Hist Arch (2020) 54:262–285
https://doi.org/10.1007/s41636-019-00221-8

ORIGINAL ARTICLE

Native Lives in Colonial Times: Insights from the Skeletal Remains of Susquehannocks, A.D. 1575–1675

Celeste Marie Gagnon · Sara K. Becker

Accepted: 27 August 2018 / Published online: 6 January 2020

Abstract The experiences of Susquehannock Indians during the early period of European colonialism (1575–1675) included changes in subsistence, health, and violence, creating stressors that affected their lived experience. To begin to understand the embodied effects of these pressures, the skeletal remains of a number of Susquehannocks, recovered from sites in Pennsylvania and Maryland, were examined for evidence of oral health (dental caries, antemortem tooth loss, and dental abscess), skeletal trauma, growth disruption, and anemia. Our approach, informed by the "Osteological Paradox," finds a trend of improvement in Susquehannock living conditions during that period that correlates well with the signing of a "Treaty of Friendship" with the colonial Maryland government in 1652. The treaty created an alliance and a southern "safe zone" for food procurement, and helped limit warfare to one front with the Iroquois to the north. This reprieve was short lived, as colonial relationships deteriorated by 1675, and Susquehannocks fled after the siege of their fort, which helped to trigger Bacon's Rebellion in colonial Virginia.

C. M. Gagnon (✉)
Department of Anthropology, Wagner College, 1 Campus Road, Staten Island, NY 10301, U.S.A.
e-mail: celeste.gagnon@wagner.edu

S. K. Becker
Department of Anthropology, University of California, Riverside, 1334 Watkins Hall, Riverside, CA 92521, U.S.A.

Extracto Las experiencias de los indios susquehannocks durante el período temprano del colonialismo europeo (1575–1675) incluyeron cambios en la subsistencia, la salud y la violencia, creando factores estresantes que afectaron su experiencia de vida. Para comenzar a comprender los efectos encarnados de estas presiones, se examinaron los restos esqueléticos de varios susquehannocks, recuperados de sitios en Pensilvania y Maryland, en busca de evidencia de salud bucal (caries dental, pérdida de dientes antemortem y absceso dental), trauma esquelético, interrupción del crecimiento y anemia. Nuestro enfoque, informado por la "Paradoja Osteológica", encuentra una tendencia de mejora en las condiciones de vida de los susquehannocks durante ese período que se correlaciona bien con la firma de un "Tratado de Amistad" con el gobierno colonial de Maryland en 1652. Este tratado creó una alianza y una "zona segura" del sur para la adquisición de alimentos, y ayudó a limitar la guerra a un frente con los iroqueses al norte. Este aplazamiento duró poco, ya que las relaciones coloniales se deterioraron en 1675, y los susquehannocks huyeron después del asedio de su fuerte, lo que ayudó a desencadenar la rebelión de Bacon en la Virginia colonial.

Résumé Les expériences des Indiens Susquehannock durant les débuts de la période du colonialisme européen (1575–1675) ont comporté des modifications liées à la subsistance, la santé et la violence. Elles ont été à l'origine de facteurs de stress ayant affecté l'expérience de leur vécu. Pour commencer à comprendre les effets

imbriqués de ces pressions, les restes squelettiques de plusieurs Susquehannocks, ayant été découverts sur des sites en Pennsylvanie et au Maryland, ont fait l'objet d'un examen pour y rechercher des indices liés à la santé buccale (caries dentaires, perte de dent avant la mort, et abcès dentaire), traumatisme du squelette, perturbation de la croissance et anémie. Notre approche, fondée sur le « Paradoxe ostéologique », met en lumière une tendance indiquant une amélioration des conditions de vie des Susquehannocks durant cette période, en corrélation positive avec la signature en 1652 du « Traité d'amitié » avec le gouvernement colonial du Maryland. Ce traité a créé une alliance et une « zone protégée » au sud pour l'approvisionnement en nourriture, et il a contribué à limiter la guerre sur un front avec les Iroquois au nord. Ce répit a été de courte durée, car les relations coloniales se sont détériorées vers 1675, et les Susquehannocks ont pris la fuite après le siège de leur fort, ayant contribué à déclencher la Révolte de Bacon dans la Virginie Coloniale.

Keywords Susquehannocks · European contact · osteological paradox · nutritional stress · Bacon's Rebellion

Introduction

The Susquehannock Indians, at the time of first European documentation by Captain John Smith[1] in 1608, resided in as many as 20 villages near Chesapeake Bay, with an estimated population between 5,000 and 7,000 people (Cadzow 1936; Eshleman 1909; Jennings 1968, 1978; Tooker 1984; J. Smith 1986). During the 1600s, early postcontact Susquehannock groups residing in the lower Susquehanna Valley of southern Pennsylvania (Fig. 1) were caught between ongoing deteriorating relationships with the Iroquois to the north and Maryland colonization to the south. In response to these pressures, the Susquehannock began raiding Maryland settlements in the 1630s, which led to an extreme response by the colonial government in 1642. The Susquehannock were officially declared enemies of the Maryland province and were to be shot on sight if seen in colonial territory. Under the Maryland Charter (1632) from the English government, the provincial territory extended farther north than the modern Maryland state boundary, bringing the area of exclusion nearly to the lower Susquehanna Valley villages (Sparks 1848; Browne 1885a, 1885b:116–117; Mathews 1898; Eshleman 1909; Tittman 1909; Peasley 1910; Land 1981; Menard and Carr 1982). This likely limited Susquehannock access to traditional wild and cultivated resources in this region to the south (Prezzano and Rieth 2001; Asch Sidell 2002; Knapp 2002; Loren 2008; Becker 2013a). This context, coupled with disease epidemics, conflict with the Iroquois to the north, and resource competition with other native groups and European colonists, led to a dramatic decline in Susquehannock population, power, and political influence (Jennings 1966, 1968, 1978, 1984; Custer 1989:337–338; Axelrod 1993; Webb 1995; Alchon 2003:132; Gagnon 2004b; Simon and Gagnon 2005; E. Jones and DeWitte 2012). To help mitigate the stress caused by natural-resource depletion, warfare, and the declining fur trade, the Susquehannocks signed a "Treaty of Friendship" with the Maryland colonial government in 1652. This document removed the shoot-on-sight order, permitted the Susquehannocks access to lands near Chesapeake Bay, and supplied armaments for use in their ongoing war with the Iroquois (Gallatin 1836; Browne 1885a, 1885b; Jennings 1968, 1982; Webb 1995). In 1673, after 20 years of warfare with the Iroquois and facing annihilation, the Susquehannocks again reached out to the Maryland government for help. They were provided with lands on which to settle north of present-day Washington, D.C. (Stephenson et al. 1963; Jennings 1968, 1978, 1982; Tooker 1984). The Susquehannocks relocated, but rather than settling on the land granted them, they moved farther south, into a fort within the territory of the Piscataway Indians (Fig. 1). The Susquehannocks resided on the south bank of Piscataway Creek until 1675, when escalating conflicts with the local colonial militia resulted in a siege of the fort, followed by its abandonment.

Our study presents an opportunity to track the physiological effects of a limited, but transformational, time in the lives of the Susquehannock people. The skeletal samples examined in this research are from two burial groups with distinct cemeteries that span approximately 100 years. The first burial group was recovered from some of the earliest Susquehannock sites known in the

[1] Throughout the text we reference specific individuals by name if they were recorded in the documentary record. As the historical record is significantly biased, the names of prominent Native Americans were not recorded, and thus the native people discussed in the text cannot be named.

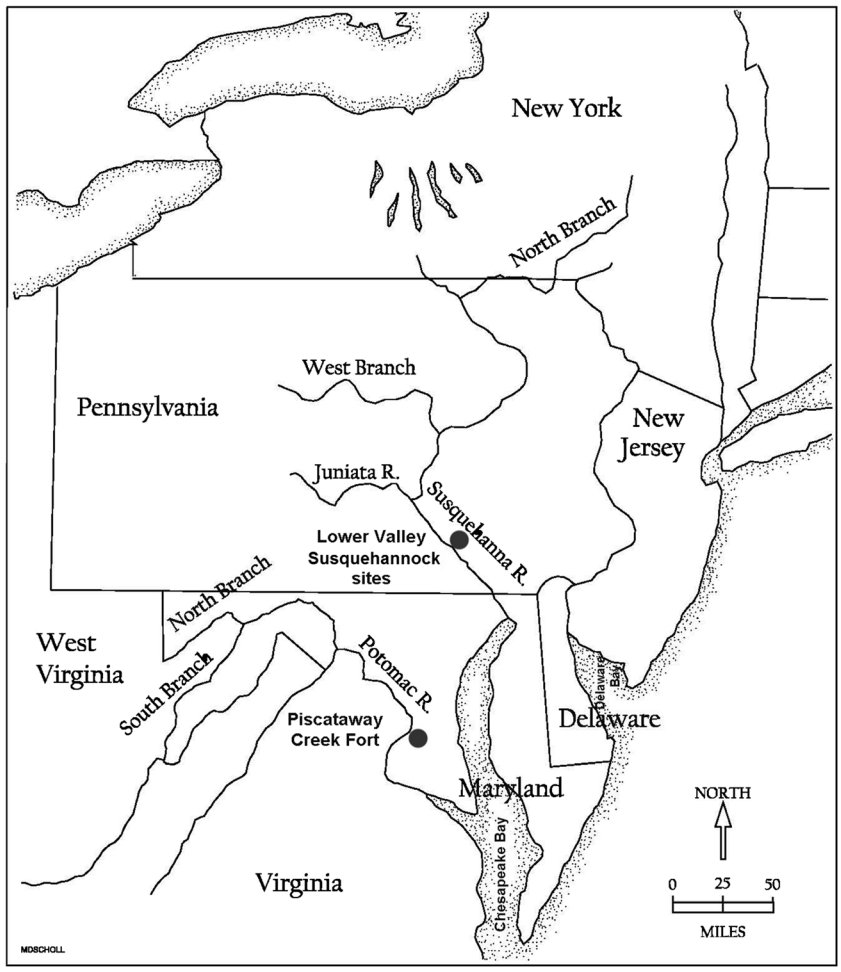

Fig. 1 Map showing location of the five pre-treaty Susquehannock settlements in the lower Susquehannock Valley of Pennsylvania (which are within 5 mi. of one another) and the post-treaty Susquehannock Fort on Piscataway lands in Maryland. (Drawing by Michael D. Scholl, 2003.)

lower Susquehanna Valley of Pennsylvania. With occupations beginning in the protohistoric period (1575–1600) and continuing into the early historical period (1600–1645), this burial sample represents people who lived during the earliest stages of European contact and died prior to the Treaty of Friendship. The second burial group was recovered from the 1674–1675 Susquehannock occupation of the fort in Maryland. While Susquehannocks only occupied this site for a short time, the individuals buried there range in age from 7 to more than 50 years at the time of death. Therefore, these remains record the stress experienced by the majority of these Susquehannocks during the more than 20 years following the 1652 Treaty of Friendship. Because the treaty provided the Susquehannocks with a colonial ally and access to resources around Chesapeake Bay, it is likely that this political relationship improved their lives.

Our research tested this proposal by comparing skeletal indicators of stress in the two samples. We anticipated that the Pennsylvania pre-treaty skeletal sample would show greater evidence of trauma, skeletal stress, and poor oral health because of the effects of warfare and a reduction in access to local resources. In contrast, we expected the post-treaty sample to show less skeletal evidence of violence, stress, and a limited diet as a result of increased access to resource-rich areas and cessation of hostilities on the Maryland front. Using evidence of (1) trauma, (2) growth disruption from linear enamel hypoplasia (LEH), (3) anemia from healed and unhealed porotic hyperostosis (PH) and cribra orbitalia (CO), and (4) diet, indicated by dental caries, antemortem tooth loss (AMTL), and dental abscess (all of which are defined below), we expected evidence of changes visible on human skeletal remains to support these ideas. Overall, our research met these expectations,

documenting some significant differences showing improvements, as indicated by decreases in the skeletal indicators of growth disruption, anemia, and poor oral health among post-treaty Susquehannocks buried in Maryland. However, we found no evidence of interpersonal violence in either sample, seemingly in contrast to many historical and ethnohistorical accounts of violence during this period. In addition, while not an initial focus, we also saw evidence of infectious disease in both groups in the form of treponematosis,[2] likely caused by acquired syphilis. Thus, our research describes a complex picture of Susquehannock life during this 100-year period in the Mid-Atlantic region, exposing the impact that European contact and short-term shifts in political interactions had on the health of Native Americans.

Susquehannocks in Time and Place

European interactions with the native groups of the areas surrounding Delaware and Chesapeake bays began with Verrazzano's voyage of 1524 (Grumet 1995). However, the first written record of the Susquehannocks appears in 1608, in documents penned by Captain John Smith (Tyler 1907; B. Kent 1984; J. Smith 1986). The Susquehannock were speakers of a northern Iroquoian language related to that of the Seneca, Cayuga, Onondaga, Oneida, and Mohawk of New York (Jennings 1966, 1968, 1978, 1982, 1984; Lounsbury 1978). A number of researchers have suggested that the Susquehannock originally inhabited an area closer to the Five Nations on the north branch of the Susquehanna River, migrating to the lower Susquehanna Valley in ca. 1575 (Stewart 1973; B. Kent 1980). Historical records and archaeological research indicate that the Lower Valley Susquehannock were horticulturists living in semipermanent, palisaded villages with multifamily longhouse dwellings, and that they buried their dead in individual graves in nearby cemeteries (Gallatin 1836; Cadzow 1936; Porter 1979; B. Kent 1984; Brashler 1987). Food remains, such as domesticated maize, pumpkin, and squash, as well as wild animal, plant, and fish resources excavated from their villages, indicate a varied and seasonal diet (Guilday et al. 1962; Brashler 1987). Maize was an important dietary component, as indicated by Susquehannock oral health (Gagnon 1996) and isotopic dietary reconstructions (Vogel and van der Merwe 1977; Buikstra 1992).

Interactions between Susquehannock and British traders were generally peaceful, reflected in an increase in European trade goods excavated from Susquehannock households and cemetery sites (Cadzow 1936; Heisey and Witmer 1962). However, this relationship deteriorated soon after English colonists settled at St. Mary's City, Maryland, in 1634 (Toogood 1969; Porter 1979; Jennings 1982; Maniez 1994). Historical records indicate that, after the establishment of St. Mary's City, Susquehannocks began to experience smallpox outbreaks, most notably their first major epidemic in 1637 (Eshleman 1909:47; Hanna 1911; Jennings 1966, 1968, 1978, 1982). In addition, perhaps pressured by ongoing conflict with the Iroquois to the north, Susquehannocks began more-intense raiding of other native tribes as well as Maryland colonists to the south (Browne 1885b; Eshleman 1909; Cadzow 1936; Kellock 1962; Jennings 1966, 1968, 1978, 1982, 1984; Toogood 1969; B. Kent 1980, 1984; Land 1981; Tooker 1984; J. Jones 2013). Multiple confrontations with the British finally led the first colonial governor of Maryland, Leonard Calvert, to declare in 1642 Susquehannocks to be "enemies of province, and as such, are to be reputed and proceeded against by all persons" (Browne 1885b:116–117). This decree resulted in multiple expeditions against the Susquehannocks in which colonial militiamen were given carte blanche to shoot them on sight (Sparks 1848; Browne 1885b; Eshleman 1909). Two years later, without the Maryland governor's approval, some colonists made efforts to make peace with the Susquehannock, who were invited to a British-built fort on Piscataway Creek, Maryland, for talks. The Susquehannocks were given medals of copper or silver with yellow and black ribbons (the colors of the Calvert family) to insure safe passage, although the British who had arranged the meeting wondered if the Susquehannock agreed to meet with "serious intentions to enter into a cessation of hostilities, or sinister designs to inveigle the friendly Piscataways" (Eshleman 1909:31). When the Maryland governor learned of this unauthorized meeting, however, he removed those involved from his council, reneged on the negotiated terms, and continued hostilities against the Susquehannocks (Browne 1885b; Eshleman 1909).

[2] A collective term to refer to the four human diseases caused by the bacteria *Treponema*; i.e., yaws (*Treponema pallidum pertenue*), bejel (*Treponema pallidum endemicum*), syphilis (*Treponema pallidum pallidum*), and pinta (*Treponema carateum*).

The years after this attempted truce were turbulent ones for Susquehannocks, as they sided with the Huron and others in various battles against the Iroquoian Confederacy, and, in doing so, made themselves a major target of Iroquois raids (Browne 1885b; Eshleman 1909). Realizing that they were fighting a war on two fronts, one to the north with the Iroquois and one to the south with the Maryland settlers, as well as experiencing diminishment of local resources and a reduction in goods associated with the fur trade, the Susquehannocks asked the colonial Maryland government for a cessation of hostilities and protection. On 5 July 1652, a "Treaty of Friendship" was established, with peace accords resigned in 1661 and 1666 (Browne 1885b; Eshleman 1909; Hanna 1911:43; Toogood 1969:44). The Maryland government also provided arms to Susquehannocks and, at times, even troops (Browne 1885a, 1885b; Hanna 1911). In return, Susquehannocks remained as a buffer between the Iroquois and Maryland colony, waging war to the north against the confederacy (Gallatin 1836:43; Hanna 1911; Jennings 1968, 1982; Webb 1995; J. Jones 2013:8–10). By 1673, after 20 years of Susquehannock population decline likely due to conflicts and disease epidemics, they asked the Maryland colonial government for assistance. Permission was granted for Susquehannocks to settle along the Potomac River on lands north of present-day Washington, D.C. (Browne 1885a, 1885b; Eshleman 1909; Hall 1910; Peasley 1910; Jennings 1968, 1982; Porter 1979; Land 1981; Menard and Carr 1982; Tooker 1984). Records do not indicate whether there was a miscommunication between Susquehannocks and the Maryland government or the proffered land was unacceptable, but instead they moved from Pennsylvania to an area 29 km (18 mi.) south of present-day Washington, D.C., settling in Maryland near the Piscataway Indians in February 1674 (Ferguson 1941; Toogood 1969; Maniez 1994). They may have chosen this area because of familiarity with the abandoned fort, the site of the aborted British/Susquehannock peace negotiations in 1644.

It is unclear whether the Susquehannocks would have been permitted by the colonial governments to continue to live in the fort in such close proximity to and on the land of the Piscataway Indians, but their occupation was disturbed by a series of incidents with a group of Doeg Indians during the latter half of 1675 (Toogood 1969; Land 1981; Maniez 1994). The Doegs, an Algonquian group that had been living farther north of Piscataway Creek, became involved in a dispute over trade goods with a wealthy Virginia colonist named Thomas Mathew. In the resulting Doeg raid, a number of Virginia colonists were killed, and the colonial militia was raised in retribution. After these events, historical accounts of Doeg and Susquehannock activities vary (Eshleman 1909; Jennings 1968, 1978, 1982, 1984; Porter 1979; Axelrod 1993). The Doegs may have fled to the Piscataway Creek area under the protection of the Susquehannock. However, a majority of historians suggests it is likely that the Susquehannocks did not help the Doegs, but were blamed for the Doeg raid by the colonial militia; e.g., Axelrod (1993), Eshleman (1909), Hanna (1911), and Land (1981). The result was a siege of the Susquehannock fort, initiated by Maryland and Virginia militia, that began in September of 1675. In response, Susquehannocks sent five hostages in good faith to Major Thomas Truman, the leader of the Maryland militia, presenting him with the previously acquired copper or silver medals with black and gold ribbons as proof of protection and friendship (Eshleman 1909:84). Members of the Virginia militia, led by Colonel John Washington, George Washington's grandfather, refused to believe that Susquehannocks were not involved in the Doeg incident, summarily executed the hostages, and began a siege of the fort.

Approximately six weeks later, the remaining Susquehannock men, women, and children fled the fort, killing as many as 10 of the encamped militia in the process (Eshleman 1909; Ferguson 1941; Kellock 1962; Toogood 1969; Axelrod 1993; Webb 1995). The aftereffects of this siege added to growing unrest between colonists and natives. After their escape from the fort, Susquehannocks retaliated for the five slain hostages by hassling and possibly killing local Virginia colonists. When the Virginia governor, Sir William Berkeley, did not pursue a reprisal against the Susquehannocks, it caused even greater unrest among colonists (Jennings 1978, 1984; Axelrod 1993). Nathaniel Bacon and his followers used the siege and lack of action against the Susquehannocks by Governor Berkeley to incite a colonial rebellion. Bacon's Rebellion (1676–1677) ousted the governor from colonial Virginia and caused the destruction of the settlement of Jamestown (Berry et al. 1915). In 1763, the last Susquehannocks living in the lower Susquehanna Valley were massacred in Conestoga, Pennsylvania, by a vigilante group, the Paxton Boys (Eshleman 1909; Jennings 1978; Tooker 1984).

The Skeleton as a Record of Lived Experience

Human remains provide a unique opportunity to learn about the lives of ancient people (Larsen 1997, 2015; Buikstra and Beck 2006; Knudson and Stojanowski 2010; Agarwal and Glencross 2011; Baadsgaard et al. 2011). People's social lives become inscribed on their bodies through the physical practices of daily living (Bourdieu 1977; Sofaer 2006; Budden and Sofaer 2009; Merleau-Ponty 2013). In particular, bioarchaeological analyses have been used to examine systemic stressors and diet in a wide range of societies; e.g., Baadsgaard et al. (2011), Buikstra and Beck (2006), Cohen and Armelagos (1984), Huss-Ashmore et al. (1982), Larsen (1997, 2015), Larsen and Milner (1994), and Steckel and Rose (2002). Using what we know about Susquehannocks from the archaeological and historical records, we are provided with an outline of their social history that can help contextualize their skeletal remains. As previously noted, at the time of first European documentation (ca. 1608), Susquehannocks had a varied diet with access to local cultivated and wild food resources. However, many disruptions to their traditional way of life, especially prior to the Treaty of Friendship in 1652, likely resulted in reduced dietary variety, greater transmission of disease, and greater risk of interpersonal violence. These changes may be visible on the skeletal remains of Susquehannocks as indicators of (1) trauma, (2) growth disruption, (3) anemia, and (4) changes in oral health. By examining Susquehannock skeletal remains, we are able to test our hypotheses about the differences between pre- and post-treaty life at a group level.

Our analyses follow other bioarchaeological studies that have used skeletal evidence to measure the wellbeing of Native Americans during the protohistoric and historical periods in the eastern United States; e.g., Baker and Kealhofer (1996), Buikstra (1992), Larsen (2001), Larsen, Griffin et al. (2001), and Larsen and Milner (1994). For example, human dental remains have often been used to investigate diet (Lukacs 1989; Hillson 1996, 2000). In particular, and of interest in this study, changes in the frequency of oral conditions have been used to track dietary- and, consequently, subsistence-related economic and sociopolitical change; e.g., Cohen and Armelagos (1984), Gagnon and Wiesen (2013), Hillson (1996), Kelley and Larsen (1991), and Turner (1979). Oral health conditions are characterized by complex etiologies, many of which are discussed in the next few sections. Because of these complexities, it is only by examining indicators at the population level that we can use them to begin to track pre- to post-treaty dietary change among these Susquehannock groups.

There are concerns with modelling this work after early skeletal biology research on health and wellbeing that used the presence of bony lesions as direct evidence of health insults. In these prior studies, frequencies of lesions caused by anemia and growth disruption in burial samples were used as metrics of population systemic stress, which was then extrapolated across burial samples to provide information about the relative "good" or "poor" health status of socially defined groups. As noted by Wood et al. (1992) in their article on the "Osteological Paradox," there is an obvious contradiction in using the dead to estimate the health of the living, as the dead are clearly in the most extreme state of poor health and, thus, not representative of the living population to which they belonged. Moreover, it must be recognized that, while skeletal lesions are manifestations of physiological stress, they alone cannot act as measures of such a complex process as health (Reitsma and McIlvaine 2014; Temple and Goodman 2014). The approach Wood et al. (1992) and others[3] suggest addresses the "hidden heterogeneity of risks" and "selective mortality" as factors that directly impact the way well-being and stress-lesion frequencies that characterize burial groups can be interpreted.

To address the hidden heterogeneity of risks, a focus on burials recovered from small-scale tribal groups' cemeteries that represent decades of use (i.e., limited periods) rather than multiple generations (i.e., hundreds of years) is recommended (Wood et al. 1992). This renders these cemeteries more socially and culturally homogeneous, limiting some of the cultural sources of variation in risk related to disease exposure and death. Thus, remains, such as those of the Susquehannocks analyzed in this study, are expected to be less affected by the problem of heterogeneous risk/frailty, as each burial sample represents one cultural group, and because cemeteries were used for short periods of time, especially when compared to burials recovered from graveyards used over generations by ethnically and socially diverse complex polities. In addition, the use of demographic factors in the analysis of stress recorded in the skeleton permits the consideration of selective mortality and,

[3] For recent and thorough reviews of the osteological paradox, see DeWitte and Stojanowski (2015) and Wright and Yoder (2003).

thus, guards against simply assuming that lesion frequency is a direct measure of health status (DeWitte and Wood 2008; Temple and Goodman 2014; DeWitte and Stojanowski 2015). What follows is an etiological explanation of how each condition (i.e., trauma, growth disruption, anemia, and oral health) can occur, their effects on the living human skeleton, and how these may be located and interpreted from deceased individuals' bones.

Trauma

Trauma to any skeletal element can give valuable information about the lifestyle of a group, helping describe risks, culturally approved behavior, and social interactions. Generally described as violent injury damage to living tissue from a force or mechanism, trauma can include environmental hazards, interpersonal violence, legalized trauma, or self-violence (Ortner and Putschar 1985; Waldron 1996; Lovell 1997; Aufderheide and Rodríguez-Martín 1998; Ortner 2003; Martin and Harrod 2015). Regardless of the ultimate and proximate causes, skeletal trauma can be separated into two categories, dislocations and fractures (Lovell 1997). Dislocations occur when a bone is displaced from the articular joint surface, and skeletal evidence of this condition depends upon how serious and long term the dislocation was. In certain cases, individuals had use of the joint, as those seen in most cases of hip dislocation (Lovell 1997; Aufderheide and Rodríguez-Martín 1998). In other cases, rupture of the synovial fluid sac causes bone necrosis that is easily identifiable (Merbs 1989; Lovell 1997).

Unlike dislocations, fractures involve the actual breaking of the bone. These breaks are categorized by the type of force applied (i.e., tension, compression, torsion, bending, shearing) and described as "indirect" if force results in an oblique, spiral, greenstick, impaction, or avulsion fracture, and "direct" if force results in a transverse, penetrating, comminuted, or crush fracture (Lovell 1997:142–143). Any fracture type can be either compound, if the bone has broken through the skin and there is risk of infection, or simple, if the break is contained and skin is not broken. Osteologically, bone involvement showing infection can distinguish compound from simple fractures (Ortner and Putschar 1985; Merbs 1989; Lovell 1997; Aufderheide and Rodríguez-Martín 1998; Ortner 2003).

Bioarchaeologists often use the pattern of dislocation or fracture to determine if the context of causative trauma was likely accidental (e.g., wrist fracture due to a fall) or interpersonal (e.g., repeated blows to the left side of the cranium). In addition, levels of healing (i.e., fully healed, partially healed, no healing) are used to estimate whether the person survived the trauma (i.e., antemortem) or died at or around the time the violence occurred (i.e., perimortem). Breakage patterns also provide bioarchaeological clues to the perimortem or postmortem nature of trauma, as dry bone has a very different fracture pattern from living bone (Merbs 1989; Lovell 1997).

Growth Disruption

Episodes of childhood-growth disturbance resulting from poor nutrition or infection can leave evidence on permanent teeth in the form of linear enamel hypoplasia (LEH) (Goodman, Armelagos et al. 1980; Hutchinson and Larsen 1988; Lamphear 1990; Duray 1996; Hillson 1996; Nelson et al. 2013). LEH occurs during tooth-crown formation, a process in which ameloblasts secrete a matrix that is replaced by apatite crystals during calcification. The matrix orients the apatite crystals in bundles, which, in turn, form enamel prisms. If the ameloblast secretory process is disrupted, the direction of its movement may be altered, as well as the chemical composition of the matrix, thus affecting the enamel prisms. These changes, called Wilson bands, are visible with a microscope once the tooth has erupted (Rose et al. 1985; Hillson 1996). If the disturbance continues, the ameloblasts will cease to make the matrix and no enamel will be laid down. Once the disturbance has ended, ameloblasts resume their secretory function. An area of decreased enamel thickness caused by the cessation in enamel formation is macroscopically visible upon tooth eruption (Rose et al. 1985). The area of decreased enamel thickness begins as a pit. The number of pits formed reflects the number of ameloblasts affected. When a series of ameloblasts are affected, the result is a line of pits that is smooth in appearance. Enamel, once formed, is not remodeled, thus hypoplastic lines are permanent features of growth disruption.

Hypoplastic defects had been noted on all deciduous and permanent teeth in prior research, with the possible exception of third molars; however, anterior teeth, namely incisors and canines, are more susceptible to stress-induced hypoplasias (Lamphear 1990).

Goodman and Armelagos (1985) attribute these differences to the greater developmental stability of the anterior teeth. Posterior teeth, which are less developmentally stable, may respond to stress through a decrease in size and/or a slowing of development, rather than through a complete cession of growth. Trauma, systemic stresses (such as malnutrition), and infectious disease can injure the ameloblasts and cause the cessation of their activity (Sweeney et al. 1969; Goodman and Armelagos 1985; Goodman 1988). Trauma-induced hypoplastic defects appear only on the injured and possibly the adjacent teeth. In contrast, hypoplasias due to general systemic stress are usually found on all teeth that were developing during the period of insult. This difference allows for differential diagnosis of the cause of LEH (Goodman and Armelagos 1985).

Anemia

Anemia is a condition characterized by a decrease in the amount of iron circulating in the bloodstream (Stuart-Madacam 1985; Roberts and Manchester 1995), which leads to the production of iron-deficient red-blood cells that cannot adequately transport oxygen. The result is often poor health and lowered work capacity (Roberts and Manchester 1995; Sullivan 2005). Anemia can be caused by diets deficient in iron, vitamin B_{12}, or folic acid, or by gastrointestinal parasites, and diarrheal or malarial infections, as well as hemolysis resulting from one of many genetic red-blood-cell variations found in environments with long-term, endemic malaria (Stuart-Macadam and S. Kent 1992; Walker et al. 2009). In cases of sustained anemia, the body responds through hypertrophy of the marrow cavity, increasing the hemopoietic marrow and, thus, red-blood-cell production capacity. This response is more common among children than among adults because, under non-anemic conditions, more of a child's marrow cavity is actively producing red-blood cells (Roberts and Manchester 1995; Sullivan 2005).

Although there is still debate in the literature, it is generally accepted that an increase in hemopoietic marrow results in expansion of the spongy, internal cranial bone (i.e., diploë) at the expense of the outer table of bone, resulting in macroscopically visible lesions on the cranium (Lallo et al. 1977; Mensforth et al. 1978; Goodman, Martin et al. 1984; Stuart-Madacam and S. Kent 1992; Walker et al. 2009; Oxenham and Cavill 2010; Smith-Guzmán 2015). When such lesions affect the superior surface of the eye orbits, they are generally referred to as cribra orbitalia (CO), while lesions that affect the superior and posterior portions of the parietals and the squama of the occipital are denoted as porotic hyperostosis (PH). The etiology of CO is much more poorly understood than that of PH, and there is some suggestion that, in children, these lesions may be the result of sub-periosteal inflammation resulting from scurvy or rickets caused by vitamin C or D deficiency, respectively (Walker et al. 2009). The presence of CO or PH, then, is a manifest indication that the affected individual was poorly nourished, subject to infection, and/or had a genetic anemia. In addition, these lesions suggest that the individual was healthy enough to survive for the time required to develop a bony response to the stress or stressors (Wood et al. 1992). Given that neither genetic anemias nor malaria appear to have been present in the Americas before European contact (Ortner and Putschar 1985), and that it appears malaria did not become endemic in the Chesapeake area until 1680 (Hutchinson 2016), we can assume that anemic responses among the individuals examined for this study indicate insufficient diet, non-malarial infection, or a synergetic interaction of these conditions.

Oral Health

Dental conditions that provide evidence of diet include dental caries, dental abscess, and antemortem tooth loss (AMTL). Dental carious lesions are areas of localized destruction caused by the acidic byproducts of bacterial fermentation of carbohydrates (Ortner and Putschar 1985; Larsen 1997, 2015; Ortner 2003). Diets high in carbohydrates and sugars promote cavitation, as they provide food for bacteria (Goodman, Martin et al. 1984; Ortner and Putschar 1985; Larsen, Shavit et al. 1991). In addition, increasing carbohydrate consumption results in an increased colonization of dental plaque by *Streptococci mutans*, *S. sobrinus*, and *Lactobacillus* sp., the first two being strongly linked to caries formation and the latter group to caries progression (Van Houte 1994). The presence of these bacteria decrease plaque pH, thus increasing its cariogenic potential, in addition to providing an environment that is inhospitable for less acid-tolerant and less cariogenic bacteria (Van Houte 1994; Lingström et al. 2000). Although carbohydrate and sugar consumption provides food sources for bacteria, other factors, such as tooth shape, help create an oral environment suitable for caries

formation (Hillson 1986; Lukacs 1989). Small grooves and fissures between cusps on the surface of premolars and molars provide a protected environment for bacteria, making these teeth more prone to carious lesions than incisors or canines. The shape and large size of premolars and molars (compared to incisors and canines) results in greater areas of contact between posterior teeth. These interproximal contact areas are also caries prone.

A final factor to be considered in caries formation is saliva flow (Van Houte 1994). Lukacs and Largaespada (2006) summarize the functions of saliva, many of which provide protective effects. These functions include mechanical removal of food debris from tooth surfaces; formation of the salivary pellicle, which coats enamel; buffering oral pH, thus creating an environment less hospitable for cariogenic bacteria and neutralizing the acid byproducts of bacterial activity; raising the level of antimicrobial proteins in the oral cavity; and introducing calcium and phosphorus ions that bond with enamel, thus increasing its hardness and making it more resistant to bacterial acids. Because of these protective effects, reduced saliva flow is associated with increased caries formation. Saliva flow is reduced with age (Streckfus et al. 1998; Dodds et al. 2005), which may contribute to the age-progressive nature of dental caries. Women have lower saliva flow rates than men (Dodds et al. 2005), making them more prone to caries. In addition, women experience changes in the composition of saliva during pregnancy, which decreases their saliva's buffering and hardening capacities (Salvolini et al. 1998).

Dental caries, as well as dental trauma, can expose living tissue in the pulp chamber to the oral environment, which leads to pulpitis and, ultimately, pulp death (Clarke and Hirsch 1991). Once pulp death has occurred, bacteria, their waste, and the histological products of inflammation travel through apical foramen at teeth root tips and into the periodontal tissue. As a result, the apical alveolar bone is resorbed. Eventually, sufficient pus may accumulate to erode the bone and allow for drainage. This stage is described as an abscess (Hillson 1996). The ultimate result of dental abscess (caused by carious lesions, extreme wear, or dental trauma) is AMTL (Ortner and Putschar 1985; Ortner 2003).

As the above review suggests, although bony stress lesions have complex and synergistic etiologies, several key causative factors include (1) subsistence change, such as decreasing diet quality resulting from increased carbohydrate consumption, reduced consumption of animal protein, or narrowing of diet breadth; and (2) increasing rates of infection resulting from increased sedentism and population density, or exposure to waterborne pathogens found in contaminated water supplies or marine foods (Ortner and Putschar 1985; Walker 1986; Larsen 1997, 2015; Ortner 2003; Blom et al. 2005). It is also important to note that only chronic, not acute, conditions are manifest in the skeleton. Hence, these data cannot reveal information about brief dietary shifts, short-term nutritional stress, or swift-acting disease, and, instead, better reflect change over longer periods.

Susquehannock Remains: Materials

A total of 102 individuals[4] were examined for this analysis (Table 1). This sample includes all the remains of all Susquehannocks excavated from the lower Susquehanna Valley and Piscataway Creek regions, covering the period in question, that are available and well-enough preserved to be analyzed. Of these, 44 were excavated between 1955 and 1985, from five sites located within 5 mi. of each other along the eastern bank of the Susquehanna River, Pennsylvania (Fig. 1). These remains are in fair to good condition and are housed at either the Pennsylvania Historical and Museum Commission (Harrisburg) or the North Museum of Natural History and Science (Lancaster). The sites from which the skeletal collections were recovered represent short-term occupations that began 50 years after Verrazzano's voyage of 1524. The sites from which recovered remains were analyzed include Schultz (36La7) and Blue Rock (36La37), dated 1575–1600; Ibaugh (36La54) and Reitz (36La92), dated 1600–1625; and Frey-Haverstick (36La6), dated 1625–1645. Although a complete discussion of the excavation history of these sites is beyond the scope of this article, a review of the relevant literature is available (Gagnon 1996). In general, the cultural affiliations of the burials used in this study were

[4] Collections housed at the Pennsylvania Historical and Museum Commission and the North Museum of Natural History and Science have been inventoried in accordance with NAGPRA regulations, but were not claimed by any descendent group at the time of study. Remains housed at the Smithsonian are held under the 1989 National Museum of the American Indian Act (NMAI Act), Public Law 101–185, and, at the time of data collection, there were no claimants for repatriation.

Table 1 List of sites used in this study

Period	Site	Individuals	Excavator	Excavation Year	Citation
Pre-treaty					
1575–1600	36La7 Schultz	5	Smith	1969	Cadzow (1936), S. Kent (1986), I. Smith (1970)
1575–1600	36La37 Blue Rock	10	Heisey	1960	Heisey and Witmer (1962)
1600–1625	36La54 Ibaugh	14	Kinsey	1958	Kinsey (1960), Kinsey and Graybill (1971)
1600–1625	36La92 Reitz	2	Holtzinger	1962	B. Kent (1984)
1625–1645	36La6 Frey-Haverstick	13	Kent	1971	B. Kent (1984)
Post-treaty					
1674–1675	18Pr8 Clagett's Cove	58	Ferguson	1939	Ferguson (1941)

determined based on the reported presence (in the original excavation notes and publication) of characteristic Susquehannock ceramics and pipes, or period-appropriate European trade goods, such as beads, iron tools, and gun parts. The earliest possible date of these burials, 1575, precedes John Smith's first mention of the Susquehannocks in 1608. However, the very presence of trade goods in the earliest burials included in this study indicate that Susquehannock lives were impacted by Europeans before Smith's exploration of the Chesapeake.

The later, historical period sample of Susquehannocks (n=58), from the site of the square, palisaded fort at Clagett's Cove (18PR8) on the Piscataway Creek in Maryland, was also included in this study. This skeletal sample, with good preservation, represents Susquehannock peoples who died during a two-year occupation (1674–1675) of the site by migrants (Ferguson 1941; Jennings 1968, 1978, 1982; Toogood 1969; Axelrod 1993; Potter 1993). In order to establish cultural affiliation within the fort, Ferguson (1941) excavated a pit containing complete burials, Native American pottery, clay-pipe fragments, and two intact clay pipes. These two intact pipes, described initially as Iroquoian and noted as identical to ones found in Susquehannock burials in Pennsylvania (Cadzow 1936; Ferguson 1941), were later confirmed by Curry (1999) as Susquehannock. Trade materials (i.e., three mouth harps, seven copper hawk bells, eight iron brackets, an iron hoe, a copper finger ring set with glass, a snuff box, fragments of a pair of scissors, and a flattened lead musket ball) from this burial pit were also noted by Ferguson as similar to those excavated at Pennsylvania Susquehannock sites (Cadzow 1936). These skeletal remains and artifacts associated with the 18PR8 fort site are housed at the National Museum of Natural History, Smithsonian Institution (Washington, D.C.). While the Pennsylvania samples consist of individual burials, the Maryland collection postcrania lack provenience due to post-excavation comingling with other collections excavated in this area; see Simon (2003) for a full explanation. Thus, the focus in this research documents oral health and stress indictors that are visible on the dentition and crania of known provenience.

Susquehannock Remains: Methods

Age at death of the individuals recovered from the six Pennsylvania Susquehannock sites was estimated using standard methods and previously established protocols in order to make data-collection methods as comparable as possible (Simon and Gagnon 2005; Gagnon 2006). In both pre- and post-treaty samples, subadult age estimates were based primarily on tooth formation and eruption (White 1991; Hillson 1996). Skeletal development, including long-bone length and the state of element fusion, was also considered for pre-treaty individuals, as they had associated postcranial remains (Johnston 1962; Scheuer and Black 2004). Based on these observations, individuals were assigned an age with an error estimate. In general, age at death is more difficult to estimate for adults than for subadults (Hoppa 2002). As the pre-treaty remains include crania and their

associated post-crania, primary focus was given to age-related changes of the pubic symphyses (Suchey and Katz 1986; Suchey et al. 1988) and of the auricular surfaces of the os coxa (Lovejoy et al. 1985; Buikstra and Ubelaker 1994), as well as cranial-suture closure (Buikstra and Ubelaker 1994). Age estimates of post-treaty adults were based on suture closure (Buikstra and Ubelaker 1994) and the general state of occlusal-surface wear on teeth (Brothwell 1981; B. Smith 1984). In order to address potential differences in adult age estimations resulting from the lack of associated postcranial remains in the post-treaty sample, age at death was transformed into an ordinal variable for these analyses, with subdults characterized in 5-year intervals and adults grouped as young (20–34 years), middle (35–50 years), or old (+50 years).

In order to analyze these skeletal collections for evidence of trauma, growth disruption, anemia, and oral health, data were collected by individual cranium and for each tooth within each individual wherever possible. For trauma, all elements were examined for evidence of ante- or perimortem trauma. If identified, trauma was recorded by element and noted as healed, partially healed, or unhealed (Bass 1981; Christensen et al. 2014). LEH and skeletal evidence of anemia were used as indicators of growth disruption and metabolic changes associated with skeletal stress. Observations of LEH were made on developmentally complete anterior teeth only, as premolars and molars are less commonly affected (Goodman and Armelagos 1985). In an effort to maximize sample size, all well-preserved permanent incisors and canines were examined with a 10× hand lens in raking light (Hutchinson and Larsen 1988; Goodman, Martinez et al. 1991; Hillson 2000). To analyze the remains for evidence of anemic responses, the frontal, parietals, and occipital of each individual were examined (Stuart-Macadam 1985, 1992a, 1992b; S. Kent 1986; Walker 1986). The presence of CO was noted only in cases of sufficient eye-orbit preservation and when the superior surface of both right and left eye orbits were affected. Similarly, a PH diagnosis required that at least both right and left parietals show porosity.

Dental caries, dental abscess, and AMTL were evaluated to assess changes in diet. All intact teeth were examined for dental caries using a 10× hand lens. While it can be difficult to differentially diagnose the early stages of cavity formation from developmental irregularities or staining, a lesion was only recorded as present when it could be seen as an irregular bordered and discolored lesion that perforated the enamel (Hillson 1986, 2000; Larsen, Shavit et al. 1991; Larsen 1997, 2015). As previously noted, different tooth types vary in their susceptibility to caries, and, thus, abscessing and AMTL. To address this issue, teeth were grouped in four categories for statistical analyses: (1) anterior (incisors and canines), (2) premolars, (3) first and second molars, and (4) third molars.

Dental abscessing was noted as affecting a preserved maxillary or mandibular alveolus when the wall of the socket was perforated and showed bony reaction indicative of response to the infection (Hillson 1986, 2000; Larsen 1997, 2015; Aufderheide and Rodríguez-Martín 1998). Due to variations in preservation, excavation techniques, and museum curation, a number of teeth were lost from the collection postmortem. In order to differentiate maxillary and mandibular antemortem from postmortem tooth loss and thereby track consumption patterns, only losses showing evidence of alveolar remodeling were considered affected by this condition (Hillson 1986, 2000; Larsen 1997, 2015).

Multiple statistical methods were used to examine differences in skeletal manifestations of trauma, stress (growth disruption and anemia), and oral health (dental caries, dental abscess, and AMTL). Differences between the pre- and post-treaty samples in the number of people affected by trauma, LEH, CO, and PH were first examined using 2 × 2 contingency tables and calculation of the Fisher's exact test. Because both indicators of anemia (CO and PH) generally suggest a childhood condition (Roberts and Manchester 1995; Sullivan 2005) and lesions can heal over time, subadults and adults were analyzed separately.

Second, to examine the possible role of frailty relative to the stress indicators, additional statistical analyses were conducted for LEH, PH, and CO. We used logistic regression to examine whether the presence of LEH was a predictor of age at death (DeWitte and Wood 2008). If differential frailty affected one or both samples, we would expect the presence of LEH to predict age at death because the stress that precipitated these growth-arrest events effected later risk of death. Assessing whether CO and PH impacted later risk of death is more difficult than for LEH because, unlike LEH, these manifestations of childhood stress can be remodeled later in life, and, so, children are expected to be more often affected by both CO and PH than adults. However, particular age patterning of rates might suggest sample differences in frailty relative to anemia. If

Fisher's exact tests showed significantly higher rates of healed CO or PH in adults than in children, it could indicate that, as children, these adults were less frail and thus survived childhood stress, going on to become adults displaying healed lesions. This is the crux of the osteological paradox (Wood et al. 1992).

To examine rates of oral health, two methods were used. First, following Turner (1979), teeth were pooled by period, then examined using 2 × 2 contingency tables and Fisher's exact tests. However, because each individual may have as many as, but not necessarily all, 32 teeth, and different tooth types are differentially prone to various oral health conditions, simple pooling is insufficient to fully explore differences in oral health (see Gagnon and Wiesen [2013] for a full discussion of statistical issues associated with oral health measures). To address this problem, dental comparisons were performed using generalized estimating equations (GEE), an extension of logistic regression that allows for nested sampling and adjusts for scalar issues of sample effects using model estimates of population parameters (Liang and Scott 1986). It does this by weighting the value of pathological tooth by type (i.e., anterior, premolar, first and second molars, and third molar) according to how much information it provides about the individual and adjusting rates for variations in age at death. This statistical method keeps assumptions of independence intact by not permitting one individual more prone to dental disease to bias the sample population and maintains the breadth of the data (i.e., multiple teeth per individual person) by not reducing the sample to individual present/absent comparisons. These dental data results were calculated in SAS 9.3, using the Wald test to identify a statistically significant relationship (p>.05) with a dependent variable (Liang and Scott 1986). Using these methods, the GEE program generated frequency estimates allowing for comparisons between each population. As noted in other studies, e.g., Becker (2013b, 2017), Gagnon (2004a, 2006), Gagnon and Wiesen (2013), Nikita (2014, 2015), and Michopoulou et al. (2015), these statistical methods are appropriate for bioarchaeological examinations.

Results

The demographic profiles of both the pre-treaty and post-treaty samples are quite similar, making comparisons between the two groups' rates of stress and dietary indicators reasonable (Table 2). Although the pre-treaty sample was smaller than the post-treaty sample, the earlier group included a smaller number of individuals of unidentified age than did the latter (11% and 22%, respectively). This difference is likely because the post-treaty sample did not have provenienced postcranial remains to aid in age estimation, but the pre-treaty samples did. This increase in individuals of indeterminate age at death in the post-treaty sample resulted in a slight decrease in the percentage of individuals in all other age categories in comparison to the pre-treaty sample.

No children under 2 years old were identified in either sample, and children under 13 years made up only 18% of the pre-treaty sample and 12% of the post-treaty sample. It is therefore clear that children were significantly underrepresented in both groups: in pre-industrialized societies approximately 50% mortality before age five is expected (Coale and Demeny 1966).

In terms of the indicators of lifestyle change, individual crania from neither sample displayed evidence of antemortem or perimortem trauma (Table 3). Although not a direct purpose of this research, several possible cases of treponemal infection were noted among the study samples. The affected individuals include an adult from the pre-treaty site 36La37 and three adults from the post-treaty Susquehannock fort (Table 3). No cases of mulberry molars or Hutchinson's incisors, both indications of congenital syphilis, were identified. Among the postcranial remains of the pre-treaty sample, tibiae were the long bones most commonly affected by both active and healed periosteal reaction (Gagnon 1996). This condition, while often associated with treponemal infection, cannot be definitively diagnosed. Periosteal reaction was also noted among the unprovenienced skeletal

Table 2 Minimum number of individuals (MNI) and distribution by age

Age	Pre-Treaty Individuals	Post-Treaty Individuals	Total
Neonate–infant (0–2)	0	0	0
Child (3–12)	8 (18%)	7 (12%)	15
Adolescent (13–19)	1 (02%)	1 (02%)	2
Adult (20–44)	28 (64%)	36 (62%)	64
Old adult (45+)	2 (05%)	1 (02%)	3
Indeterminate	5 (11%)	13 (22%)	18
Total	44	58	102

Table 3 Pathology and trauma prevalence by individual

Condition	Pre-Treaty Total (*N*)	Pre-Treaty % Affected	Post-Treaty Total (*N*)	Post-Treaty % Affected	Fisher's Exact *P*
LEH	**35**	**80.0**	**28**	**25.0**	**.0001**
	Subadult (*N*)	% Affected	Subadult (*N*)	% Affected	Fisher's Exact *P*
Cranial trauma	8	0	7	0	
CO	3	66.7	1	0	1.000
PH	2	0	7	0	
	Adults (*N*)	% Affected	Adults (*N*)	% Affected	Fisher's Exact *P*
Cranial trauma	14	0	31	0	
CO	12	25.0	26	7.7	.301
PH	10	10.0	30	3.3	.442
Treponematosis	14	7.1	31	9.8	1.000

remains from Maryland, with tibiae showing the greatest levels of involvement (Simon 2003). These results do not support historical accounts of violence or violent interactions, but do support reports of disease outbreaks among the Susquehannock.

Of the 102 individuals examined, approximately half could be inspected for LEH. Pre-treaty individuals were more than three times as likely to be affected as post-treaty individuals (Table 3), a difference that was statically significant. However, LEH was not found to be a predictor of age at death in either the pre-treaty or the post-treaty samples (Table 4). This suggests that the stress, which precipitated these growth-arrest events, did not impact later risk of death, and, thus, differences between the groups in the percentage of individuals affected represent differences in actual experienced stress.

Among the small number of subadults who could be observed for active anemic responses, two cases of CO (66.7%) were found in pre-treaty individuals, and no cases were identified among the post-treaty sample (Table 3). This difference is not statistically significant. No cases of PH were found in either subadult sample. In adults, a greater number could be examined for healed evidence of anemia, and rates of occurrence were greater than among subadults. Of pre-treaty adults, 25% displayed CO and 10% had PH. These rates were higher than the 7.7% CO and 3.3% PH found among the post-treaty individuals, but were not statistically significant. In addition, neither sample's adults were found to have significantly higher rates of CO or PH than children (Table 5). This suggests no difference between the samples in the impact that the stress that caused these anemic responses had on later risk of death.

Table 4 Logistic regression: LEH as predictor of age at death

Period	*N*	χ^2	*DF*	*P*
Pre-treaty	17	.6289	1	.4277
Post-treaty	31	3.5351	1	.0601

When evaluating indicators of diet, the age-progressive nature of dental pathological conditions was considered, so, for analyses, the sample was divided into deciduous teeth of subadults and permanent teeth of adults. Among children's deciduous teeth, the frequency of caries was found to be slightly higher in the post-treaty period, but this difference was not statistically significant (Table 6). In contrast to subadults, caries rates among adult teeth were higher in the pre-treaty sample than in the post-treaty sample (20.8% and 16.0%, respectively, Table 6). This difference was significant (Fisher's p=.0232). However, as the 2 × 2 contingency table analyses did not account for differences in adult ages at death, this analysis cannot fully address the age-progressive nature of oral health conditions. To address this shortcoming, GEE with logistic regression, which can adjust for greater variations in the samples, was also used to analyze dental caries. Carious lesions in deciduous teeth could not be examined using GEE, as the small sample size could not support the modeling. However, the adult sample was large enough to support GEE analyses, and the pooled-adult sample was compared across time (Table 7). None of the contrasts were found to be significant. However, GEE-estimated percentages show a temporal decrease in dental caries.

Table 5 Anemic responses by age

Sample	CO		PH		
	Total (N)	% Affected	Total (N)	% Affected	Fisher's Exact *P*
Pre-treaty					
Subadults	3	66.7	2	0.0	.242
Adults	12	25.0	10	10.0	1.000
Post-treaty					
Subadults	1	0.0	7	7.7	1.000
Adults	26	7.7	30	3.3	1.000

Overall rates of dental abscess were very low, with pre-treaty individuals less frequently affected than post-treaty individuals (1.4% and 4.6%, respectively) (Table 6). A temporal difference in the pooled sample was identified as significant by the Fisher's exact test (p=.006), but this difference was not significant in the GEE temporal contrast (Wald p=.0557) (Table 7).

Both pre- and post-treaty samples were affected by AMTL, with 24.2% and 23.7% of teeth, respectively, being lost before death (Table 6). Fisher's exact test by individual did not identify significant differences (p=.939). However, the GEE analysis did, showing the observed rate to be strongly affected by tooth representation, as the contrast identified the pre-treaty sample to have been more significantly impacted (Wald p=.0044) than the post-treaty sample (Table 7).

Discussion

Insults to the human skeleton can create skeletal markers that can provide clues about the living conditions of native groups (Cohen and Armelagos 1984; Cohen 1989; Goodman 1991; Goodman and Martin 2002; Knudson and Stojanowski 2010; Temple and Goodman 2014). We examined the skeletal remains of pre- and post-treaty Susquehannocks for evidence of trauma, growth disruption, anemic responses, and oral health insults. We expected to find that life was harder for the pre-treaty group of Susquehannocks, who had been buried in Pennsylvania prior to 1652, than for those who died after the Treaty of Friendship with the Maryland colony. However, we anticipated that trauma rates would stay consistent because of historical accounts of conflict between the Susquehannocks and other groups throughout the 1600s. Our analyses yielded a complex picture of the lived Susquehannock experience during the relatively short time from 1575 through 1675. This 100-year period was one of dramatic social change for the Susquehannocks, including contact with Europeans, loss of population from epidemic disease, warfare with both native and European groups, inconstant availability of local resources, and power fluctuations associated with the fur trade.

First, contrary to what we expected given historical accounts, there was no evidence of cranial trauma and only a few cases of antemortem postcranial trauma in these Susquehannock groups. As evidence for interpersonal violence is most commonly found on crania (Lambert 1994; Larsen 1997, 2015), and as historical

Table 6 Occurrence of dental pathological conditions

Condition	Pre-Treaty		Post-Treaty		
	Teeth (*N*)	% Affected	Teeth (*N*)	% Affected	Fisher's Exact *P*
Deciduous caries	54	11.1	34	14.7	.743
Adult caries	**385**	**20.8**	**445**	**16.0**	**.023**
Adult abscesses	**484**	**1.4**	**455**	**4.6**	**.006**
Adult AMTL	484	24.2	459	23.7	.939

Table 7 GEE estimates of adult dental pathological conditions (model adjusts for variation in tooth type present)

Condition	Teeth (*N*)	Pre-Treaty Estimated %	Post-Treaty Estimated %	Wald *P*
Caries	717	23.2	17.5	.4499
Abscesses	929	1.2	3.8	.0557
AMTL	**931**	**18.4**	**16.9**	**.0044**

records indicate extensive raiding documented in this region throughout the 1600s, the lack of any evidence of cranial trauma in these skeletal samples is particularly puzzling (Browne 1885b; Eshleman 1909; Cadzow 1936; Kellock 1962; Jennings 1966, 1968, 1978, 1982, 1984; Toogood 1969; B. Kent 1980, 1984; Land 1981; Tooker 1984; J. Jones 2013). There are several possibilities to explain this apparent absence. First, it is likely that many wounds affected only soft tissue. Second, it possible that the remains of people killed during warfare, as well as the bodies of Susquehannock hostages murdered at the start of the siege, were not recovered or returned to Susquehannock settlements for reburial. Finally, the interments of victims of violence may not have been excavated. However, we can only speculate about the lack of evidence of cranial trauma indicative of interpersonal violence in the pre- and post-treaty burials. Thus, although the history of the area would lead us to expect skeletal evidence of violent interactions, these skeletal samples do not provide evidence to bolster historical accounts.

Colonial records also indicate that Susquehannocks were victims of disease during the 1600s (Alchon 2003:132). Evidence of illness was found among Susquehannocks, with four adults showing skeletal pathological lesions consistent with treponemal disease. The cranial lesions identified are consistent with the rounded lesions that eroded through both outer and inner tables of cranial bone (i.e., gummatous caries sicca lesions) diagnostic of tertiary-stage acquired syphilis (Becker 2013a). In general, acquired syphilis has three stages with a sporadic latency period between the secondary and tertiary phases, a latency that lasts at least 1 year, but could be as long as 15–20 years. It also takes at least three years to reach the tertiary stage where the infection involves the skeleton (Aufderheide and Rodríguez-Martín 1998; M. Kent and Romanelli 2008). Thus, skeletal evidence of infection would require the initial infection to have taken place at least four years prior to death. Therefore, although the affected individuals were buried in Maryland, the short occupation of the Maryland fort suggests that the men were infected before their resettlement to Piscataway Creek. In addition, although no other definitive evidence of treponematosis was identified, significant tibial periosteal reactions among the population suggest it is possible that other members of the Susquehannock group were infected with this disease. Thus, the four diagnosed cases may represent only a portion of the infected population. As acquired syphilis has been called the "great imitator" due to the potential lack of symptoms in the primary stage and the variety of skin lesions in the secondary stage (M. Kent and Romanelli 2008; Centers for Disease Control and Prevention 2014), it may be that historical accounts of multiple Susquehannock smallpox outbreaks may represent not only smallpox, but also second-phase acquired syphilis.

The most enlightening skeletal change in this study was the evidence of LEH. Because LEH represents a growth interruption in enamel formation caused by systemic physiological strain (Hutchinson and Larsen 1988; Larsen 1997, 2015; Hillson 2000), its occurrence in these populations suggests that Susquehannocks weathered regular periods of stress, possibly caused by malnutrition, acute infections, or a synergetic interaction of both. Since the presence of LEH was not a predictor of age at death (along with no adults of either sample being more often affected by anemic response), we suggest that the events that caused these growth disturbances were not central factors in the frailty of the study individuals. Instead, the statistically significant decreases in LEH between the pre- and post-treaty samples indicate that these Susquehannocks enjoyed fewer episodes of stress and better metabolic health after 1645. Historical accounts describe a wide and varied seasonal diet among Susquehannocks (Guilday et al. 1962; Brashler 1987). As horticulturists, maize and other domestics were also key resources (Vogel and van der Merwe 1977; Prezzano and Rieth 2001), and the use of these resources appears to have increased in importance over time (Asch Sidell 2002; Knapp 2002). Hence, the historically noted years of warfare and land restriction (Gallatin 1836; Jennings 1968, 1982; Webb 1995; J. Jones 2013) may have decreased the Susquehannocks' ability to forage for wild resources, causing them to rely on a few dietary staples instead of their wide variety of foods prior to 1645. A similar pattern of resource restriction with focus on

domesticated staples has been documented among Mississippian groups of central Illinois during times of war (VanDerwarker and Wilson 2016). If violence interfered with Susquehannocks' cycle of planting and gathering, or if any of their key resources failed, the consequence could have been high levels of growth disruption noted as disturbances in enamel formation, especially as higher rates were found in the Pennsylvania sample. Thus, the drop in LEH rates likely involved a change that increased Susquehannock quality of life post-1645, in particular the signing the Treaty of Friendship with the colonial government of Maryland and the resulting reopening of hunting and harvesting lands to the south, away from the Iroquoian conflict.

Rates of both active CO and PH among subadults and healed lesions among adults were also higher among pre- than post-treaty individuals, although these differences were not significant. These conditions have been connected to iron, vitamin B_{12}, or folic acid insufficiency, as well as gastrointestinal parasites or diarrhea. Thus, dietary deficiencies or conditions that cause nutritional malabsorption may have been contributing factors to the development of anemia among Susquehannocks prior to 1645. This may be true especially if maize was the primary staple crop of the Susquehannocks (Vogel and van der Merwe 1977; Prezzano and Rieth 2001; Asch Sidell 2002; Knapp 2002) because maize is deficient in iron, vitamin B_{12}, and folic acid. In addition, maize contains iron-binding phytates (Loren 2008) that reduce the bioavailability of iron in meal that has not undergone nixtamalization. Hence, the consumption of maize as a staple food in a diet with reduced variety could have led to increased anemia rates and resulted in the elevated rates of CO and PH among pre-treaty individuals.

It is interesting to note that iron-rich marine resources, such as oysters and fish, if available in the Chesapeake region, could have offset micronutrient insufficiencies of a maize-heavy diet. Historical and ethnohistorical accounts do report marine exploitation and trade in marine resources by various native groups in the Mid-Atlantic, including the Susquehannock (Eshleman 1909; Ferguson and Ferguson 1960; Potter 1993; J. Jones 2013). A modern study by Layrisse et al. (1968) described cases of low iron among maize consumers that was raised significantly (300%) by the introduction of saltwater fish to the diet. MedlinePlus (2014) and the National Institutes of Health (2014) also list oysters, which are only able to survive in salinized waters, such as Chesapeake Bay, as a food containing a high bioavailability of iron and vitamin B_{12}. Because over 50% of the freshwater input to Chesapeake Bay enters from the north as the Susquehanna River drains into the bay, and less than 20% is provided by the Potomac River in the south (Schubel and Pritchard 1986), salinity increases as one moves south in the bay. Hence, marine resources high in iron (e.g., saltwater fish, oysters) would have been more readily available in the southern end of the bay and near the mouth of the Potomac River. Higher rates of PH and CO in the pre-treaty sample may indicate that higher-salinity areas and their resources were difficult for the Susquehannocks to access prior to the Treaty of Friendship. Hence, a reduction in the skeletal evidence of anemia in the post-1645 sample may have been a result of the addition or re-addition of marine resources to the diet during the post-treaty period.

Indicators of poor oral health were present in both pre- and post-treaty adults. Pre-treaty adults were more commonly affected by dental caries; however, the GEE analysis did not identify this difference as significant. Dental abscesses appeared, at first, to significantly increase in the post-treaty sample, but GEE analysis failed to support this finding. The indicator of oral health with the greatest significance appears to be AMTL, with overall rates decreasing from the pre- to post-treaty period. Given that AMTL is commonly caused by untreated dental caries and subsequent abscessing (Hillson 1986, 2000), the AMTL and dental caries data together suggest that the diet of pre-treaty Susquehannocks may have included a greater proportion of cariogenic foods than did the diet of the post-treaty peoples. Maize is a good candidate for this foodstuff, as it can be highly cariogenic, especially when prepared as soft, sticky corn porridge, commonly noted as a foodstuff among Native American groups in the eastern United States (Larsen 1991; King and Ubelaker 1995; Hillson 2000; Bonavia 2013).

Overall, the significant decrease in growth disruptions and AMTL, along with the decrease in anemic responses and dental caries in the post-treaty burial group, may represent longer periods of peace and the resumption of traditional seasonal food cycles. Historical accounts note Susquehannocks continued to use nearby Pennsylvania lands for food resources after the war with the Iroquois began early in the 1600s (Scharf 1882; Eshleman 1909), although these local lands may have been depleted by 1650 (J. Jones 2013:10). In addition, the colonial period border of the Maryland

colony, where Susquehannocks could have been shot on sight as enemies of this province (Sparks 1848; Browne 1885b; Eshleman 1909), was close to Lower Valley Susquehannock lands (Mathews 1898; Tittman 1909), likely restricting resource procurement in the southern region. Thus, even though many Susquehannocks in the post-treaty group experienced the war with the Iroquois, they could have increased their southern-ranging hunting, fishing, and gathering of lacustrine resources in Maryland after signing the Treaty of Friendship, benefiting from a more varied diet and safer hunting grounds (Hall 1910; Toogood 1969:44). In addition, the Susquehannocks' eventual move to Maryland may have been, in part, to continue utilizing resources in that area that had guarded against periods of hunger during the 1650s–1670s, thus reestablishing their seasonal food cycle as well as distancing themselves from the Iroquois.

Conclusions

This investigation examined embodied stress in two groups of Susquehannock Indians who lived during a period of approximately 100 years (ca. 1575–1675). Historical accounts of violence and disease resulting from Susquehannock contact with other local native groups as well as European colonists suggested to us that life during this period was stressful for Susquehannocks, and that our bioarchaeological data would show evidence of this stress. Both the pre-treaty sample from Pennsylvania and the post-treaty sample from Maryland include adults who had treponematosis at the times of their deaths, likely in the form of tertiary acquired syphilis. As it would have taken at least four years to reach the tertiary stage, the men buried in Maryland likely suffered the effects of their infection before their relocation to Piscataway Creek. We also documented significant decreases in LEH and AMTL in the post-treaty Maryland burial group, coupled with a consistent, but not significant, decrease in dental caries and anemic responses. Together the data suggest an improvement in diet among Susquehannocks in the 1650s and through the 1670s.

Historical accounts of warfare and conflict document the Susquehannocks fighting a two-front war prior to 1650, one against Iroquois and other northern neighbors, and another against Maryland colonists to the south. The Treaty of Friendship signed in 1652 between Susquehannocks and the Maryland government could have opened land previously under dispute and facilitated the return of Susquehannocks to a more traditional seasonal collection of foodstuffs, including iron-rich marine resources, thus leading to an improvement in their health. Finally, the lack of violence evidenced on the skeletal remains in this study sample is perplexing, as historical accounts describe significant warfare in the region. However, it is possible that the bodies of those killed in war, whether in various skirmishes in Pennsylvania or during the siege in Maryland, were not recovered. Hence, accounts of violence could be as described, but these people do not appear in our burial samples.

The Susquehannock samples in this study expand the understanding of historical and ethnohistorical accounts of the stress associated with native/colonial relationships in the Mid-Atlantic region. This research also highlights how recent concepts in bioarchaeology concerning the osteological paradox can be utilized by examining skeletal populations, even smaller ones as in these samples. Additionally, the use of multiple tests and statistical analyses can provide ways to address hidden heterogeneity of risks/frailty and selective mortality, which problematize simple interpretations of skeletal data, providing a window into the actual lived experience of Susquehannocks. For example, our data show that, after 1645, life was less stressful than previously, and the likely pivot point for this short-lived improvement was the signing of a Treaty of Friendship with Maryland's colonial government. While living conditions likely improved after 1645, the ongoing social conflicts and mistrust between Europeans and Native Americans took their toll on Susquehannocks. By 1675, they had suffered a violent siege of their fort by colonial militia and the death of five of their people held as hostages. The colonial response to these events eventually triggered Bacon's Rebellion and continued unrest in the region for years to come.

Acknowledgments: Access to collections was provided by the Pennsylvania Historical and Museum Commission, the State Museum of Pennsylvania, the North Museum of Natural Science, Franklin and Marshall College, and the National Museum of Natural History (NMNH), Smithsonian Institution. Funds for this research were provided by the NMNH and Arizona State University. Personal thanks go to Beth Miller, Dave Hunt, Doug Ubelaker, Charles Merbs, Karen Rosenberg, and Michael D. Scholl.

Compliance with ethical standards

Conflict of Interest Statement On behalf of all the authors, the corresponding author states that there is no conflict of interest.

References

Agarwal, Sabrina C., and Bonnie A. Glencross (editors)
2011 *Social Bioarchaeology*. Blackwell, Oxford, UK.

Alchon, Susan Austin
2003 *A Pest in the Land: New World Epidemics in a Global Perspective*. University of New Mexico Press, Albuquerque.

Asch Sidell, Nancy
2002 Paleoethnobotantical Indicators of Subsistence and Settlement Change in the North East. In *Northeast Subsistence—Settlement Change A.D. 700–1300*, John P. Hart and Christina B. Rieth, editors, pp. 241–263. New York State Museum/New York State Education Department, Albany.

Aufderheide, Arthur C., and Conrado Rodríguez-Martín
1998 *The Cambridge Encyclopedia of Human Paleopathology*. Cambridge University Press, Cambridge, UK.

Axelrod, Alan
1993 *Chronicle of the Indian Wars: From Colonial Times to Wounded Knee*. Prentice Hall, New York, NY.

Baadsgaard, Aubrey, Alexis T. Boutin, and Jane E. Buikstra (editors)
2011 *Breathing New Life into the Evidence of Death: Contemporary Approaches to Bioarchaeology*. School for Advanced Research Press, Santa Fe, NM.

Baker, Brenda J., and Lisa Kealhofer (editors)
1996 *Bioarchaeology of Native American Adaptation in the Spanish Borderlands*. University of Florida Press, Gainesville.

Bass, William M.
1981 *Human Osteology: A Laboratory and Field Manual of the Human Skeleton*. Missouri Archaeological Society, Columbia.

Becker, Sara K.
2013a Health Consequences of Contact on Two Seventeenth Century Native Groups from the Mid-Atlantic Region of Maryland. *International Journal of Historical Archaeology* 17(4):713–730.

Becker, Sara K.
2013b *Labor and the Rise of the Tiwanaku State (AD 500–1100): A Bioarchaeological Study of Activity Patterns*. Doctoral dissertation, Department of Anthropology, University of North Carolina at Chapel Hill, Chapel Hill. University Microfilms International, Ann Arbor, MI.

Becker, Sara K.
2017 Community Labor and Laboring Communities within the Tiwanaku State (C.E. 500–1100). *Archaeological Papers of the American Anthropological Association* 28(1):38–53.

Berry, John, Francis Moryson, and Herbert Jefferys
1915 A True Narrative of the Rise, Progress and Cessation of the Late Rebellion in Virginia, Most Humbly and Impartially Recorded by His Majesties Commissioners, Appointed to Inquire into the Affairs of the Said Colony. In *Narrative of the Insurrections 1675–1690*, Charles McLean Andrews, editor, pp. 111–113. Charles Scribner's Sons, New York, NY.

Blom, Deborah E., Jane E. Buikstra, L. Keng, P. D. Tomczak, and E. Shoreman
2005 Anemia and Childhood Morality: Latitudinal Patterning along the Coast of Pre-Columbian Peru. *American Journal of Physical Anthropology* 127(2):152–169.

Bonavia, Duccio
2013 *Maize: Origin, Domestication, and Its Role in the Development of Culture*. Cambridge University Press, New York, NY.

Bourdieu, Pierre
1977 *Outline of a Theory of Practice*. Cambridge University Press, Cambridge, UK.

Brashler, Janet G.
1987 A Middle 16th Century Susquehannock Village in Hampshire County, West Virginia. *West Virginia Archaeology* 39(2):1–30.

Brothwell, Don R.
1981 *Digging up Bones*. Oxford University Press, Oxford, UK.

Browne, William Hand (editor)
1885a *Archives of Maryland*, Vol. 1, *Proceedings and Acts of the General Assembly January 1637/8–September 1664*. Maryland Historical Society, Baltimore.

Browne, William Hand (editor)
1885b *Archives of Maryland*, Vol. 3, *Proceedings of the Council of Maryland 1636–1667*. Maryland Historical Society, Baltimore.

Budden, Sandy, and Joanna Sofaer
2009 Non-Discursive Knowledge and the Construction of Identity: Potters, Potting and Performance at the Bronze Age Tell of Százhalombatta, Hungary. *Cambridge Archaeological Journal* 19(2):203–220.

Buikstra, Jane E.
1992 Diet and Disease in Late Prehistory. In *Disease and Demography in the Americas*, John Verano and Douglas Ubelaker, editors, pp. 87–101. Smithsonian Institution Press, Washington, DC.

Buikstra, Jane E., and Lane A. Beck (editors)
2006 *Bioarchaeology: The Contextual Analysis of Human Remains*. Academic Press, Burlington, MA.

Buikstra, Jane. E., and Douglas H. Ubelaker
1994 *Standards for Data Collection from Human Skeletal Remains*. Arkansas Archaeological Survey, Research Series, No. 44. Fayetteville.

Cadzow, Donald A.
1936 *Archaeological Studies of the Susquehannock Indians of Pennsylvania*. Pennsylvania Historical and Museum Commission, Harrisburg.

Centers for Disease Control and Prevention
2014 Syphilis—CDC Fact Sheet. Sexually Transmitted Diseases (STDs), Centers for Disease Control and Prevention <http://www.cdc.gov/Std/Syphilis/Stdfact-Syphilis.htm>. Accessed 8 July 2014.

Christensen, Angi M., Nicholas V. Passalacqua, and Eric J. Bartelink
2014 *Forensic Anthropology: Current Methods and Practice*. Academic Press, San Diego, CA.

Clarke, Nigel G., and Robert S. Hirsch
1991 Physiological, Pulpal, and Periodontal Factors Influencing Alveolar Bone. In *Advances in Dental Anthropology*, Mark A. Kelley and Clark Spencer Larsen, editors, pp. 241–266. Wiley-Liss, New York, NY.

Coale, Ansley J., and Paul Demeny
1966 *Regional Model Life Tables and Stable Populations*. Princeton University Press, Princeton, NJ.

Cohen, Mark Nathan
1989 *Health and the Rise of Civilization*. Yale University Press, New Haven, CT.

Cohen, Mark Nathan, and George J. Armelagos (editors)
1984 *Paleopathology at the Origins of Agriculture*. Academic Press, Orlando, FL.

Curry, Dennis C.
1999 *Feast of the Dead: Aboriginal Ossuaries in Maryland*. Archeological Society of Maryland and Maryland Historical Trust Press, Myersville.

Custer, Jay F.
1989 *Prehistoric Cultures of the Delmarva Peninsula: An Archaeological Study*. Associated University Presses, Cranbury, NJ.

DeWitte, Sharon N., and Christopher M. Stojanowski
2015 The Osteological Paradox 20 Years Later: Past Perspectives, Future Directions. *Journal of Archaeological Research* 23(4):397–450.

DeWitte, Sharon N., and James W. Wood
2008 Selectivity of Black Death Mortality with Respect to Preexisting Health. *Proceedings of the National Academy of Sciences* 105(5):1436–1441.

Dodds, Michael, Dorthea A. Johnson, and Chih-Ko Yeh
2005 Health Benefits of Saliva: A Review. *Journal of Dentistry* 33(3):223–233.

Duray, Stephen M.
1996 Dental Indicators of Stress and Reduced Age at Death in Prehistoric Native Americans. *American Journal of Physical Anthroplogy* 99(2):275–286.

Eshleman, Henry Frank
1909 *Lancaster County Indians: Annals of the Susquehannocks and other Indian Tribes of the Susquehanna Territory from about the Year 1500 to 1763, the Date of Their Extinction. An Exhaustive and Interesting Series of Historical Papers Descriptive of Lancaster County's Indians Prior to and during the Advent of the Paleface*. Express Print Company, Lancaster, PA.

Ferguson, Alice L. L.
1941 The Susquehannock Fort on Piscataway Creek. *Maryland Historical Magazine* 36(1):1–9.

Ferguson, Alice L. L., and Henry G. Ferguson
1960 *The Piscataway Indians of Southern Maryland*. Alice Ferguson Foundation, Accokeek, MD.

Gagnon, Celeste M.
1996 The Effects of European Contact on Native American Health in the Lower Susquehanna River Valley. Master's thesis, Department of Anthropology, Arizona State University, Tempe.

Gagnon, Celeste M.
2004a Food and the State: Bioarchaeological Investigations of Diet in the Moche Valley of Peru. *Dental Anthropology Journal* 17(2):45–54.

Gagnon, Celeste M.
2004b Stability within the Context of Change: Native American Health during Contact in the Lower Susquehanna Valley, Pennsylvania. *Archaeology of Eastern North America* 32:101–121.

Gagnon, Celeste M.
2006 *Daily Life and the Development of the State in the Moche Valley of North Coastal Peru: A Bioarchaeological Analysis.* Doctoral dissertation, Department of Anthropology, University of North Carolina at Chapel Hill, Chapel Hill. University Microfilms International, Ann Arbor, MI.

Gagnon, Celeste M., and Chris Wiesen
2013 Using General Estimating Equations to Analyze Oral Health in the Moche Valley of Perú. *International Journal of Osteoarchaeology* 23(5): 557–572.

Gallatin, Albert
1836 *Synopsis of the Indian Tribes within the United States East of the Rocky Mountains and in the British and Russian Possessions in North America*. AMS Press, New York, NY.

Goodman, Alan H.
1988 Childhood Stress and Decreased Longevity in a Prehistoric Population. *American Anthropologist* 90(4):936–944.

Goodman, Alan H.
1991 Health, Adaptation and Maladaption in Past Societies. In *Health in Past Societies: Biocultural Interpretations of Human Skeletal Remains in Archaeological Contexts*, Helen Bush and Marke Zvelebil, editors, pp. 31–38. British Archaeology Reports, International Series S567. Oxford, UK.

Goodman, Alan H., and George J. Armelagos
1985 Factors Affecting the Distribution of Enamel Hypoplasias within the Human Permanent Dentition. *American Journal of Physical Anthropology* 68(4):479–493.

Goodman, Alan H., George J. Armelagos, and Jerome C. Rose
1980 Enamel Hypoplasias as Indicators of Stress in Three Prehistoric Populations from Illinois. *Human Biology* 52(3):515–528.

Goodman, Alan H., and Debra L. Martin
2002 Reconstructing Health Profiles from Skeletal Remains. In *The Backbone of History: Health and Nutrition in the Western Hemisphere*, Richard H. Steckel and Jerome C. Rose, editors, pp. 11–60. Cambridge University Press, New York, NY.

Goodman, Alan H., Debra L. Martin, and George J. Armelagos
1984 Indications of Stress from Bone and Teeth. In *Paleopathology at the Origins of Agriculture*,

Mark N. Cohen and George J. Armelagos, editors, pp. 13–49. Academic Press, New York, NY.

Goodman, Alan H., Celia Martinez, and Adolfo Chavez
1991 Nutritional Supplementation and the Development of Linear Enamel Hypoplasias in Children from Tezonteopan, Mexico. *American Journal of Clinical Nutrition* 53(3):773–781.

Grumet, Robert S.
1995 *Historic Contact*. University of Oklahoma Press, Norman.

Guilday, John E., Paul W. Parmalee, and Donald P. Tanner
1962 Aboriginal Butchering Techniques at the Eschelman Site (36 La 12), Lancaster County, Pennsylvania. *Pennsylvania Archaeologist* 32(2):59–83.

Hall, Clayton Coleman (editor)
1910 *Narratives of Early Maryland: 1633–1684*. Charles Scribner's Sons, New York, NY.

Hanna, Charles Augustus
1911 *The Wilderness Trail, or, the Ventures and Adventures of the Pennsylvania Traders on the Allegheny Path: With Some New Annals of the Old West, and the Records of Some Strong Men and Some Bad Ones*, Vol. 1. G. P. Putnam's Sons, New York, NY.

Heisey, Henry W., and J. Paul Witmer
1962 Of Historic Susquehannock Cemeteries. *Pennsylvania Archaeologist* 32(3&4):99–130.

Hillson, Simon
1986 *Teeth*. Cambridge University Press, Cambridge, UK.

Hillson, Simon
1996 *Dental Anthropology*. Cambridge University Press, Cambridge, UK.

Hillson, Simon
2000 Dental Pathology. In *Biological Anthropology of the Human Skeleton*, M. Anne Katzenberg and Shelley Saunders, editors, pp. 249–286. Wiley-Liss, New York, NY.

Hoppa, Robert D.
2002 Paleodemography: Looking Back and Thinking Ahead. In *Paleodemography*, Robert D. Hoppa and James W. Vaupel, editors, pp. 9–28. Cambridge University Press, Cambridge, UK.

Huss-Ashmore, Rebecca, Alan H. Goodman, and George J. Armelagos
1982 Nutritional Inference from Paleopathology. In *Advances in Archaeological Method and Theory*, Vol. 5, Michael B. Schiffer, editor, pp. 395–474. Academic Press, New York, NY.

Hutchinson, Dale L.
2016 *Disease and Discrimination*. University Press of Florida, Tallahassee.

Hutchinson, Dale L., and Clark Spencer Larsen
1988 Determination of Stress Episode Duration from Linear Enamel Hypoplasias: A Case Study from St. Catherines Island, Georgia. *Human Biology* 60(1):93–110.

Jennings, Francis
1966 The Indian Trade of the Susquehanna Valley. *Proceedings of the American Philosophical Society* 110(6):406–424.

Jennings, Francis
1968 Glory, Death, and Transfiguration: The Susquehannock Indians in the Seventeenth Century. *Proceedings of the American Philosophical Society* 112(1):15–53.

Jennings, Francis
1978 Susquehannock. In *Handbook of North American Indians*, Vol. 15, *Northeast*, B. Trigger, editor, pp. 362–367. Smithsonian Institution Press, Washington, DC.

Jennings, Francis
1982 Indians and Frontiers in Seventeenth-Century Maryland. In *Early Maryland in a Wider World*, David B. Quinn, editor, pp. 216–241. Wayne State University, Detroit, MI.

Jennings, Francis
1984 *The Ambiguous Iroquois Empire: The Covenant Chain of Indian Tribes with English Colonies*. Norton, New York, NY.

Johnston, Francis E.
1962 Growth of the Long Bones of Infants and Young Children at Indian Knoll. *American Journal of Physical Anthropology* 20(3):249–253.

Jones, Eric E., and Sharon N. DeWitte
2012 Using Spatial Analysis to Estimate Depopulation for Native American Populations in Northeastern North America, A.D. 1616–1645. *Journal of Anthropological Archaeology* 31(1):83–92.

Jones, Jacqueline
2013 *A Dreadful Deceit: The Myth of Race from the Colonial Era to Obama's America*. Basic, New York, NY.

Kelley, Marc A., and Clark Spencer Larsen (editors)
1991 *Advances in Dental Anthropology*. Wiley-Liss, New York, NY.

Kellock, Katherine A.
1962 *Colonial Piscataway in Maryland*. Alice Ferguson Foundation, Accokeek, MD.

Kent, Barry C.
1980 An Update on Susquehanna Iroquoian Pottery. In *Proceedings of the 1979 Iroquois Pottery Conference, Research Records No. 13*, Charles F. Hayes, editor, pp. 99–103. Rochester Museum and Science Center, Rochester, NY.

Kent, Barry C.
1984 *Susquehanna's Indians*. Pennsylvania Historical and Museum Commission, Anthropological Series No. 6. Harrisburg.

Kent, Molly E., and Frank Romanelli
2008 Reexamining Syphilis: An Update on Epidemiology, Clinical Manifestations, and

Management. *Annals of Pharmacotherapy* 42(2):226–236.

Kent, Susan
1986 The Influence of Sedentism and Aggregation on Porotic Hyperostosis and Anemia: A Case Study. *Journal of the Royal Anthropological Institute*, new ser., 21(4):605–636.

King, Julia A., and Douglas H. Ubelaker (editors)
1995 *Living and Dying on the 17th Century Patuxent Frontier*. Maryland Historical Trust Press, Crownsville.

Kinsey, Fred W.
1960 Additional Notes on the Albert Ibaugh Site. *Pennsylvania Archaeologist* 30(3&4):81–103.

Kinsey, Fred W., and Jeffery R. Graybill
1971 Murry Site and Its Role in Lancaster and Funk Phases of Shenks Ferry Culture. *Pennsylvania Archaeologist* 41(4):7–44.

Knapp, Timothy D.
2002 Pits, Plants, and Place: Recognizing Late Prehistoric Subsistence and Settlement Diversity in the Upper Susquehanna Drainage. In *Northeast Subsistence-Settlement Change A.D. 700–1300*, John P. Hart and Christina B. Rieth, editors, pp. 167–191. New York State Museum/New York State Education Department, Albany.

Knudson, Kelly J., and Christopher M. Stojanowski (editors)
2010 *Bioarchaeology and Identity in the Americas*. University Press of Florida, Gainesville.

Lallo, John W., George J. Armelagos, and Robert P. Mensforth
1977 The Role of Diet, Disease, and Physiology in the Origin of Porotic Hyperostosis. *Human Biology* 49(3):471–483.

Lambert, Patricia M.
1994 *War and Peace on the Western Front: A Study of Violent Conflict and Its Correlates in Prehistoric Hunter-Gatherer Societies of Coastal Southern California*. Doctoral dissertation, Department of Anthropology, University of California at Santa Barbara, Santa Barbara. University Microfilms International, Ann Arbor, MI.

Lamphear, Kim M.
1990 Frequency and Distribution of Enamel Hypoplasias in a Historic Skeletal Sample. *American Journal of Physical Anthropology* 81(1):35–43.

Land, Aubrey C.
1981 *Colonial Maryland: A History*. KTO Press, Millwood, NY.

Larsen, Clark Spencer
1991 *Bioarchaeology of Spanish Florida: The Impact of Colonialism*. University of Florida Press, Gainesville.

Larsen, Clark Spencer
1997 *Bioarchaeology: Interpreting Behavior from the Human Skeleton*. Cambridge University Press, Cambridge, UK.

Larsen, Clark Spencer
2001 *Bioarchaeology of Spanish Florida: The Impact of Colonialism*. University of Florida Press, Gainesville.

Larsen, Clark Spencer
2015 *Bioarchaeology: Interpreting Behavior from the Human Skeleton*, 2nd edition. Cambridge University Press, Cambridge, UK.

Larsen, Clark Spencer, Mark C. Griffin, Dale L. Hutchinson, Vivian E. Noble, Lynette Norr, Robert F. Pastor, Christopher B. Ruff, Katherine F. Russell, Margaret J. Schoeninger, Michael Schultz, Scott W. Simpson, and Mark F. Teaford
2001 Frontiers of Contact: Bioarchaeology of Spanish Florida. *Journal of World Prehistory* 15(1):69–123.

Larsen, Clark Spencer, and George R. Milner
1994 *In the Wake of Contact: Biological Responses to Conquest*. Wiley-Liss, New York, NY.

Larsen, Clark Spencer, Rebecca Shavit, and Mark C. Griffin
1991 Dental Caries Evidence for Dietary Change: An Archaeological Context. In *Advances in Dental Anthropology*, Mark A. Kelley and Clark Spencer Larsen, editors, pp. 179–202. Wiley-Liss, New York, NY.

Layrisse, Miguel, Carlos Martínez-Torres, and Marcel Roche
1968 Effect of Interaction of Various Foods on Iron Absorption. *American Journal of Clinical Nutrition* 21(10):1175–1183.

Liang, Kung-Yee, and Scott L. Scott
1986 Longitudinal Data Analysis Using Generalized Linear Models. *Biometrika* 73(1):13–22.

Lingström, Peter, Floris O. J. Van Ruyven, Johannes Van Houte, and Ralph Kent
2000 The Ph of Dental Plaque in Its Relation to Early Enamel Caries and Dental Plaque Flora in Humans. *Journal of Dental Research* 79(2):770–777.

Loren, Diana DiPaolo
2008 *In Contact: Bodies and Spaces in the Sixteenth- and Seventeenth-Century Eastern Woodlands*. AltaMira Press, Lanham, MD.

Lounsbury, Floyd G.
1978 Iroquoian Languages. In *Handbook of North American Indians*, Vol. 15, *Northeast*, Bruce G. Trigger, editor, pp. 334–343. Smithsonian Institution Press, Washington, DC.

Lovejoy, C. Owen, Richard S. Meindl, Thomas R. Pryzbeck, and Robert P. Mensforth
1985 Chronological Metamorphosis of the Auricular Surface of the Ilium: A New Method for the Determination of Adult Skeletal Age at Death. *American Journal of Physical Anthropology* 68(1):15–28.

Lovell, Nancy C.
1997 Trauma Analysis in Paleopathology. *American Journal of Physical Anthropology* 104(S25):139–170.

Lukacs, John R.
1989 Dental Paleopathology: Methods for Reconstructing Dietary Patterns. In *Reconstruction of Life from the Skeleton*, Mehmet Yasar İşcan and Kenneth A. R. Kennedy, editors, pp. 261–286. Allen R. Liss, New York, NY.

Lukacs, John R., and Leah L. Largaespada
2006 Explaining Sex Differences in Dental Caries Prevalence: Saliva, Hormones, and "Life-History" Etiologies. *American Journal of Human Biology* 18(4):540–555.

Maniez, Erica S.
1994 *Piscataway Creek to Point of Rocks: The Decline of an Empire*. Brunswick Railroad Museum, Brunswick, MD.

Martin, Debra L., and Ryan P. Harrod
2015 Bioarchaeological Contributions to the Study of Violence. *American Journal of Physical Anthropology* 156(S59):116–145.

Mathews, Edward Bennett
1898 *The Maps and Map-Makers of Maryland*. Johns Hopkins Press, Baltimore, MD.

MedlinePlus
2014 Iron in Diet. Medical Encyclopedia, MedlinePlus <https://medlineplus.gov/ency/article/002422.htm>. Accessed 9 October 2019.

Menard, Russell R., and Lois G. Carr
1982 The Lords Baltimore and the Colonization of Maryland. In *Early Maryland in a Wider World*, David B. Quinn, editor, pp. 167–215. Wayne State University Press, Detroit, MI.

Mensforth, Robert P., Owen Lovejoy, John W. Lallo, and George J. Armelagos
1978 The Role of Constitutional Factors, Diet, and Infectious Disease in the Etiology of Porotic Hyperostosis and Periosteal Reactions in Prehistoric Infants and Children. *Medical Anthropology* 2(1):1–59.

Merbs, Charles F.
1989 Trauma. In *Reconstruction of Life from the Skeleton*, Mehmet Yasar İşcan and Kenneth A. R. Kennedy, editors, pp. 161–189. Alan R. Liss, New York, NY.

Merleau-Ponty, Maurice
2013 *Phenomenology of Perception*, Donald Landes, translator. Routledge, New York, NY.

Michopoulou, Efrossyni, Efthymia Nikita, and Efstratios D. Valakos
2015 Evaluating the Efficiency of Different Recording Protocols for Entheseal Changes in Regards to Expressing Activity Patterns Using Archival Data and Cross-Sectional Geometric Properties. *American Journal of Physical Anthropology* 158(4):557–568.

National Institutes of Health
2014 Iron: Fact Sheet for Health Professionals. Office of Dietary Supplements, National Institutes of Health <http://ods.od.nih.gov/Factsheets/Iron-Healthprofessional>. Accessed 9 October 2019.

Nelson, Suchitra, Jeffrey M. Albert, Christina Geng, Shelley Curtan, Kurt Lang, Samantha A. Miadich, Masahiro Heima, Anchal Malik, Gerald A. Ferretti, Hafsteinn Eggertsson, Rebecca L. Slayton, and Peter Milgrom
2013 Increased Enamel Hypoplasia and Very Low Birthweight Infants. *Journal of Dental Research* 92(9):788–794.

Nikita, Efthymia
2014 The Use of Generalized Linear Models and Generalized Estimating Equations in Bioarchaeological Studies. *American Journal of Physical Anthropology* 153(3):473–483.

Nikita, Efthymia
2015 A Critical Review of the Mean Measure of Divergence and Mahalanobis Distances Using Artificial Data and New Approaches to the Estimation of Biodistances Employing Nonmetric Traits. *American Journal of Physical Anthropology* 157(2):284–294.

Ortner, Donald J.
2003 *Identification of Pathological Conditions in Human Skeletal Remains*, 2nd edition. Academic Press, San Diego, CA.

Ortner, Donald J., and Walter G. J. Putschar
1985 *Identification of Pathological Conditions in Human Skeletal Remains*. Smithsonian Institution Press, Washington, DC.

Oxenham, Marc F., and Ivor Cavill
2010 Porotic Hyperostosis and Cribra Orbitalia: The Erythropoietic Response to Iron-Deficiency Anaemia. *Journal of Anthropological Science* 118(1):199–200.

Peasley, William
1910 A Relation of Maryland. In *Narratives of Early Maryland: 1633–1684*, Clayton Colman Hall, editor, pp. 63–112. Charles Scribner's Sons, New York, NY.

Porter, Frank W.
1979 *Indians in Maryland and Delaware*. Indiana University Press, Bloomington.

Potter, Stephen R.
1993 *Commoners, Tribute, and Chiefs: The Development of Algonquian Culture in the Potomac Valley*. University Press of Virginia, Charlottesville.

Prezzano, Susan C., and Christina B. Rieth
2001 Late Prehistoric Cultures of the Upper Susquehanna Valley. In *Archaeology of the Appalachian Highlands*, Lynne P. Sullivan and Susan C. Prezzano, editors, pp. 168–176. University of Tennessee Knoxville, Knoxville.

Reitsma, Laurie J., and Britney Kyle McIlvaine
2014 Reconciling "Stress" and "Health" in Physical Anthropology: What Can Bioarchaeologists Learn from the other Subdisciplines? *American Journal of Physical Anthropology* 155(2):181–185.

Roberts, Charlotte, and Keith Manchester
1995 *The Archaeology of Disease*. Cornell University Press, Ithaca, NY.

Rose, Jerome C., Keith W. Condon, and Alan H. Goodman
1985 Diet and Dentition: Developmental Disturbances. In *The Analysis of Prehistoric Diets*, Robert I. Gilbert and James H. Mielke, editors, pp. 281–305. Academic Press, New York, NY.

Salvolini, Eleonora, Roberto DiGiorgio, A. Curatola, Laura Mazzanti, and Giovanni Fratto
1998 Biochemical Modifications of Human Whole Saliva Induced by Pregnancy. *British Journal of Obstetrics and Gynaecology* 105(6):656–660.

Scharf, John Thomas
1882 *History of Western Maryland: Being a History of Frederick, Montgomery, Carroll, Washington, Allegany, and Garrett Counties from the Earliest Period to the Present Day; Including Biographical Sketches of Their Representative Men*. L. H. Everts, Philadelphia, PA.

Scheuer, Louise, and Sue Black
2004 *Developmental Juvenile Osteology*. Academic Press, London, UK.

Schubel, Jerry R., and Donald W. Pritchard
1986 Responses of Upper Chesapeake Bay to Variation in Discharge of the Susquehanna River. *Estuaries* 9(4):236–249.

Simon, Sara K.
2003 The Effect of Chiefdom Formation on the Health of Aboriginal Populations in the Chesapeake Bay Area of Maryland and Virginia. Master's thesis, Department of Anthropology, California State University, Los Angeles.

Simon, Sara K., and Celeste M. Gagnon
2005 Abstract: The Effect of Migration on the Dental and Skeletal Health of Protohistoric and Early Historic Susquehannock Indians, AD 1575–1675. *American Journal of Physical Anthropology* 40(S):191.

Smith, B. Holly
1984 Patterns of Molar Wear in Hunter-Gatherers and Agriculturalists. *American Journal of Physical Anthropology* 63(1):39–56.

Smith, Ira F.
1970 Schultz Site Settlement Patterns and External Relations: A Preliminary Discussion and Possible Interpretation. *The Bulletin: Journal of the New York State Archeology Association* 50:27–34.

Smith, John
1986 The Generall Historie of Virginia, New England, and the Summer Isles. In *The Complete Works of Captain John Smith*, Vol. 3, Philip L. Barbour, editor. University of North Carolina Press, Chapel Hill.

Smith-Guzmán, Nicole E.
2015 The Skeletal Manifestation of Malaria: An Epidemiological Approach Using Documented Skeletal Collections. *American Journal of Physical Anthropology* 158(4):624–635.

Sofaer, Joanna R.
2006 *The Body as Material Culture: A Theoretical Osteoarchaeology*. Cambridge University Press, Cambridge, UK.

Sparks, Jared
1848 *The Library of American Biography*, Vol. 19. Charles C. Little and James Brown, Boston, MA.

Steckel, Richard H., and Jerome C. Rose
2002 *The Backbone of History: Health and Nutrition in the Western Hemisphere*. Cambridge University Press, Cambridge, UK.

Stephenson, Robert L., Alice L. L. Ferguson, and Henry G. Ferguson
1963 *The Accokeek Creek Site: A Middle Atlantic Seaboard Cultural Sequence*. University of Michigan Press, Ann Arbor.

Stewart, Marilyn C.
1973 A Proto-Historic Susquehannock Cemetery near Nichols, Tioga County. *The Bulletin: Journal of the New York State Archeology Association* 58:1–21.

Streckfus, Charles F., Baur Ursula, L. Jackson Brown, Carolyn Bacal, Jeffrey Metter, and Todd Nick
1998 Effects of Estrogen Status and Aging on Salivary Flow Rates in Healthy Caucasian Women. *Gerontology* 44(1):32–39.

Stuart-Macadam, Patricia
1985 Porotic Hyperostosis: New Evidence to Support the Anemia Theory. *American Journal of Physical Anthroplogy* 74(4):521–526.

Stuart-Macadam, Patricia
1992a Anemia in Past Human Populations. In *Diet, Demography, and Disease*, P. Stuart-Macadam and S. Kent, editors, pp. 151–170. Aldine de Gruyter, New York, NY.

Stuart-Macadam, Patricia
1992b Porotic Hyperostosis: A New Perspective. *American Journal of Physical Anthroplogy* 87(1):39–47.

Stuart-Macadam, Patricia, and Susan Kent
1992 *Diet, Demography and Disease: Changing Perspectives on Anemia*. Aldine de Gruyter, New York, NY.

Suchey, Judy M., Sheilagh T. Brooks, and Darryl Katz
1988 *Instructional Materials Accompanying Female Pubic Symphyseal Models of the Suchey-Brooks System*. France Casting, Fort Collins, CO.

Suchey, Judy M., and Darryl Katz
1986 Skeletal Age Standards Derived from an Extensive Multiracial Sample of Modern Americans. *American Journal of Physical Anthroplogy* 69(2):269.

Sullivan, Amy
2005 Prevalence and Etiology of Acquired Anemia in Medieval York, England. *American Journal of Physical Anthropology* 128(2):252–272.

Sweeney, Edward A., Jorge Cabrara, Juan Urrutia, and Leonardo Mata
1969 Factors Associated with Linear Hypoplasia of Human Deciduous Incisors. *Journal of Dental Research* 48(6):275–279.

Temple, Daniel H., and Alan H. Goodman
2014 Bioarchaeology Has a "Health" Problem: Conceptualizing "Stress" and "Health" in

Bioarchaeological Research. *American Journal of Physical Anthropology* 155(2):186–191.

Tittman, Otto H.
1909 *Report on the Resurvey of the Maryland-Pennsylvania Boundary Part of the Mason and Dixon Line*. Harrisburg Publishing Company, Harrisburg, PA.

Toogood, Anna Coxe
1969 *Piscataway Park: General Historic Background Study*. U.S. Office of Archaeology and Historic Preservation, Division of History, Washington, DC.

Tooker, Elizabeth
1984 The Demise of the Susquehannocks: A 17th Century Mystery. *Pennsylvania Archaeologist* 54(3&4):1–10.

Turner, Christy
1979 Dental Anthropological Indications of Agriculture among the Jomon People of Central Japan. X. Peopling of the Pacific. *American Journal of Physical Anthroplogy* 51(4):619–635.

Tyler, Lyon Gardiner (editor)
1907 *Narratives of Early Virginia 1606–1625*. Charles Scribner's Sons, New York, NY.

VanDerwarker, Amber M., and Gregory D. Wilson
2016 War, Food, and Structured Violence in the Mississippian Central Illinios Valley. In *The Archaeology of Food and Warfare*, Amber M. VanDerwarker and Gregory D. Wilson, editors, pp. 75–105. Springer, New York, NY.

Van Houte, Johannes
1994 Role of Micro-Organisms in Caries Etiology. *Journal of Dental Research* 73(3):672–681.

Vogel, John C., and Nikolaas Johannes van der Merwe
1977 Isotopic Evidence for Early Maize Cultivation in New York State. *American Antiquity* 42(2):238–242.

Waldron, Tony
1996 Legalized Trauma. *International Journal of Osteoarchaeology* 6(1):114–118.

Walker, Phillip L.
1986 Porotic Hyperostosis in a Marine-Dependant California Population. *American Journal of Physical Anthropology* 69(3):345–354.

Walker, Phillip L., Rhonda R. Bathurst, Rebecca Richman, Thor Gjerdrum, and Valerie A. Andrushko
2009 The Causes of Porotic Hyperostosis and Cribra Orbitalia: A Reappraisal of the Iron-Deficiency-Anemia Hypothesis. *American Journal of Physical Anthropology* 139(2):109–125.

Webb, Stephen Saunders
1995 *1676: The End of American Independence*. First Syracuse University Press, Syracuse, NY.

White, Tim D.
1991 *Human Osteology*. Academic Press, San Diego, CA.

Wood, James W., George R. Milner, Henry C. Harpending, and Kenneth M. Weiss
1992 The Osteological Paradox: Problems of Inferring Prehistoric Health from Skeletal Samples. *Current Anthropology* 33(4):343–370.

Wright, Lori E., and Cassaday J. Yoder
2003 Recent Progress in Bioarchaeology: Approaches to the Osteological Paradox. *Journal of Archaeological Research* 11(1):43–70.