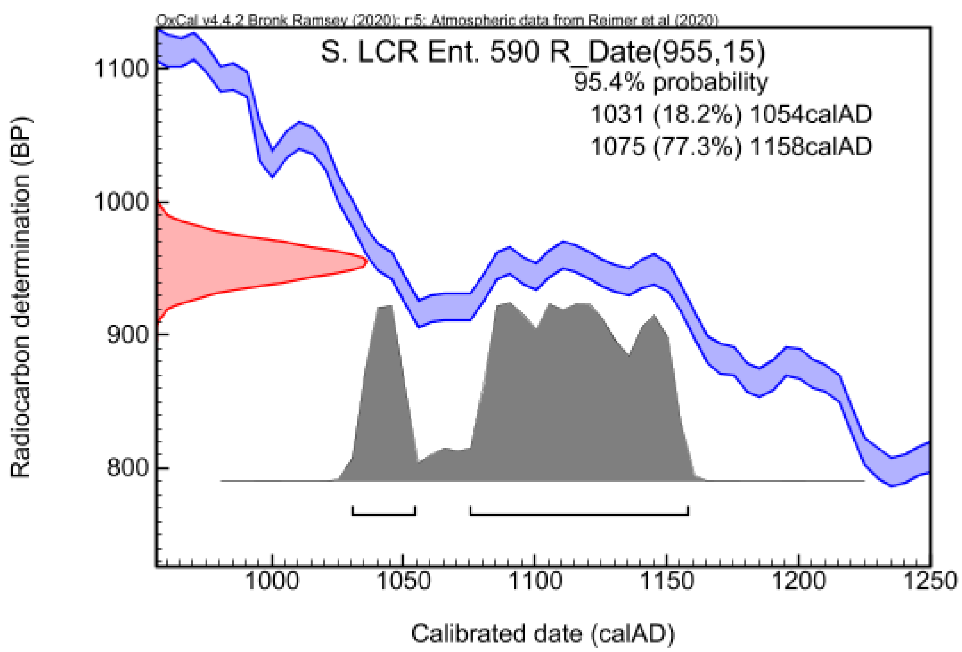
Appendix 4.12 - Largo Cândido dos Reis Ent. 521 calibration.



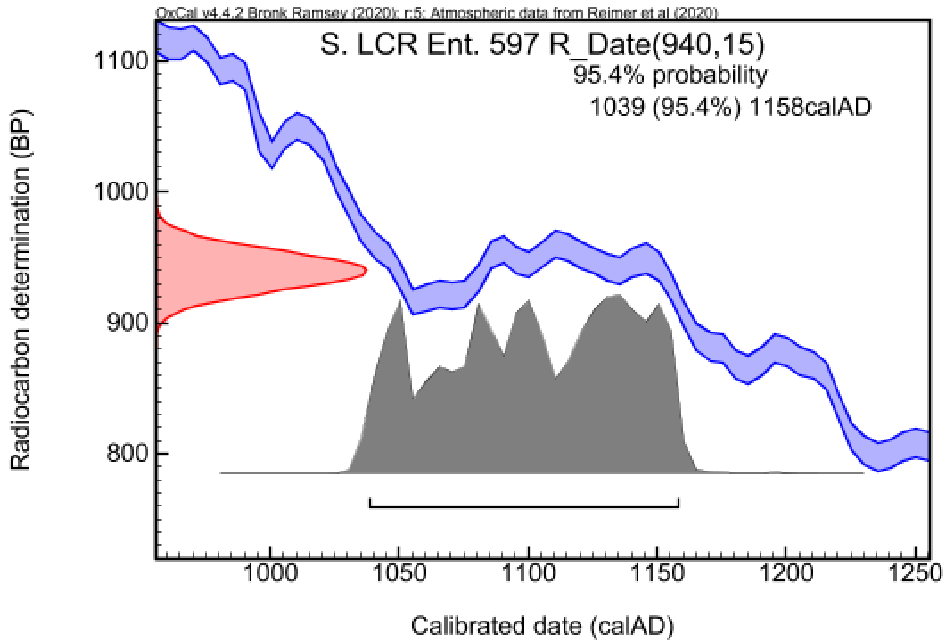
Appendix 4.13 - Largo Cândido dos Reis Ent. 577 calibration



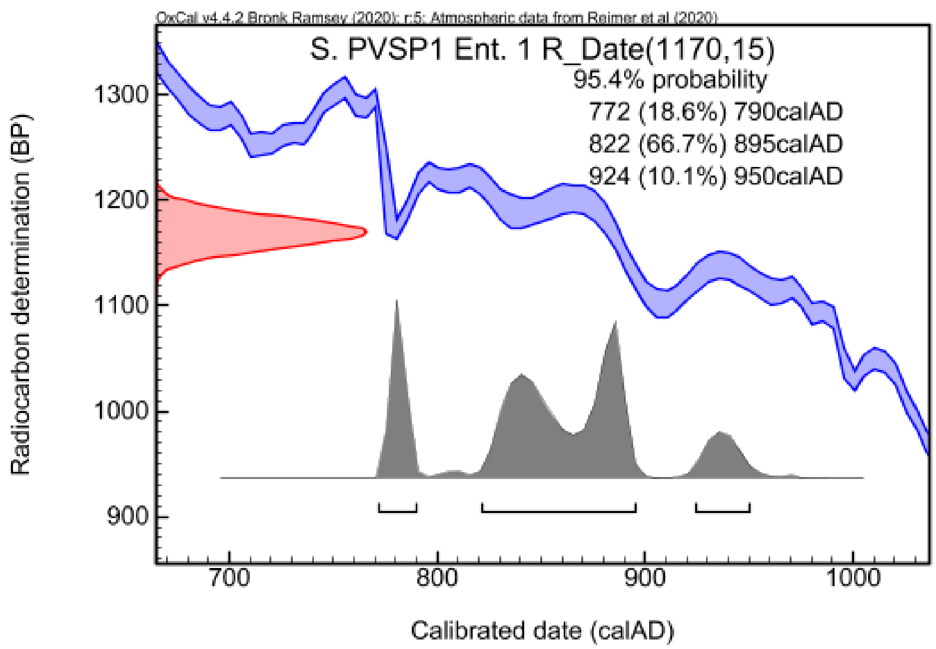
Appendix 4.14 - Largo Cândido dos Reis Ent. 590 calibration



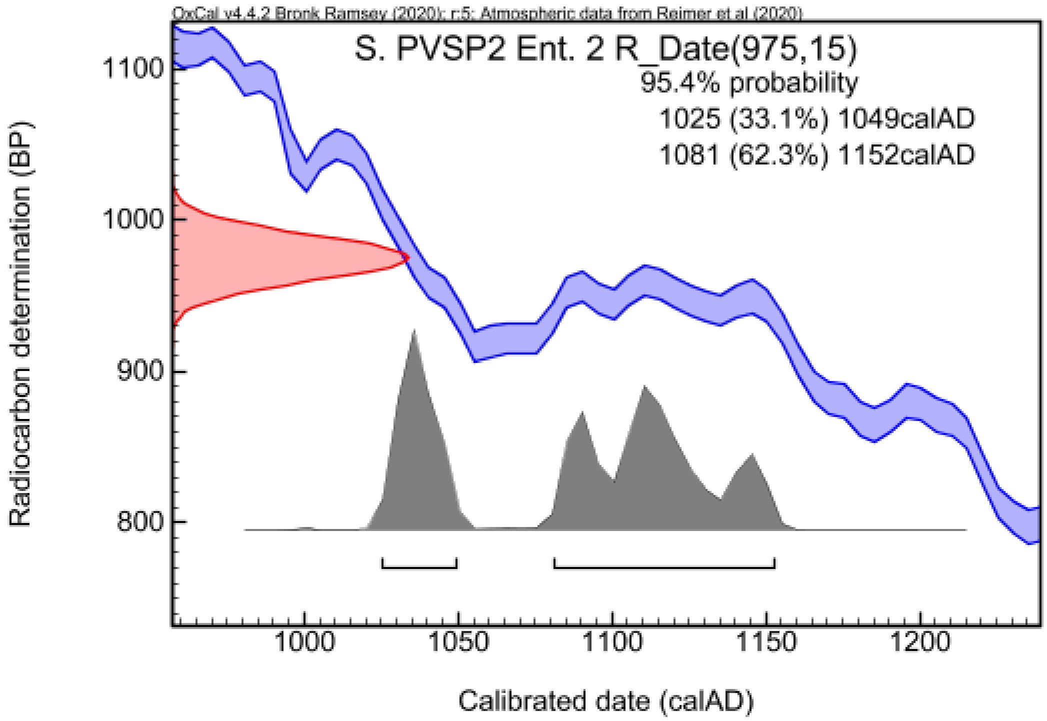
Appendix 4.15 - Largo Cândido dos Reis Ent. 597 calibration



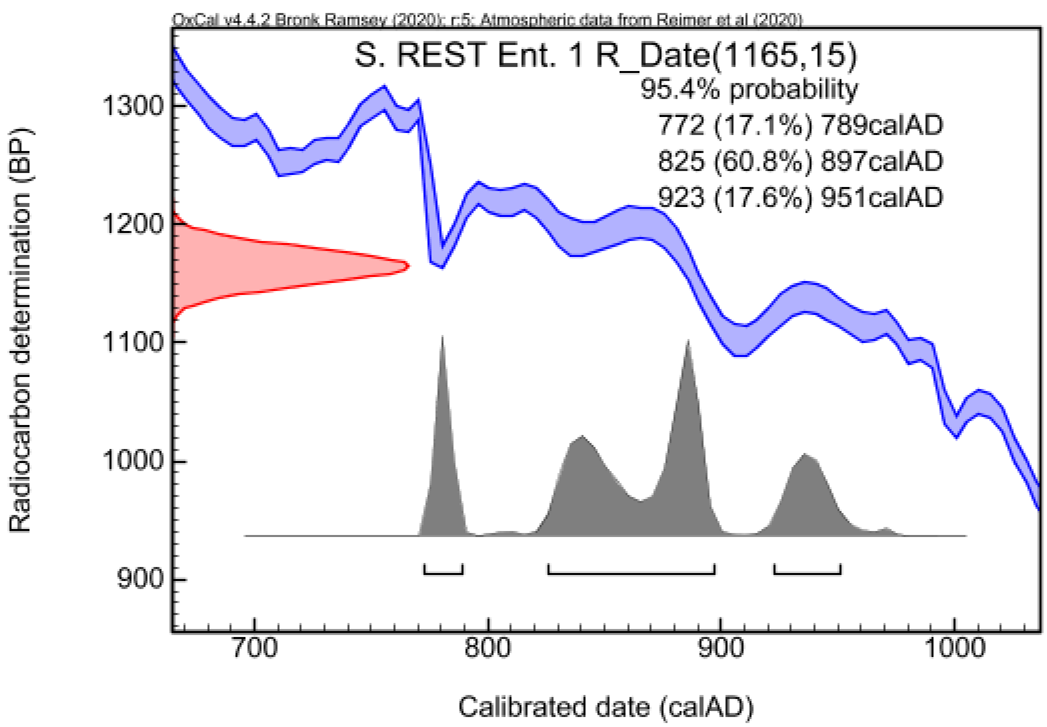
Appendix 4.16 - Praça Visconde Serra do Pillar Ent. 1 calibration.



Appendix 4.17 - Praça Visconde Serra do Pillar Ent. 2 calibration.



Appendix 4.18 - Travessa dos Capuchos Ent. 1 calibration.



Appendix – Chapter 5

Appendix 5.1 – Stable isotope values

Sample	Funerary	Sex	Collagen yield	$\delta^{15}N$	$\delta^{13}C$	%N	%C	C:N wt	C:N Atomic
#1 S. REST Ent. 1	Islamic	Indet.	4.3	10.5	-18.5	15.7	42.9	2.7	3.2
#2 S. LCR Ent. 12	Islamic	F	2.7	10.2	-18.2	15.6	42.8	2.7	3.2
#3 S. LCR Ent. 590	Islamic	M	2.1	10.6	-18.9	15.3	42.4	2.8	3.2
#4 S. LCR Ent. 597	Islamic	M	3.6	11.0	-18.6	15.6	43.4	2.8	3.3
#5 S. PVSP1 Ent. 1	Islamic	Indet.	5.7	9.4	-19.4	15.5	43.1	2.8	3.2
#6 S. PVSP2 Ent. 2	Islamic	Indet.	7.3	9.8	-18.9	16.1	43.8	2.7	3.2
#7 S. CI90 Ent. 4	Islamic	Indet.	1.5	10.8	-19.0	15.3	43.0	2.8	3.3
#8 S. CI90 Ent. 25	Islamic	Indet.	3.6	10.7	-18.1	15.3	42.5	2.8	3.2
#9 S. 5Out Ent. 955	Islamic	F	2.1	11.0	-19.0	15.3	42.3	2.8	3.2
#10 S. 5Out Ent. 2334	Islamic	M	3.6	10.6	-19.0	15.3	42.2	2.7	3.2
#11 S. 5Out Ent. 639	Islamic	F	3.6	10.2	-18.8	15.8	42.6	2.7	3.2
#12 S. 5Out Ent. 956	Islamic	F	6.8	9.4	-19.1	16.0	43.1	2.7	3.1
#13 S. 5Out Ent. 2075	Islamic	F	4.2	10.8	-19.1	15.7	42.8	2.7	3.2
#14 S. LCR Ent. 173	Islamic	M	3.5	10.3	-18.3	15.8	42.8	2.7	3.2
#15 S. LCR Ent. 521	Islamic	M	2.9	10.2	-18.8	16.0	43.7	2.7	3.2
#16 S. LCR Ent. 440	Islamic	M	5.3	10.4	-18.6	15.8	43.4	2.7	3.2
#17 S. LCR Ent. 577	Islamic	M	2.8	10.2	-18.6	15.5	42.4	2.7	3.2
#18 S. LCR Ent. 405 (Oss.)	Christian	Indet.	7.7	12.5	-17.0	15.9	43.4	2.7	3.2

Appendix 5.2 - Comparison of AMTL by tooth type, sex, and funerary group at Largo Cândido dos Reis and Avenida 5 de Outubro

Funerary group	**Tooth type**	**Female N obs./total**	**Female crude frequency (%)**	**Male N obs./total**	**Male crude frequency (%)**	***G***	**p-value**
Islamic	Incisors	30/204	14.71	25/238	10.50	1.77	0.18
	Canines	12/112	10.71	6/123	4.88	2.86	0.09
	Premolars	18/232	12.07	31/257	12.06	0.00	0.99
	Molars	121/332	36.45	108/354	30.51	2.72	0.10
Christian	Incisors	14/106	13.21	9/153	5.88	4.07	0.04
	Canines	4/54	7.41	4/86	4.65	-	0.49*
	Premolars	22/119	18.49	32/164	19.51	0.05	0.83
	Molars	69/173	39.88	80/229	34.93	1.03	0.31

* p-value of Fisher's Exact test due to expected counts < 5

Appendix 5.3 - Comparison of calculus by tooth type, sex, and funerary group at Largo Cândido dos Reis and Avenida 5 de Outubro

Funerary group	**Tooth type**	**Female N obs./total**	**Female crude frequency (%)**	**Male N obs./total**	**Male crude frequency (%)**	***G***	**p-value**
Islamic	Incisors	112/161	69.57	138/222	62.16	2.27	0.13
	Canines	61/91	67.03	65/117	55.56	2.84	0.09
	Premolars	95/188	50.53	105/227	46.26	0.75	0.38
	Molars	108/202	53.47	92/251	36.65	12.85	<0.01
	Total	376/642	58.57	400/817	48.96	13.36	<0.01
Christian	Incisors	65/95	68.42	95/137	69.34	0.02	0.88
	Canines	32/50	64.00	42/76	55.26	0.96	0.33
	Premolars	49/97	50.12	62/120	51.67	0.03	0.87
	Molars	58/106	54.72	59/130	45.38	2.04	0.15
	Total	204/348	68.62	258/463	55.72	0.68	0.41

Appendix 5.4 - Comparison of calculus severity by sex and funerary group at Largo Cândido dos Reis and Avenida 5 de Outubro

	Islamic							**Christian**						
	Females		Males					Females		Males				
Score*	N	%	N	%	*G*	p	Bonferroni adjusted p-value	N	%	N	%	*G*	p	Bonferroni adjusted p-value
1	343	90.74	340	85.00	6.05	0.01	0.03	159	77.94	168	65.12	9.21	<0.01	<0.01
2	27	7.14	59	14.75	11.72	<0.01	<0.01	34	16.67	74	28.68	9.4	<0.01	<0.01
3	8	2.12	1	0.25	-	0.02**	0.04	11	5.39	16	6.20	0.14	0.71	0.99

*Following Brothwell (1981), where 1 = minor calculus, 2 = moderate calculus, and 3 = severe calculus.
** p-value from a Fisher's Exact test (α = 0.05) due to expected counts being less than 5.

Appendix 5.5 - Comparison of calculus severity by funerary group, separated by sex at Largo Cândido dos Reis and Avenida 5 de Outubro

	Females							**Males**						
	Islamic		Christian					Islamic		Christian				
Score*	N	%	N	%	*G*	p	Bonferroni adjusted p-value	N	%	N	%	*G*	p	Bonferroni adjusted p-value
1	343	90.74	159	77.94	17.57	<0.01	<0.01	340	85.00	168	65.12	34.56	<0.01	<0.01
2	27	7.14	34	16.67	12.192	<0.01	<0.01	59	14.75	74	28.68	18.49	<0.01	<0.01
3	8	2.12	11	5.39	4.25	0.04	0.08	1	0.25	16	6.20	23.922	<0.01	<0.01

Appendix 5.6 - Comparison of calculus location by sex and funerary group
at Largo Cândido dos Reis and Avenida 5 de Outubro

Score*	Islamic							Christian						
	Females		Males					Females		Males				
	N	%	N	%	*G*	p	Bonferroni adjusted p-value	N	%	N	%	*G*	p	Bonferroni adjusted p-value
Lingual	52	13.83	82	20.50	6.09	0.01	0.03	50	24.51	84	32.56	4.14	0.04	0.08
Labial	120	31.91	129	32.25	0.01	0.92	0.99	39	19.12	56	21.71	0.57	0.45	0.90
Buccal	59	15.69	67	16.75	0.16	0.69	0.99	28	13.73	47	18.22	1.89	0.17	0.34
Inter-Proximal	82	21.81	57	14.25	7.55	<0.01	0.01	25	12.25	34	13.18	0.09	0.77	0.99
Multiple	63	16.76	65	16.25	0.04	0.85	0.99	62	30.39	37	14.34	17.61	<0.01	<0.01

Appendix 5.7 - Comparison of calculus location by funerary group, separated by sex
at Largo Cândido dos Reis and Avenida 5 de Outubro

Score*	Females							Males						
	Islamic		Christian					Islamic		Christian				
	N	%	N	%	*G*	p	Bonferroni adjusted p-value	N	%	N	%	*G*	p	Bonferroni adjusted p-value
Lingual	52	13.83	50	24.51	15.31	<0.01	<0.01	82	20.50	84	32.56	20.74	<0.01	<0.01
Labial	120	31.91	39	19.12	6.27	0.01	0.02	129	32.25	56	21.71	3.68	0.06	0.11
Buccal	59	15.69	28	13.73	0	0.99	0.99	67	16.75	47	18.22	1.7	0.19	0.39
Inter-Proximal	82	21.81	25	12.25	8.45	<0.01	<0.01	57	14.25	34	13.18	0.15	0.7	0.99
Multiple	63	16.76	62	30.39	21.26	<0.01	<0.01	65	16.25	37	14.34	0.01	0.93	0.99

Appendix 5.8 – Individual periodontitis scores by sex and funerary group at Largo Cândido dos Reis and Avenida 5 de Outubro

Funerary group	**Sex**	**N individuals**	**N healthy[1] N (%)**	**N gingivitis[2] (%)**	**N periodontitis[3] (%)**	**N only 1-2 sites of periodontitis[3] (%)**	**N w/ at least 50% of septa showing periodontitis[3] (%)**
Islamic	Female	20	0 (0.00)	5 (25.00)	15 (75.00)	4 (20.00)	7 (11.11)
	Male	30	2 (6.67)	7 (23.33)	23 (76.67)	4 (13.33)	11 (38.10)
Christian	Female	13	0 (0.00)	2 (15.31)	11 (84.62)	1 (7.69)	3 (23.08)
	Male	22	0 (0.00)	5 (22.73)	17 (77.27)	3 (13.64)	8 (36.36)

[1] Kerr (1991) category 1, meaning no signs of inflammation
[2] Kerr (1991) category 2, localized foramina or grooves, indicative of gingivitis
[3] Kerr (1991) categories 3-5, alterations in alveolar contours and septal breakdown

Appendix 5.9 - Interdental septa periodontitis scores by sex and funerary group at Largo Cândido dos Reis and Avenida 5 de Outubro

Funerary group	**Sex**	**Total obs. Septa**	**Category 1 (healthy) N (%)**	**Category 2 (gingivitis) N (%)**	**Category 3 (acute periodontitis) N (%)**	**Category 4 (quiescent periodontitis) N (%)**	**Category 5 (angular defect) N (%)**	**Total Periodontitis (Categories 3-5) N (%)**
Islamic	Female	401	150 (37.41)	91 (22.69)	38 (9.48)	78 (19.45)	44 (10.97)	160 (39.90)
	Male	591	256 (43.32)	124 (20.98)	59 (9.98)	64 (10.66)	89 (15.06)	211 (35.70)
	Total	992	406 (40.93)	215 (21.67)	97 (9.78)	141 (14.21)	133 (13.41)	371 (37.40)
Christian	Female	256	99 (38.67)	56 (21.88)	50 (19.53)	30 (11.72)	21 (8.20)	101 (39.45)
	Male	377	136 (36.07)	96 (25.46)	38 (10.08)	47 (12.47)	60 (15.92)	145 (38.46)
	Total	633	235 (37.12)	152 (24.01)	88 (13.90)	77 (12.16)	81 (12.80)	246 (38.86)

[1] Kerr (1991) category 1, meaning no signs of inflammation
[2] Kerr (1991) category 2, localized foramina or grooves, indicative of gingivitis
[3] Kerr (1991) categories 3-5, alterations in alveolar contours and septal breakdown

Appendix 5.10 - Comparison of maxillary and mandibular periodontitis (score > 2) by sex and funerary group at Largo Cândido dos Reis and Avenida 5 de Outubro

Funerary group	**Sex**	**Maxilla N obs./total**	**Maxilla crude frequency (%)**	**Mandible N obs./total**	**Mandible crude frequency (%)**	***G***	**p-value**
Islamic	Female	80/194	41.24	80/207	38.65	0.28	0.60
	Male	112/308	36.36	99/283	34.98	0.12	0.73
Christian	Female	52/110	47.27	49/146	33.56	4.93	0.03
	Male	69/168	41.07	76/209	36.36	0.87	0.35

Appendix 5.11 - Comparison of caries location by sex and funerary group at Largo Cândido dos Reis and Avenida 5 de Outubro

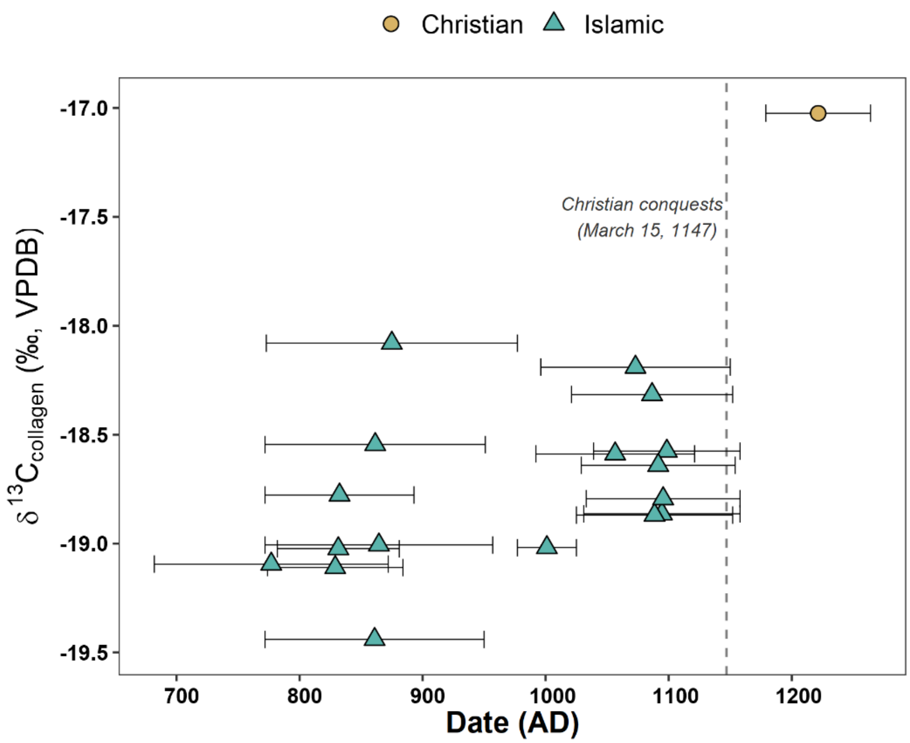
	Islamic						**Christian**					
	Female		Male				Female		Male			
	N carious/Total	%	N carious/Total	%	G	P	N carious/Total	%	N carious/Total	%	G	P
Pit/Fissure	8/101	7.92	4/79	5.06	0.60	0.44	6/29	20.69	9/60	15.00	-	0.55*
Smooth	11/101	10.89	21/79	26.58	7.46	<0.01	8/29	27.59	7/60	11.67	-	0.07*
Cervical	32/101	31.68	28/79	35.44	0.77	0.38	4/29	13.79	21/60	35.00	4.73	0.03
Root	21/101	20.79	3/79	3.80	12.59	<0.01	1/29	3.45	4/60	6.67	-	1.00*
Large	29/101	28.71	23/79	29.11	0.00	0.95	10/29	34.48	19/60	31.67	0.07	0.79

**p*-value resulting from a Fisher's Exact test (α = 0.05) due to expected counts being less than 5.

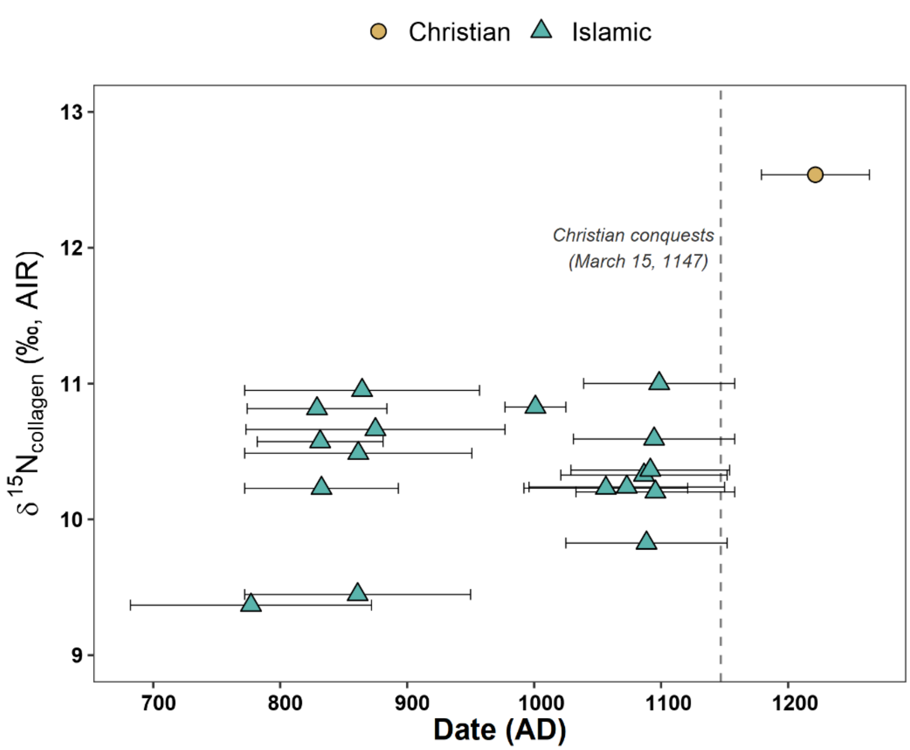
Appendix 5.12 - List of possible plants used for *miswāk* (adapted from Kanner 1935: 80-81)

Reference name	English common name	Scientific name	Presence in Iberia
Basham	Arabian balsam tree	*Coimmiphora gileadensis* (L.)	None
Dirv	Mastic tree	*Pistacia lentiscus*	Yes, native
Utum	Wild olive tree	*Olea oleaster*	Yes, native
Arak	Arak	*Salvadora persica*	None
Urgaun	Date palm (stem)	*Phoenix dactylifera*	Introduced to Spain
Garid	Date palm (leaf rib)	*Phoenix dactylifera*	Introduced to Spain
Ruchama	Wooly bindweed	*Convolvulus lanatus Vahl*	None
Ishil	Grey-leaved saucer berry tree	*Cordia sinensis*	None
Jastaur	Uknown	Unknown	Unknown
Tiwama	Unknown	Unknown	Unknown
Tum	Garlic(?)	*Alloum sativum*	Introduced into Spain
Darum	Thistle shrub	Uknown	Unknown
-	Lilly	*Lillium*	Some (e.g., *Lillium Tourn. ex L.*)
-	Sugar cane	*Saccharum*	Introduced to Spain
-	Mahaleb cherry tree	*Prunus mahaleb*	Yes, native
-	Camel grass/Beard grass	*Cymbopogon schoenanthus/Andropogon*	None
-	Dragon lily/Black arum	*Dracunculus*	Introduced to Portugal

Appendix 5.13 – Stable isotope results, δ^{13}C by calibrated radiocarbon date



Appendix 5.14 – Stable isotope results, δ^{15}N by calibrated radiocarbon date



Appendix – Chapter 6

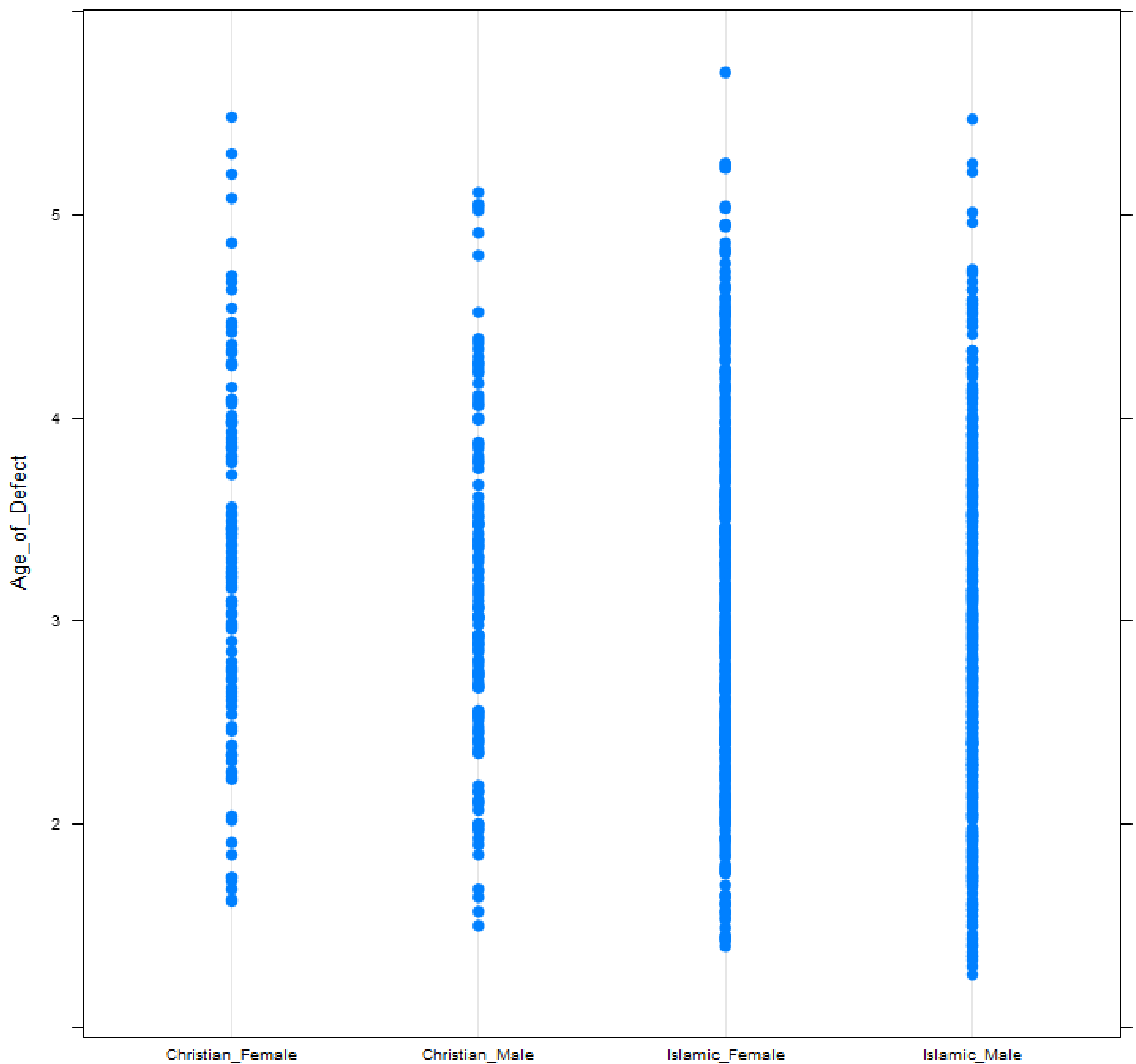
Appendix 6.1 - Unworn crown height metrics (in mm) by tooth class, sex, and funerary group.

		Islamic						Christian					
		Male			Female			Male			Female		
		N	Mean	Maximum Value	N	Mean	Maximum Value	N	Mean	Maximum Value	N	Mean	Maximum Value
Maxilla	Medial Incisors	22	9.99	12.08	14	9.87	10.61	12	8.97	10.37	11	9.6	11.21
	Lateral Incisors	22	9.04	10.37	13	9.03	10.21	15	8.42	10.14	12	8.7	9.86
	Canines	24	9.46	11.72	14	9.31	10.72	16	9.81	12.19	11	9.31	10.79
Mandible	Medial Incisors	21	8.17	9.89	14	8.01	9.49	22	7.91	9.6	12	7.7	8.96
	Lateral Incisors	22	8.65	10.17	14	8.95	9.86	26	8.35	9.97	13	8.33	9.7
	Canines	22	10.34	12.65	16	10.35	11.08	24	10.44	12.8	14	9.91	12.31

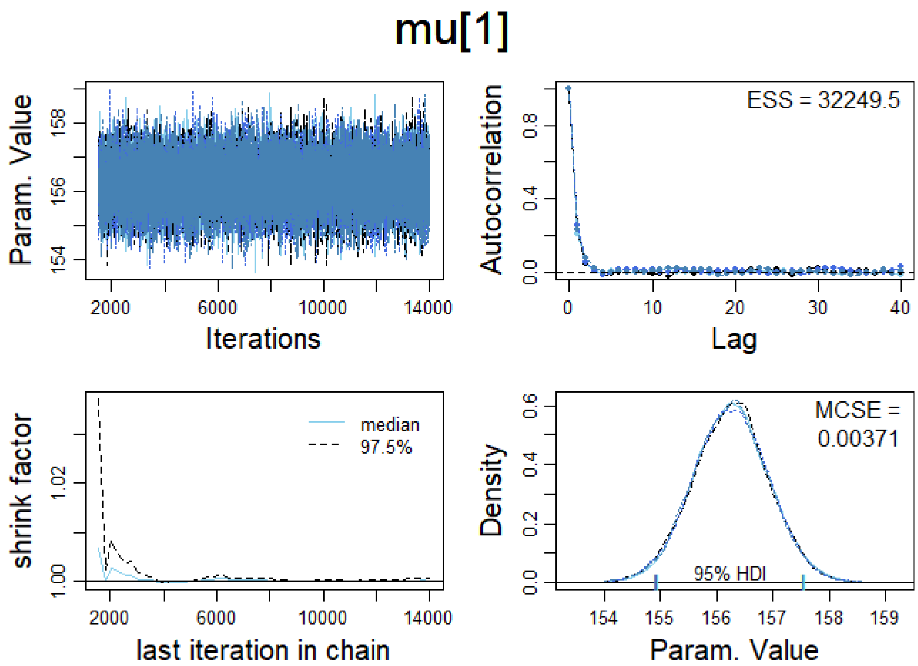
Appendix 6.2 - Shapiro-Wilk tests for measurable LEH.

Group	W	*p*-value
Christian Females	0.99	0.45
Christian Males	0.98	0.08
Islamic Females	0.99	<0.01
Islamic Males	0.98	<0.01

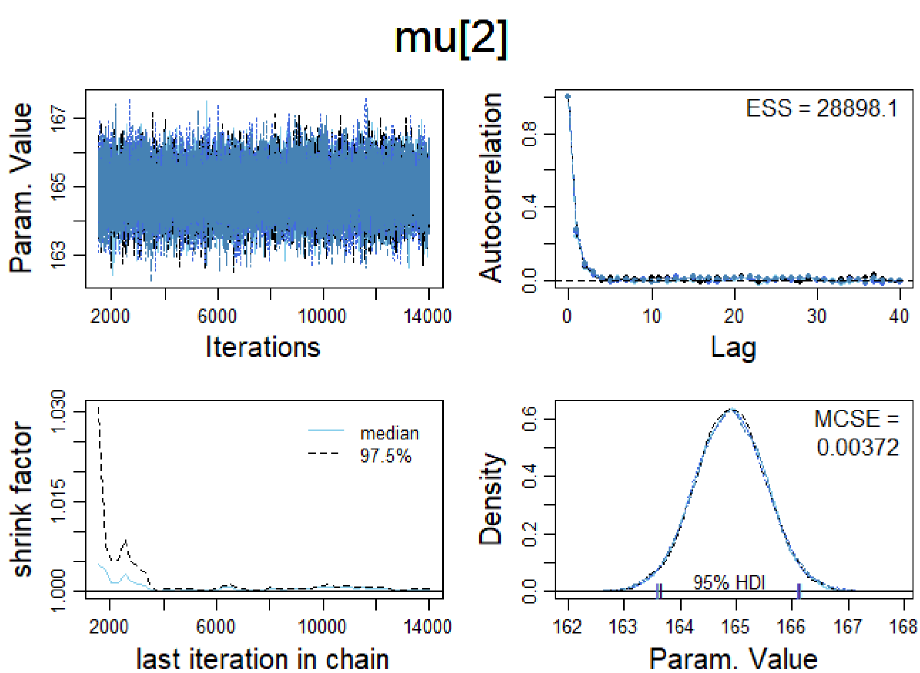
Appendix 6.3 - Dot plot for LEH chronology by funerary group and sex



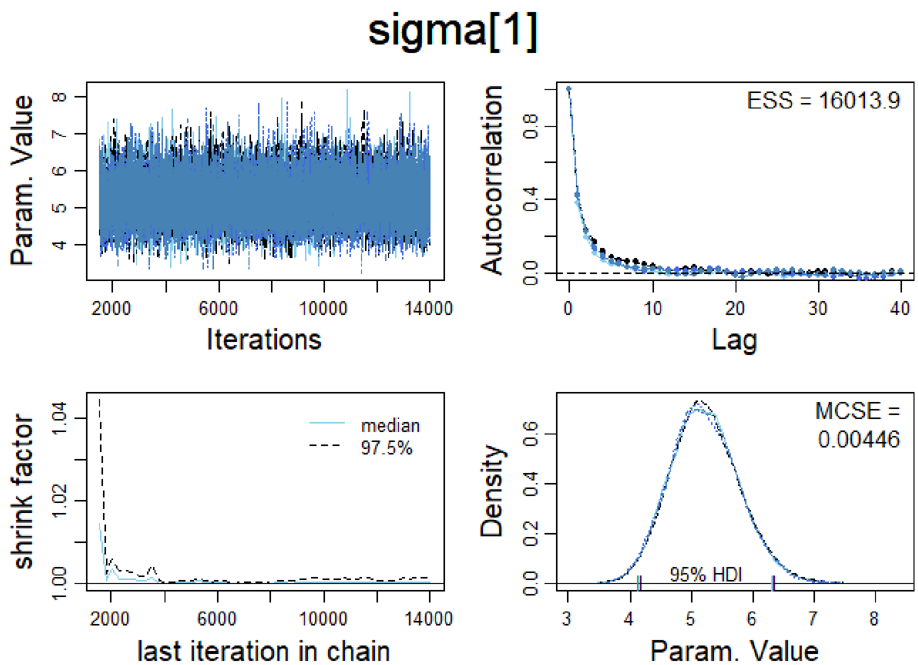
Appendix 6.4 - Markov chain Monte Carlo (MCMC) Diagnostics for mean (mu; µ) of all Females (regardless of funerary group) stature estimates (in cm).



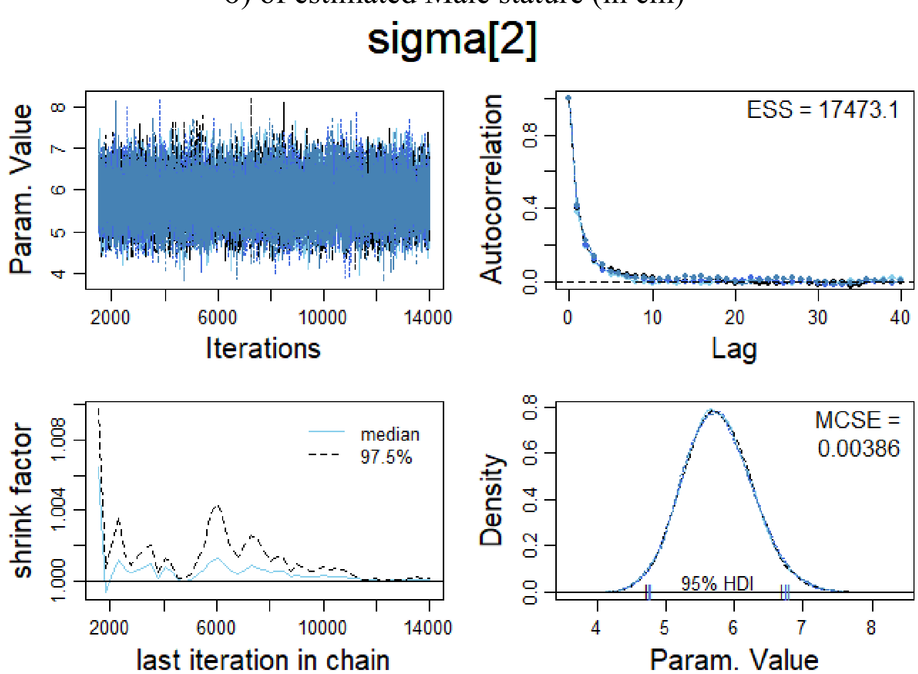
Appendix 6.5 - Markov chain Monte Carlo (MCMC) Diagnostics for mean (mu; µ) of all Males (regardless of funerary group) stature estimates (in cm).



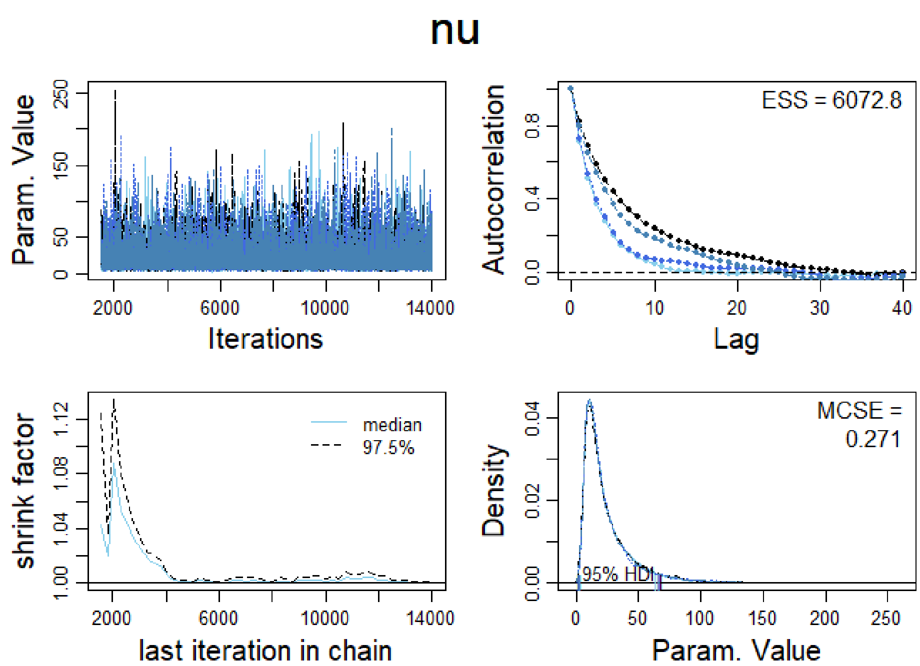
Appendix 6.6 - Markov chain Monte Carlo (MCMC) Diagnostics for standard deviation (sigma; σ) of estimated Female stature (in cm)



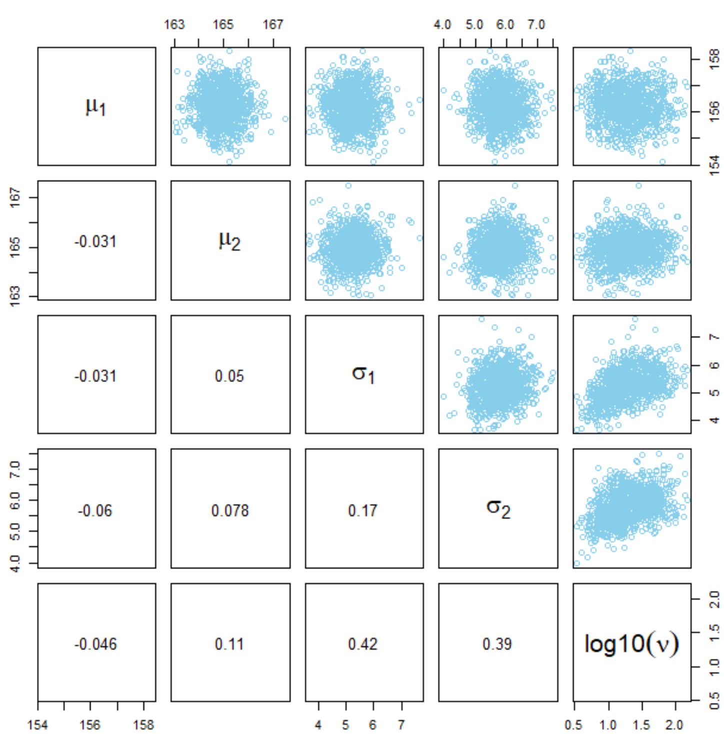
Appendix 6.7 - Markov chain Monte Carlo (MCMC) Diagnostics for standard deviation (sigma; σ) of estimated Male stature (in cm)



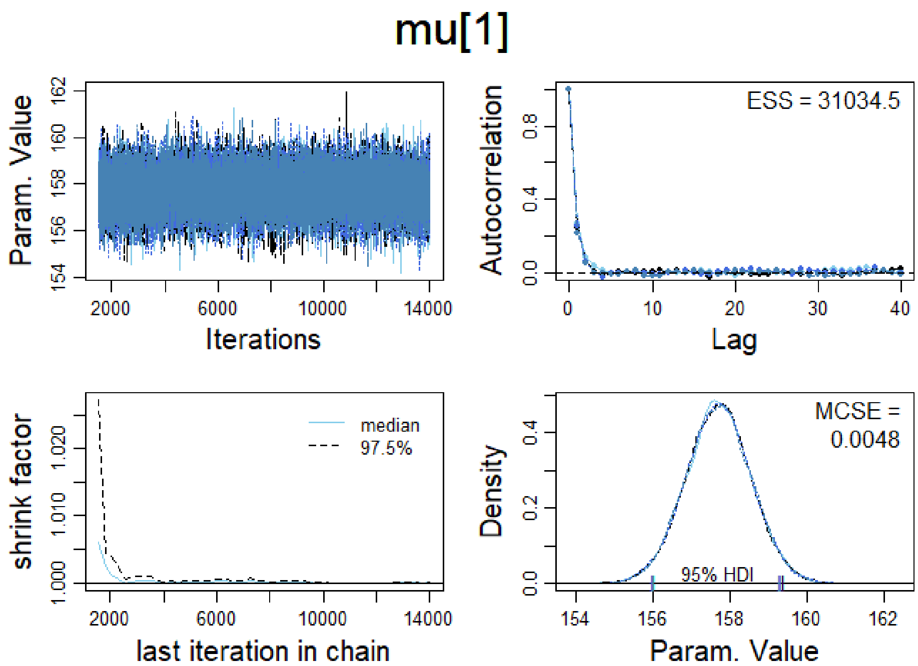
Appendix 6.8 - Markov chain Monte Carlo (MCMC) Diagnostics for Degrees of Freedom (nu; ν) for sex comparison



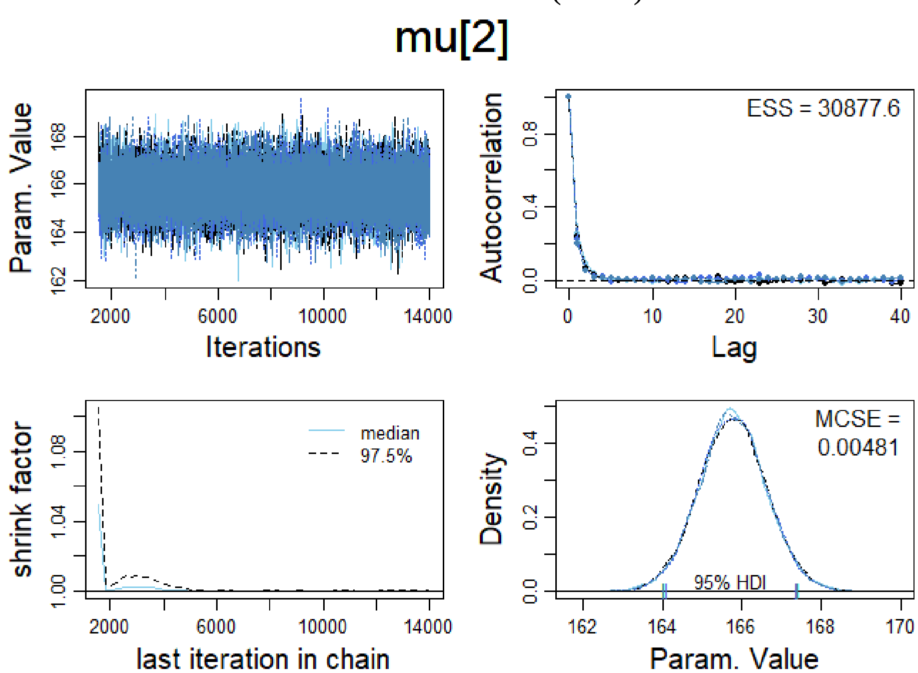
Appendix 6.9 - Markov chain Monte Carlo (MCMC) Diagnostics posterior pairwise correlations between parameters for Female (μ_1, σ_1) and Christian (μ_2, σ_2) stature estimates (in cm)



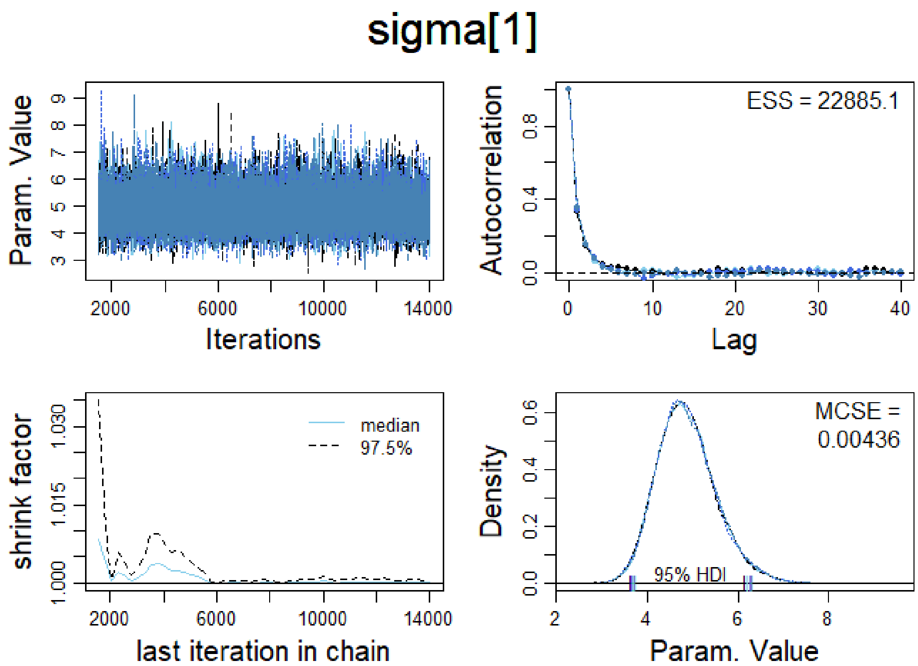
Appendix 6.10 - Markov chain Monte Carlo (MCMC) Diagnostics for mean (mu; μ) of Islamic Female stature estimates (in cm).



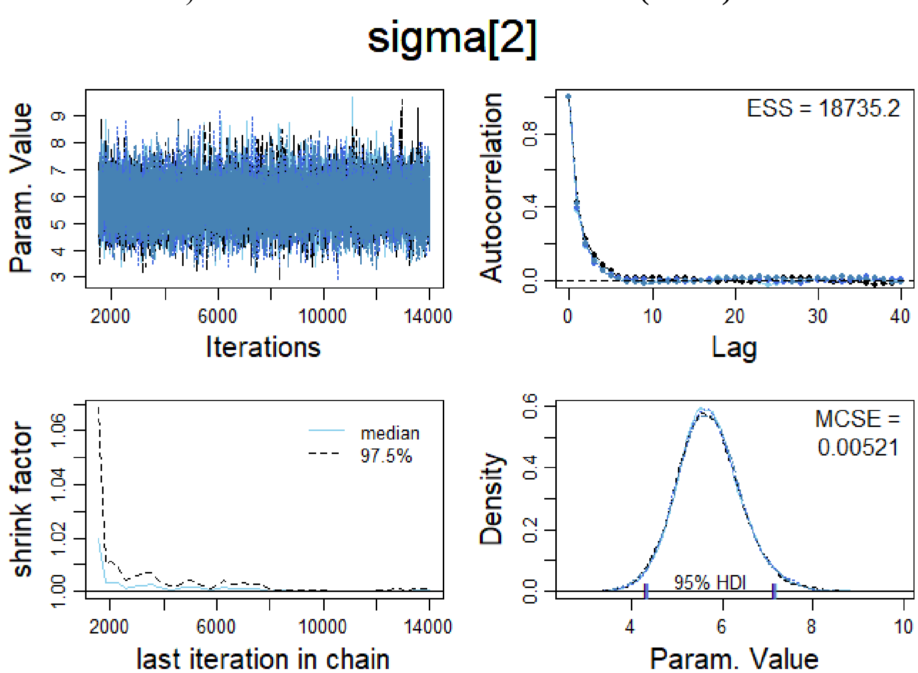
Appendix 6.11 - Markov chain Monte Carlo (MCMC) Diagnostics for mean (mu; μ) of Islamic Male stature estimates (in cm).



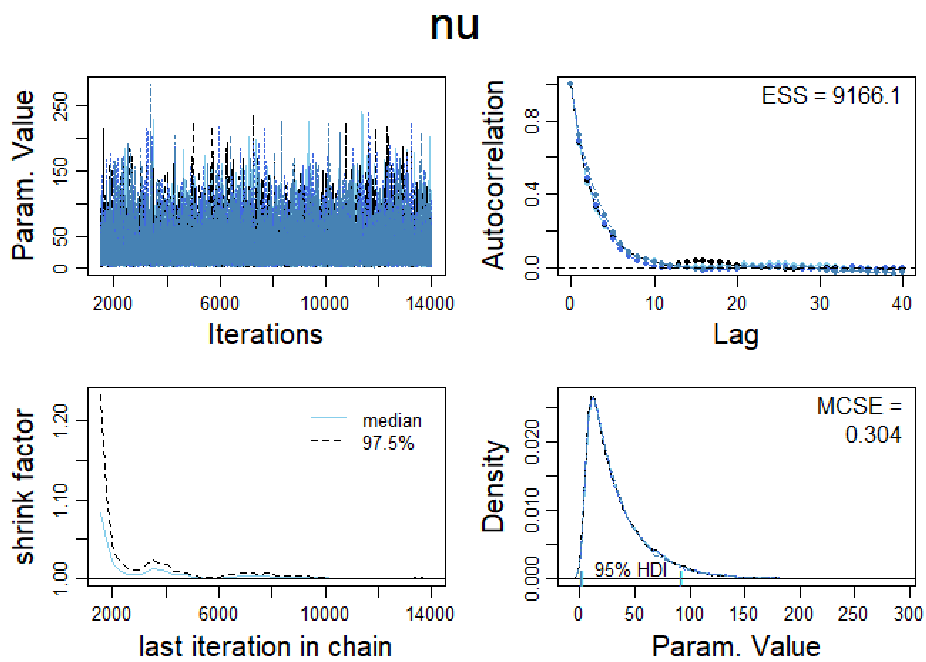
Appendix 6.12 - Markov chain Monte Carlo (MCMC) Diagnostics for standard deviation (sigma; σ) of estimated Islamic Female stature (in cm).



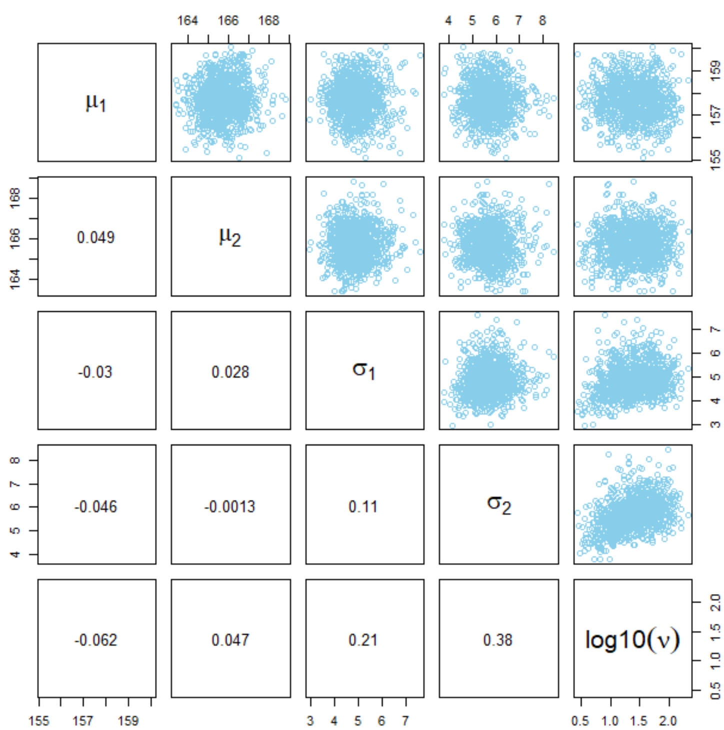
Appendix 6.13 - Markov chain Monte Carlo (MCMC) Diagnostics for standard deviation (sigma; σ) of estimated Islamic Male stature (in cm).



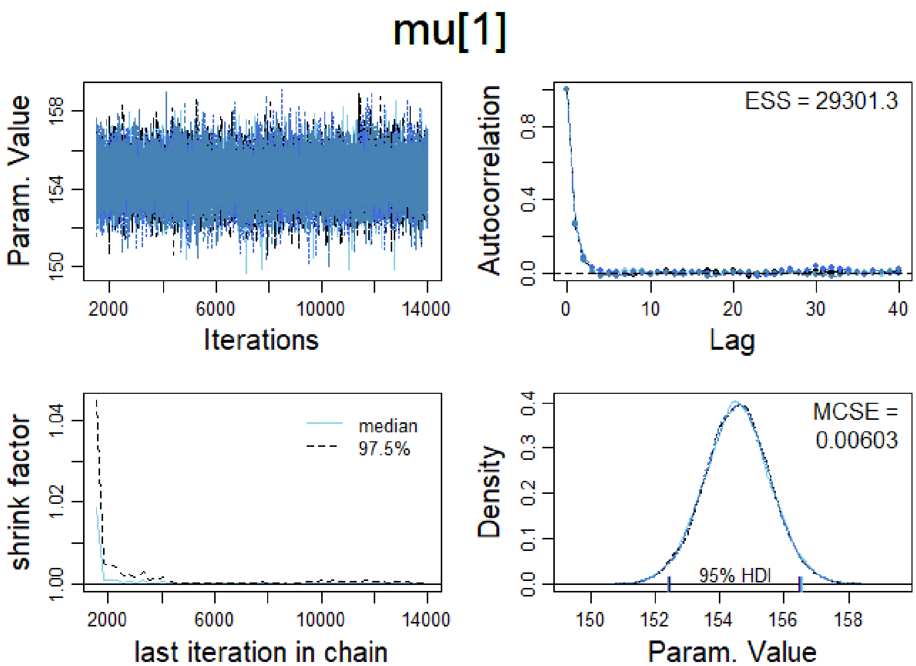
Appendix 6.14 - Markov chain Monte Carlo (MCMC) Diagnostics for Degrees of Freedom (nu; ν) for Islamic sex comparison



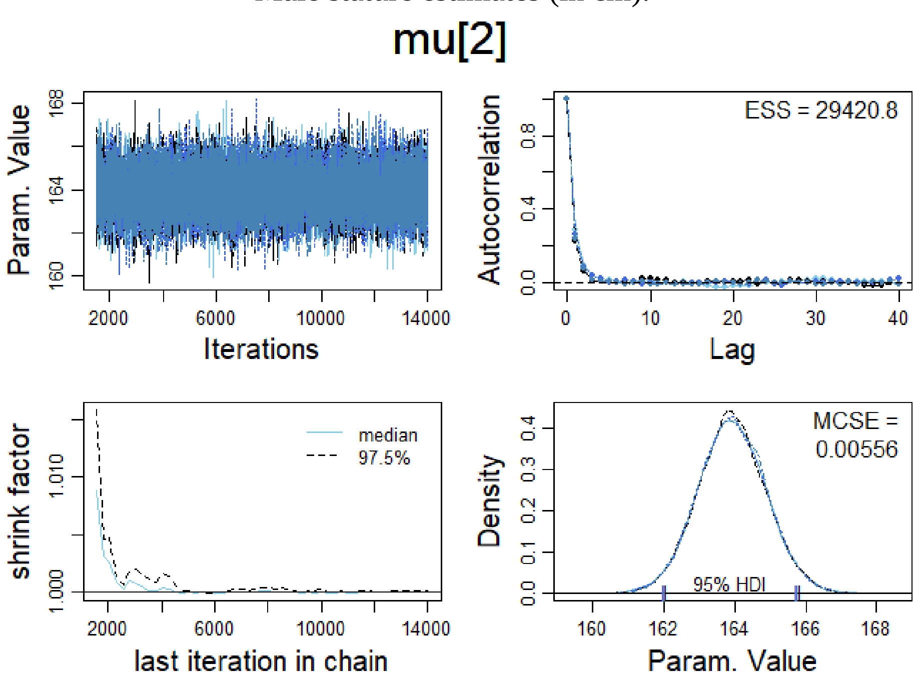
Appendix 6.15 - Markov chain Monte Carlo (MCMC) Diagnostics posterior pairwise correlations between parameters for Islamic Female (μ_1, σ_1) and Islamic Male (μ_2, σ_2) stature estimates (in cm)



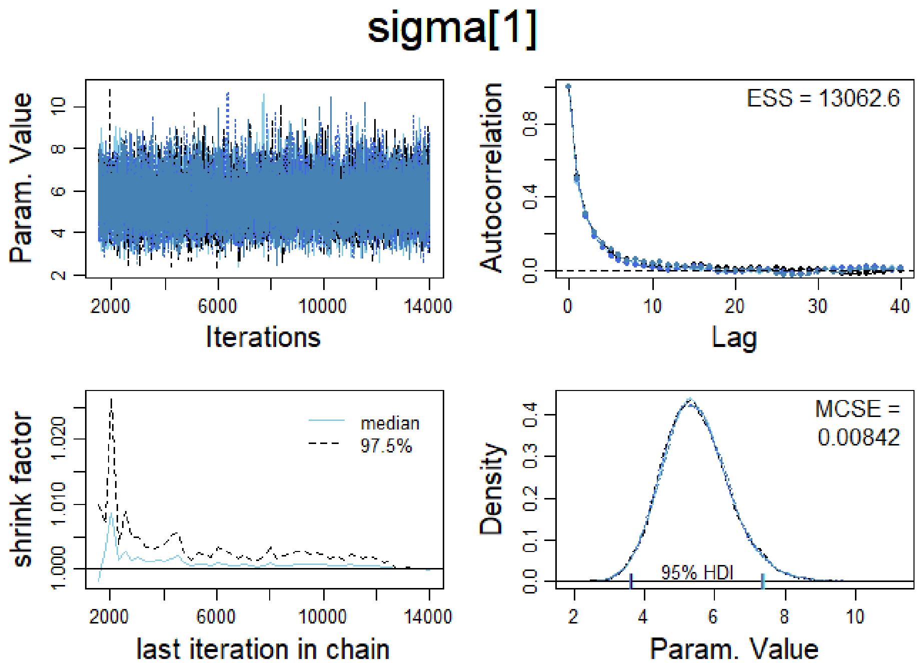
Appendix 6.16 - Markov chain Monte Carlo (MCMC) Diagnostics for mean (mu; µ) of Christian Female stature estimates (in cm).



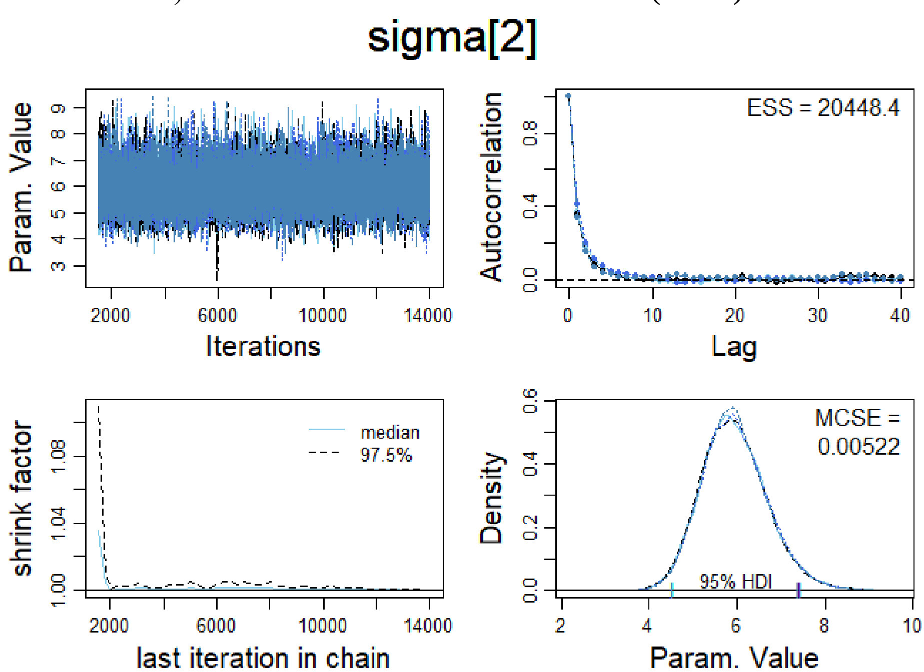
Appendix 6.17 - Markov chain Monte Carlo (MCMC) Diagnostics for mean (mu; µ) of Christian Male stature estimates (in cm).



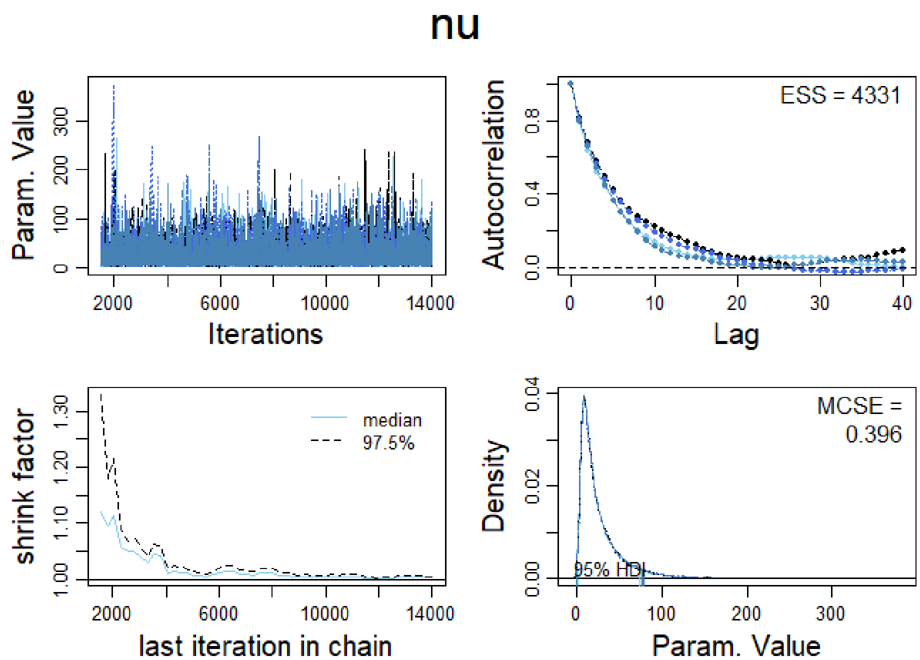
Appendix 6.18 - Markov chain Monte Carlo (MCMC) Diagnostics for standard deviation (sigma; σ) of estimated Christian Female stature (in cm).



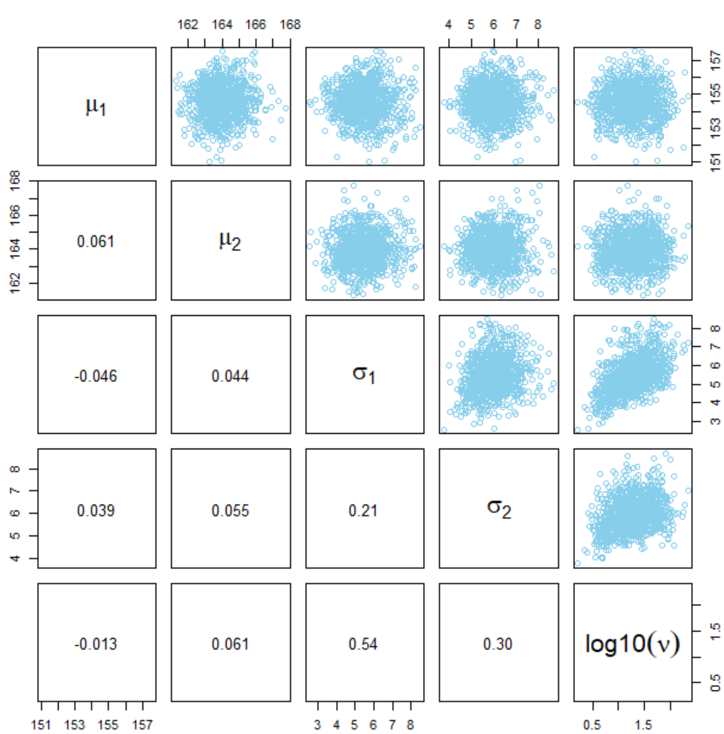
Appendix 6.19 - Markov chain Monte Carlo (MCMC) Diagnostics for standard deviation (sigma; σ) of estimated Christian Male stature (in cm).



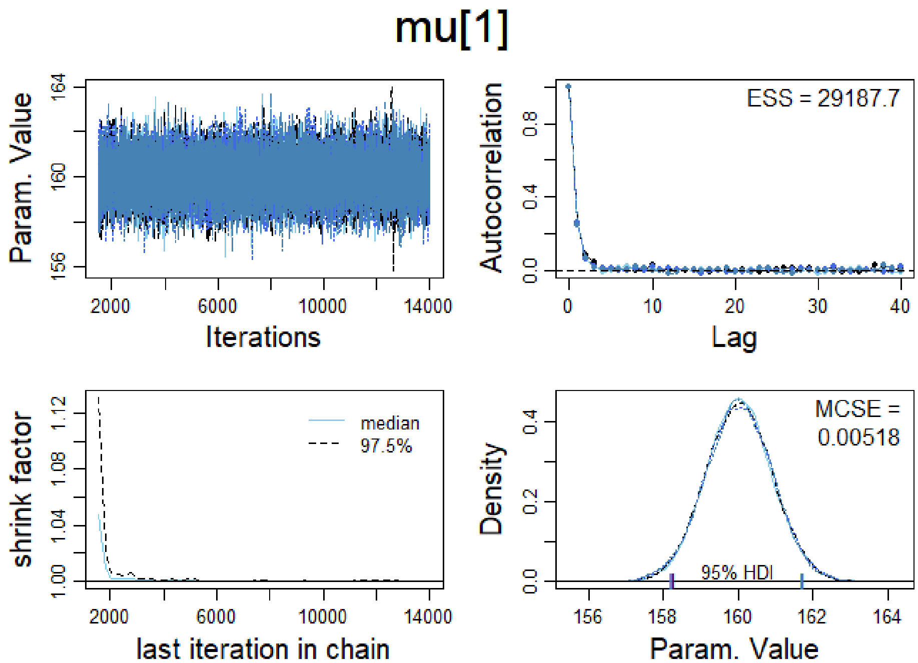
Appendix 6.20 - Markov chain Monte Carlo (MCMC) Diagnostics for Degrees of Freedom (nu; ν) for Christian sex comparison



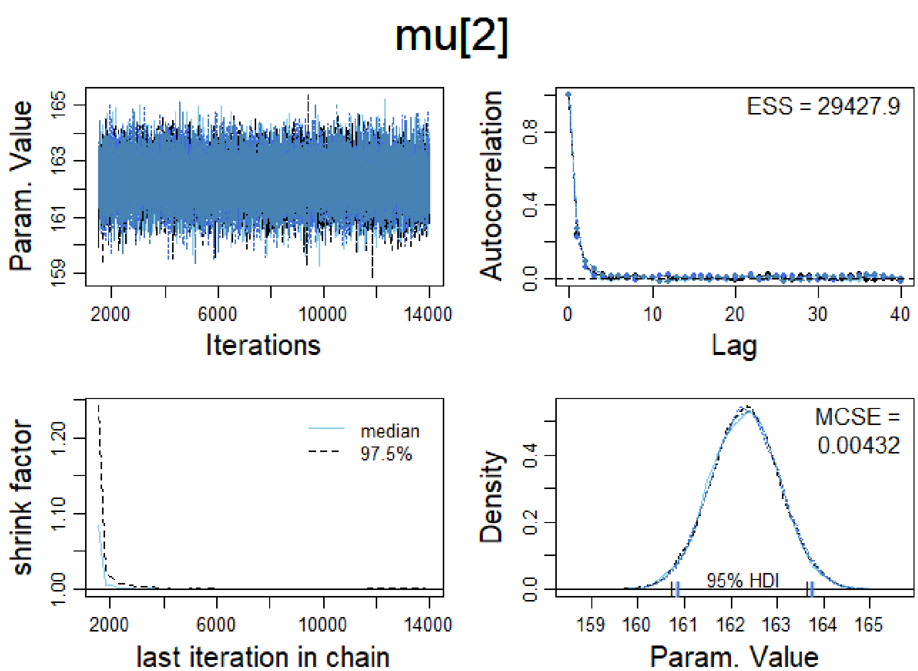
Appendix 6.21 - Markov chain Monte Carlo (MCMC) Diagnostics posterior pairwise correlations between parameters for Christian Female (μ_1, σ_1) and Christian Male (μ_2, σ_2) stature estimates (in cm)



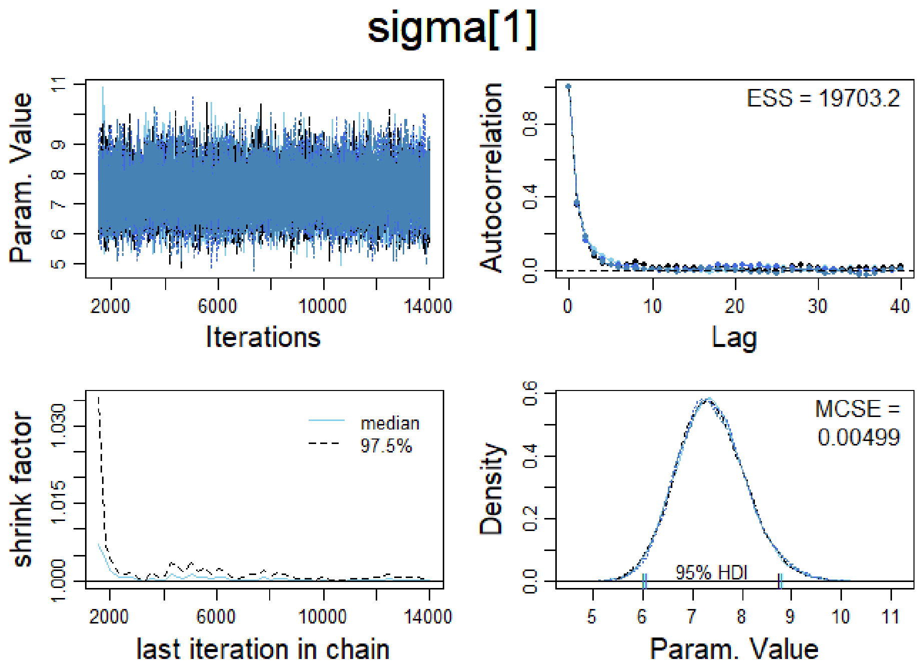
Appendix 6.22 - Markov chain Monte Carlo (MCMC) Diagnostics for mean (mu; µ) of Christian stature estimates (in cm), with sexes lumped.



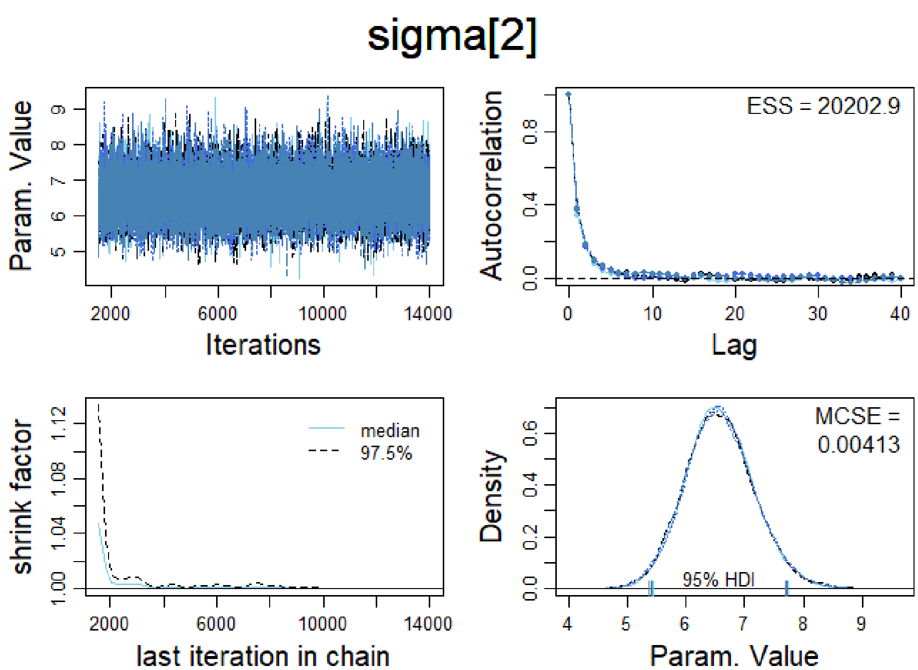
Appendix 6.23 - Markov chain Monte Carlo (MCMC) Diagnostics for mean (mu; µ) of Islamic stature estimates (in cm), with sexes lumped.



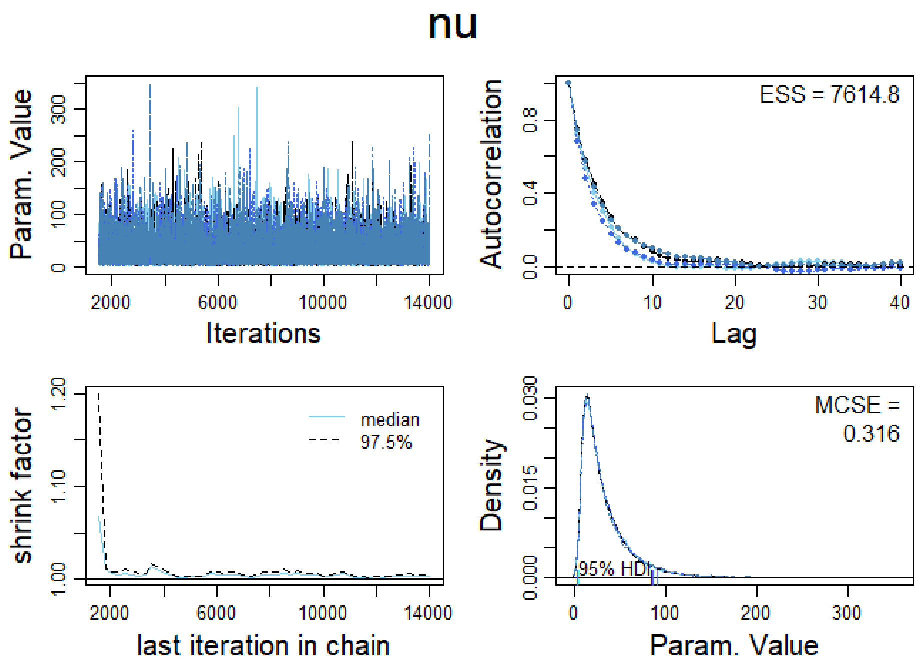
Appendix 6.24 - Markov chain Monte Carlo (MCMC) Diagnostics for standard deviation (sigma; σ) of estimated Christian stature (in cm), with sexes lumped.



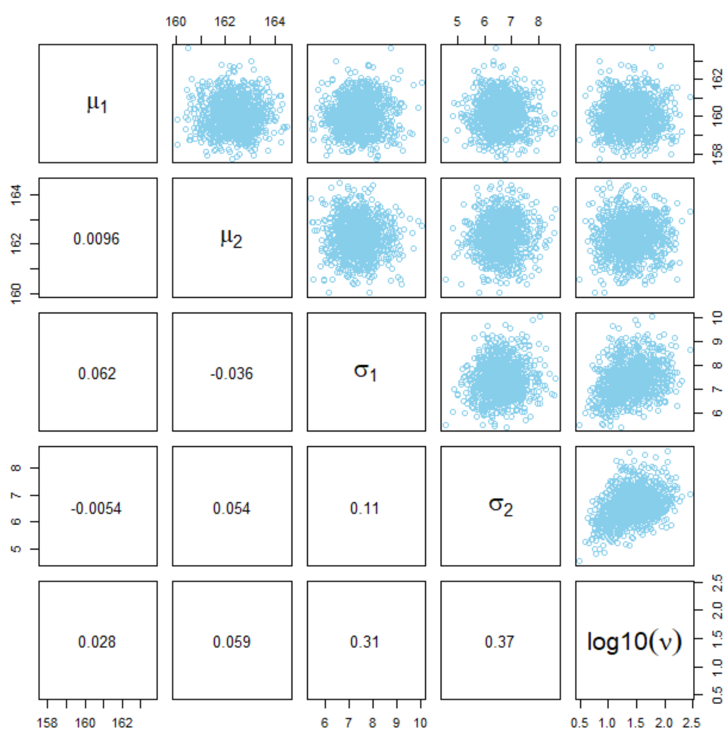
Appendix 6.25 - Markov chain Monte Carlo (MCMC) Diagnostics for standard deviation (sigma; σ) of estimated Islamic stature (in cm), with sexes lumped.



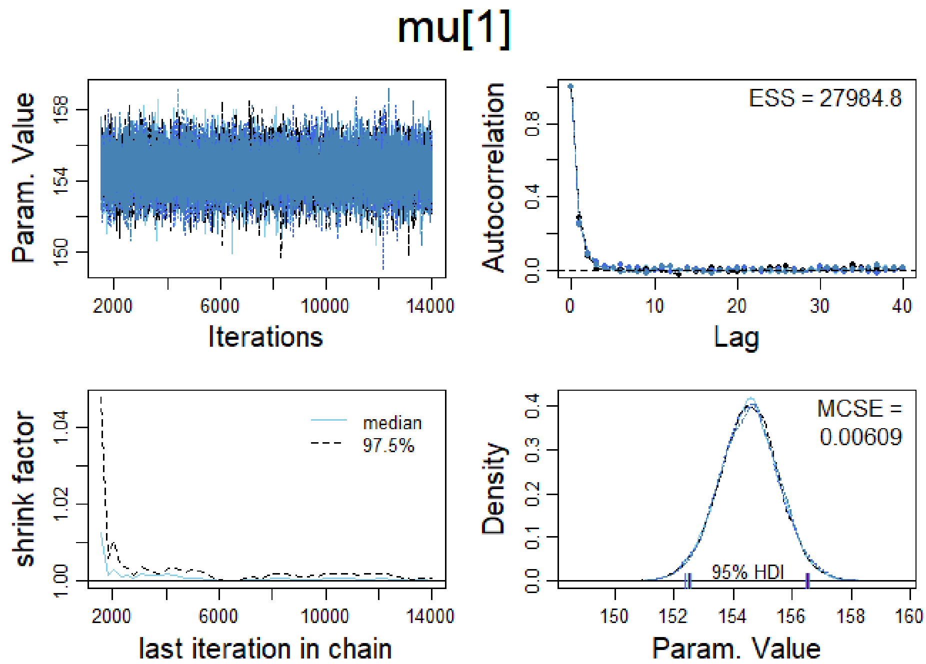
Appendix 6.26 - Markov chain Monte Carlo (MCMC) Diagnostics for Degrees of Freedom (nu; ν) for funerary comparison, with sexes lumped.



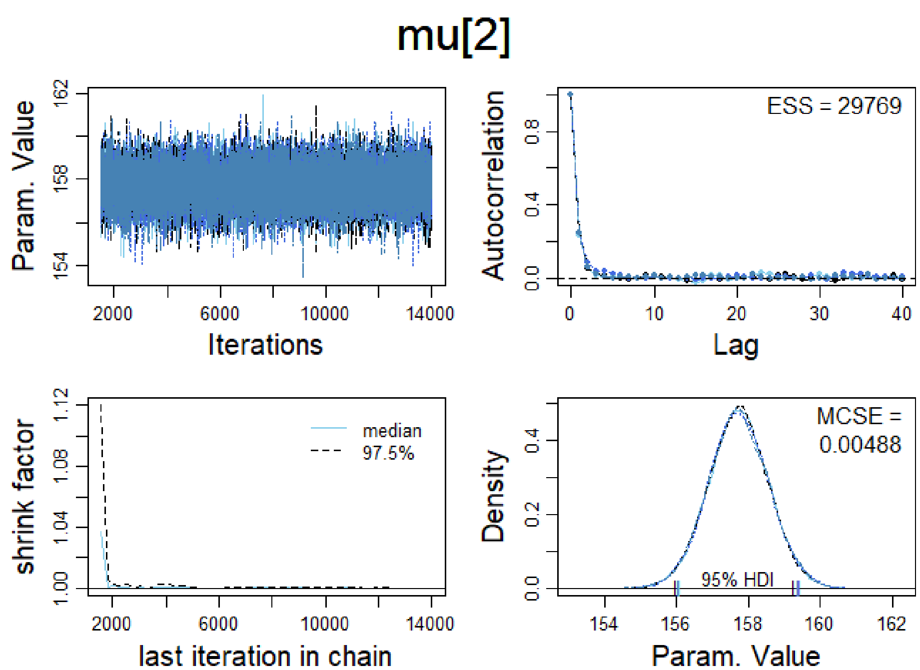
Appendix 6.27 - Markov chain Monte Carlo (MCMC) Diagnostics posterior pairwise correlations between parameters for Christian (μ_1, σ_1) and Islamic (μ_2, σ_2) stature estimates (in cm), with sexes lumped.



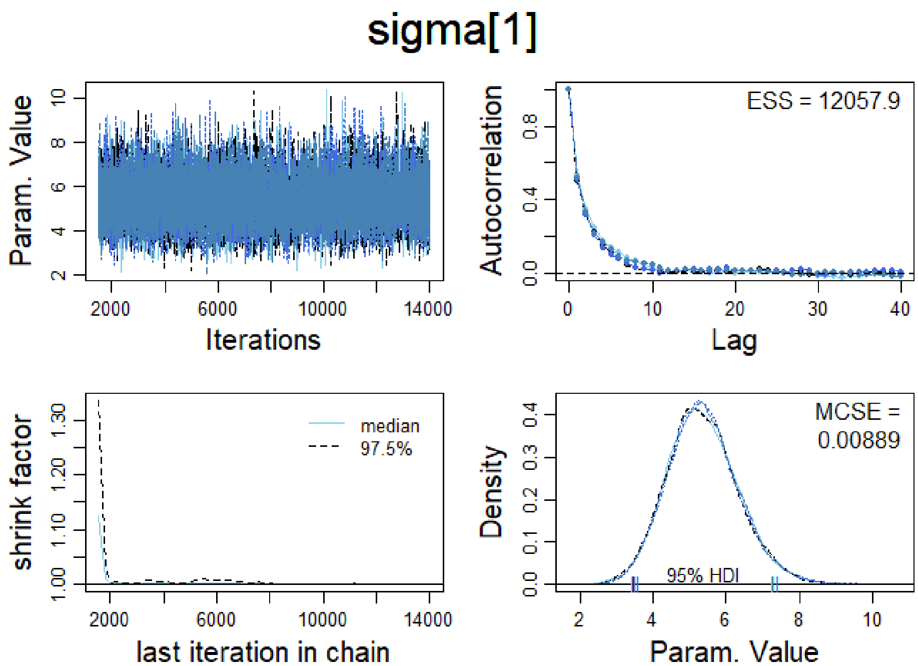
Appendix 6.28 - Markov chain Monte Carlo (MCMC) Diagnostics for mean (mu; μ) of Christian Female stature estimates (in cm).



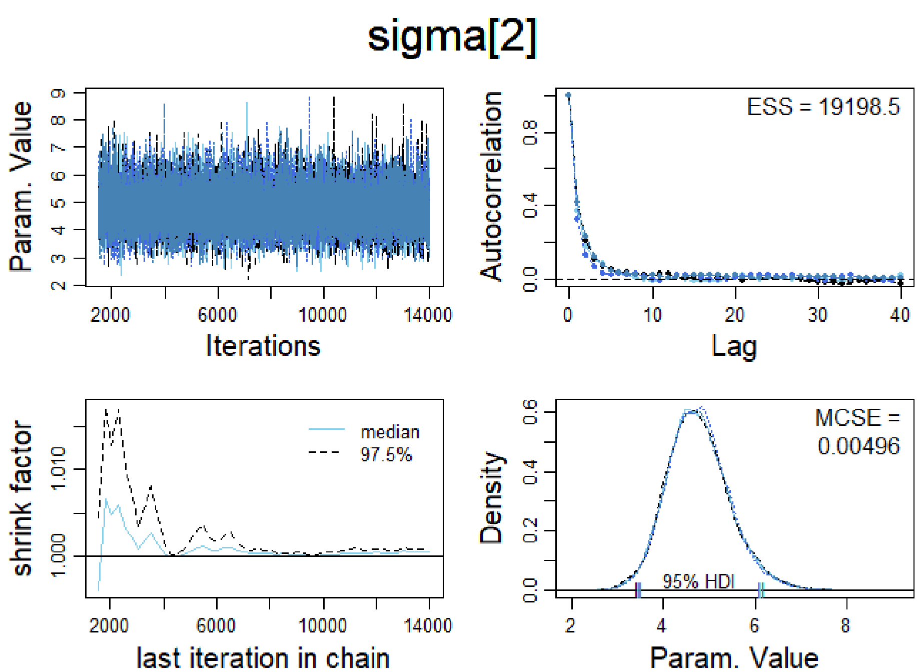
Appendix 6.29 - Markov chain Monte Carlo (MCMC) Diagnostics for mean (mu; μ) of Islamic Female stature estimates (in cm).



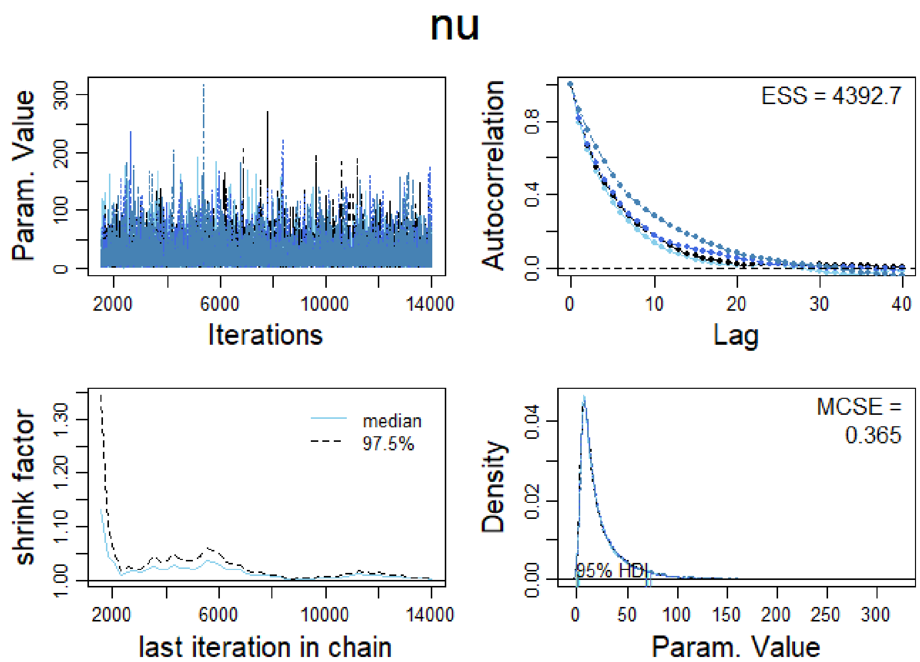
Appendix 6.30 - Markov chain Monte Carlo (MCMC) Diagnostics for standard deviation (sigma; σ) of estimated Christian Female stature (in cm).



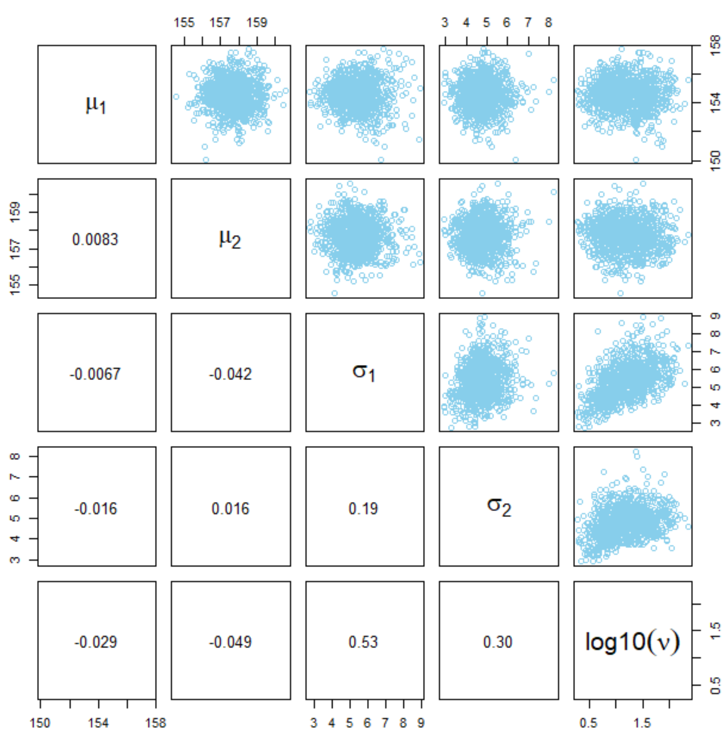
Appendix 6.31 - Markov chain Monte Carlo (MCMC) Diagnostics for standard deviation (sigma; σ) of estimated Islamic Female stature (in cm).



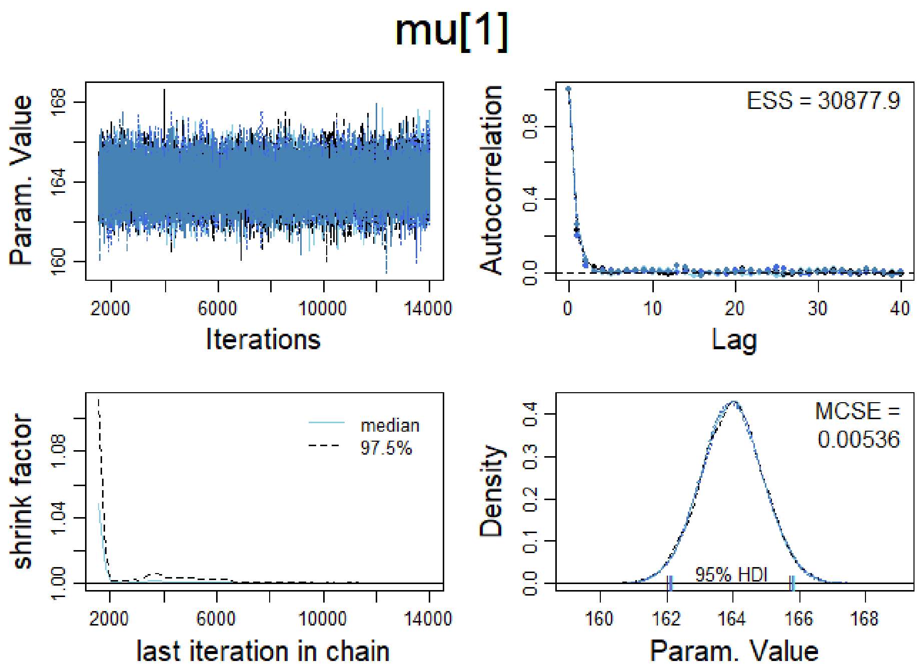
Appendix 6.32 - Markov chain Monte Carlo (MCMC) Diagnostics for Degrees of Freedom (nu; ν) for Female funerary comparison.



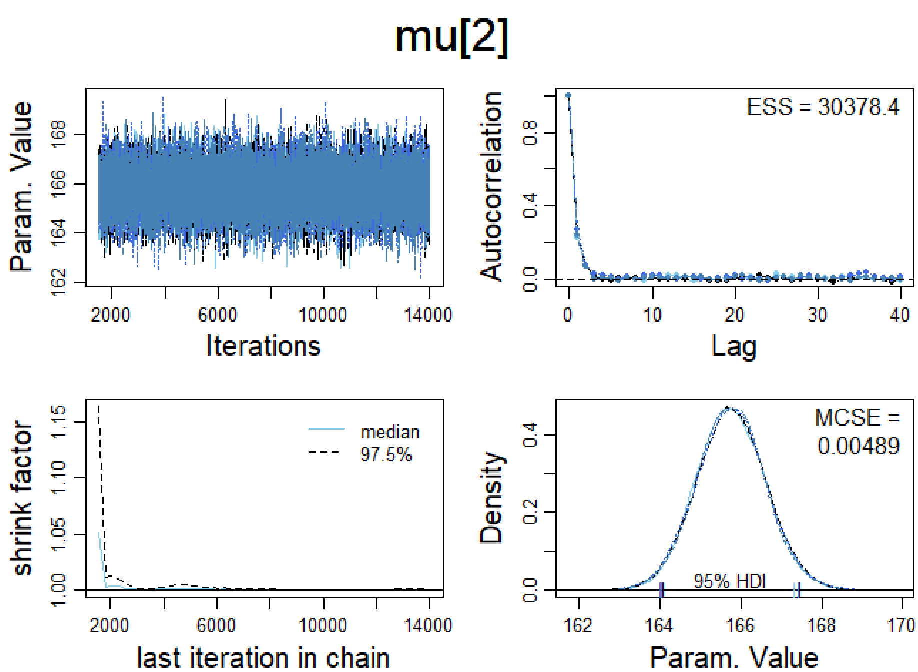
Appendix 6.33 - Markov chain Monte Carlo (MCMC) Diagnostics posterior pairwise correlations between parameters for Christian Female (μ_1, σ_1) and Islamic Female (μ_2, σ_2) stature estimates (in cm).



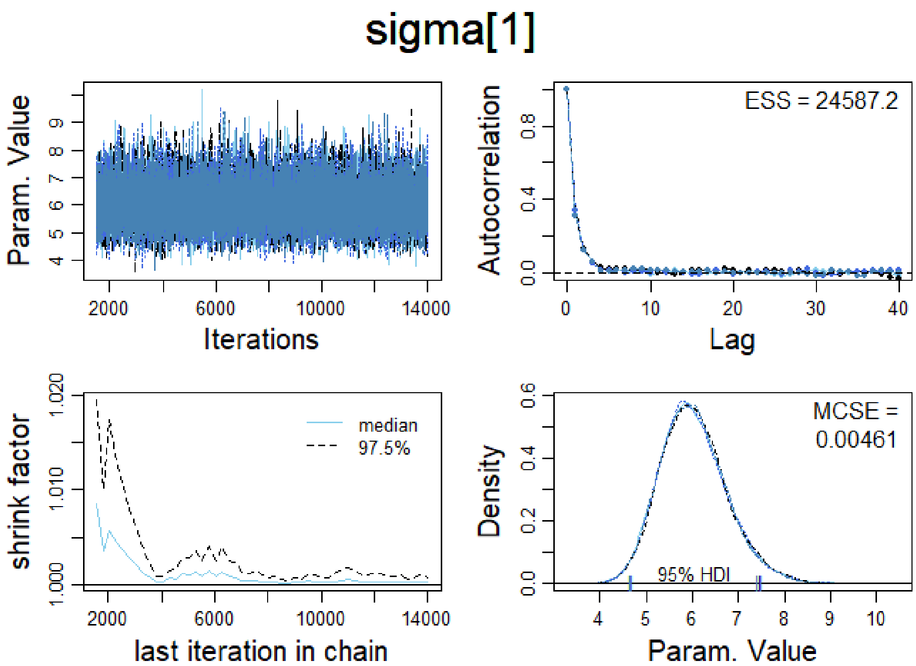
Appendix 6.34 - Markov chain Monte Carlo (MCMC) Diagnostics for mean (mu; µ) of Christian Male stature estimates (in cm).



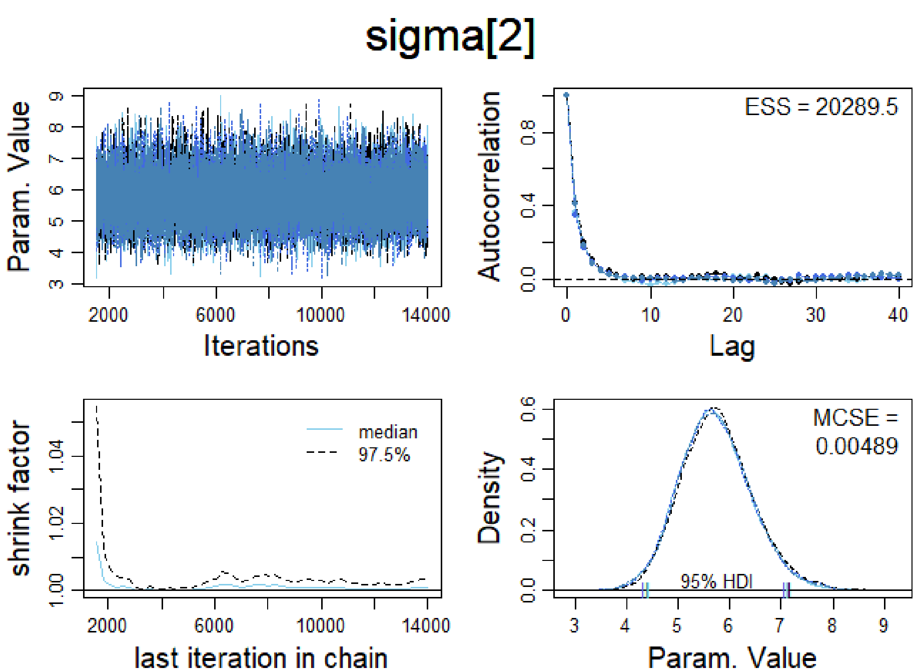
Appendix 6.35 - Markov chain Monte Carlo (MCMC) Diagnostics for mean (mu; µ) of Islamic Male stature estimates (in cm).



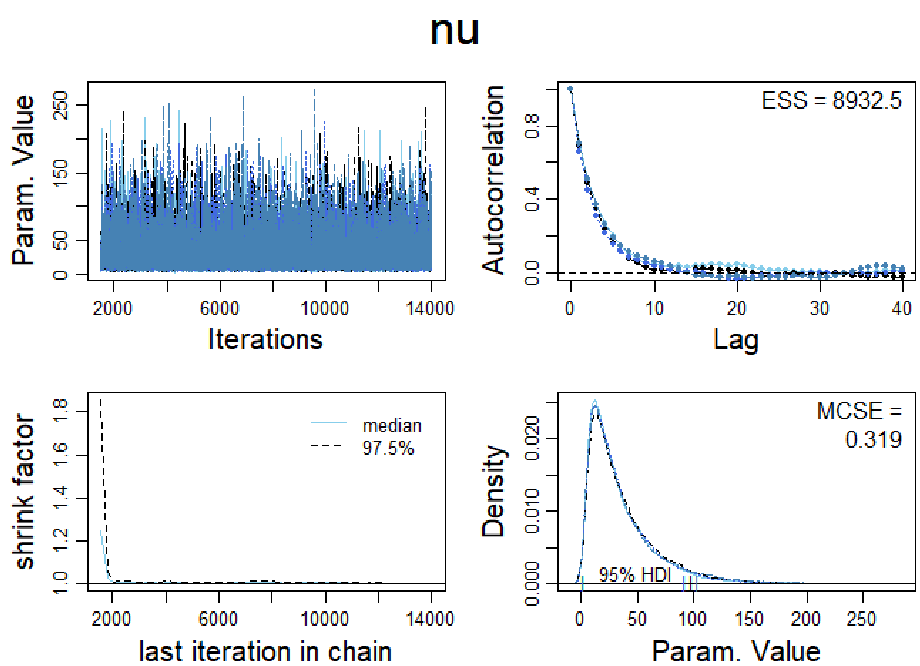
Appendix 6.36 - Markov chain Monte Carlo (MCMC) Diagnostics for standard deviation (sigma; σ) of estimated Christian Male stature (in cm).



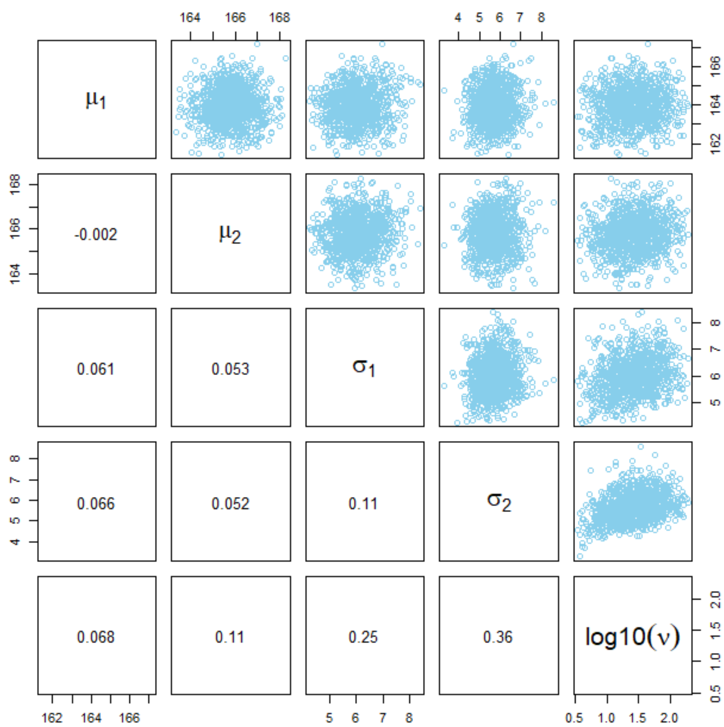
Appendix 6.37 - Markov chain Monte Carlo (MCMC) Diagnostics for standard deviation (sigma; σ) of estimated Islamic Male stature (in cm).



Appendix 6.38 - Markov chain Monte Carlo (MCMC) Diagnostics for Degrees of Freedom (nu; ν) for Male funerary comparison.



Appendix 6.39 - Markov chain Monte Carlo (MCMC) Diagnostics posterior pairwise correlations between parameters for Christian Male (μ_1, σ_1) and Islamic Male (μ_2, σ_2) stature estimates (in cm).



Appendix 6.40 - Shapiro-Wilk tests for stature estimates (in cm).

Group	W	*p*-value
Christian Females	0.90	<0.01
Christian Males	0.97	0.37
Islamic Females	0.98	0.58
Islamic Males	0.98	0.17

Appendix – Chapter 7

Appendix 7.1 - Reliability analysis for metacarpal radiogrammetry parameters examining n = 40 re-measures

	Bland-Altman		**ICC (ICC2)**			**Average difference**		**Average difference (%)**		**Change in absolute mean difference**			**Paired**		**TEM**				**CV**
Metric	% within 2s	% outside	ICC (ICC2)	F	p	Mean	SD	Mean	SD	Mean 1	Mean 2	|M1-M2|	t	p	Absolute TEM	VAV	Relative TEM	R	%
TL	97.5	2.5	0.999	1487	< 0.01	0.2	0.13	0.29	0.19	67.14	67.21	0.08	-2.13	0.04	0.17	67.17	0.25	0.99	0.25
TW	97.5	2.5	0.998	1072	< 0.01	0.06	0.03	0.57	0.36	8.41	8.43	0.02	1.79	0.08	0.04	8.42	0.48	0.99	0.48
MW	90	10	0.992	245	<0.01	0.08	0.08	1.84	1.71	4.11	4.09	0.02	0.9	0.38	0.08	4.10	1.90	0.99	1.78
CT	95	5	0.981	107	<0.01	0.11	0.08	2.48	2.11	4.31	4.34	0.03	-1.54	0.13	0.09	4.32	2.15	0.99	2.29
CI	95	5	0.984	124	<0.01	1.09	0.93	2.12	2.01	51.42	51.66	0.24	-1.11	0.27	0.97	51.54	1.89	0.99	2.05
CTI	95	5	0.977	86.8	<0.01	0.16	0.13	2.36	2.08	6.41	6.45	0.04	-1.17	0.25	0.14	6.43	2.11	0.99	2.21

Appendix 7.2 – Handedness (asymmetry) analysis for metacarpal radiogrammetry parameters examining n = 21 paired metacarpals

	Bland-Altman		**Average difference**		**Change in absolute mean difference**			**Paired**	
Metric	% within 2s	% outside	Mean	SD	Mean 1	Mean 2	|M1-M2|	t	p
TL	90.5	9.5	0.67	0.88	67.29	67.97	0.70	-2.74	0.01
TW	95.2	4.8	0.22	0.32	7.88	8.16	0.28	-2.91	0.01
MW	95.2	4.8	0.44	0.29	3.89	3.88	0.01	0	0.99
CT	95.2	4.8	0.28	0.35	3.99	4.27	0.28	-2.5	0.02
CI	100	0	5.11	4.01	50.75	52.44	1.69	-1.21	0.24
CTI	95.2	4.8	0.63	0.48	5.92	6.29	0.37	-2.34	0.03

Appendix 7.3 - Normality tests (Shapiro-Wilk) for metacarpal radiogrammetry parameters by funerary group and sex at Largo Cândido dos Reis and Avenida 5 de Outubro

Funerary Group	Sex	W (p)	W (p)	W (p)
Islamic	***Female***	***18-29 (n = 4)***	***30-49 (n = 13)***	***30-49 (n = 14)***
	TL	0.95 (0.69)	0.94 (0.48)	0.88 (0.06)
	TW	0.90 (0.45)	0.96 (0.75)	0.97 (0.92)
	MW	0.90 (0.43)	0.97 (0.90)	0.97 (0.91)
	CT	0.94 (0.66)	0.92 (0.21)	0.97 (0.82)
	CI	0.94 (0.64)	0.97 (0.91)	0.97 (0.92)
	CTI	0.87 (0.81)	0.93 (0.32)	0.97 (0.84)
	Male	***18-29 (n = 5)***	***30-49 (n = 7)***	***30-49 (n = 15)***
	TL	0.66 (0.00)*	0.99 (0.99)	0.97 (0.88)
	TW	0.94 (0.67)	0.88 (0.24)	0.92 (0.17)
	MW	0.95 (0.73)	0.98 (0.95)	0.98 (0.97)
	CT	0.93 (0.57)	0.83 (0.09)	0.94 (0.44)
	CI	0.90 (0.40)	0.98 (0.94)	0.97 (0.82)
	CTI	0.96 (0.82)	0.93 (0.53)	0.98 (0.94)
Christian	***Female***	***18-29 (n = 5)***	***30-49 (n = 6)***	***50+ (n = 10)***
	TL	0.98 (0.96)	0.91 (0.46)	0.89 (0.16)
	TW	1.00 (1.00)	0.84 (0.12)	0.94 (0.58)
	MW	0.91 (0.58)	0.86 (0.18)	0.93 (0.40)
	CT	0.84 (0.16)	0.76 (0.02)*	0.94 (0.56)
	CI	0.96 (0.82)	0.80 (0.06)	0.93 (0.49)
	CTI	0.92 (0.53)	0.82 (0.09)	0.88 (0.13)
	Male	***18-29 (n = 11)***	***30-49 (n = 23)***	***50+ (n = 9)***
	TL	0.99 (0.94)	0.99 (0.85)	0.97 (0.89)
	TW	0.95 (0.61)	0.98 (0.97)	0.95 (0.68)
	MW	0.97 (0.93)	0.95 (0.45)	0.95 (0.65)
	CT	0.84 (0.03)*	0.89 (0.02)*	0.92 (0.36)
	CI	0.94 (0.49)	0.95 (0.36)	0.81 (0.34)
	CTI	0.86 (0.12)	0.95 (0.26)	0.97 (0.87)

Appendix 7.4 - Normality tests (Shapiro-Wilk) for rib cross sectional area indices by funerary group and sex at Largo Cândido dos Reis and Avenida 5 de Outubro

Funerary Group	**Sex**	**W (p)**	**W (p)**
Islamic	***Female***	***18-49 (n = 15)***	***50+ (n = 10)***
	Tt.Ar	0.93 (0.26)	0.93 (0.46)
	En.Ar	0.91 (0.12)	0.97 (0.84)
	Ct.Ar	0.94 (0.34)	0.94 (0.56)
	CI	0.94 (0.42)	0.97 (0.85)
	Male	***18-49 (n = 16)***	***50+ (n = 13)***
	Tt.Ar	0.98 (0.95)	0.98 (0.99)
	En.Ar	0.96 (0.61)	0.93 (0.36)
	Ct.Ar	0.92 (0.16)	0.91 (0.17)
	CI	0.97 (0.89)	0.91 (0.17)
Christian	***Female***	***18-49 (n = 8)***	***50+ (n = 11)***
	Tt.Ar	0.99 (0.99)	0.96 (0.79)
	En.Ar	0.98 (0.95)	0.94 (0.49)
	Ct.Ar	0.98 (0.96)	0.94 (0.58)
	CI	0.92 (0.40)	0.94 (0.70)
	Male	***18-49 (n = 26)***	***50+ (n = 9)***
	Tt.Ar	0.97 (0.53)	0.93 (0.51)
	En.Ar	0.96 (0.37)	0.97 (0.91)
	Ct.Ar	0.98 (0.79)	0.96 (0.80)
	CI	0.98 (0.86)	0.87 (0.13)

Appendix 7.5 - Islamic Total Length (TL) by Age and Sex.

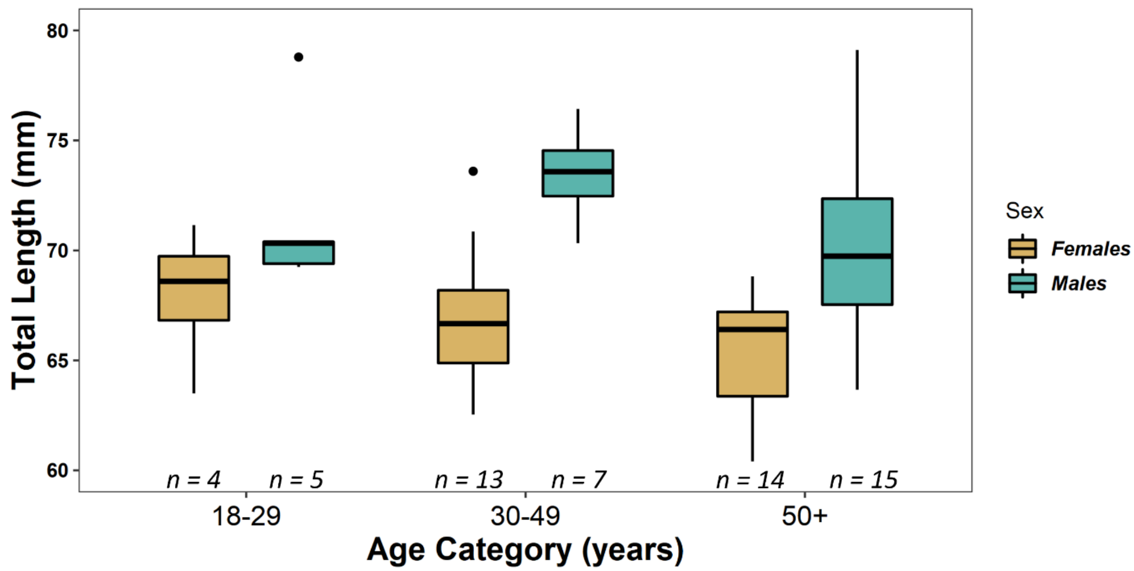
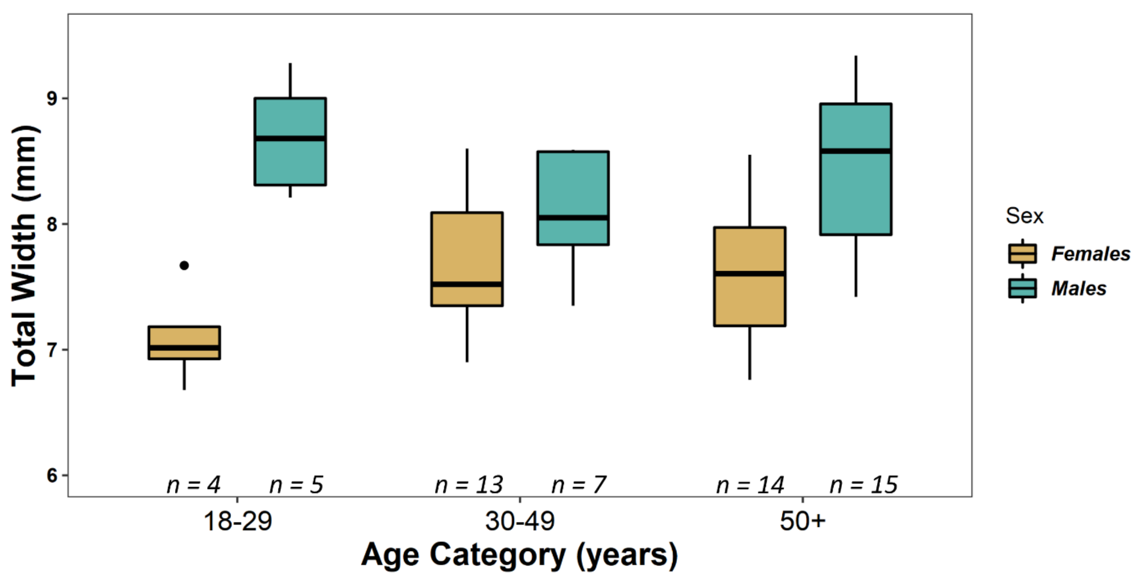
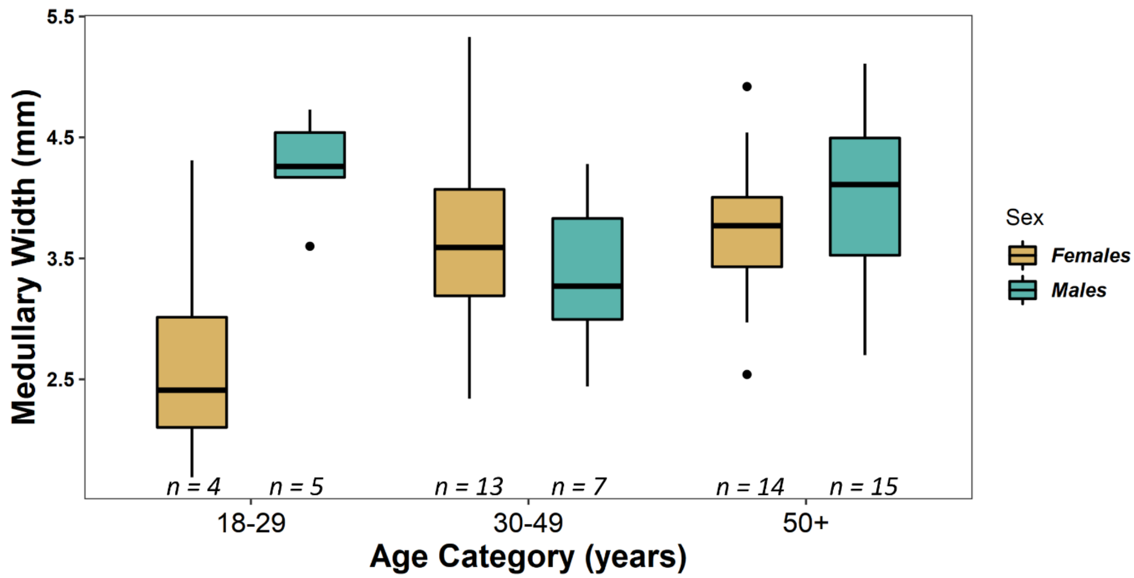


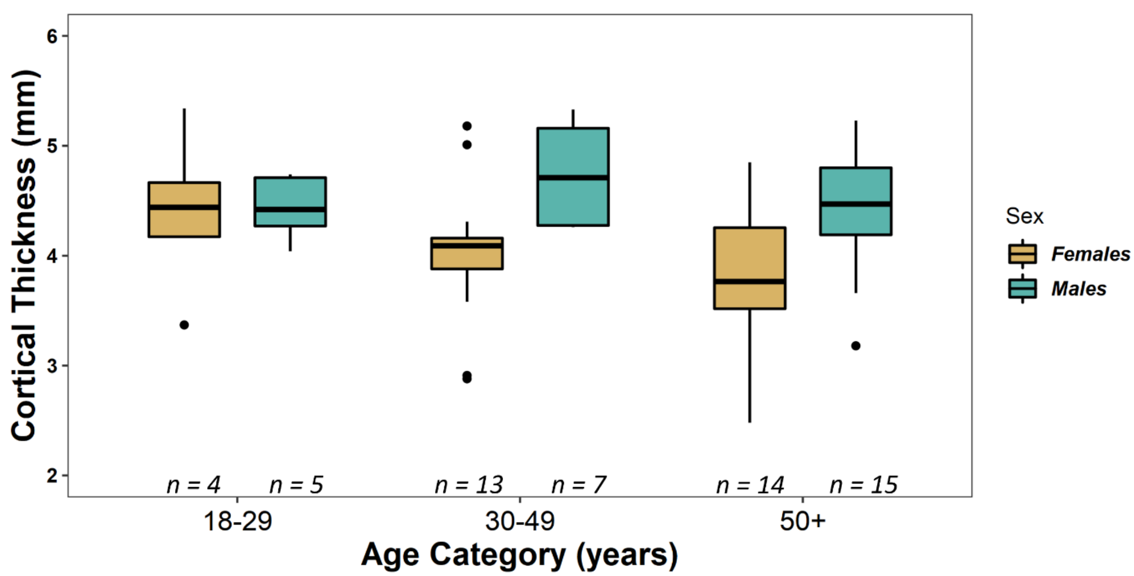
Figure 7.6 - Islamic Total Width (TW) by Age and Sex.



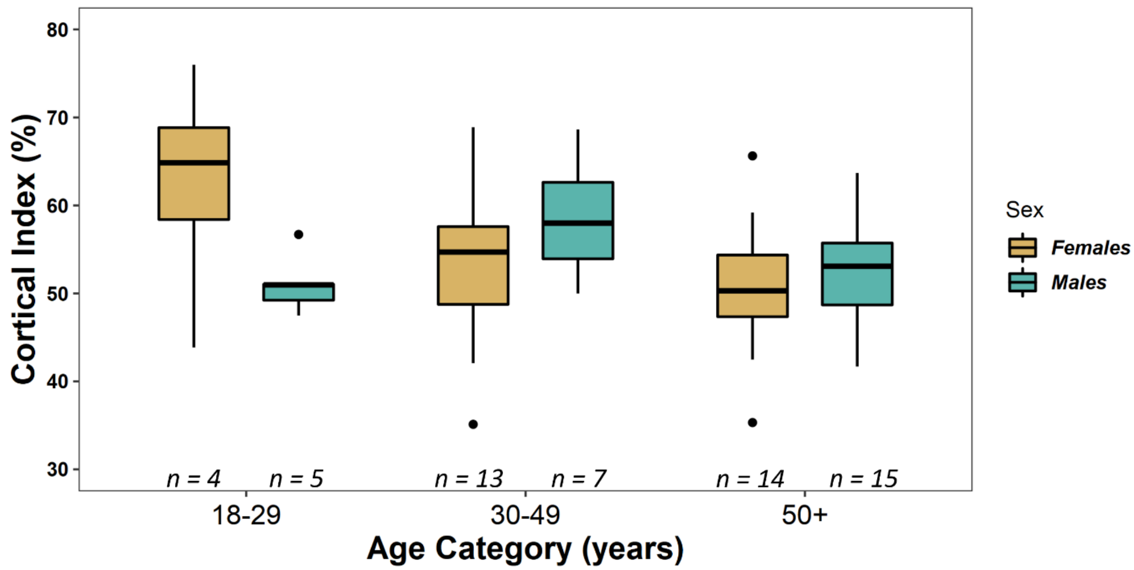
Appendix 7.7 - Islamic Medullary Width (MW) by Age and Sex.



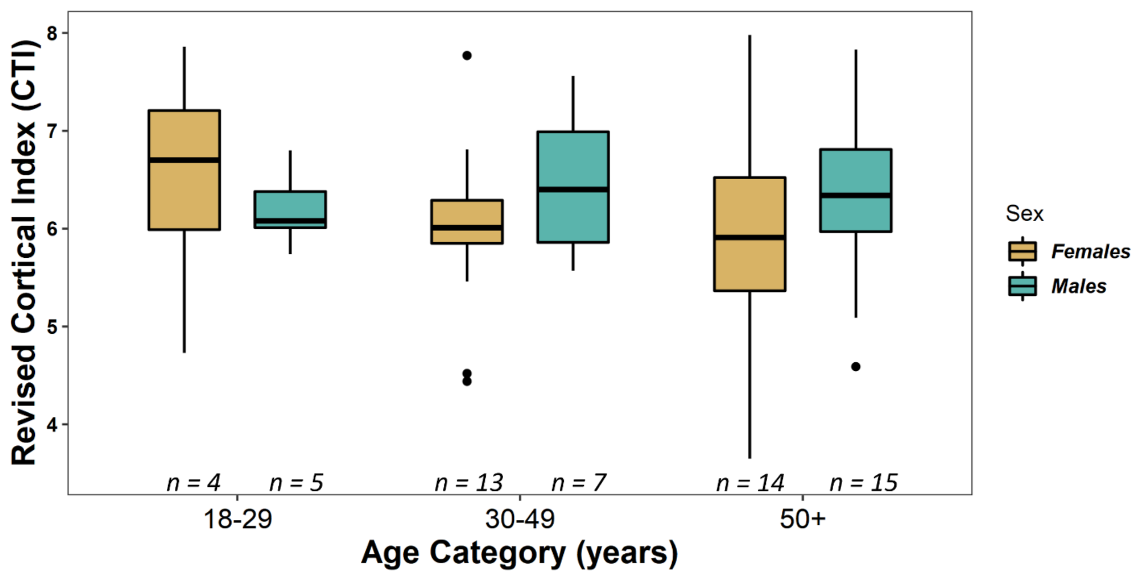
Appendix 7.8 - Islamic Cortical Thickness (CT) by Age and Sex.



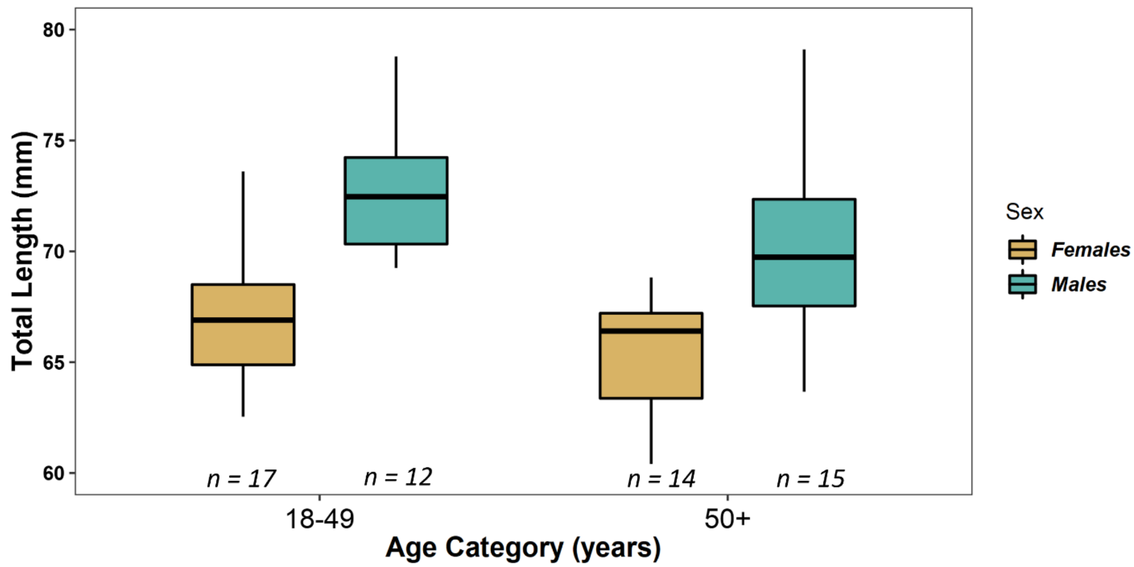
Appendix 7.9 - Islamic Cortical Index (CI) by Age and Sex.



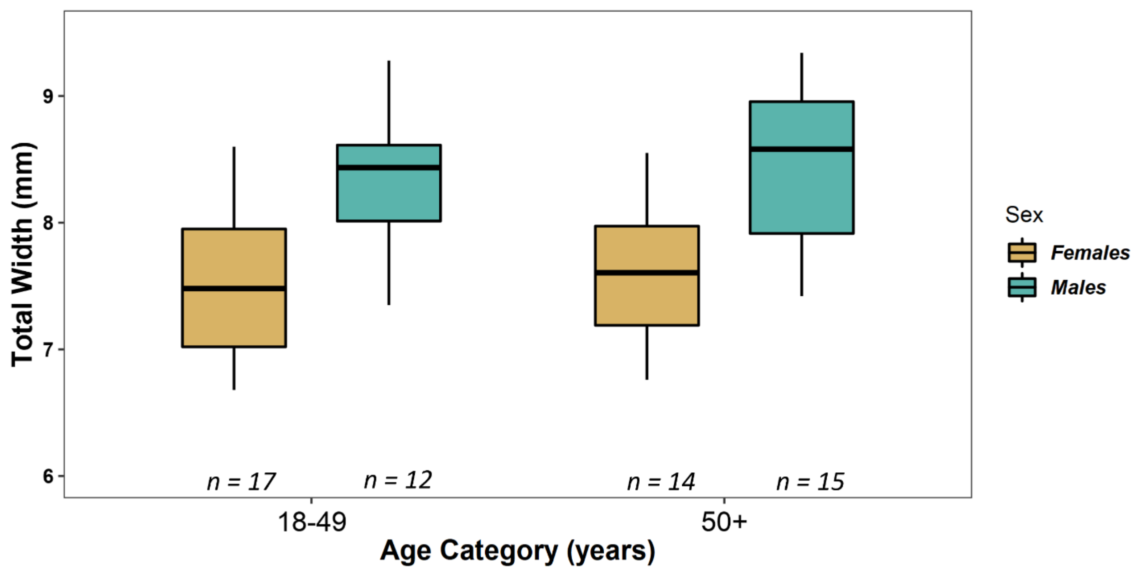
Appendix 7.10 - Islamic Revised Cortical Thickness Index (CTI) by Age and Sex.



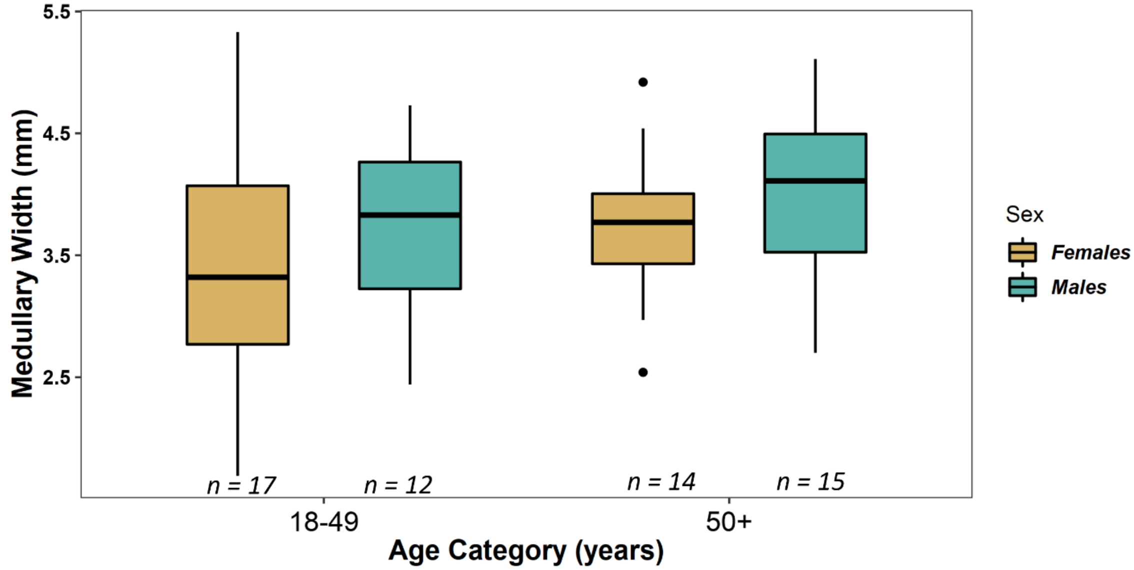
Appendix 7.11 - Islamic Total Length (TL) by Age and Sex, Ages collapsed.



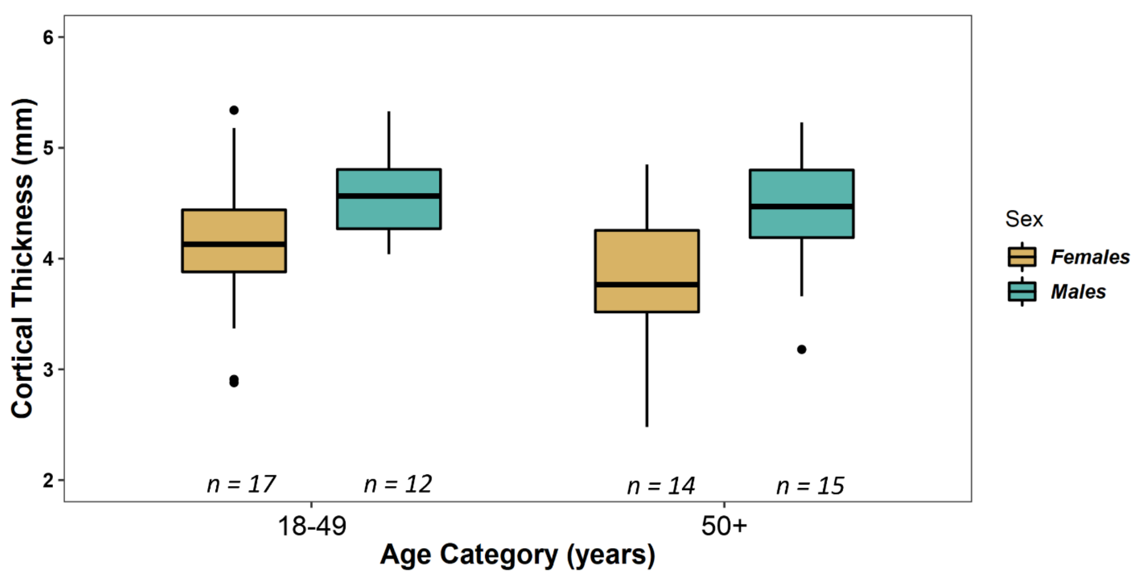
Appendix 7.12 - Islamic Total Width (TW) by Age and Sex, Ages collapsed.



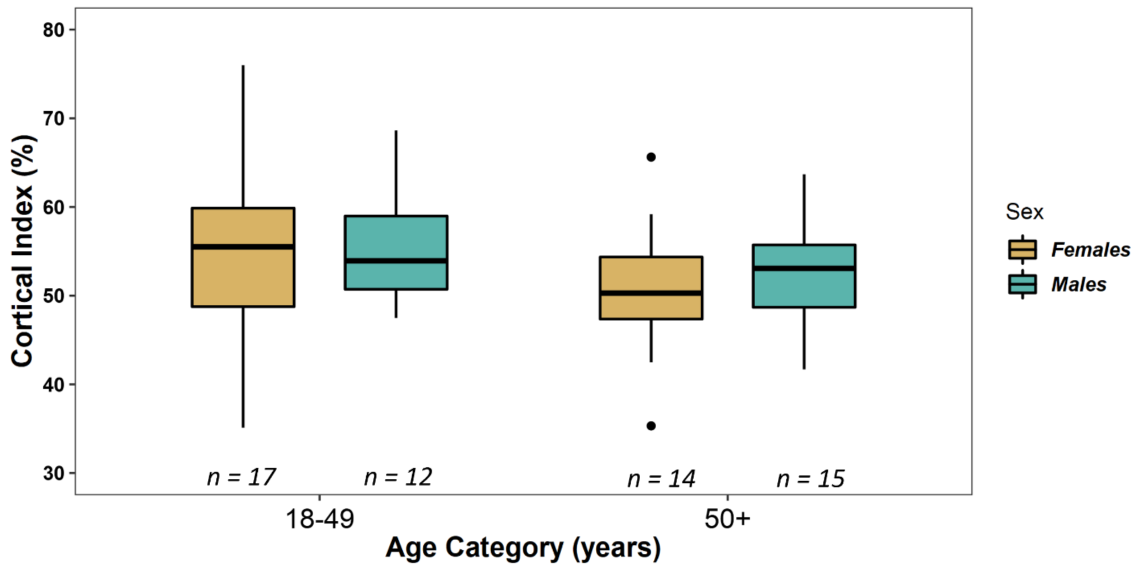
Appendix 7.13 - Islamic Medullary Width (MW) by Age and Sex, Ages collapsed.



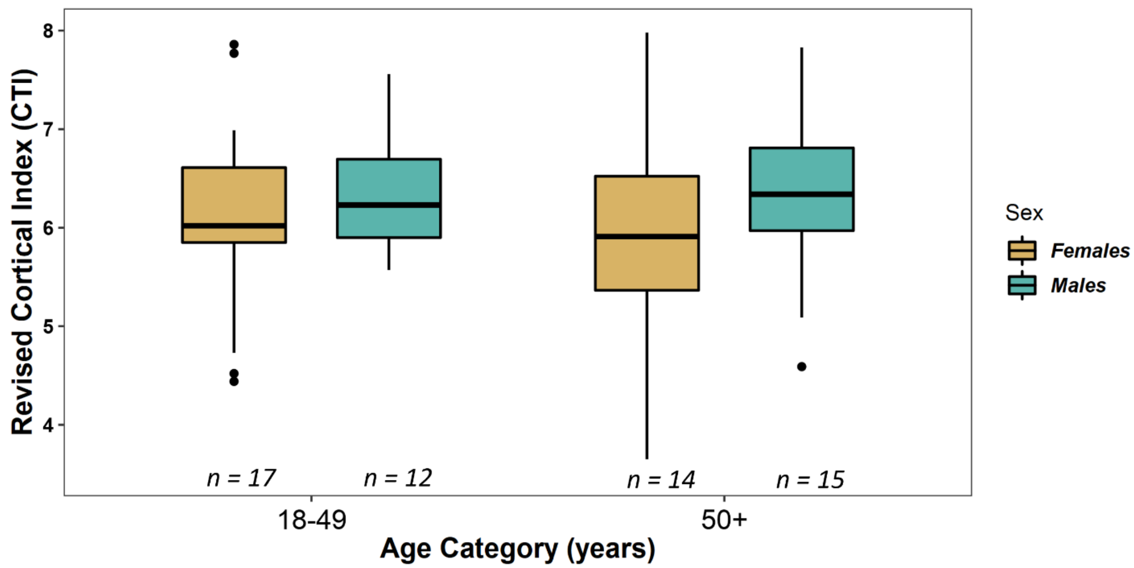
Appendix 7.14 - Islamic Cortical Thickness (CT) by Age and Sex, Ages collapsed.



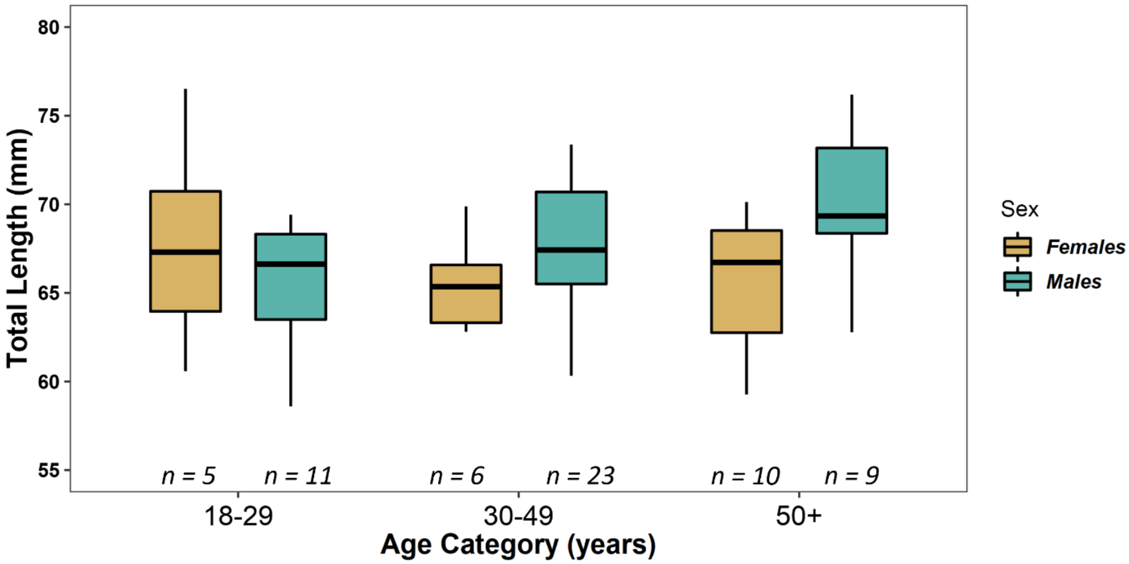
Appendix 7.15 - Islamic Cortical Index (CI) by Age and Sex, Ages collapsed.



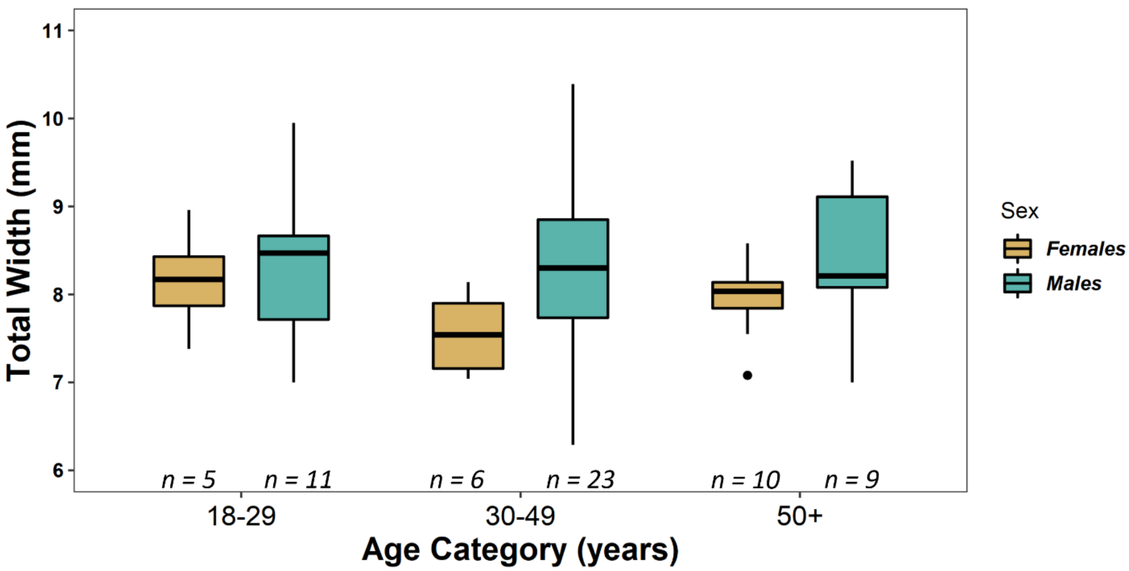
Appendix 7.16 - Islamic Revised Cortical Thickness Index (CT) by Age and Sex, Ages collapsed.



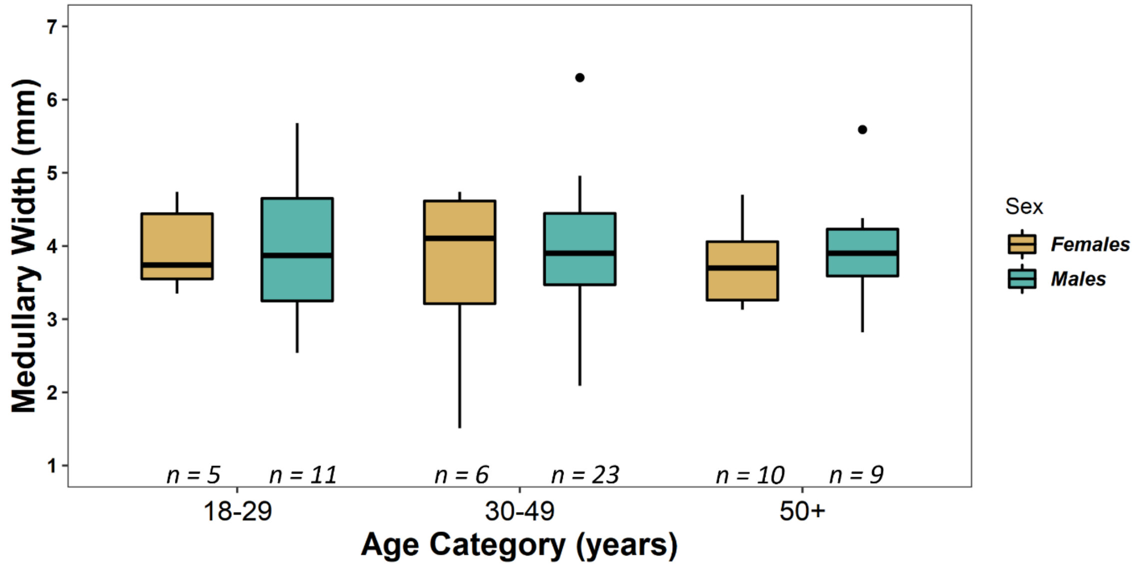
Appendix 7.17 - Christian Total Length (TL) by Age and Sex.



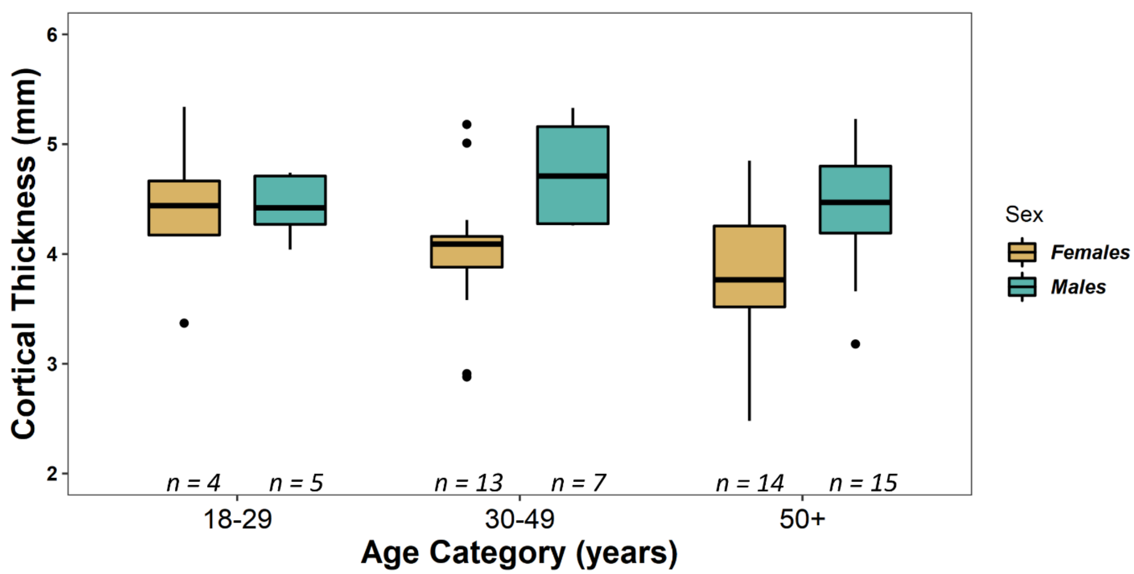
Appendix 7.18 - Christian Total Width (TW) by Age and Sex.



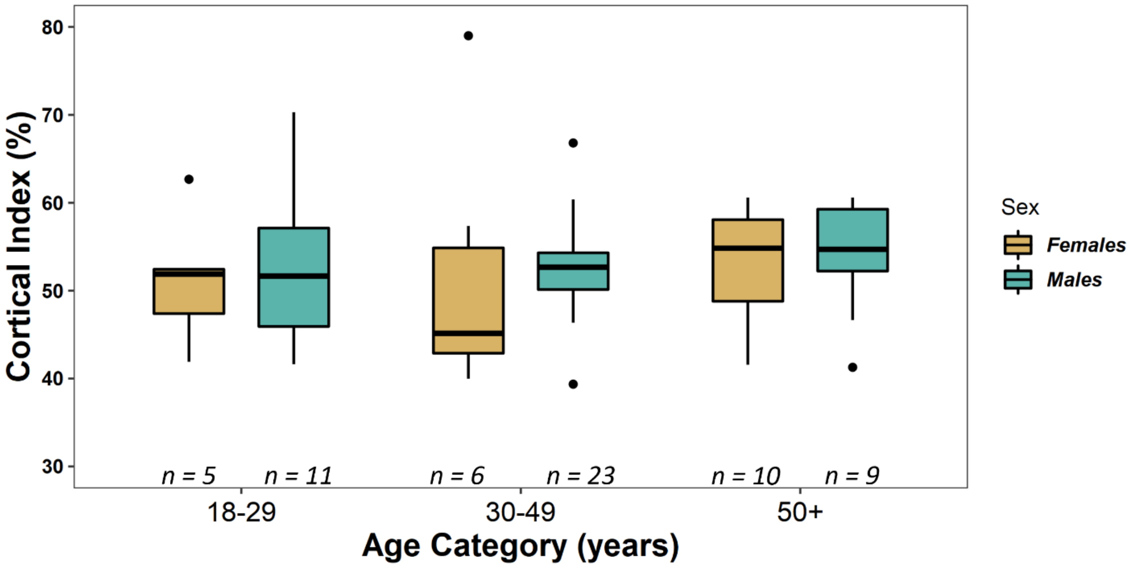
Appendix 7.19 - Christian Medullary Width (MW) by Age and Sex.



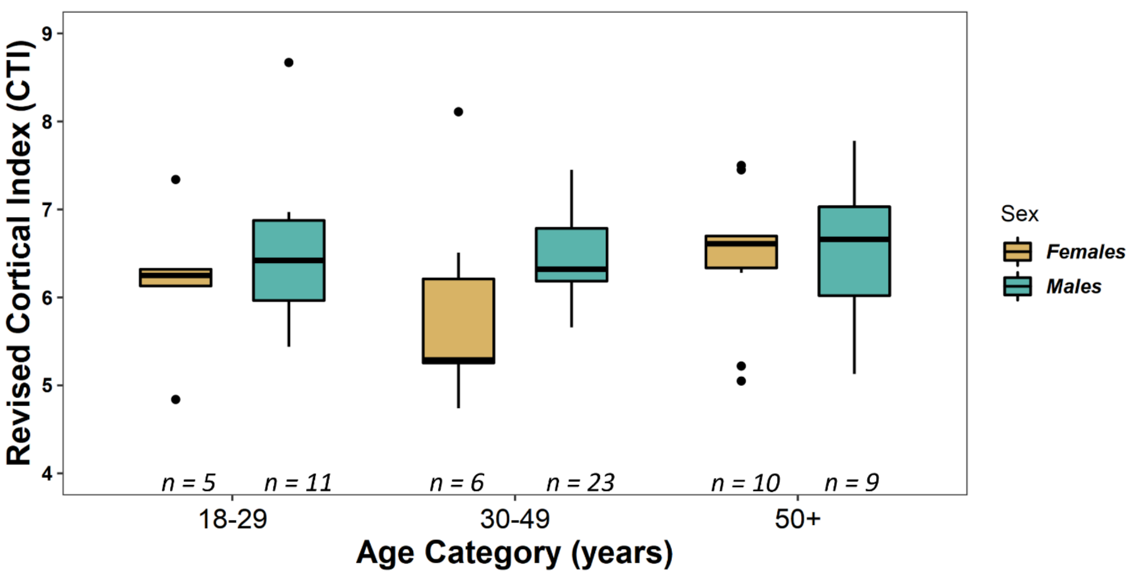
Appendix 7.20 - Christian Cortical Thickness (CT) by Age and Sex.



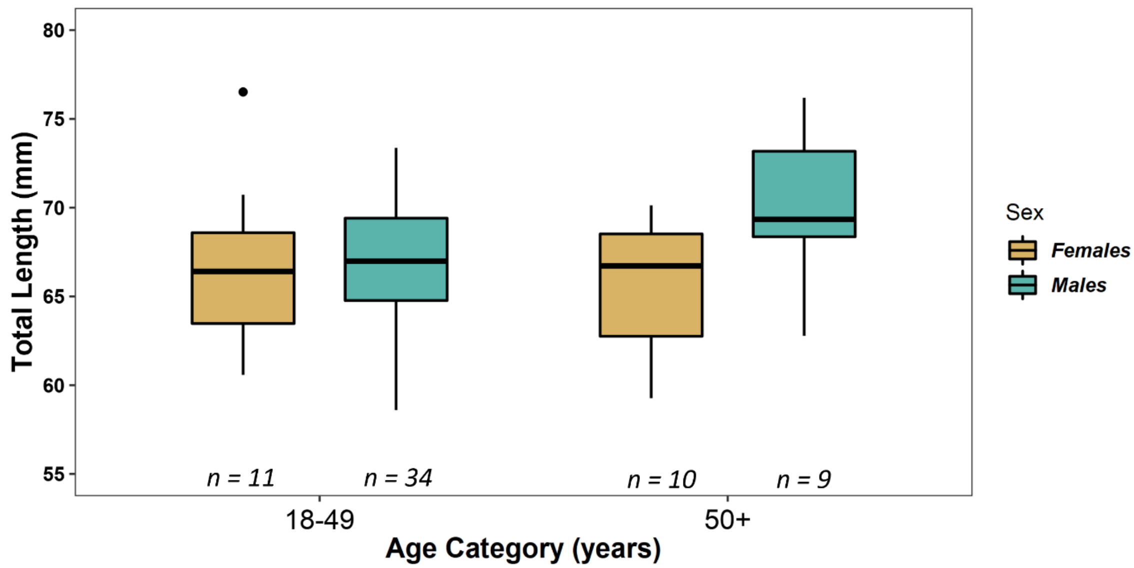
Appendix 7.21 - Christian Cortical Index (CI) by Age and Sex.



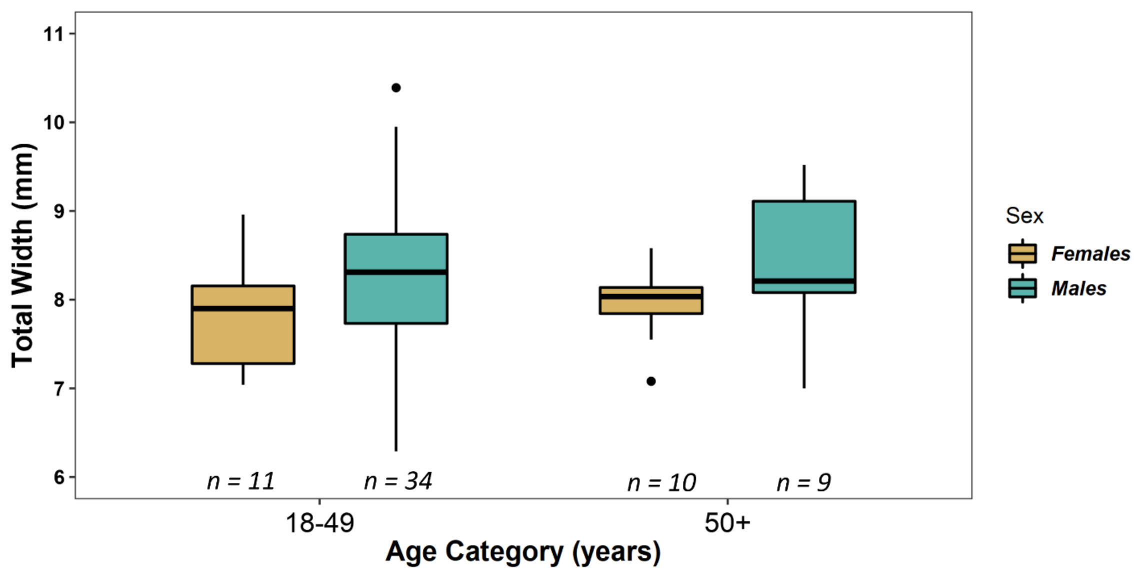
Appendix 7.22 - Christian Revised Cortical Thickness Index (CTI) by Age and Sex.



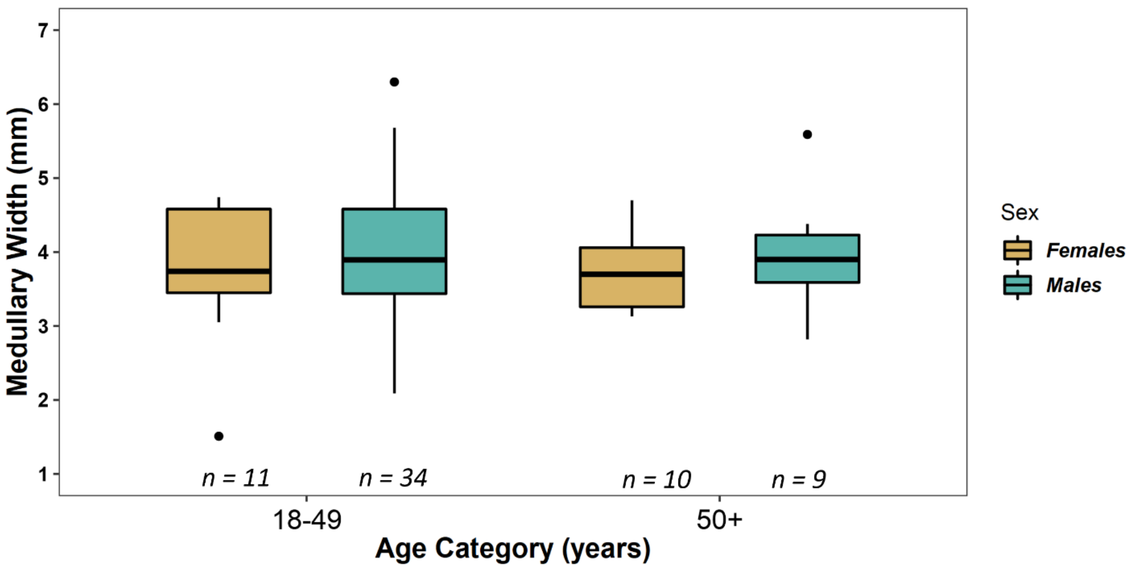
Appendix 7.22 - Christian Total Length (TL) by Age and Sex, Ages collapsed.



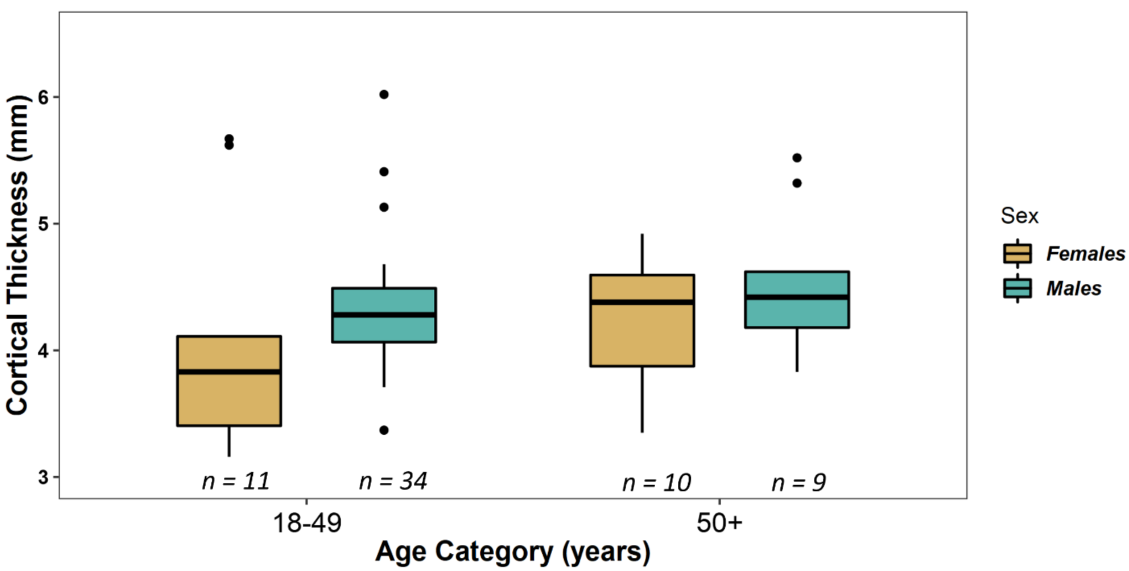
Appendix 7.23 - Christian Total Width (TW) by Age and Sex, Ages collapsed.



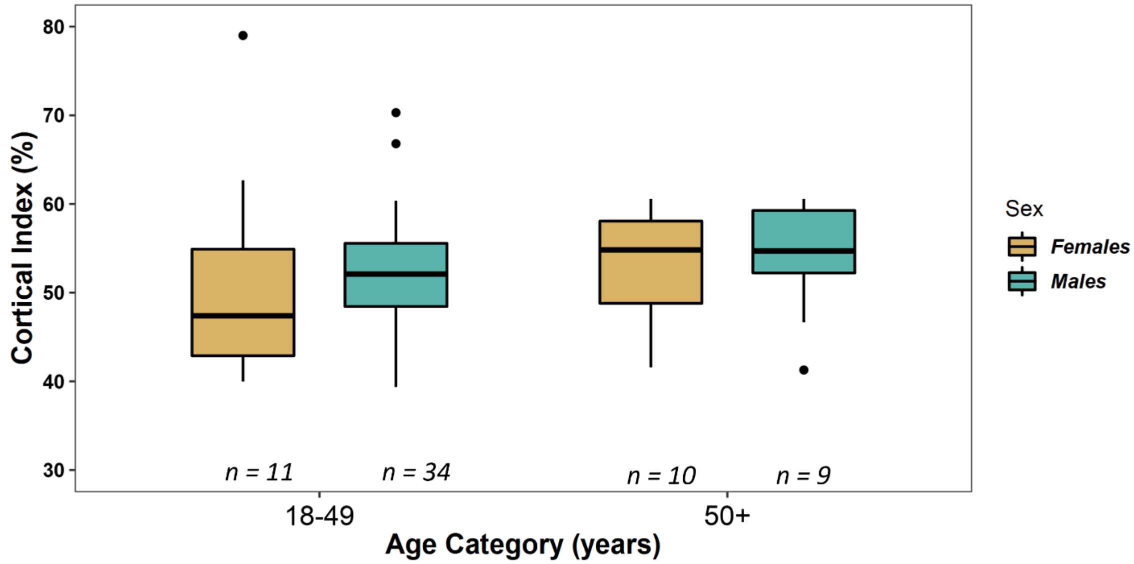
Appendix 7.24 - Christian Medullary Width (MW) by Age and Sex, Ages collapsed.



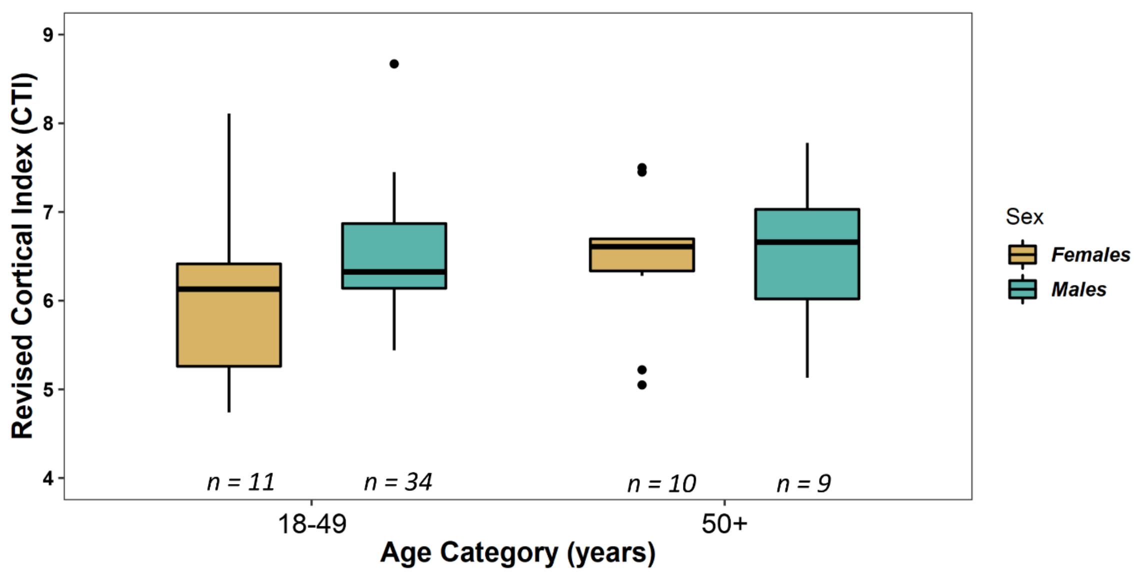
Appendix 7.25 - Christian Cortical Thickness (CT) by Age and Sex, Ages collapsed.



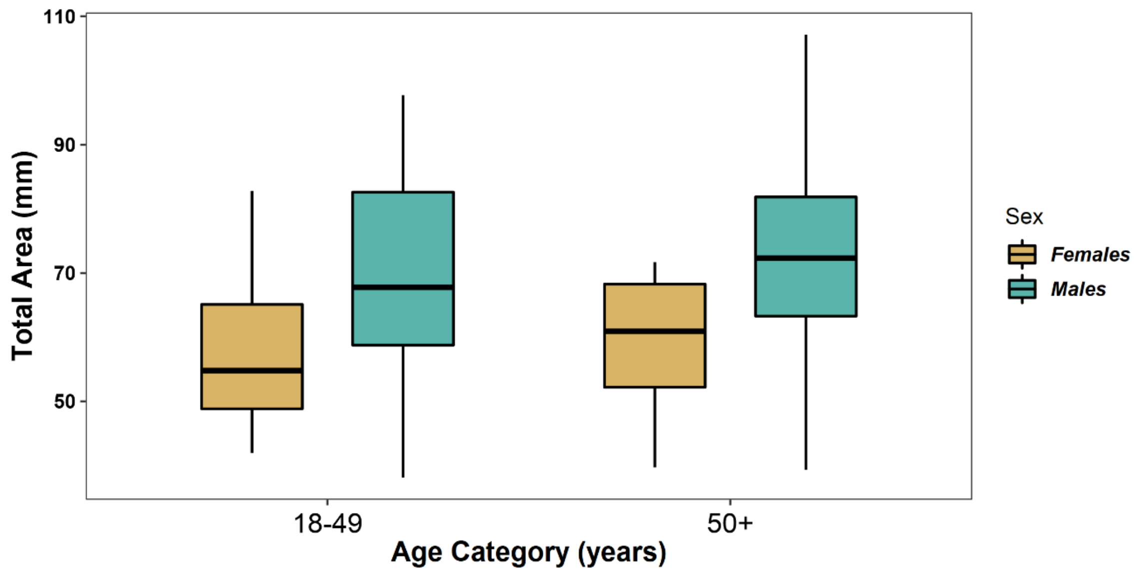
Appendix 7.26 - Christian Cortical Index (CI) by Age and Sex, Ages collapsed.



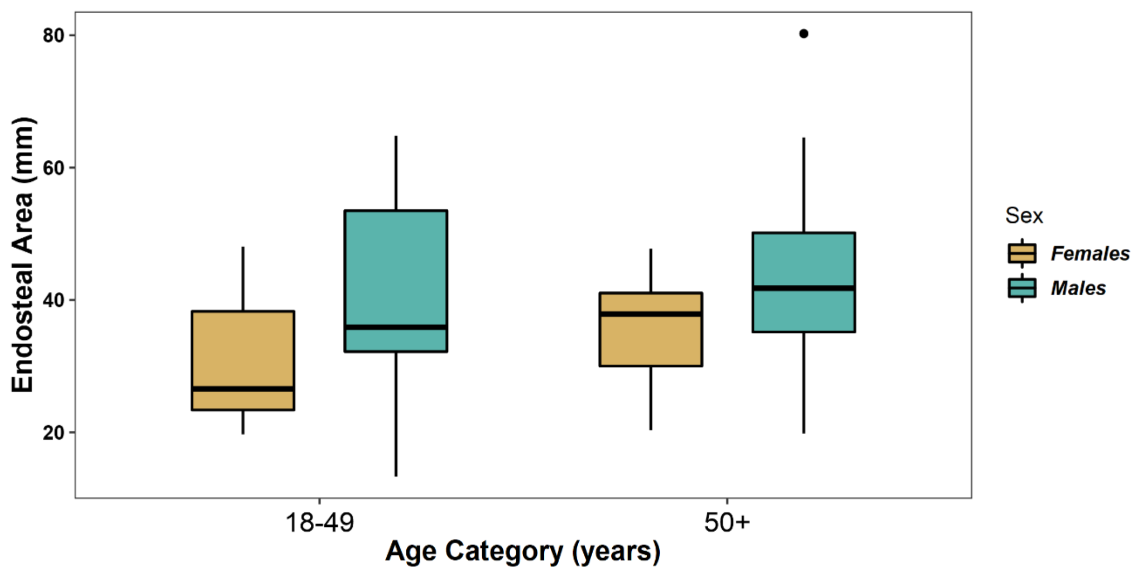
Appendix 7.27 - Christian Revised Cortical Thickness Index (CTI) by Age and Sex, Ages collapsed.



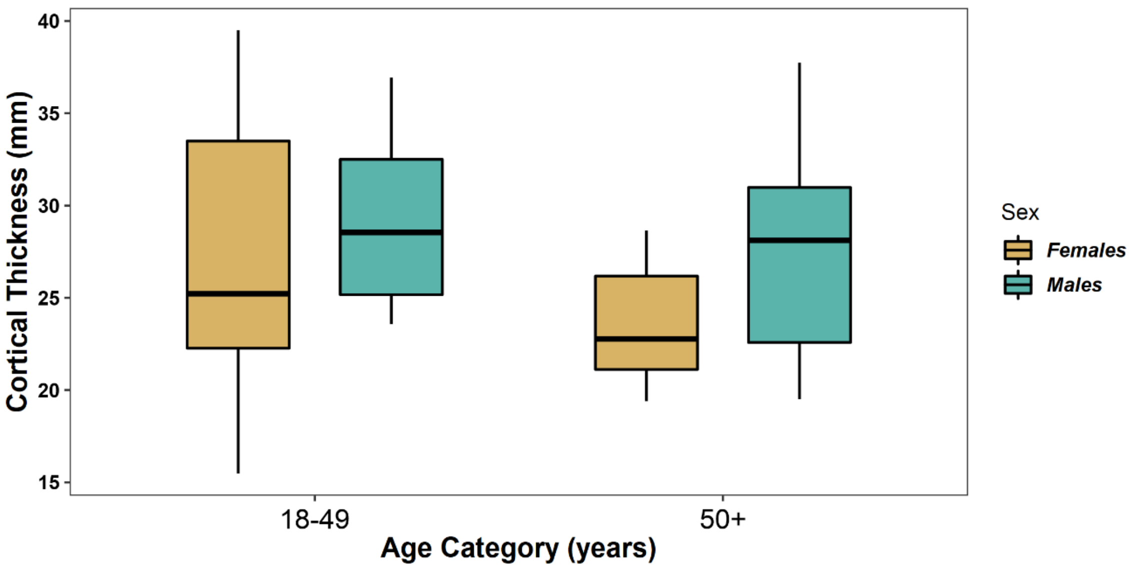
Appendix 7.28 - Islamic Total Area (Tt.Ar) by Age and Sex, Ages collapsed.



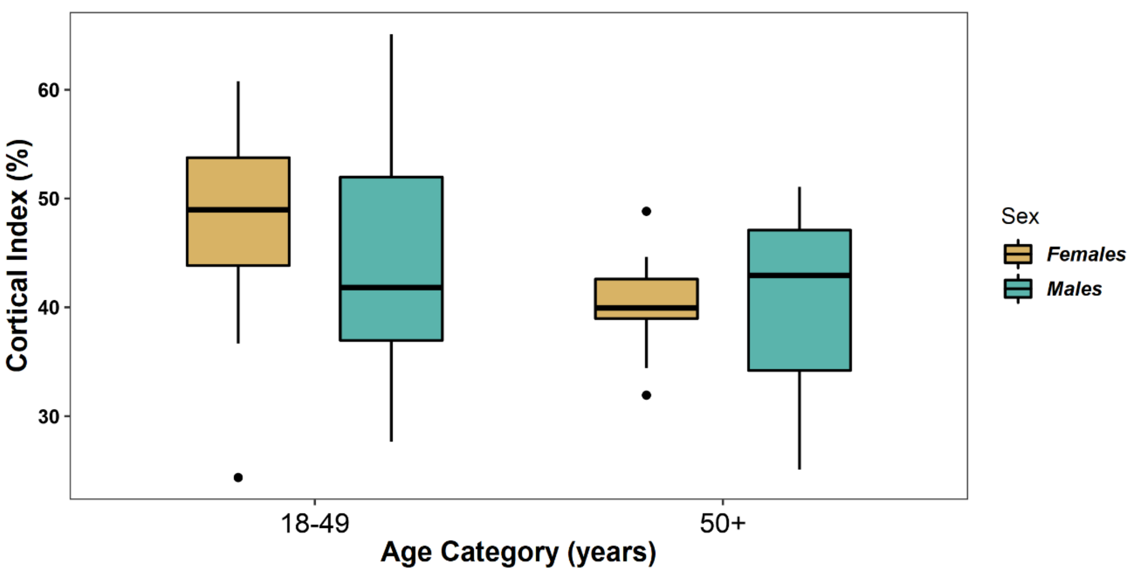
Appendix 7.29 - Islamic Endosteal Area (En.Ar) by Age and Sex, Ages collapsed.



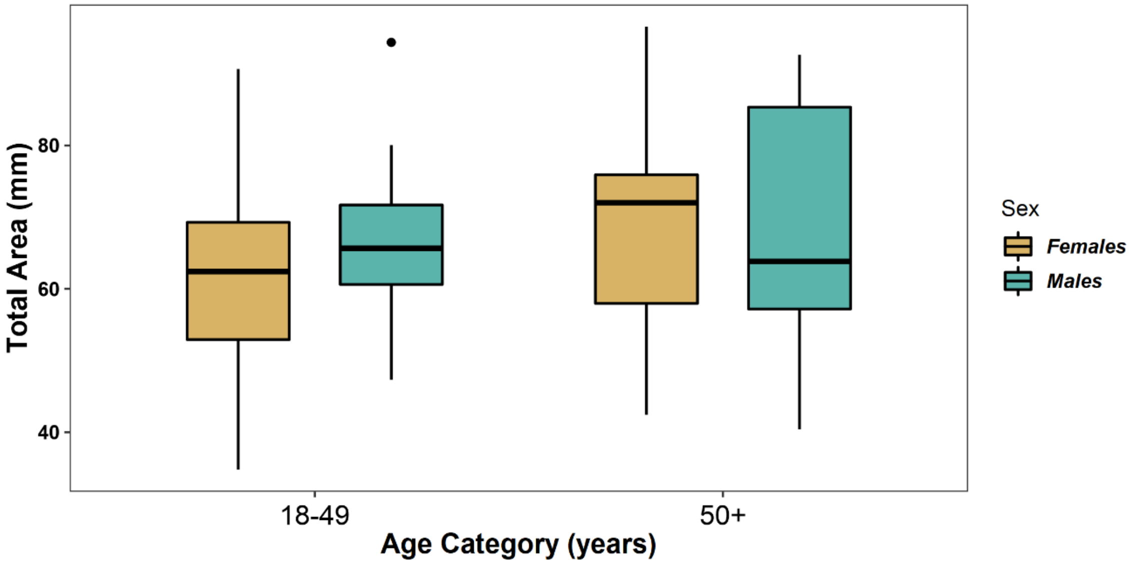
Appendix 7.30 - Islamic Cortical Thickness (Ct.Ar) by Age and Sex, Ages collapsed.



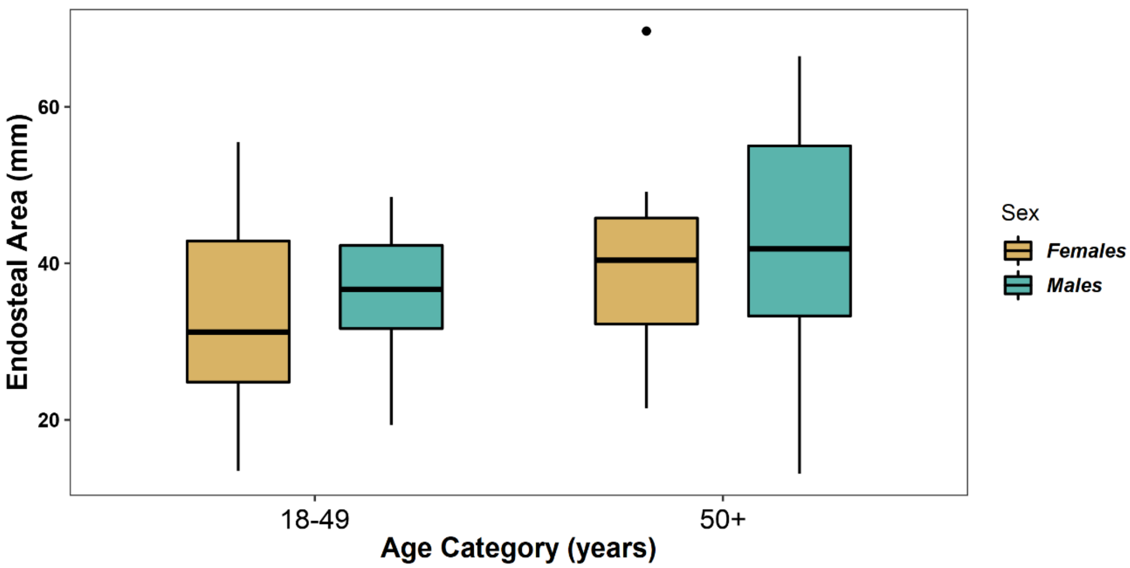
Appendix 7.31 - Islamic Cortical Index (CI) by Age and Sex, Ages collapsed.



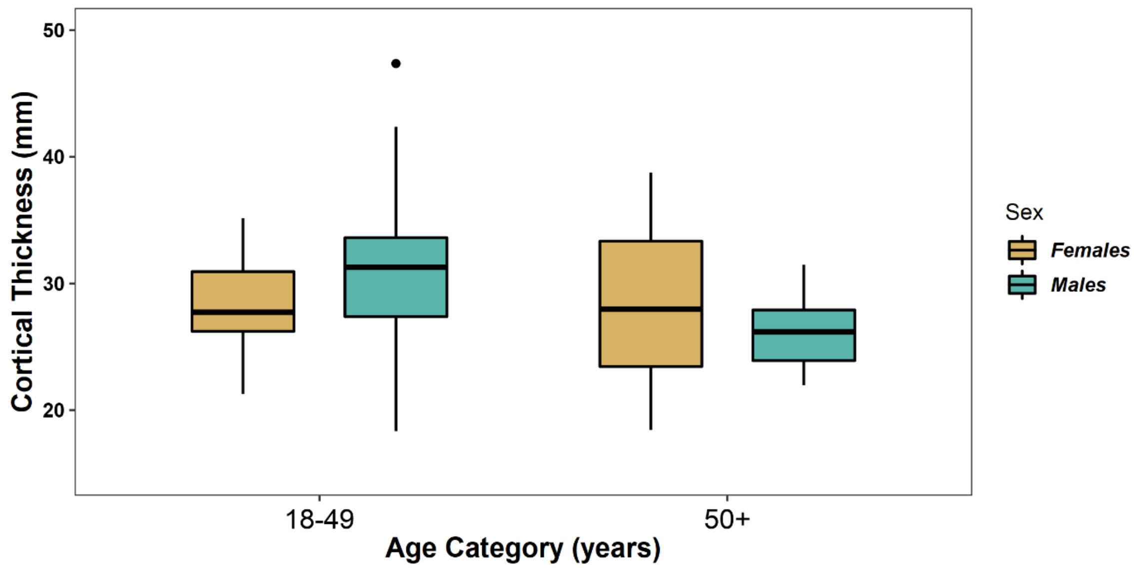
Appendix 7.32 - Christian Total Area (Tt.Ar) by Age and Sex, Ages collapsed.



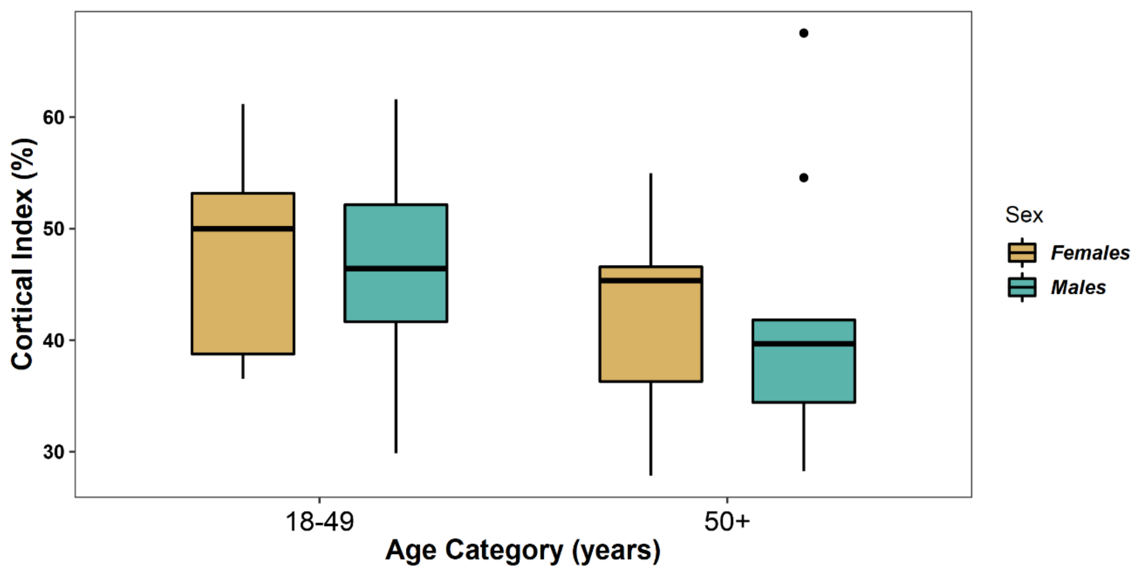
Appendix 7.33 - Christian Endosteal Area (En.Ar) by Age and Sex, Ages collapsed.



Appendix 7.34 - Christian Cortical Thickness (Ct.Ar) by Age and Sex, Ages collapsed.



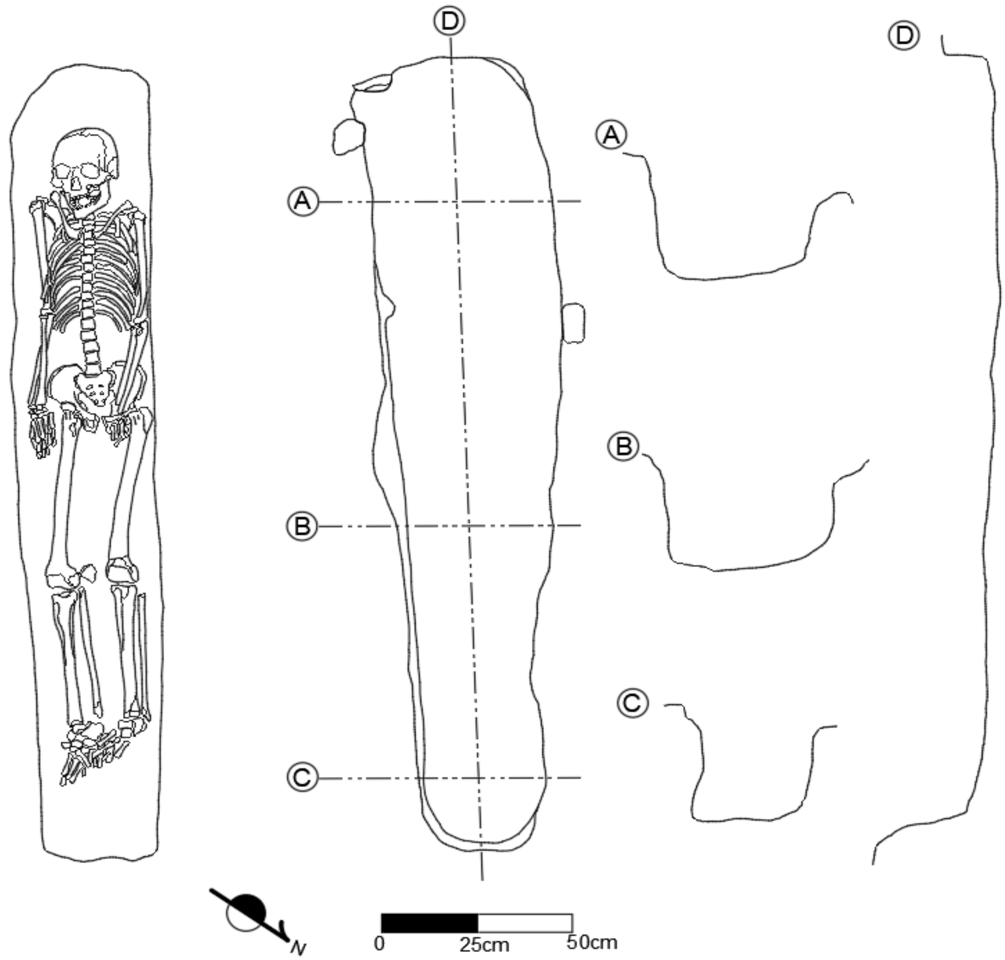
Appendix 7.35 - Christian Cortical Index (CI) by Age and Sex, Ages collapsed.



Appendix - Chapter 9

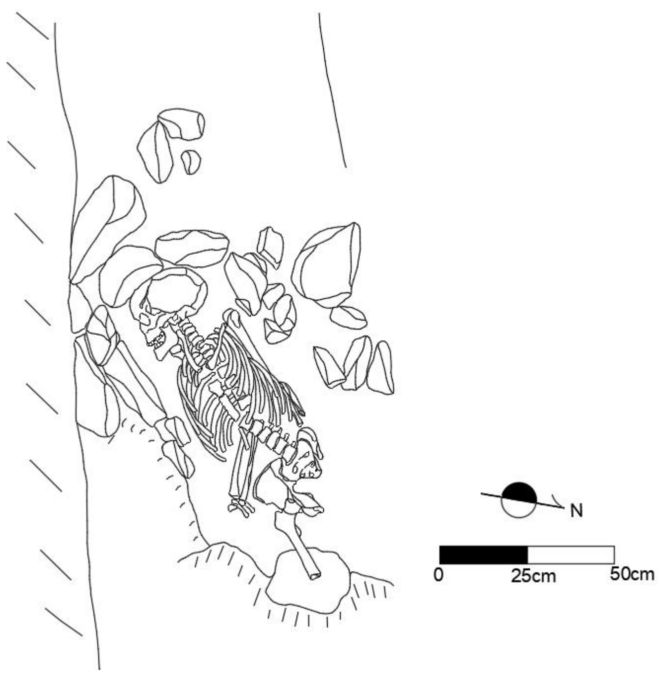
Appendix 9.1 - Ent 402, a typical Islamic burial from the site showcasing a relatively narrow, shallow grave in SW (head) to NE (feet) orientation. Photo: António Matias, courtesy of Câmara Municipal de Santarém.

Appendix 9.2 - Burial plan and profiles for Ent. 402. Drawing by Trent Trombley, based on field drawings by António Matias.



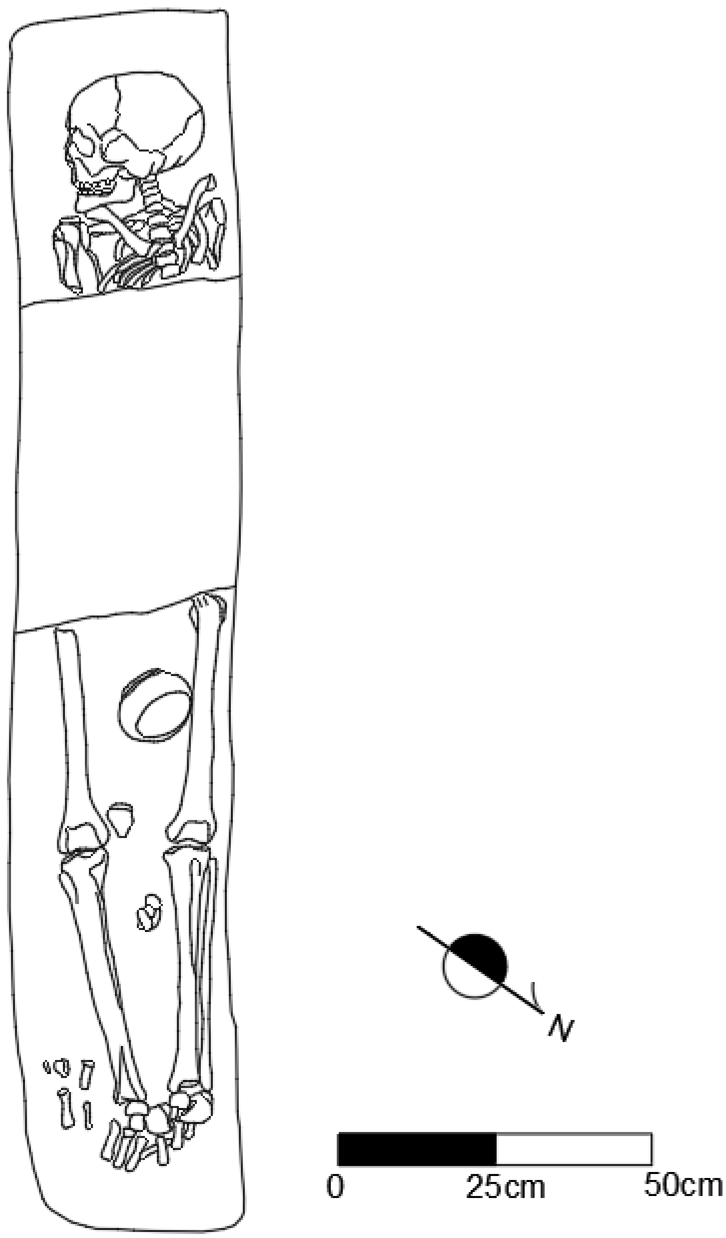
Appendix 9.3 - Ent. 183, Islamic grave with headspace outlined in stones. Photo: António Matias, courtesy of Câmara Municipal de Santarém.

Appendix 9.4 - Burial plan for Ent. 183. Drawn by Trent Trombley, based on field drawings by António Matias.

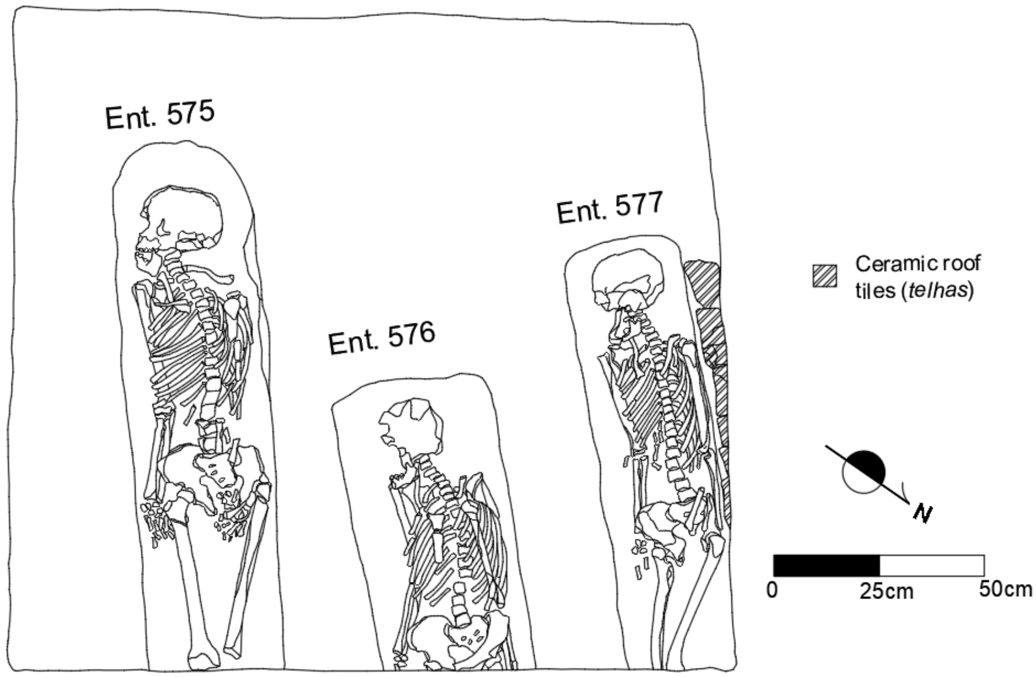


Appendix 9.5 - Ent. 173, an Islamic grave with the only evidence of grave goods at the site. Note the trench (*vala*) running NW to SE that reduces the thoracic cavity. Photo: António Matias, courtesy of Câmara Municipal de Santarém.

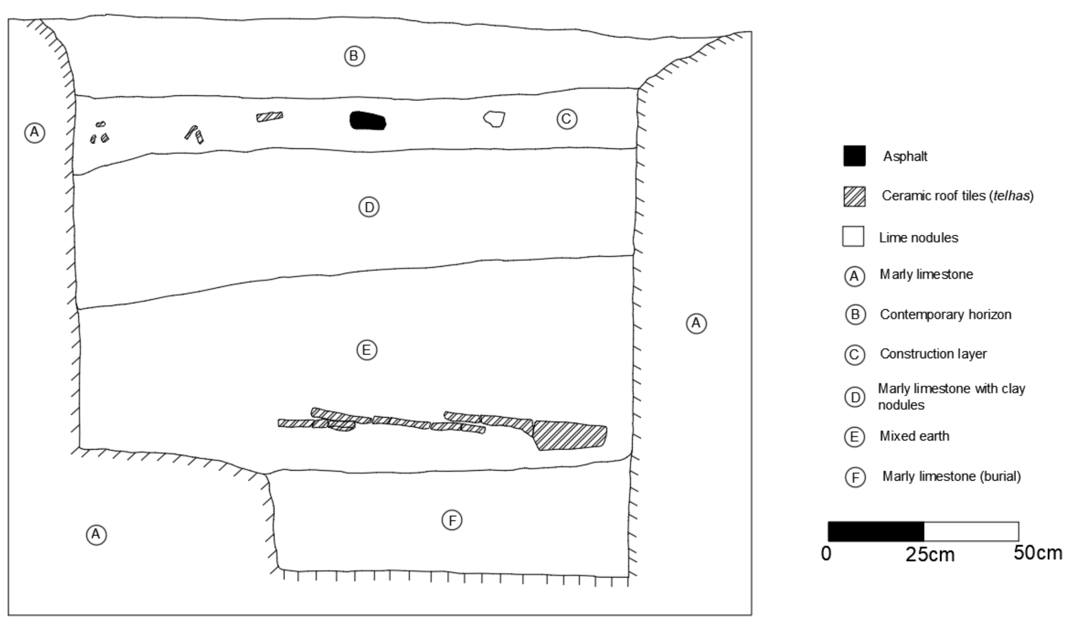
Appendix 9.6 - Burial plan for Ent. 173. Note the trench bisecting the thoracic cavity, and the presence of a ceramic vessel between the femora. Drawn by Trent Trombley, based on field drawings by António Matias.



Appendix 9.7 - Burial plan for Ent. 575-577. Drawn by Trent Trombley, based on field drawings by António Matias.

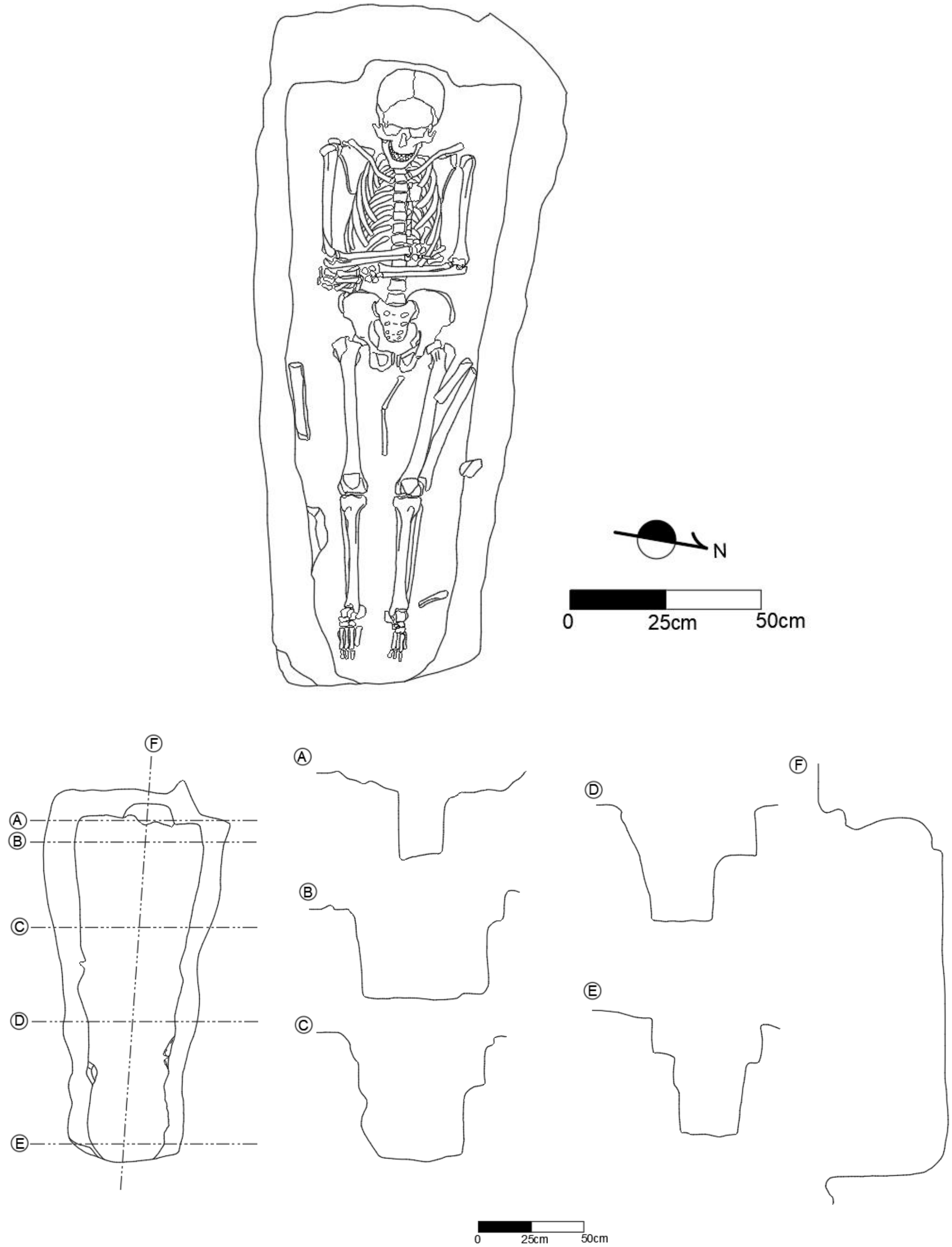


Appendix 9.8 - Sector 10 profile for Ent. 577. Drawn by Trent Trombley, based on field drawings by António Matias.



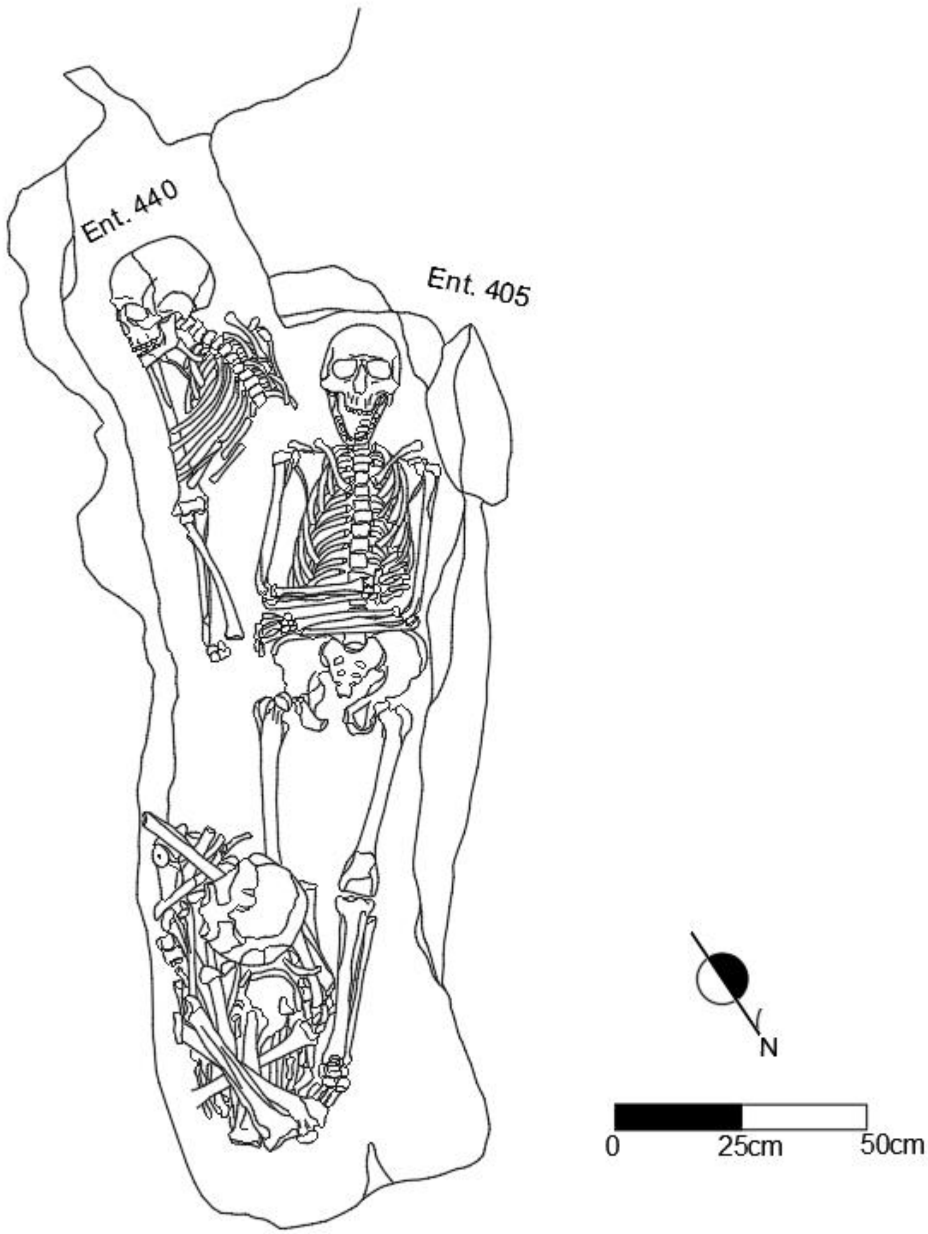
Appendix 9.9 - Ent. 383, typical Christian anthropomorphic grave with sizeable depth in SW (head) to NE (feet) orientation. Note the beveled relief superficial to the negative grave space, likely constructed for a lid/cover. Photo: António Matias, courtesy of Câmara Municipal de Santarém.

Appendix 9.10 - Burial plan and profiles for Ent. 383. Drawing by Trent Trombley, based on field drawings by António Matias.



Appendix 9.11 - Example of two mortuary rites in the same space. Islamic individual (Ent. 440 – upper left) was reduced by Christian individual (Ent. 405). Note the difference in orientation, bodily position, and inclusion of ossuary at the foot of Ent. 405. Photo: António Matias, courtesy of Câmara Municipal de Santarém.

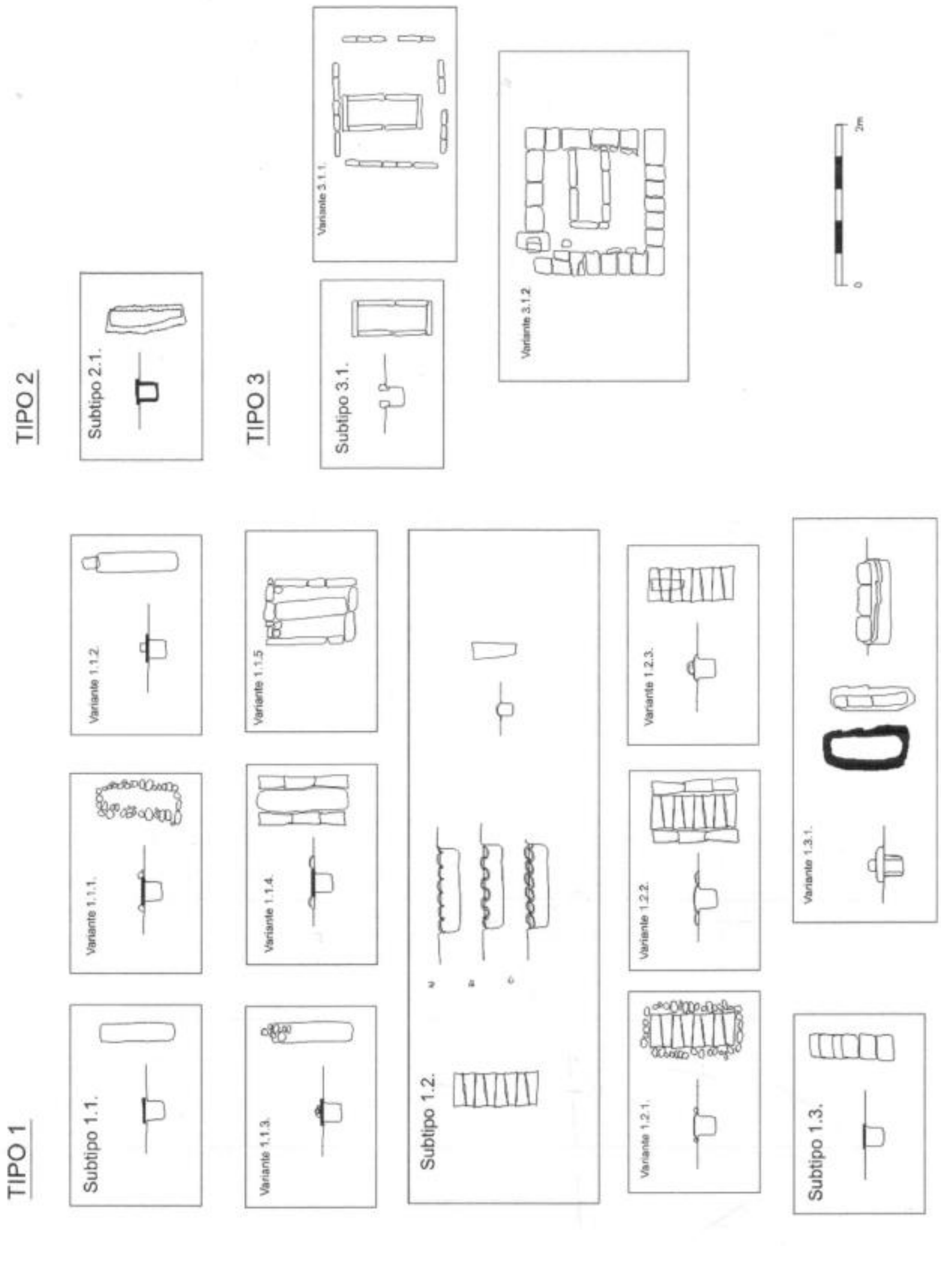
Appendix 9.12 - Burial plan for Ent. 440 (Islamic) and Ent. 405 (Christian). Drawing by Trent Trombley, based on field drawings by António Matias.



Appendix 9.13 - Typology of Islamic burials from Córdoba (adapted from Casal 2003: 120-144).

1. ***Type 1*** – Simple pit
    - *1.1. Subtype*
        - *1.1.1.* *Variant* – Simple pit without covering; outlined by rocks.
        - *1.1.2.* *Variant* – Simple pit without covering; with adobe marking the headspace.
        - *1.1.3.* *Variant* – Simple pit without covering; with boulders externally surrounding the headspace.
        - *1.1.4.* *Variant* – Simple pit without covering; outlined by tiles arranged longitudinally.
        - *1.1.5.* *Variant* – Simple pit without covering; included in a larger "funerary space" outlined by slabs or ashlar cobbles (*sillarejos*).
    - *1.2. Subtype*
        - *1.2.1.* *Variant* – Simple pit with tile covering; outlined by rocks.
        - *1.2.2.* *Variant* – Simple pit with tile covering; outlined by tiles arranged longitudinally.
        - *1.2.3.* *Variant* – Simple pit with tile covering; and one tile marking the headspace.
    - *1.3. Subtype*
        - *1.3.1.* *Variant* – Simple pit with adobe covering; marked by a pyramidal structure of adobe.
2. ***Type 2*** – Pit with walls covered in adobe.
    - 2.1. *Subtype* – Pit covered in adobe "without covering."
3. ***Type 3*** – Pit bounded by ashlar cobbles (*sillarejos*).
    - *3.1. Subtype*
        - *3.1.1.* Variant – Pit outlined by ashlar cobbles (*sillarejos*) "without cover" included in a larger ashlar cobble-outlined "funerary space."
        - *3.1.2.* Variant – Pit outlined by ashlar cobbles (*sillarejos*) "without cover" included in a larger "funerary space" outlined by ashlar (*sillares*).

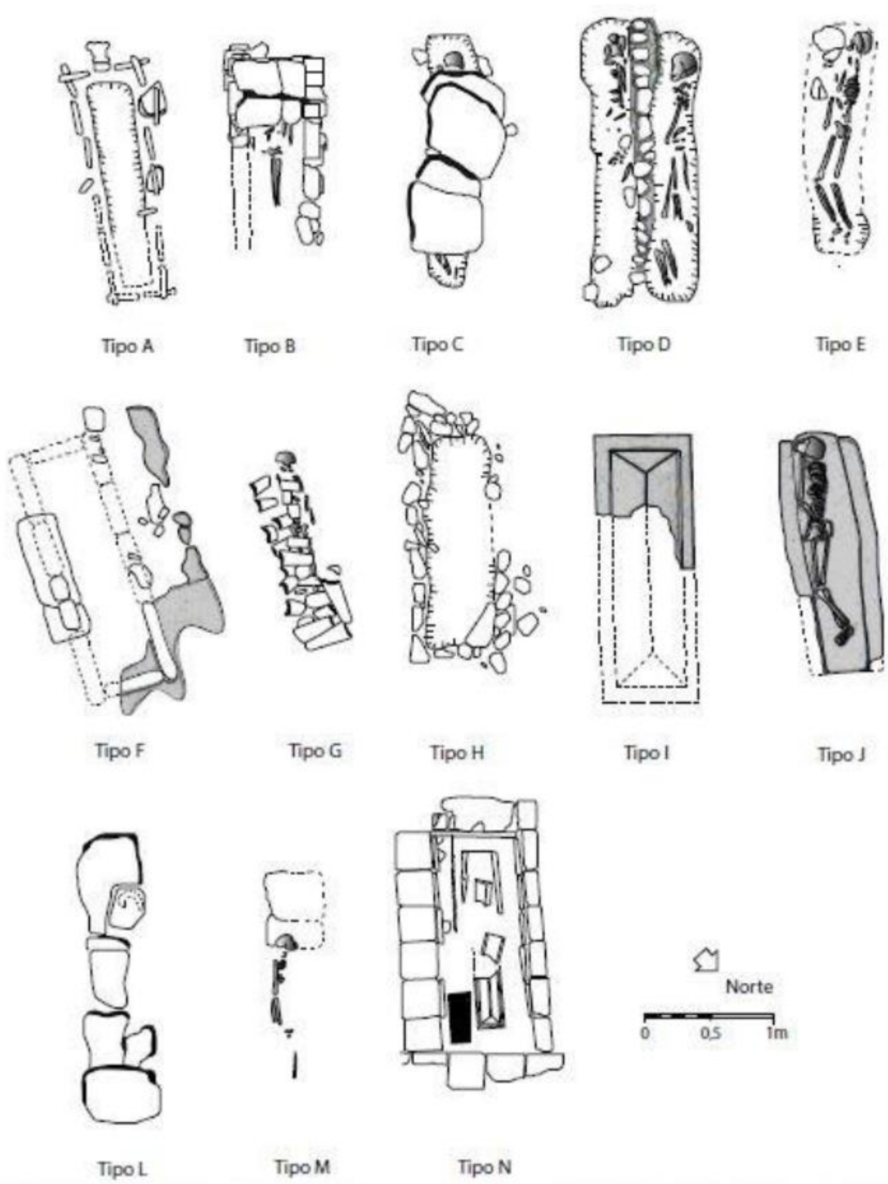
Appendix 9.14 - Typological sketches of Islamic graves from Córdoba (retrieved from Casal 2003:144)



Appendix 9.15 - Islamic grave typologies throughout Spain (adapted from Fernández Guirado 1994: 44-51; Peral Bejarano 1995: 26-31; Gonzaga 2018: 16-19).

Type	Variant	Description
A	*19*	Pit with interior covered in mortar and exterior in glazed tile; marked by a stele
	20	Funerary mosque
B	*15.1*	Tomb with walls composed of tiles and covered with slate slabs
C	*17*	Tombs covered with slate slabs in various positions
D	*16*	Grave outlined by stony elements. Double grave(s) that share a wall.
E	*1*	Simple pit excavated in the sediment; frequently rectangular and shallow with no outline or covering
	1.1	Simple pit excavated in the rock with a side-step (*lahd* + *saqq*)
F	*8*	Simple pit composed of stepped/stacked ashlar to the surface
	9	Rectangular tomb with walls composed of tiles and plaster
	10	Tomb with walls composed of tiles and plasters
	11	Pit with walls and covering of tiles
	12	Lavish stepped-tomb
	12.1	Simple pit but with a tombstone/wake
	13	Simple pit excavated in the rock, with lateral steps and covered with tiles, mortar, and various rocks/ceramic fragments
	14	Pantheon structure
	15	Tomb with a rectangular plan with walls covered in tile and mortar; accompanied by a semi-circular niche for the head. Covering composed of tiles, mortar, and slate
G	*2*	Simple pit with tile (*telhas*) covering
	2.1	Simple pit constructed only for sub-adults and consisting of tiles
	3	Pit with adobe covering
	3.1	Pit with a slightly-sloped adobe covering
	3.2	Tombs covered in slate slabs
	3.3	Tombs covered in Roman tiles (*tegulae*)
	4	Tombs covered inside and out with adobe
	5	Lateral pit (*lahd*) with adobe covering
	6	Simple pit with a pyramidal structure of adobe
	7	Pit covered inside with adobe accompanied by pyramidal shape
H	*16*	Grave outlined by stony elements
I	*18*	Rectangular tomb structure, without a pit excavated in the soil but rather marked by surface-construction of mortar walls topped with tiles. Held coffin inside and covering was composed of plaster to imitate a *mqabriyya*
J	*1.2*	Simple anthropomorphic pit with bottom and walls covered in clay
K	-	Grand pantheon with multiple individuals
L	-	Shallow pit with covering of plaster and adobe
M	-	Elevated tomb
N	-	Tomb inside of a pantheon covered with fine cobbles, sand, lime, and decorated with triangular *azulejos*.

Appendix 9.16 - Illustrations of Islamic tomb typologies throughout Andalusia (Retrieved from Gonzaga 2018: 20; based on original Appendix by Fernández Guirado 1995: 58).

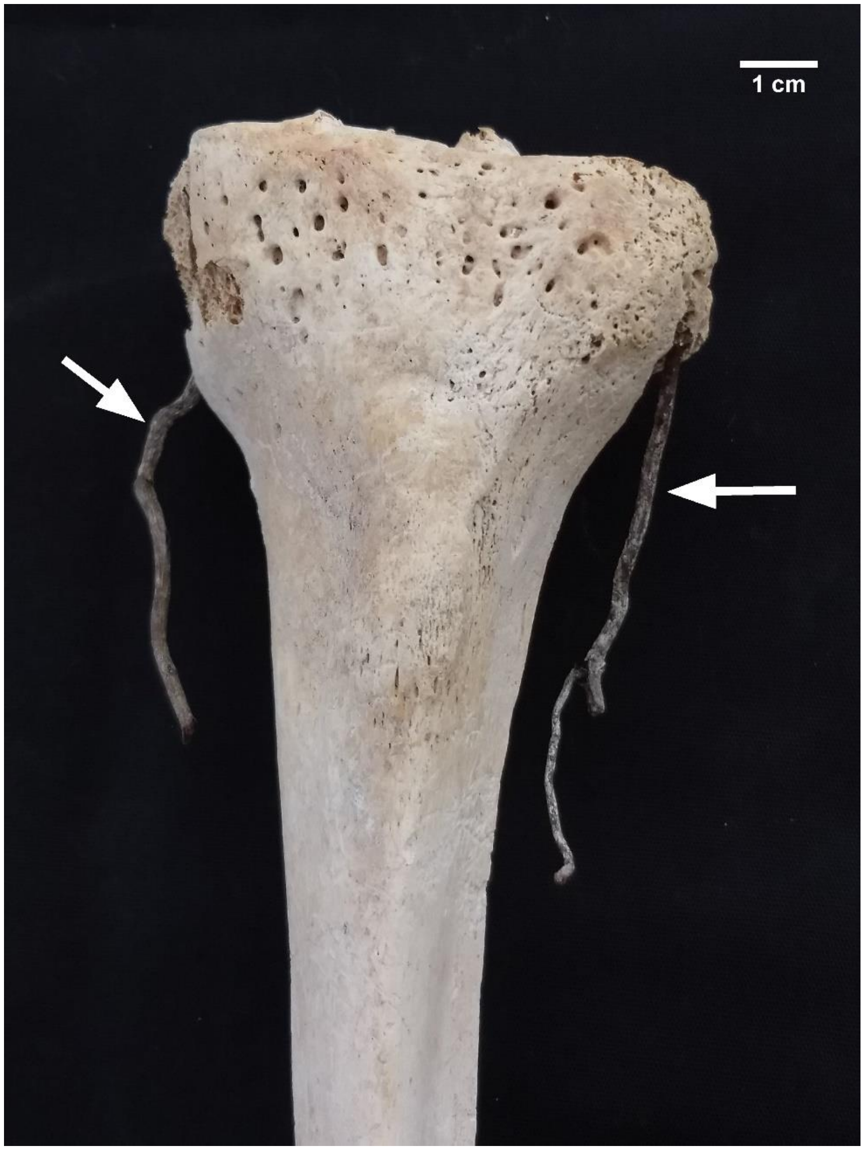


Appendix 9.17 - Ent. 388 tibia exhibiting heavy erosion (5+)

Appendix 9.18 - Ent. 507 humerus exhibiting heavy erosion (5+)

Appendix 9.19 - Ent. 76 femur exhibiting heavy erosion (5+)

Appendix 9.20 - Ent. 239_B tibia exhibiting medio-lateral root tunneling (white arrows).

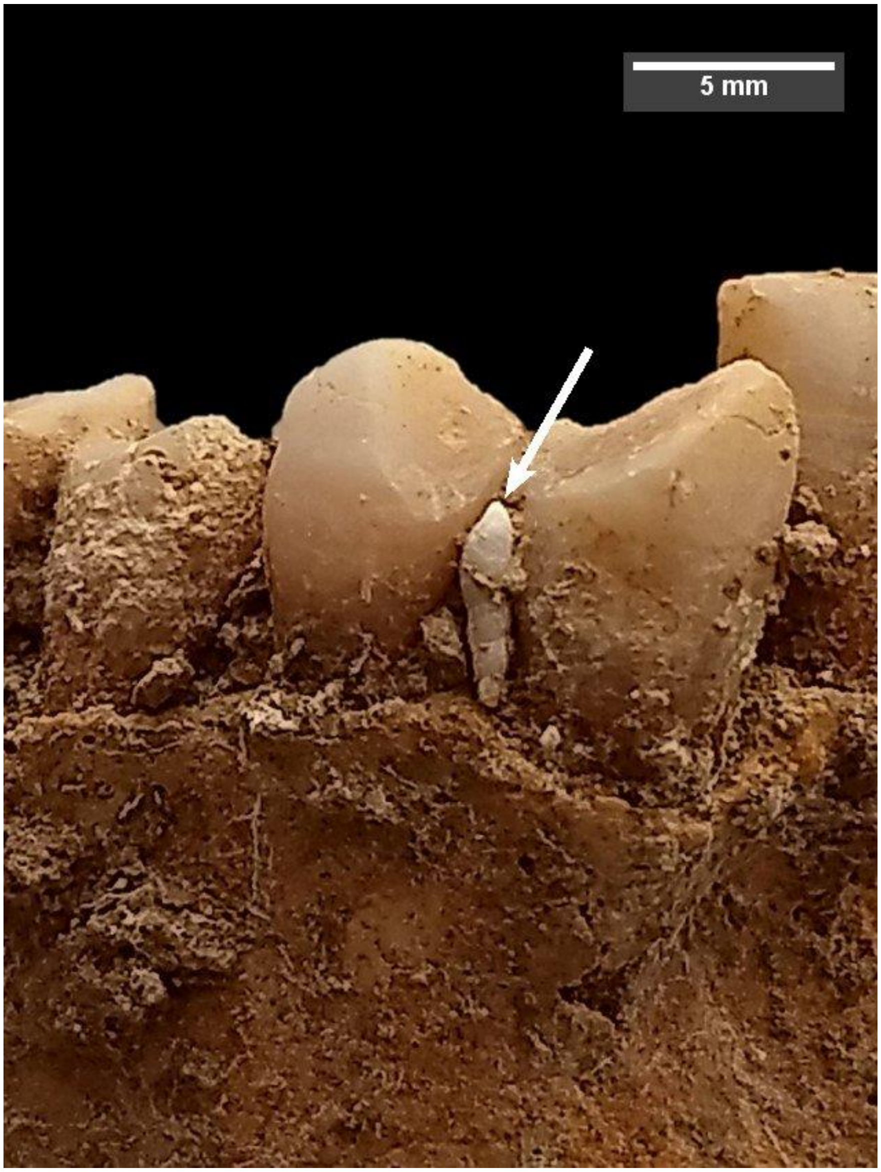


Appendix 9.21 - Ent. 181 lumbar vertebrae exhibiting likely signs of root tunneling (arrows).

Appendix 9.22 - Ent. 212 exhibiting minor black staining throughout periosteum.

Appendix 9.23 - Ent. 212 fragment exhibiting black staining both periosteally and in trabecular bone.

Appendix 9.24 - Ent. 10 with snail shell between mandibular right canine (27) and premolar (28).

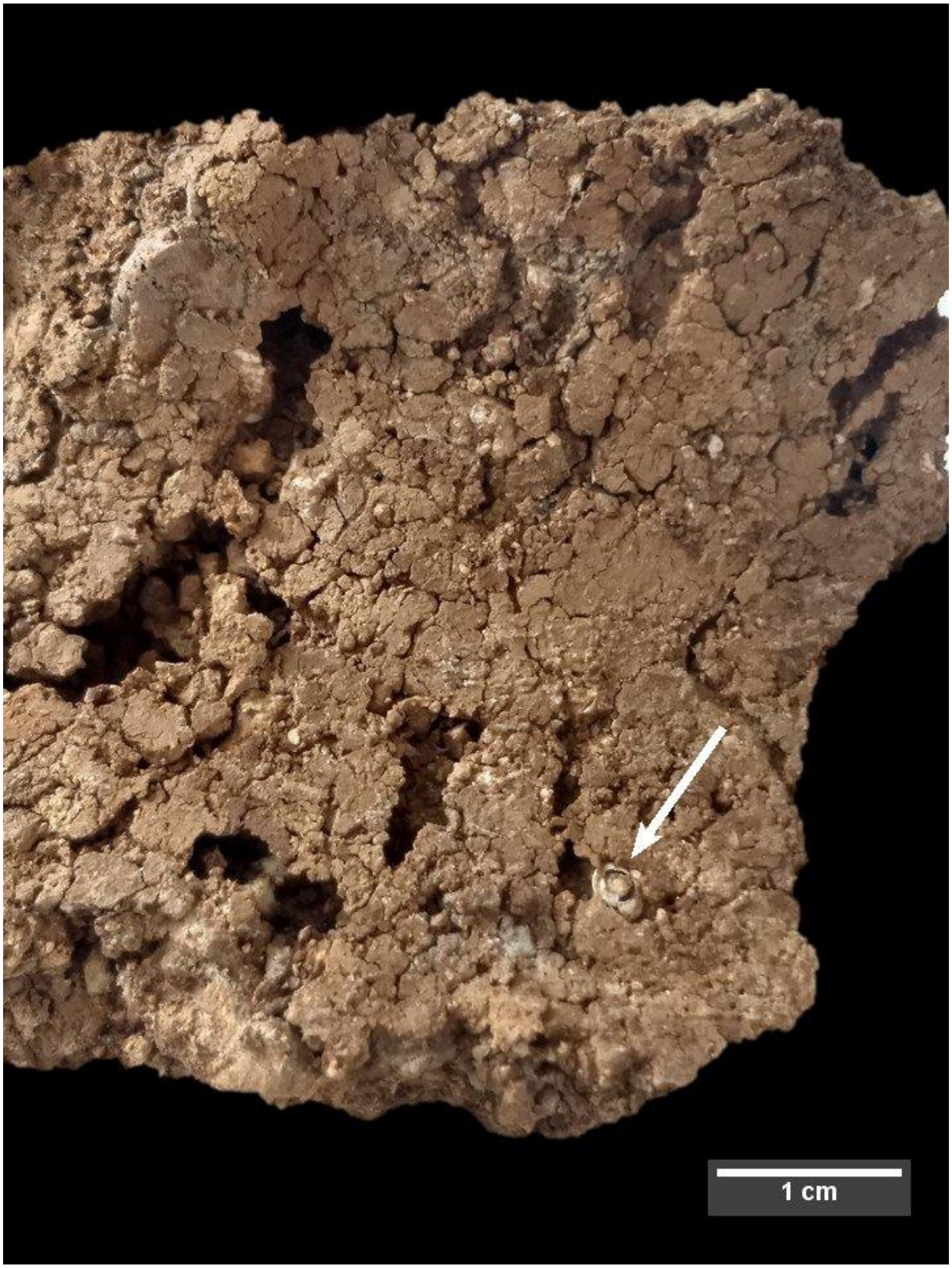


Appendix 9.25 - Ent. 16 with snail shell lodged in internal acoustic meatus.

Appendix 9.26 - Ent. 217 cranial endocast with likely invertebrate tunneling and root activity.

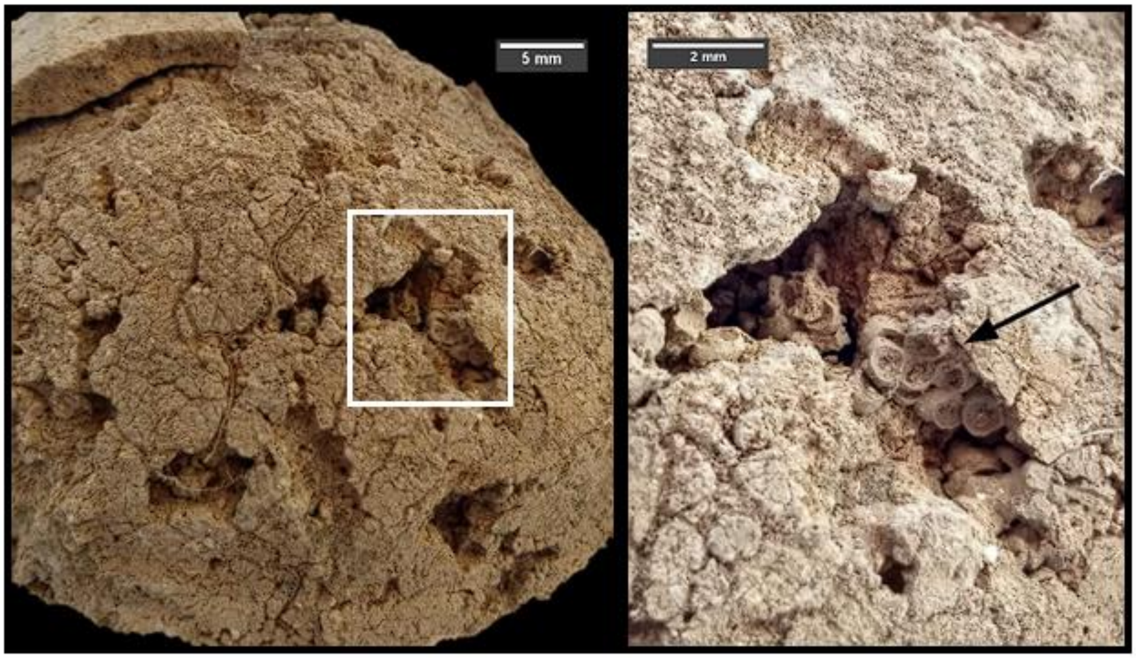
Appendix 9.27 - Ent. 221 with snail shell (likely *Theba pisana*) lodged in endocranial matrix.

Appendix 9.28 - Ent. 557 with snail shell lodged in invertebrate tunneling void (arrow). Intact matrix recovered from iliac fossa.



Appendix 9.29 - Ent. 52 with possible invertebrate casing (white arrow).

Appendix 9.30 - Ent. 72 with possible invertebrate casings/impressions (black arrow in right photo) observed in endocranial matrix. Left photo shows endocranial matrix (note cranial vault fragment in upper left corner). Right photo is zoomed in area outlined in white rectangle.



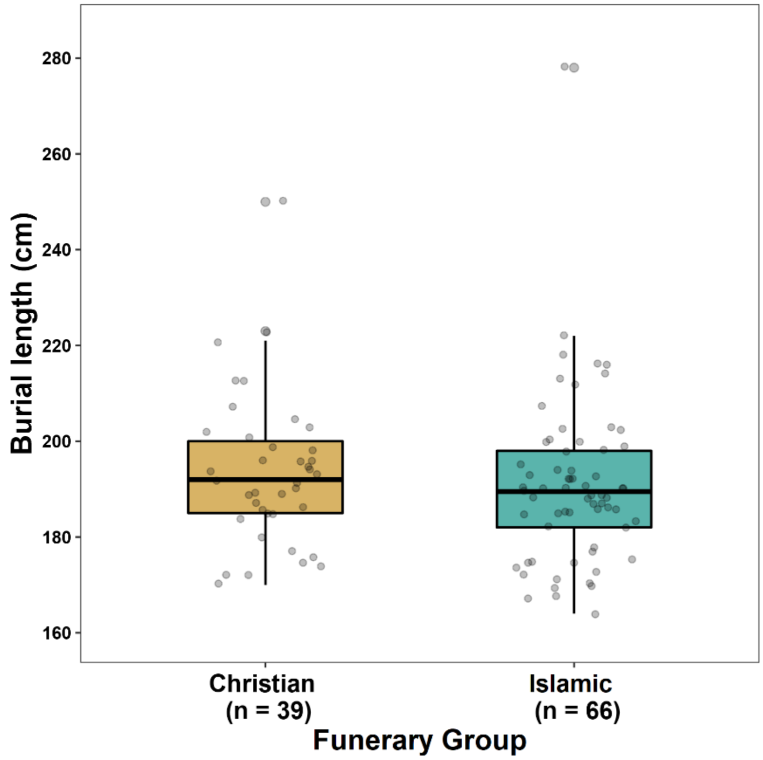
Appendix 9.31 - Distribution of Islamic tomb typologies at LCR (following Fernández Guirado 1995: 44-51, Peral Bejarano 1995: 26-31, and Gonzaga 2018: 16-19)

Typology	**Variant**	**Description**	*N*	*%*
E	1	Simple grave excavated in the sediment, frequently rectangular and shallow (*darih*). No outline/boundary nor *šaqq*	230	98.29
H	16	Grave encircled by stony elements	2	0.85
J	1.2	Anthropomorphic shape, covered in clays	1	0.43
G	2	Simple pit covered in ceramic roof tiles (*telhas*)	1	0.43
Total			**234**	**100.00**

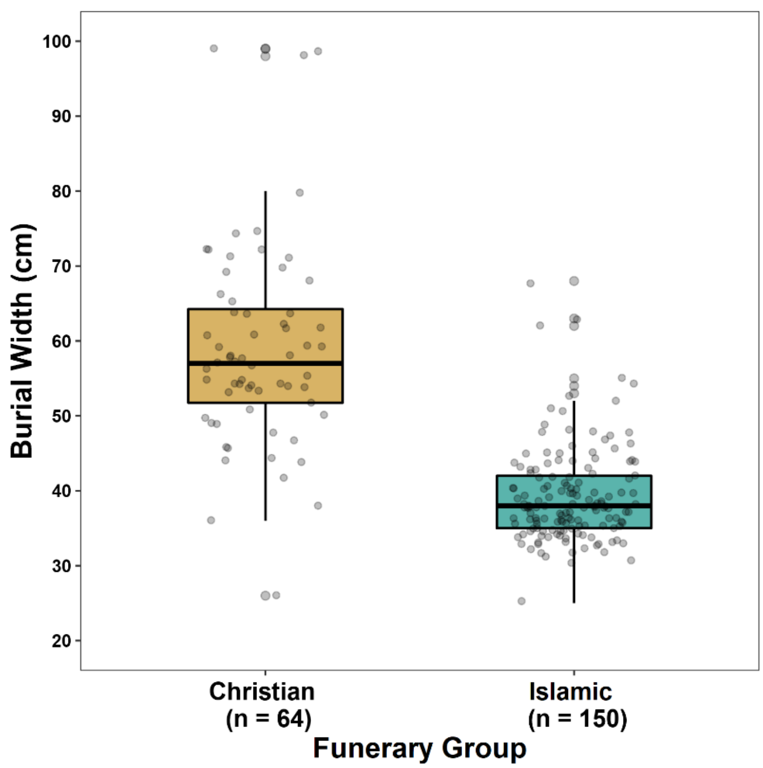
Appendix 9.32 - Distribution of reductions by funerary group at Largo Cândido dos Reis

Category	***Islamic*** N (%)	***Christian*** N (%)	X^2	*p*-value
No reduction	209 (68.75)	136 (63.85)	-	-
Reduction (total)	95 (31.25)	77 (36.15)	1.14	0.29
Reduction by interment	22 (7.24)	34 (15.96)	8.99	0.01*
Reduction by landscaping	54 (17.76)	32 (15.02)	0.49	0.41
Reduction by construction	12 (3.95)	7 (3.29)	0.02	0.87
Reduction by plumbing, electrical cables/boxes, etc.	7 (2.30)	4 (1.88)	-	0.76

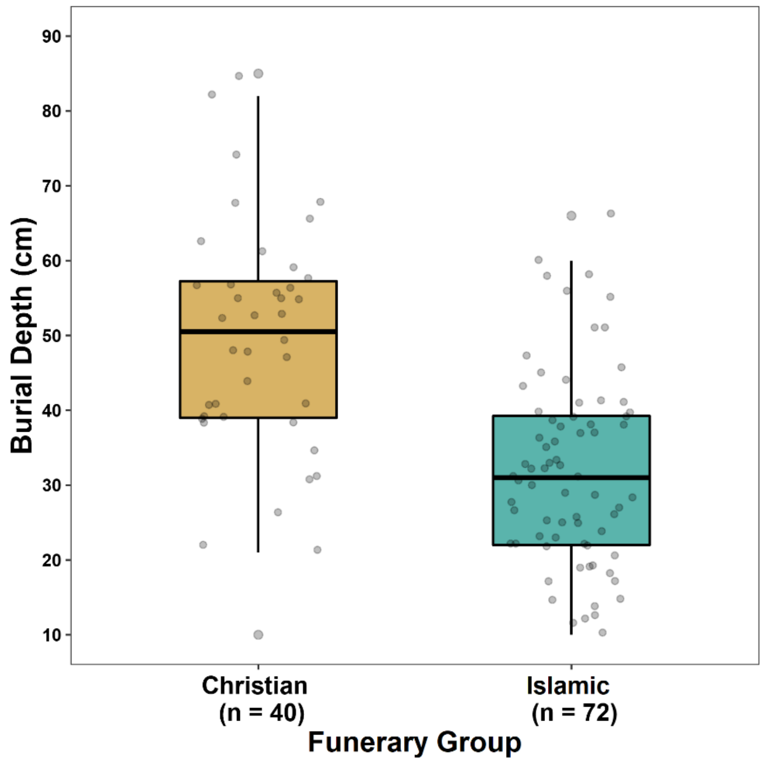
Appendix 9.33 - Distribution of burial length (in cm) by funerary group



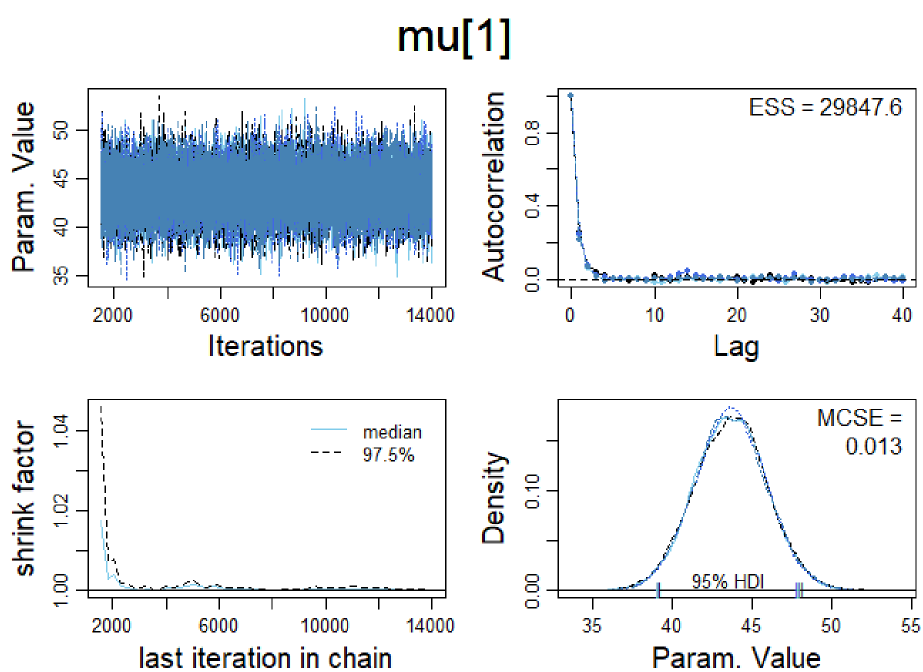
Appendix 9.34 - Distribution of burial width (in cm) by funerary group



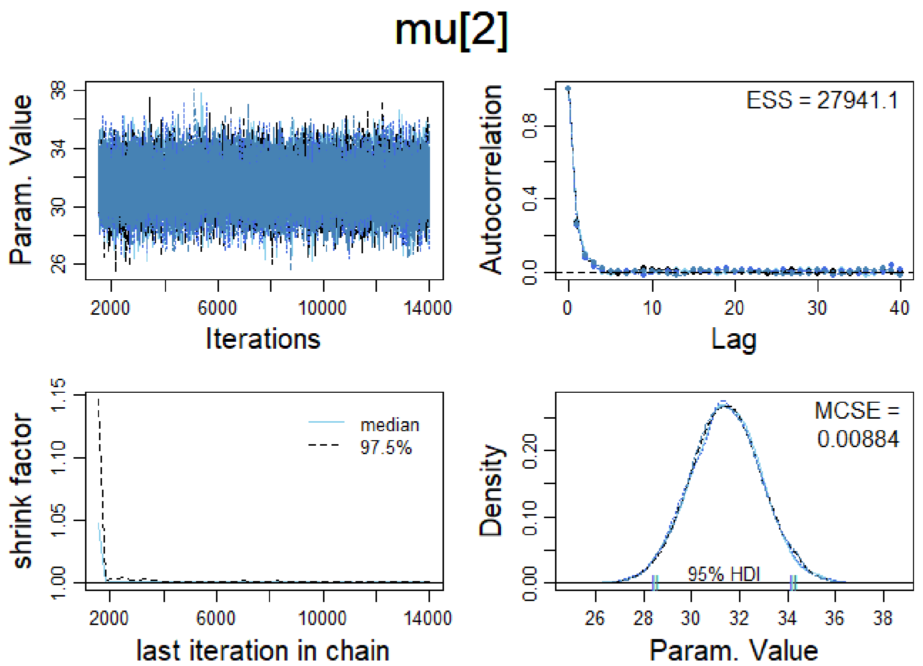
Appendix 9.35 - Distribution of burial depth (in cm) by funerary group



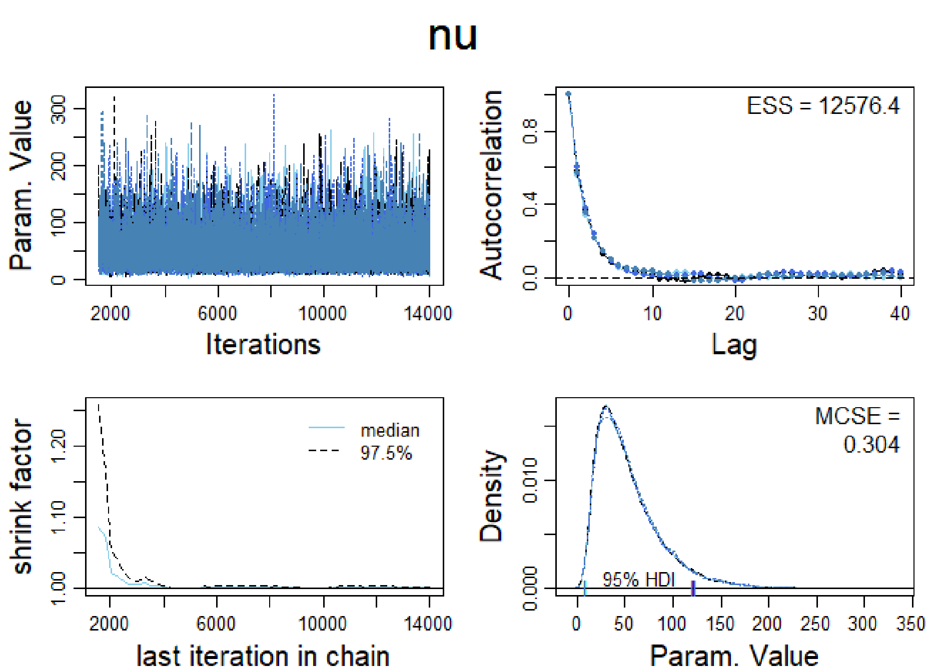
Appendix 9.36 - Markov chain Monte Carlo (MCMC) Diagnostics for mean (mu; μ) of Christian Preservation Scores (ACI)



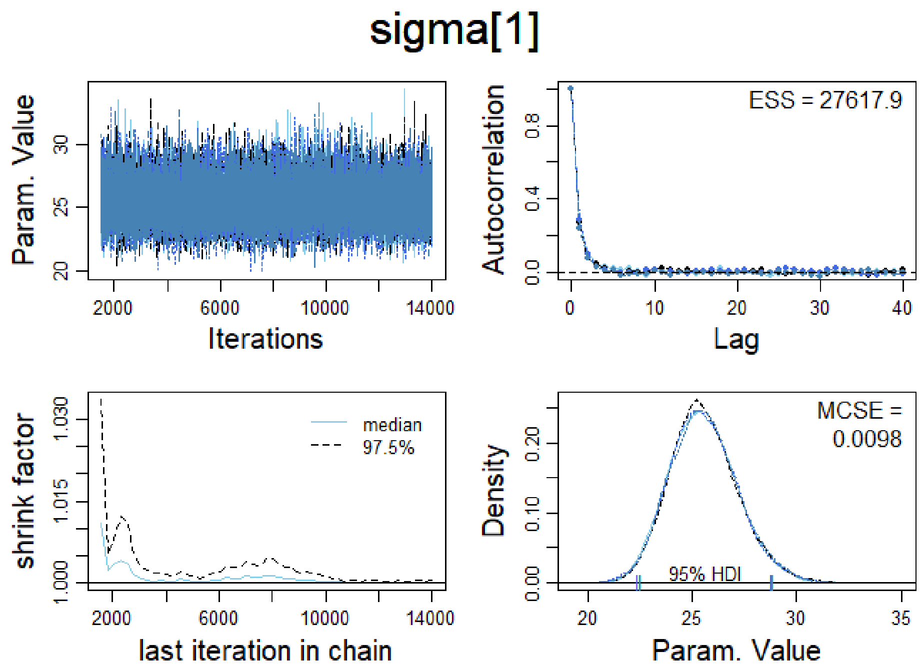
Appendix 9.37 - Markov chain Monte Carlo (MCMC) Diagnostics for mean (mu; μ) of Islamic Preservation Scores (ACI)



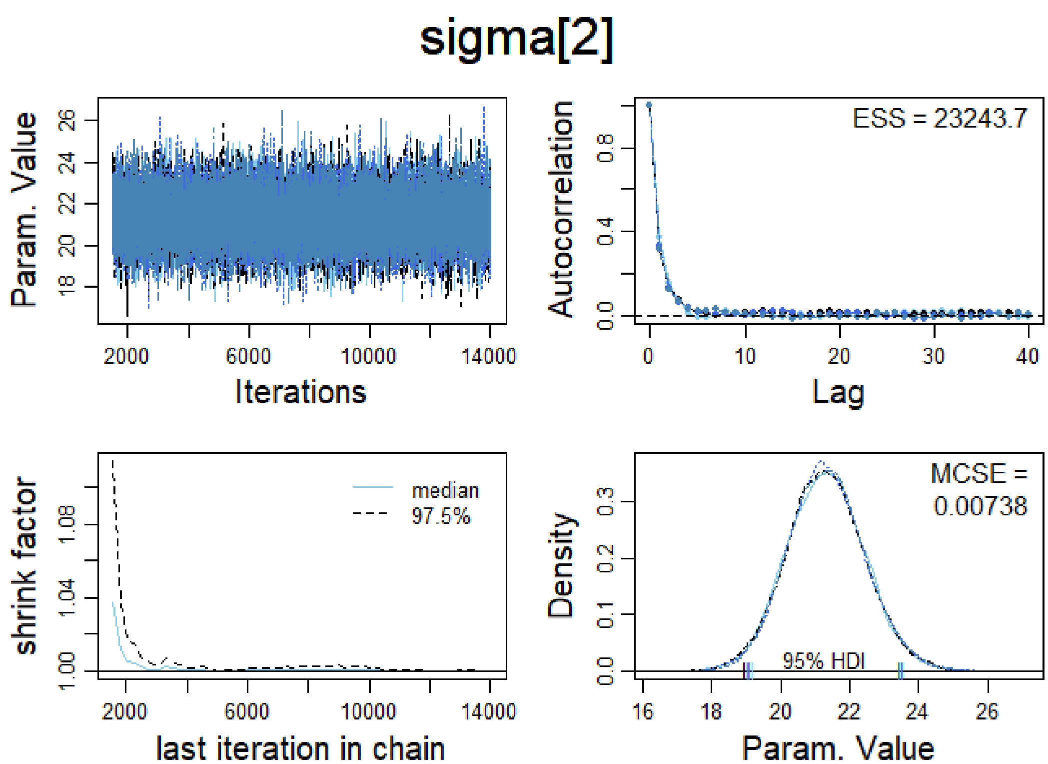
Appendix 9.38 - Markov chain Monte Carlo (MCMC) Diagnostics for Degrees of Freedom (nu; ν)



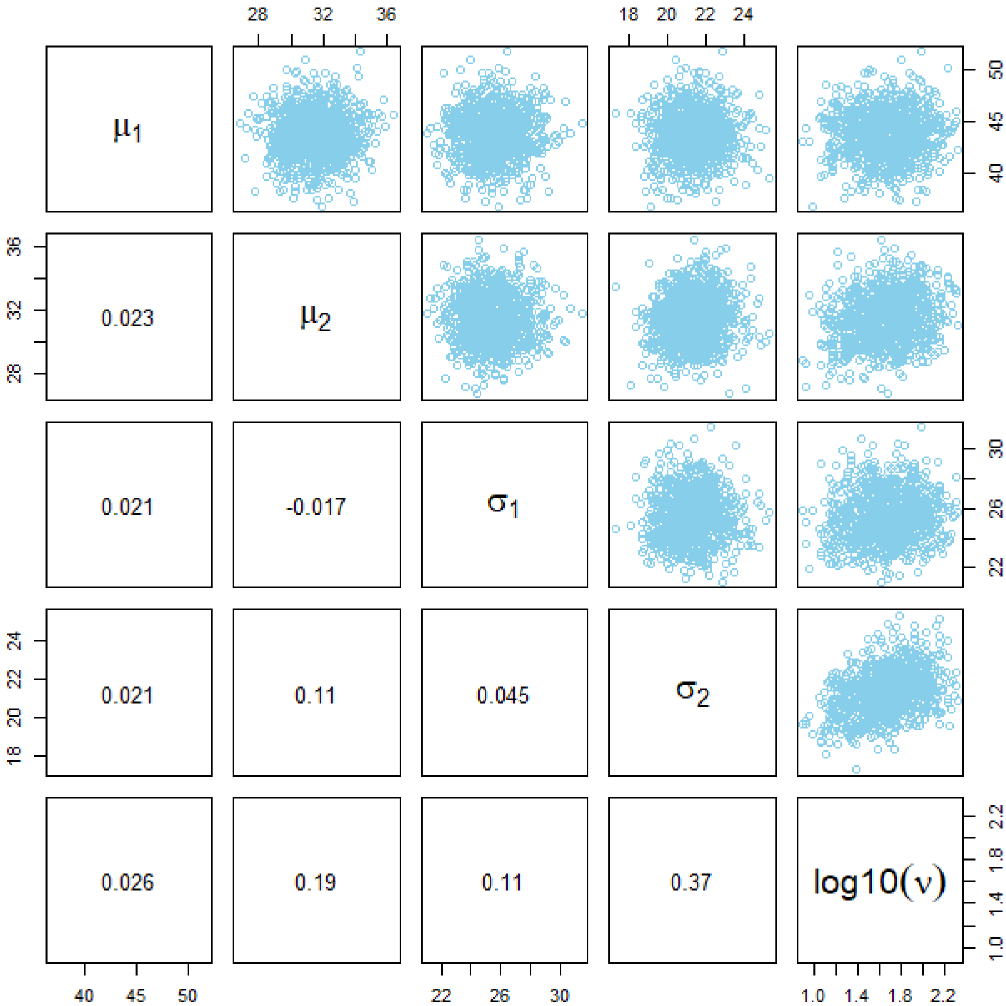
Appendix 9.39 - Markov chain Monte Carlo (MCMC) Diagnostics for standard deviation (sigma; σ) of Christian Preservation Scores (ACI)



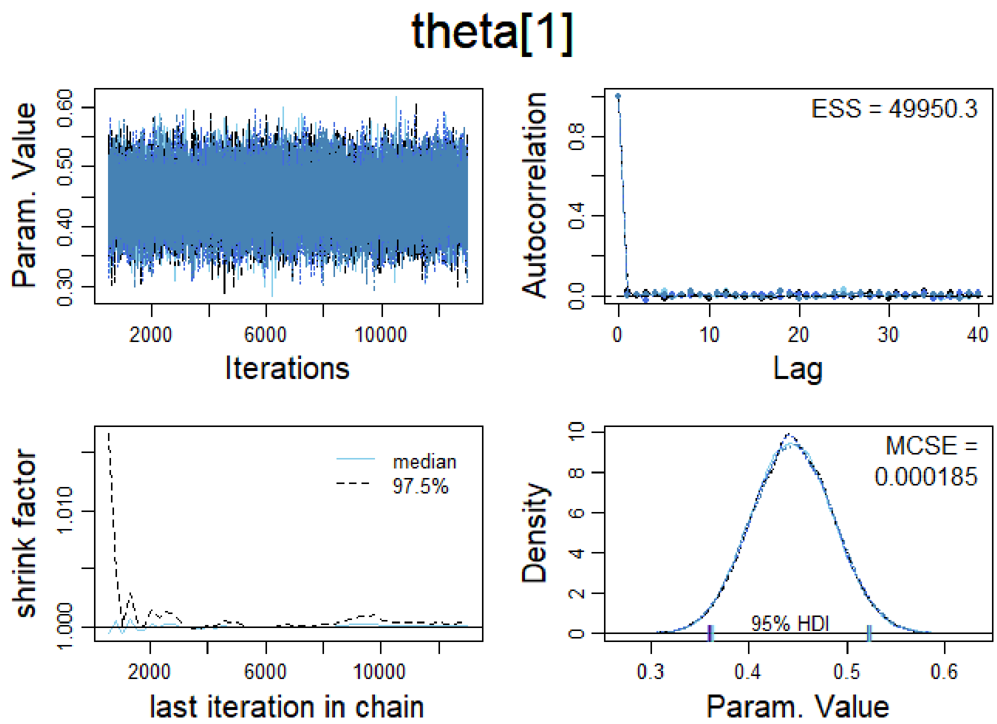
Appendix 9.40 - Markov chain Monte Carlo (MCMC) Diagnostics for standard deviation (sigma; σ) of Islamic Preservation Scores (ACI)



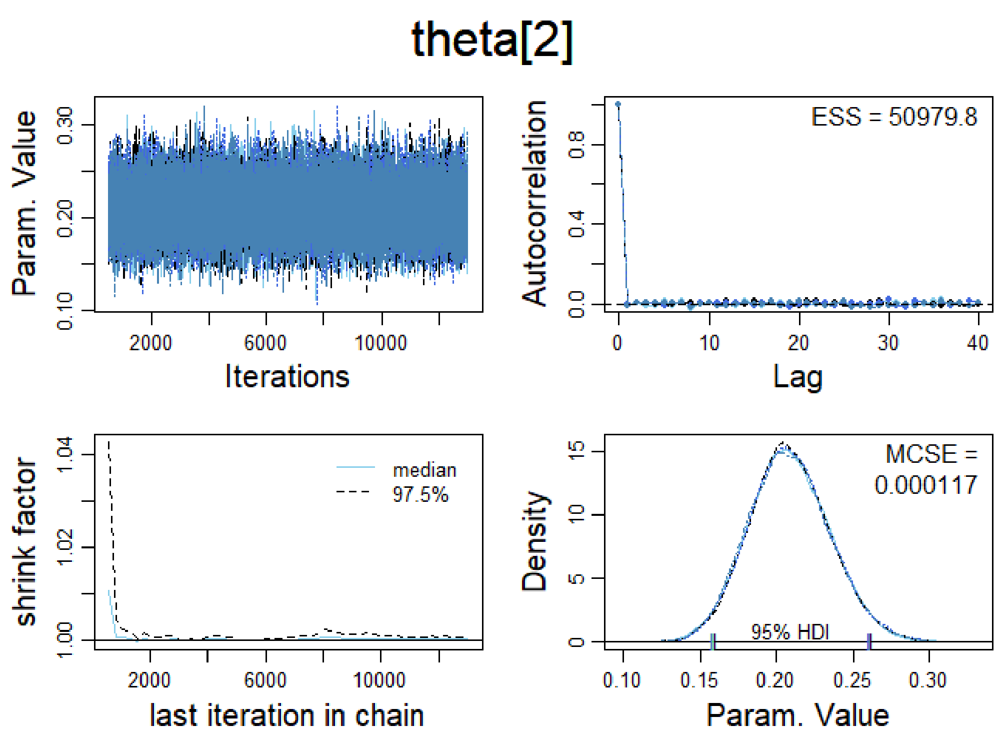
Appendix 9.41 - Montecarlo Markov Chain (MCMC) Diagnostics posterior pairwise correlations between parameters for Christian (μ_1, σ_1) and Islamic (μ_2, σ_2) preservation scores (ACI)



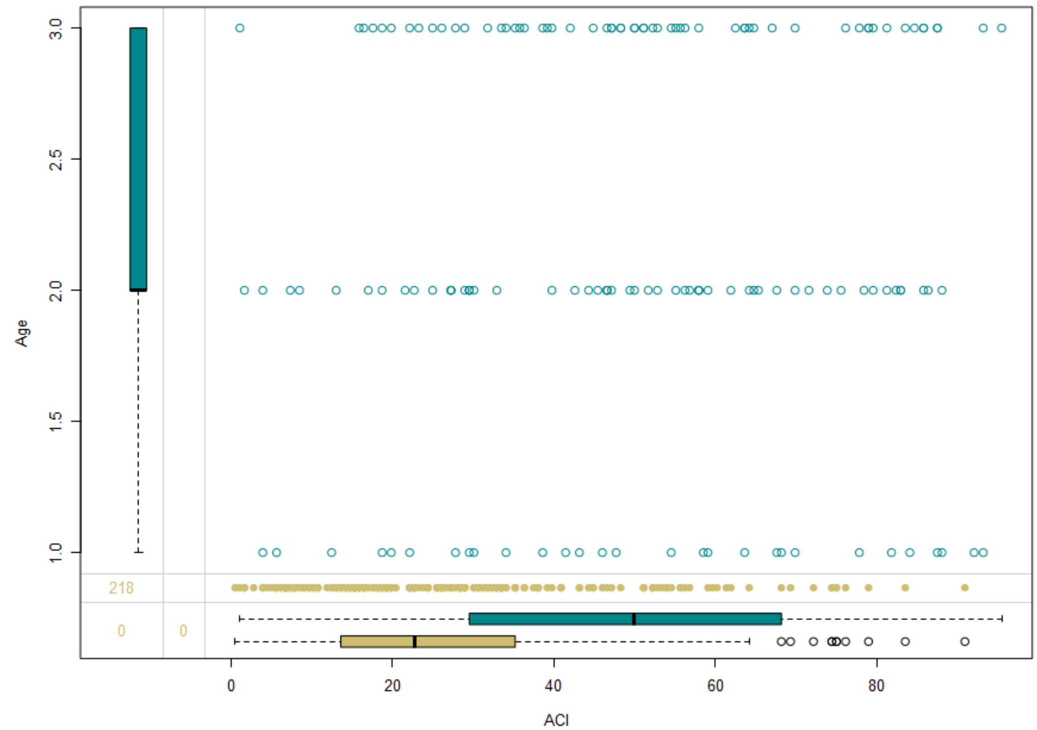
Appendix 9.42 - Markov chain Monte Carlo (MCMC) Diagnostics for the proportion of well-preserved Christian skeletons (theta 1; θ)



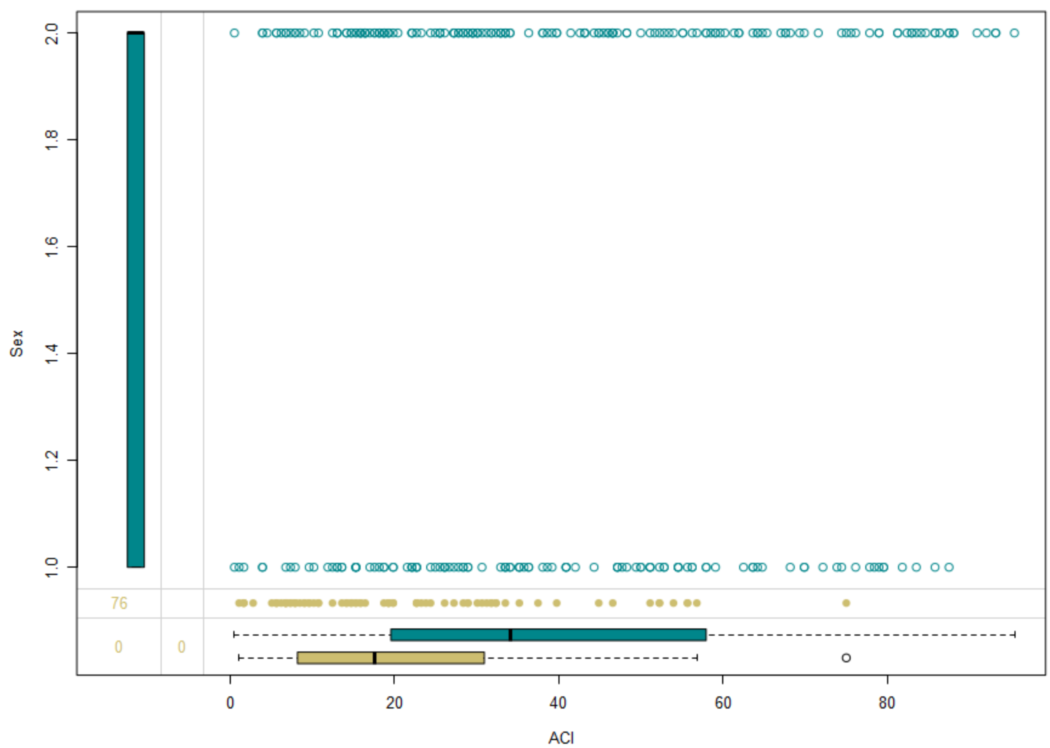
Appendix 9.43 - Markov chain Monte Carlo (MCMC) Diagnostics for the proportion of well-preserved Islamic skeletons (theta 2; θ)



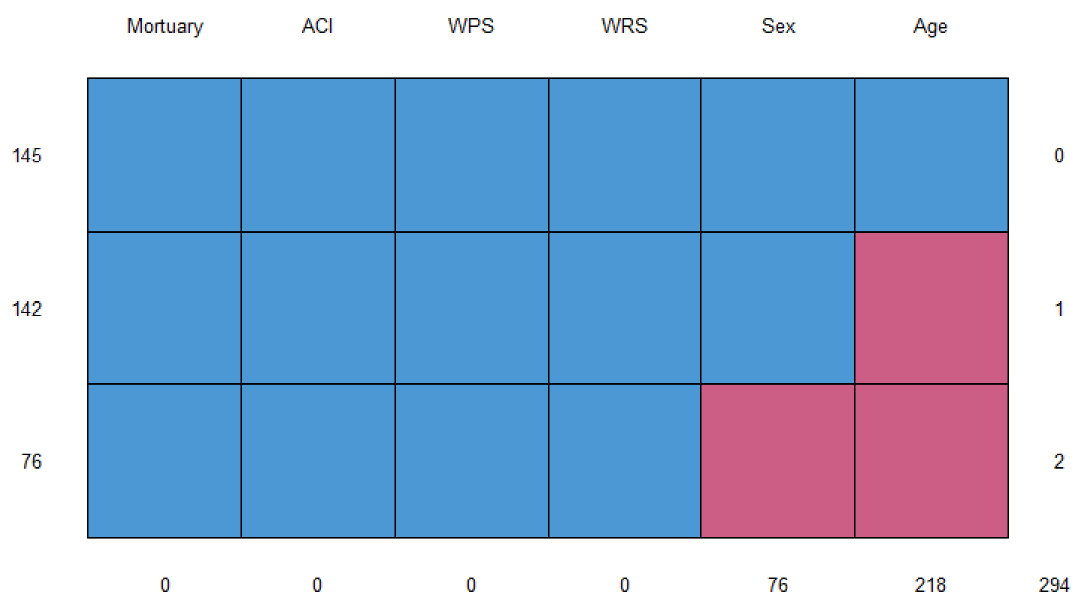
Appendix 9.44 - Anatomical Conservation Index (ACI) by Age data pattern



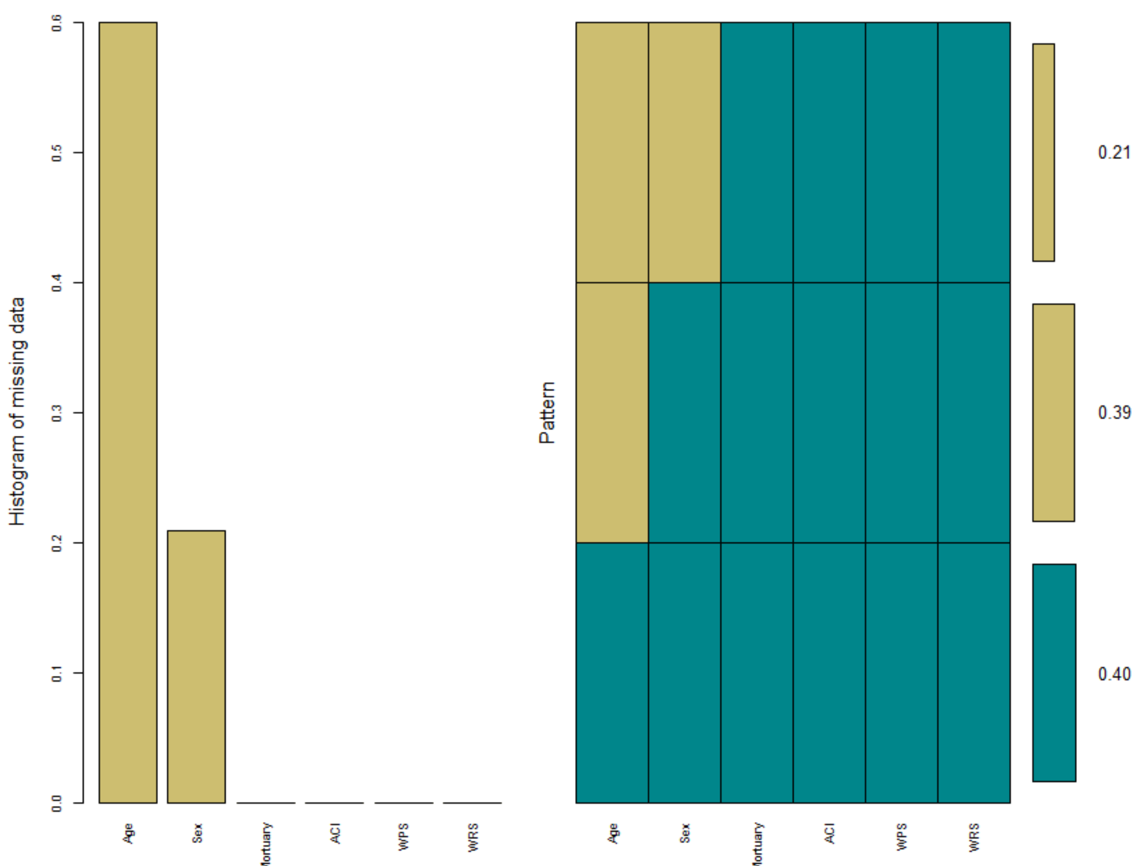
Appendix 9.45 - Anatomical Conservation Index (ACI) by Sex data pattern



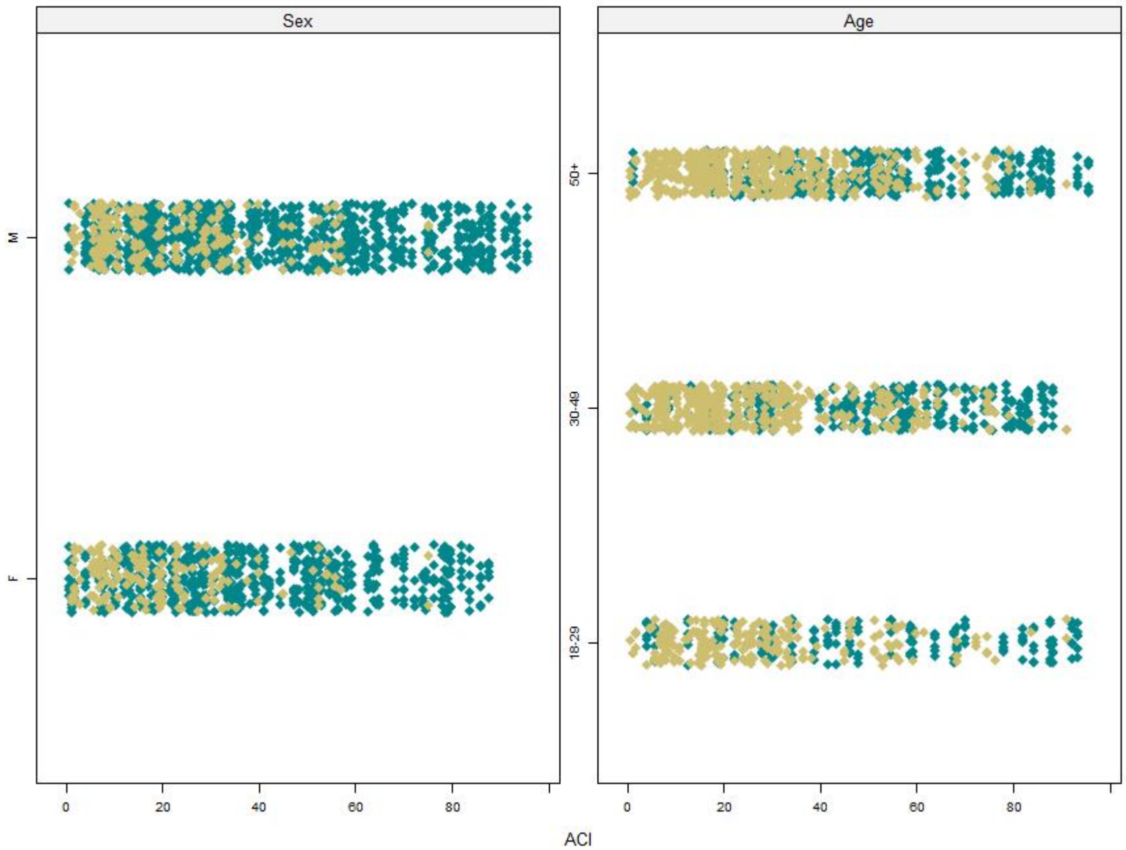
Appendix 9.46 - Anatomical Conservation Index (ACI) missing data pattern, where blue corresponds to data presence, and red corresponds to data absence.



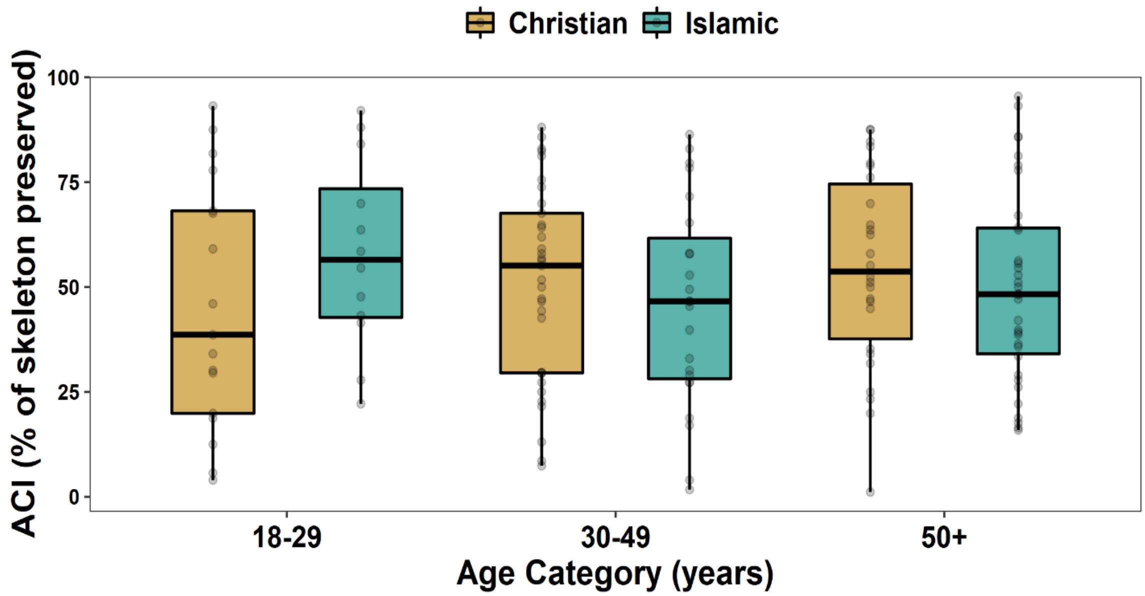
Appendix 9.47 - Anatomical Conservation Index (ACI) missing data Aggr Plot



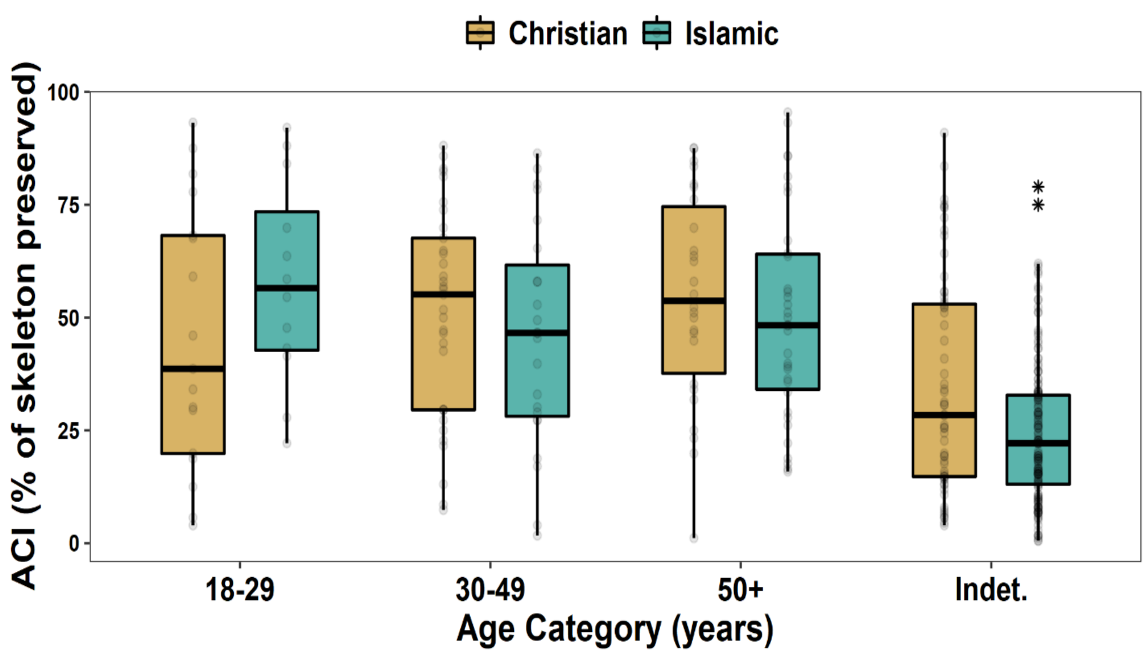
Appendix 9.48 - Anatomical Conservation Index (ACI) XY plot of missing values after imputation. Gold scatter points are imputed, and map similar to the shape of observed points (turquoise) suggesting plausible values.



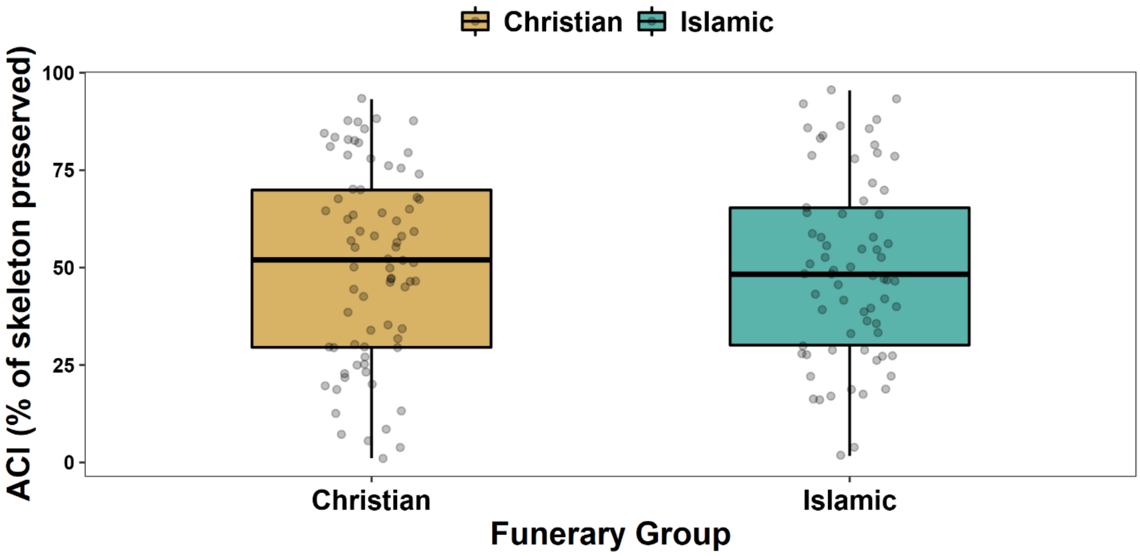
Appendix 9.49 - Anatomical Conservation Index (ACI) by age and funerary group, indeterminates excluded



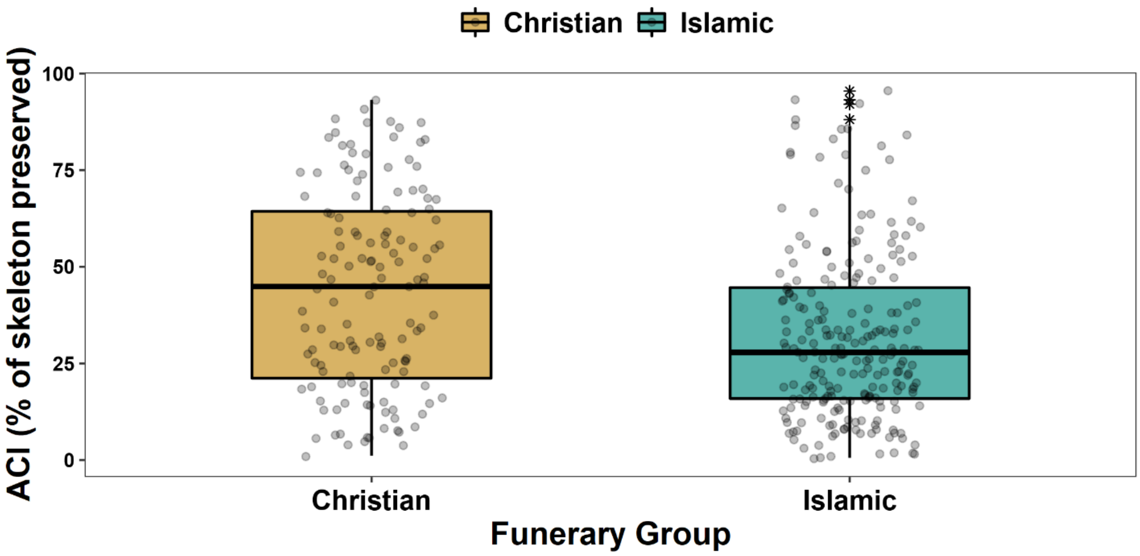
Appendix 9.50 - Anatomical Conservation Index (ACI) by age and funerary group, indeterminates included



Appendix 9.51 - Anatomical Conservation Index (ACI) by Funerary Group, indeterminates excluded.



Appendix 9.52 - Anatomical Conservation Index (ACI) by Funerary Group, indeterminates included.



Appendix 9.53 - Distribution of Bone Representation Index (BRI) values by element and religious group at Largo Cândido dos Reis.

Element	**Christian**	**Islamic**	***Z***	***p*-value**
Cranium	56.34	55.34	0.53	0.60
Mandible	46.32	61.67	-2.85	0.01*
Teeth	49.26	61.67	-2.31	0.02*
Cervical Vertebrae	52.94	59.91	-1.30	0.19
Thoracic vertebrae	66.18	64.32	0.36	0.72
Lumbar vertebrae	62.50	52.86	1.79	0.07
Sternum	39.71	16.74	4.87	0.01*
Ribs	73.53	68.72	0.97	0.33
Sacrum	62.50	49.34	2.44	0.10
Os Coxae - R	65.44	58.59	1.30	0.19
Os Coxae - L	61.03	53.30	1.44	0.15
Clavicle - R	52.94	58.59	-1.05	0.29
Clavicle - L	50.74	51.54	-0.15	0.88
Scapula - R	51.47	55.07	-0.67	0.50
Scapula - L	55.88	46.70	1.69	0.09
Humerus - R	58.82	66.96	1.69	0.09
Humerus - L	61.03	59.91	-1.50	0.13
Radius - R	59.56	55.51	0.76	0.45
Radius - L	63.24	53.30	1.85	0.06
Ulna - R	58.82	55.95	0.54	0.59
Ulna - L	63.24	53.74	1.77	0.08
Hand - R	64.71	50.22	2.69	0.01*
Hand - L	66.91	45.37	3.98	0.01*
Femur - R	72.79	66.96	1.16	0.25
Femur - L	72.06	60.79	2.18	0.03*
Patella - R	48.53	24.23	4.75	0.01*
Patella - L	45.59	23.35	4.41	0.01*
Tibia - R	73.53	61.23	2.39	0.02*
Tibia - L	71.32	59.91	2.20	0.03*
Fibula - R	71.32	59.03	2.36	0.02*
Fibula - L	71.32	57.71	2.60	0.01*
Foot - R	59.07	38.91	6.46	0.01*
Foot - L	54.66	36.12	5.98	0.01*

Appendix 9.54 - Side differences in Bone Representation Index (BRI) values by religious group at Largo Cândido dos Reis.

	Christian				Islamic			
Element	R	L	*z*	*p*-value	R	L	*z*	*p*-value
Claviculae	52.94	50.74	0.36	0.72	58.59	51.54	1.51	0.13
Scapulae	51.47	55.88	-0.73	0.47	55.07	46.70	1.78	0.08
Humerii	58.82	61.03	0.37	0.71	66.96	59.91	1.56	0.12
Radii	59.56	63.24	-0.62	0.54	55.51	53.30	0.47	0.64
Ulnae	58.82	63.24	-0.75	0.45	55.95	53.74	0.47	0.64
Hands	64.71	66.91	-0.38	0.70	50.22	45.37	1.03	0.30
Ossa coxae	65.44	50.74	0.75	0.45	58.59	53.30	1.13	0.26
Femora	72.79	72.06	0.14	0.89	66.96	60.79	1.37	0.17
Patellae	48.53	45.59	0.49	0.62	24.23	23.35	0.22	0.83
Tibiae	73.53	71.32	0.41	0.68	61.23	59.91	0.29	0.77
Fibulae	71.32	71.32	0.00	1.00	59.03	57.71	0.29	0.77
Feet	59.07	54.66	1.27	0.20	38.91	36.12	1.06	0.30

Appendix 9.55 - Effect Likelihood Ratio test results for Well-Preserved Skeletons (WPS) at Largo Cândido dos Reis, indeterminates included.

Variable	DF	χ^2	*p*-value
Funerary group	1	0.93	0.33
Sex	1	0.02	0.80
Age	2	0.14	0.93

Appendix 9.56 - Effect Likelihood Ratio test results for Well-Preserved Skeletons (WPS) at Largo Cândido dos Reis, indeterminates excluded.

Variable	DF	χ^2	*p*-value
Funerary group	1	11.16	< 0.01*
Sex	2	1.35	0.51
Age	3	27.07	< 0.01*

Appendix 9.57 - Results of binomial logistic regression using single imputation of age and sex variables for indeterminates at Largo Cândido dos Reis..

Imputation	Predictor	Comparison	OR point estimate	*p*-value (> χ^2)	OR 95% CI
Sex = F Age = 18-29	Funerary Group	Christian vs. Islamic	2.70	< 0.01	1.64-4.46
	Sex	F vs. M	0.76	0.28	0.46-1.25
	Age	18-29 vs. 30-49	0.32	< 0.01	0.17-0.62
		18-29 vs. 50+	0.24	<0.01	0.13-0.45
		30-49 vs. 50+	0.75	0.47	0.35-1.61
Sex = F Age = 30-49	Funerary Group	Christian vs. Islamic	2.90	< 0.01	1.77-4.75
	Sex	F vs. M	0.69	0.14	0.42-1.13
	Age	18-29 vs. 30-49	0.38	0.02	0.17-0.85
		18-29 vs. 50+	0.75	0.55	0.30-1.90
		30-49 vs. 50+	0.28	< 0.01	0.15-0.52
Sex = F Age = 50+	Funerary Group	Christian vs. Islamic	2.62	< 0.01	1.60-4.28
	Sex	F vs. M	0.77	0.30	0.47-1.26
	Age	18-29 vs. 30-49	0.98	0.97	0.30-2.48
		18-29 vs. 50+	0.40	0.03	0.18-0.91
		30-49 vs. 50+	0.41	< 0.01	0.22-0.77
Sex = M Age = 18-29	Funerary Group	Christian vs. Islamic	2.75	< 0.01	1.67-4.53
	Sex	F vs. M	0.94	0.83	0.55-1.61
	Age	18-29 vs. 30-49	0.31	< 0.01	0.16-0.58
		18-29 vs. 50+	0.24	< 0.01	0.13-0.46
		30-49 vs. 50+	0.79	0.55	0.37-1.70
Sex = M Age = 30-49	Funerary Group	Christian vs. Islamic	2.99	< 0.01	1.83-4.88
	Sex	F vs. M	0.95	0.85	0.56-1.62
	Age	18-29 vs. 30-49	2.76	0.01	1.22-6.22
		18-29 vs. 50+	0.78	0.60	0.31-1.97
		30-49 vs. 50+	0.28	< 0.01	0.15-0.52
Sex = M Age = 50+	Funerary Group	Christian vs. Islamic	2.68	< 0.01	1.64-4.38
	Sex	F vs. M	0.76	0.33	0.47-1.29
	Age	18-29 vs. 30-49	0.99	0.99	0.39-2.59
		18-29 vs. 50+	2.57	0.02	1.14-5.75
		30-49 vs. 50+	2.59	< 0.01	1.39-4.80

Appendix 9.56 - Effect Likelihood Ratio test results for Well-Preserved Skeletons (WPS) with single imputation of demographic variables at Largo Cândido dos Reis.

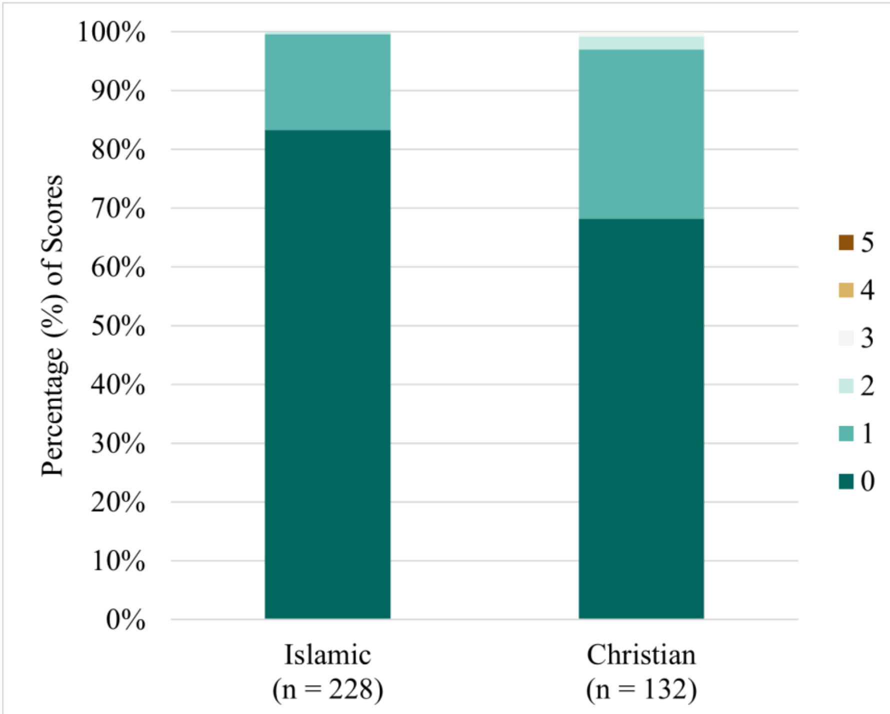
Imputation	Variable	DF	χ^2	*p*-value
Sex = F Age = 18-29	Funerary group	1	15.36	< 0.01
	Sex	1	1.19	0.27
	Age	2	25.63	< 0.01
Sex = F Age = 30-49	Funerary group	1	18.24	< 0.01
	Sex	1	2.23	0.14
	Age	2	19.54	< 0.01
Sex = F Age = 50+	Funerary group	1	14.79	< 0.01
	Sex	1	1.06	0.30
	Age	2	10.41	< 0.01
Sex = M Age = 18-29	Funerary group	1	16.03	< 0.01
	Sex	1	0.05	0.83
	Age	2	26.19	< 0.01
Sex = M Age = 30-49	Funerary group	1	19.50	< 0.01
	Sex	1	0.04	0.85
	Age	2	19.05	< 0.01
Sex = M Age = 50+	Funerary group	1	15.64	< 0.01
	Sex	1	0.94	0.33
	Age	2	11.99	< 0.01

Appendix 9.59 - Two-way ANOVA results of Age on Anatomical Conservation Index (ACI) score at Largo Cândido dos Reis.

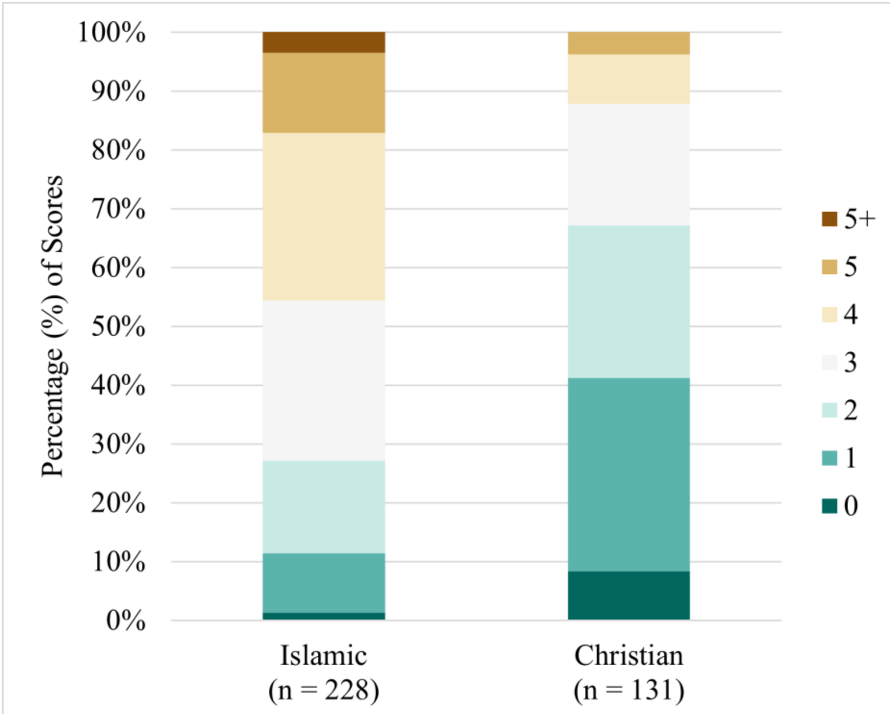
	18-29	***30-49***	***50+***	***Indet.***
	18-29	3.40[a] (4.83)[b] -6.10, 12.90[c] 0.48[d]	-0.47 (4.76) -9.85, 8.88 0.92	22.28 (4.22) 13.98, 30.59 0.01*
		30-49	-3.89 (3.91) -11.58, 3.80 0.32	18.88 (3.23) 12.52, 25.34 0.01*
			50+	22.77 (3.13) 16.61, 28.93 0.01*

[a] $\bar{x}_i - \bar{x}_j$
[b] Std. error of difference
[c] Lower Confidence level, Upper Confidence Level
[d] p-Value
* Statistically significant at the $\alpha = 0.05$ level

Appendix 9.60 - Distribution of weathering scores by funerary group (5 = heavy weathering, 0 = no weathering).



Appendix 9.61 - Distribution of Erosion scores by funerary group
(5+ = heavy erosion, 0 = no erosion).

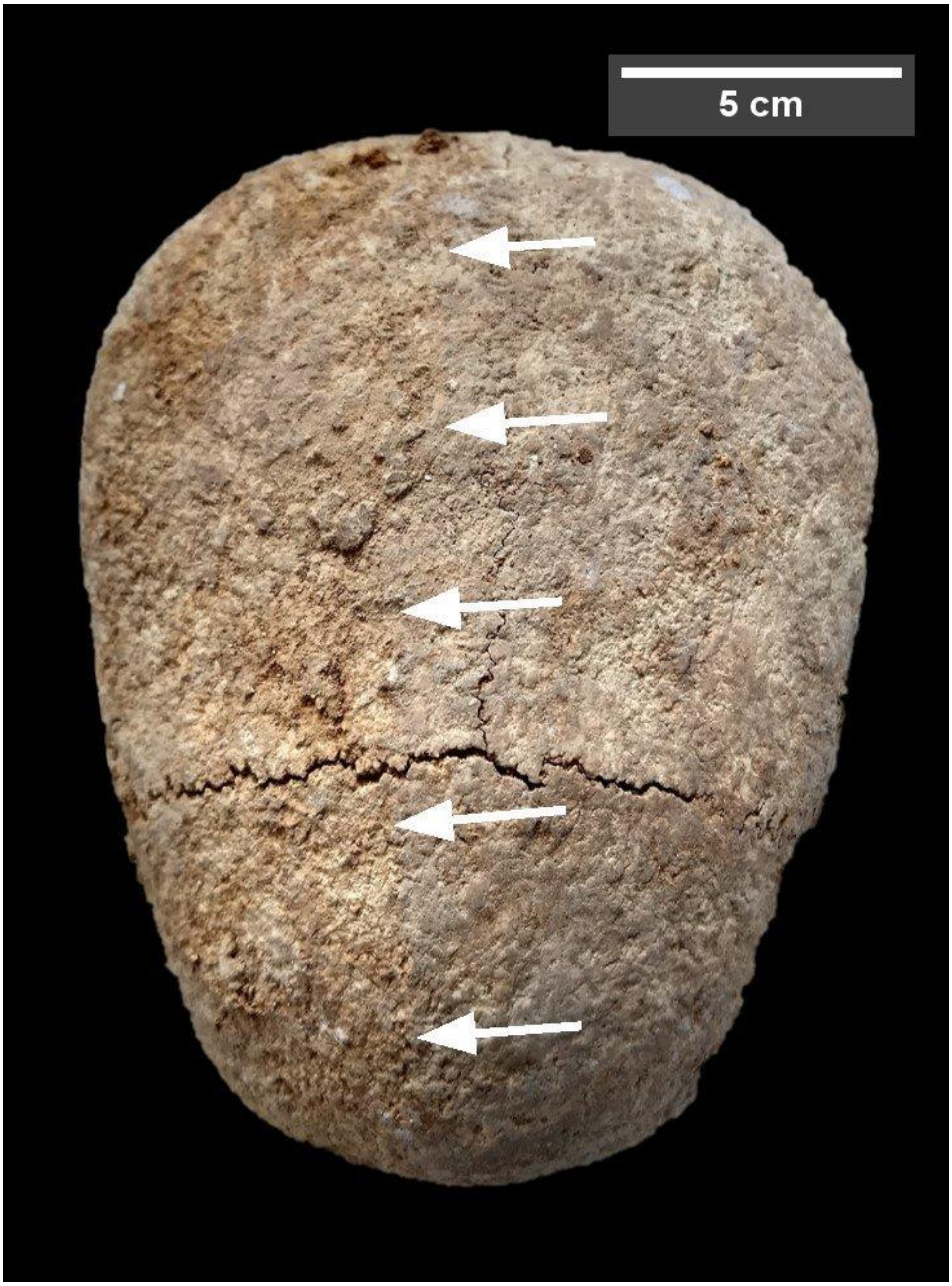


Appendix 9.62 - Photos of Largo Cândido dos Reis in 1960s prior to excavation (2004), looking northeast. Retrieved from: http://www.eugostodesantarem.pt/imagens/passado-recente/santarem-largo-candido-dos-reis.

Appendix 9.63 - Photos of Largo Cândido dos Reis in 1970s prior to excavation (2004), looking northeast. Retrieved from: http://www.eugostodesantarem.pt/imagens/passado-recente/santarem-largo-candido-dos-reis

Appendix 9.64 - Photos of Largo Cândido dos Reis in 1980s prior to excavation (2004), looking west. Retrieved from: http://www.eugostodesantarem.pt/imagens/passado-recente/santarem-largo-candido-dos-reis

Appendix 9.64 - Superior view of cranium from Islamic burial Ent. 39. Arrows showcase how erosion is more severe along the right side of cranium, the portion in contact with the burial floor.



Appendix 9.65 - Ent. 43 left maxillary central incisor exhibiting heavy erosion (5+) affecting both the root and enamel.

Appendix 9.66 - Eigenvalues from PCA of biometric snail shell study from Largo Cândido dos Reis.

Eigenvalue	Variance (%)	Cumulative variance (%)
2.956003402	73.90008505	73.90009
0.936278499	23.40696247	97.30705
0.105456075	2.63640187	99.94345
0.002262025	0.05655061	100.00000

Appendix 9.67 - Coordinates from PCA of biometric snail shell study from Largo Cândido dos Reis.

Variable	Dim. 1	Dim. 2	Dim. 3	Dim. 4
Height	0.9559617	0.1223697	0.2667637	0.0003052384
Greater Width (GW)	0.9541264	-0.2780429	-0.1058138	-0.0337409565
Lesser Width (LW)	0.9541437	-0.2765876	-0.1094791	0.0335179152
Whorl Count	0.47065246	0.8760682	-0.1054086	-0.0001691032

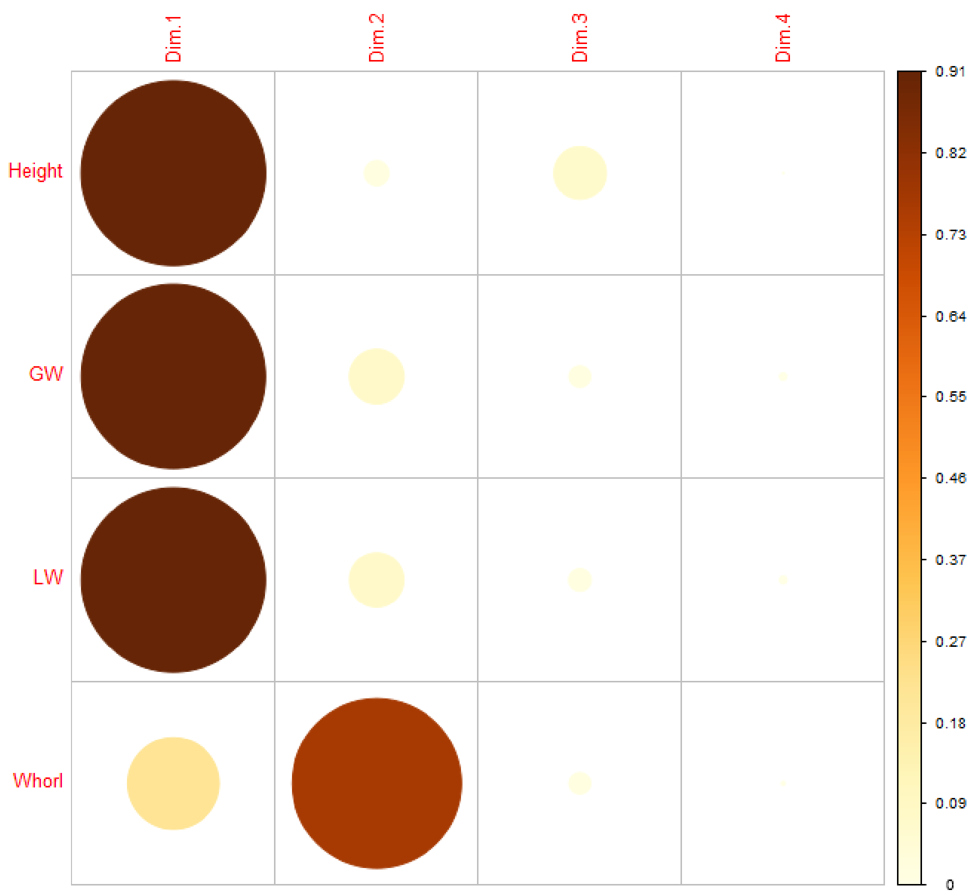
Appendix 9.68 - Contribution from PCA of biometric snail shell study from Largo Cândido dos Reis.

Variable	Dim. 1	Dim. 2	Dim. 3	Dim. 4
Height	30.91548	1.599347	67.48105	0.004118898
Greater Width (GW)	30.79689	8.256932	10.61728	50.328903118
Lesser Width (LW)	30.79801	8.170722	11.36556	49.665713811
Whorl Count	7.48962	81.972999	10.53612	0.001264173

Appendix 9.69 - Quality of representation (Cos^2) from PCA of biometric snail shell study from Largo Cândido dos Reis.

Variable	Dim. 1	Dim. 2	Dim. 3	Dim. 4
Height	0.9138627	0.01497434	0.07116287	9.317049e-08
Greater Width (GW)	0.9103571	0.07730787	0.01119656	1.138452e-03
Lesser Width (LW)	0.9103902	0.07650072	0.01198567	1.123451e-03
Whorl Count	0.2213934	0.76749556	0.01111097	2.859589e-08

Appendix 9.70 - Correlation plot of variables with quality of representation (Cos^2).



Appendix – Chapter 10

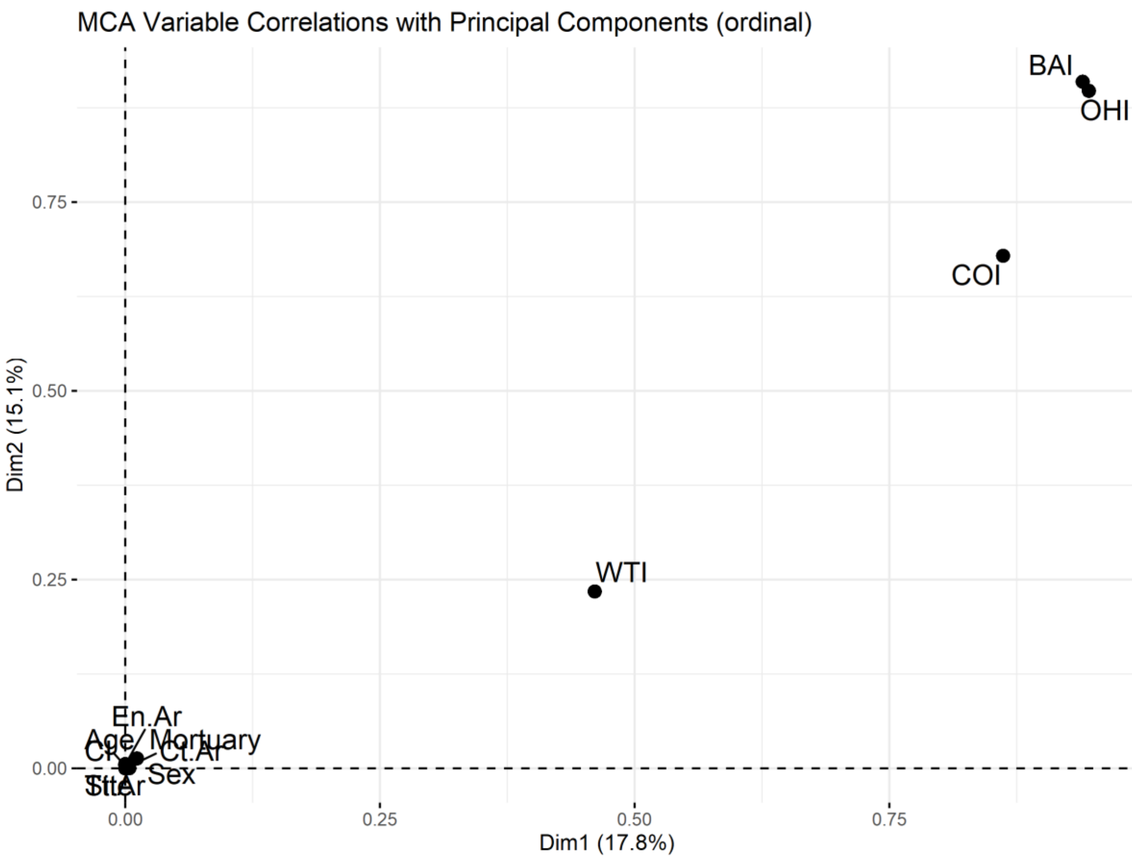
Appendix 10.1 - Histotaphonomic indices by Funerary Group and Sex (n = 29 Islamic females, n = 32 Islamic males; n = 24 Christian females, n = 43 Christian males)

		OHI		**BAI**		**WTI**		**COI**		**CRI**	
	Score	Female N (%)	Male N (%)	Female N (%)	Male N (%)	Female N (%)	Male N (%)	Female N (%)	Male N (%)	Female N (%)	Male N (%)
Islamic	5	0 (0.00)	0 (0.00)	1 (3.45)	1 (3.13)	12 (41.34)	18 (56.25)	1 (3.45)	2 (6.25)	6 (20.69)	6 (18.75)
	4	3 (10.34)	2 (6.25)	3 (10.34)	2 (6.25)	8 (27.59)	4 (12.50)	4 (13.79)	4 (12.50)	5 (17.24)	6 (18.75)
	3	3 (10.34)	6 (18.75)	2 (6.90)	2 (6.25)	4 (13.79)	6 (18.75)	1 (3.45)	2 (6.25)	0 (0.00)	0 (0.00)
	2	2 (6.90)	2 (6.25)	3 (10.34)	5 (15.63)	3 (10.34)	3 (9.38)	4 (13.79)	13 (40.63)	1 (3.45)	2 (6.25)
	1	4 (13.79)	4 (12.50)	3 (10.34)	4 (12.50)	2 (6.90)	0 (0.00)	19 (65.52)	16 (50.00)	0 (0.00)	1 (3.13)
	0	17 (58.62)	18 (56.25)	17 (58.62)	18 (56.25)	0 (0.00)	1 (3.13)	—	—	0 (0.00)	0 (0.00)
	Indet.	—	—	—	—	—	—	—	—	17 (58.62)	17 (53.13)
Christian	5	1 (4.17)	0 (0.00)	1 (4.17)	0 (0.00)	15 (62.50)	26 (60.47)	1 (4.17)	1 (2.33)	6 (25.00)	12 (27.91)
	4	2 (8.33)	5 (11.63)	2 (8.33)	5 (11.63)	8 (33.33)	11 (25.58)	1 (4.17)	3 (6.98)	1 (4.17)	3 (6.98)
	3	2 (8.33)	3 (6.98)	1 (4.17)	3 (6.98)	0 (0.00)	4 (9.30)	1 (4.17)	4 (9.30)	0 (0.00)	1 (2.33)
	2	1 (4.17)	1 (2.33)	2 (8.33)	1 (2.33)	1 (4.17)	2 (4.65)	6 (25.00)	6 (13.95)	1 (4.17)	0 (0.00)
	1	3 (12.50)	8 (18.60)	3 (12.50)	7 (16.28)	0 (0.00)	0 (0.00)	15 (62.50)	29 (67.44)	1 (4.17)	1 (2.33)
	0	15 (62.50)	26 (60.47)	15 (62.50)	27 (62.79)	0 (0.00)	0 (0.00)	—	—	0 (0.00)	1 (2.33)
	Indet.	—	—	—	—	—	—	—	—	15 (62.50)	25 (58.14)

Appendix 10.2 – Multiple Correspondence Analysis with histotaphonomic indices as categorical variables

Dimension	Eigenvalue	Variance (%)	Cumulative Variance (%)
Dim.1	0.802040881395917	17.8231306976871	17.8231306976871
Dim.2	0.680011937270628	15.1113763837917	32.9345070814788
Dim.3	0.569048183872873	12.645515197175	45.5800222786538
Dim.4	0.536579365148271	11.9239858921838	57.5040081708376
Dim.5	0.500211246389316	11.1158054753181	68.6198136461557
Dim.6	0.227543975086083	5.05653277969074	73.6763464258465
Dim.7	0.224607540852647	4.99127868561438	78.6676251114608
Dim.8	0.204972002205822	4.55493338235161	83.2225584938124
Dim.9	0.178202684508115	3.96005965573588	87.1826181495483
Dim.10	0.156828743654345	3.48508319231878	90.6677013418671
Dim.11	0.124503842022414	2.76675204494254	93.4344533868096
Dim.12	0.106495671053036	2.36657046784525	95.8010238546549
Dim.13	0.0724122829760728	1.60916184391273	97.4101856985676
Dim.14	0.0652154200044205	1.44923155565379	98.8594172542214
Dim.15	0.0232782131005881	0.517293624457514	99.3767108786789
Dim.16	0.0188615123093284	0.419144717985075	99.795855596664
Dim.17	0.00723004704635631	0.160667712141251	99.9565233088053
Dim.18	0.00195645110376391	0.0434766911947535	100

Appendix 10.3 – Multiple Correspondence Analysis variable correlation with principal components, with histotaphonomic indices as categorical variables



Appendix 10.4 – Multiple Correspondence Analysis with histotaphonomic indices as binomial variable (poorly preserved = 0; well-preserved = 1)

Dimension	**Eigenvalue**	**Variance (%)**	**Cumulative Variance (%)**
Dim.1	0.66612	66.612	66.61
Dim.2	0.24976	24.976	91.59
Dim.3	0.06440	6.440	98.03
Dim.4	0.0973	1.973	100.00

Appendix 10.5 – Multiple Correspondence Analysis variable correlation bi-plot with principal components, with histotaphonomic indices as ordinal variables