Title

Prevalence and Clinical Significance of Incidental Findings in Orthodontic Large Field of View Cone-Beam Computed Tomography Scans

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Prevalence and Clinical Significance of Incidental Findings in Orthodontic Large Field of View Cone-Beam Computed Tomography Scans

A thesis submitted in partial satisfaction of the requirements for

the degree Master of Science in Oral Biology

by

Guiselle Natalie Murillo

2025

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ABSTRACT OF THE THESIS

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by

Guiselle Natalie Murillo

Master of Science in Oral Biology

University of California, Los Angeles, 2025

Professor Sanjay M. Mallya, Chair

The increasing use of Cone Beam Computed Tomography (CBCT) in orthodontics is driven by its ability to provide three-dimensional (3D) images, offering detailed insights into dental and skeletal structures crucial for accurate diagnosis and treatment planning. CBCT's enhanced visualization capabilities contribute to improved treatment outcomes and a more comprehensive understanding of craniofacial complexities. Often, the CBCTs taken for orthodontic purposes are large field of view (FOV) scans capturing the entire craniofacial complex, instead of focusing on a small region of interest. As a result, there may be incidental findings (IFs) throughout the scan, which are defined as unexpected observations unrelated to the primary purpose of the imaging study. It is important to understand the prevalence of IFs, their location, and clinical severity to better serve the patient’s overall well-being.

The purpose of this study was to identify the most common IFs and their prevalence in large FOV maxillofacial CBCTs and understand their clinical significance, particularly in

orthodontic treatment. We aimed to do this by investigating the prevalence and characteristics of the IFs listed in radiology reports, categorizing each IF as having either mild, moderate, or severe clinical significance, and reviewing their clinical treatment notes to examine whether the IFs influenced the patient's orthodontic treatment. Furthermore, we examined whether there were differences in IFs across different age groups and genders. We hypothesized that there would be a difference in the prevalence of IFs across different ages and gender.

Our study was designed as a retrospective analysis of 256 radiology reports from CBCT scans taken for initial orthodontic evaluation. All reports were derived from large FOV CBCTs of patients at the UCLA Orthodontic Clinic and were obtained from the UCLA Oral and Maxillofacial Radiology Clinic. Radiology reports were reviewed for IFs and organized using Microsoft Excel. Descriptive statistics were used to analyze the IFs and chi-squared test was performed to assess whether there was a difference in IFs across different ages and gender. Our results demonstrated that of all the IFs in this study, airway IFs were most prevalent (22.92%), followed by paranasal (20.12%), dentoalveolar (19.52%), temporomandibular joint (TMJ) (15.02%), calcification (11.61%), nasal (6.51%), osseous (3.30%), and other (1.10%) IFs. The chi-squared analysis revealed a statistically significant difference in the distributions of IFs in the calcifications category across different genders (P value= 0.040). Additionally, statistical significance was found between age and TMJ IFs (P value < 0.001), osseous IFs (P value < 0.001), and calcification IFs (P value < 0.001). Most IFs (64.76%) were of mild clinical significance, followed by moderate clinical significance (44.54%), and only a small percentage (4.30%) of severe clinical significance. This study found a total of 15 different IFs that influenced orthodontic treatment, most of which were of dentoalveolar origin.

This study provides orthodontists with a comprehensive list of common IFs found in routine orthodontic CBCTs. With this information, orthodontists will be better equipped to thoroughly analyze CBCTs and improve the well-being of their patients by identifying pathologies that may have otherwise gone unnoticed.

The thesis of Guiselle Murillo is approved.

Yong Kim

Jimmy Kuanghsian Hu

Sanjay M. Mallya, Committee Chair

University of California, Los Angeles

2025

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LIST OF ABBREVIATIONS

Abbreviation	**Definition**
2D	Two Dimensional
3D	Three Dimensional
AI	Artificial Intelligence
CBCT	Cone-Beam Computed Tomography
FOV	Field of View
IF	Incidental Finding
TMJ	Temporomandibular Joint
MARPE	Miniscrew-Assisted Rapid Palatal Expansion
SARPE	Surgically Assisted Rapid Palatal Expansion

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ACKNOWLEDGEMENTS

I would like to acknowledge my research mentor, Dr. Sanjay Mallya, for his invaluable guidance, support, and encouragement throughout this project. His expertise and dedication have been instrumental in shaping this research, and I am truly grateful for his mentorship. The insight I gained from him on the importance of accurate CBCT analysis and the evolving role of AI in radiographic interpretation will guide me in private practice. I will apply this knowledge to ensure thorough evaluations to enhance patient care.

I would also like to sincerely thank my committee members, Dr. Yong Kim and Dr. Jimmy Hi, for their time, valuable feedback, and guidance throughout this process. Their dedication to research and unwavering support for us orthodontic residents have been truly inspiring, and I am grateful for their contributions to both this project and our education.

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Lastly, I would like to thank my family, boyfriend, co-residents, and friends for their support, patience, and encouragement throughout this project.

INTRODUCTION

i. Cone-beam Computed Tomography

Introduced around 1998, cone-beam computed tomography (CBCT) has significantly enhanced the orthodontic diagnosis and treatment planning process[1]. Traditionally, two dimensional (2D) radiographs, including panoramic and lateral cephalometric images, have been routinely utilized in orthodontics. However, one of the greatest drawbacks of 2D imaging, is its inability to provide an accurate representation of the craniofacial complex. For instance, overlapping between anatomical structures is common, making it difficult to discern positions of teeth, roots, and surrounding structures[2]. Furthermore, 2D radiography is prone to distortion and magnification errors, which can lead to tracing errors and compromise the precision of measurements[2, 3]. CBCTs, on the other hand, provide superior image quality compared to conventional imaging, leading to enhanced visualization[1-4]. CBCTs produce 3D imaging which allows orthodontists to clearly evaluate structures, such as the temporomandibular joint (TMJ) (Figure 1a), impacted teeth (Figure 1b), supernumerary teeth (Figure 1c), and more. The 3D nature, allows clinicians to generate sections and obtain views that cannot be generated by conventional 2D x-rays, such as axial and coronal views[4]. CBCTs also aid in upper airway analysis, pre-treatment planning for orthognathic surgery, and cleft lip/palate cases[4, 5]. The introduction of CBCTs has significantly advanced the field of orthodontics by providing 3D, high-resolution images of the craniofacial complex.

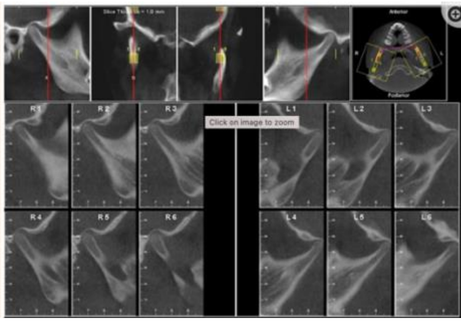
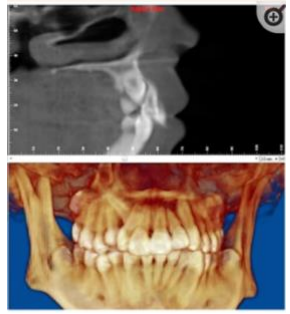
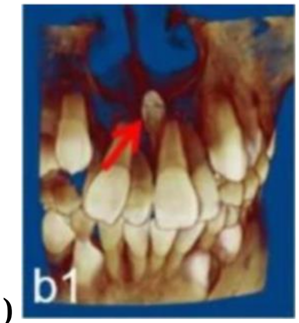
A)  B)  C) 

Figure 1: CBCT images demonstrating examples of detectable findings, such as a) Condylar cross-sections, b) impacted canines, and c) supernumerary teeth

Although there are many benefits to the use of CBCTs, they also carry risks. CBCTs expose patients to higher radiation doses compared to conventional 2D radiographs. CBCTs use a cone-shaped source of ionizing radiation and a 2D detector as shown in Figure 2[4]. The increased radiation is primarily attributed to the 3D nature of CBCT imaging. In a CBCT scan, the cone-shaped X-ray beam rotates around the patient, capturing multiple 2D images from different angles[4, 6]. These images are then reconstructed into a 3D representation of the patient's anatomy.

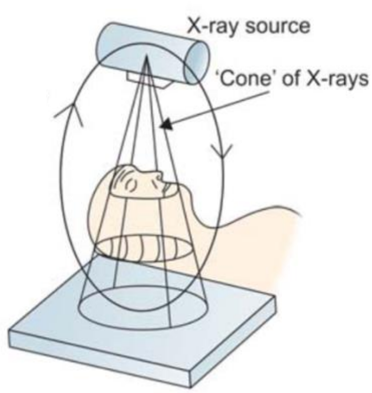


Figure 2: Schematic representation of the image acquisition method in CBCTs[4]

Additionally, CBCTs may expose patients to higher radiation levels due to the necessity of scanning a larger tissue volume. CBCTs have the capability of capturing regions with different fields of view (FOVs). However, it is important to note that the effective dose, which represents the overall risk of harm from exposure to ionizing radiation, increases as the FOV increases[6]. Unlike patients receiving implants or endodontic treatment in which only a specific region is analyzed, orthodontics requires a large FOV because it involves assessing and planning for the entire craniofacial complex, which includes the teeth, jaws, and surrounding structures. Therefore, to minimize harm to patients, practitioners must make informed decisions on when selection of CBCT imagining will provide more benefit than harm to a patient. The higher radiation dose becomes a trade-off for the detailed and comprehensive information it provides.

ii. Incidental Findings (IFs)

Not only must practitioners be cautious of the increased radiation dose that large FOV CBCTs provide, but they must also be confident in interpreting all the findings presented in the 3D rendering. With such a large FOV, it is pertinent that the clinician is knowledgeable and able to analyze the volume in its entirety as it is possible to come across incidental findings (IFs). An IF is defined as a finding that was unintentionally discovered upon assessing a radiographic image that was taken for reasons that are unrelated to the present illness[7, 8]. IFs can range from anatomical variations and developmental anomalies to pathologic conditions. For example, an orthodontic CBCT might reveal the presence of cysts, tumors, or other oral and maxillofacial abnormalities. Since the CBCT provides detailed views of the entire craniofacial region, IFs may occur in areas beyond the immediate focus of orthodontic treatment. Therefore, it is critical that the orthodontist analyze all structures even out of the primary region of interest as some unrelated pathology may be present and radiographically visible. It is recommended that if a clinician is not well versed in interpretating CBCTs, then a referral should be made to an oral and maxillofacial radiologist for a comprehensive evaluation of the image[5, 7-10]. These findings may have implications for the overall health and well-being of the patient beyond orthodontic considerations, thus it is critical that a practitioner is able to comprehensively evaluate the x-ray and identify all conditions or abnormalities.

iii. Frequency of IFs

Studies have investigated IFs from CBCTs, but the frequency of IFs vary from study to study. One study analyzed 272 CBCT scans and found the highest rate of IFs were airway findings (35.0%), followed by soft tissue calcifications (20.0%), bone (17.5%), TMJ (15.4%), endodontic (11.3%) and dental development (0.7%)[9]. Whereas another study that evaluated 250 CBCT scans found that the highest number of findings were of sino-nasal origin (44.7%), followed by airway (20.0%), dentoalveolar (19.1%), calcifications (14.5%), and TMJ (0.3%)[10]. Such conflicting findings warrant further investigation. One reason for differences in findings could be attributed to the difference in the FOV used for recording the CBCTs. Another reason may be that the studies analyzed CBCTs from various population groups, such as patients presenting for implant assessment, orthodontics, TMJ evaluation, etc. Very few studies have investigated an orthodontic sample exclusively. Thus, it is pertinent to conduct additional studies that focus on orthodontic patients to provide orthodontists with a clear understanding of the frequency and nature of IFs expected in this patient population.

iv. Clinical Significance of IFs

Many studies have ranked IFs based on their clinical severity; however, there is a lack of consensus among these classifications. For instance, one study found that 43.46% of IFs did not need treatment or referral to another professional, 28.97% required monitoring[11], and 27.55%

required immediate treatment or referral[12]. While another study concluded 27.0% of IFs did not require referral, while 72.0% required monitoring, and only 1% required referral[10]. Again, in these studies, there is a lack of consistency amongst the FOVs and patient populations included. More studies that focus on one specific FOV and patient population must be performed to accurately determine the clinical significance of IFs found in CBCTs. Specifically, for our study we focused on analyzing CBCT reports solely from an orthodontic patient population and large FOVs. Such studies are important to accurately determine the clinical significance of such IFs and facilitate appropriate monitoring, referral, and treatment of patients in a timely manner.

v. Impact of IFs on Treatment

To date, no studies have examined patient clinical records to determine which IFs on CBCT scans may have influenced the treatment for which the scan was originally obtained. Although determining the clinical significance of an IF is useful for deciding when a referral is necessary, it provides limited guidance on how clinicians should proceed with their treatment plan. This study aims to review IFs alongside patient chart notes to assess whether these IFs influenced the patient's orthodontic treatment. Filling this gap in research can aid orthodontists in understanding which IFs may influence their treatment course.

The purpose of this study is to gain a better understanding for the prevalence and nature of IFs specifically in the orthodontic population. Whether most IFs found in orthodontic CBCTs require further management or intervention is still up for debate. Additionally, there is no clear consensus on the recommended management of most common IFs[13].Therefore, this emphasizes the importance of collaboration between medical and dental professionals to combine their respective expertise and ensure a holistic approach to diagnosis, treatment planning, and patient management. All in all, this study will help guide orthodontists in understanding which IFs are most common, their clinical significance, and understanding to what degree these IFs impact the course of orthodontic treatment.

OBJECTIVES AND SPECIFIC AIMS

Objective: Our goal is to examine the prevalence, clinical significance, and treatment impact of IFs in large FOV CBCT scans obtained as initial records for an orthodontic sample exclusively.

Specific Aims:

1) To identify and categorize all IFs found in large FOV CBCT reports of UCLA Orthodontic patients generated for initial records.
    a. Perform descriptive statistics to identify the prevalence of IFs across the study sample.
2) Identify if there is a difference in IF prevalence across genders and age groups.
    a. Perform statistical analysis to test our hypothesis that there is a difference between IFs across gender and age.
3) Categorize each IF as either having mild, moderate, or severe clinical significance.
4) Reference patient chart notes to determine what, if any, influence the IFs had on orthodontic treatment.

DESIGN AND METHODOLOGY

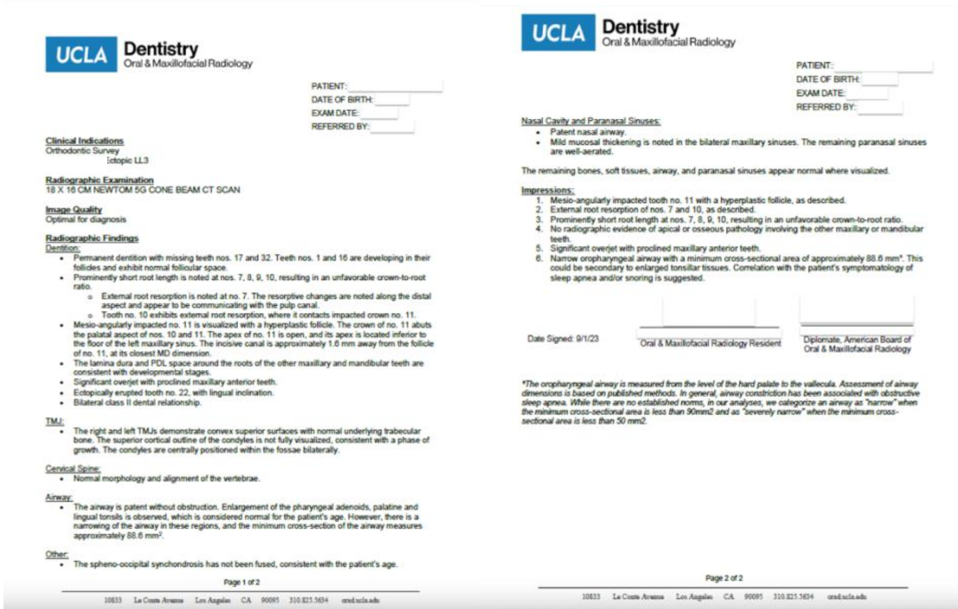
i. Experimental Design

We conducted a retrospective study to analyze the prevalence and nature of IFs in large FOV CBCTs scans taken as initial records for patients of the UCLA Orthodontic Clinic. All CBCTs were taken at UCLA's Oral and Maxillofacial Radiology Clinic and the reports generated were accessed through a UCLA secured Dropbox folder. A total of 629 reports in the Dropbox were screened, but only 256 reports met the following inclusion and exclusion criteria and were included in the sample.

Inclusion: Patients of the UCLA Orthodontic Clinic, who took a large FOV CBCT (18x16 CM) for initial orthodontic records, with no history of orthodontic treatment.

Exclusion: Scans that had significant metallic or movement artifacts, patients with craniofacial syndromes, scans taken before September 29, 2020, patients that had previously taken a large FOV CBCT at another UCLA Dental Clinic, and any patient whose treatment notes did not indicate a primary reason for requesting the CBCT.

A sample size calculation was not conducted. Instead, the adequacy of the sample size was deemed appropriate by comparison with similar studies in the existing literature[7, 9, 10, 12, 14]. Reports written prior to September 29, 2020, were excluded due to an inconsistent reporting format prior to this date. All scans were generated from scans taken on an 18 X 16 CM NewTom 5G Cone Beam CT. An Oral and Maxillofacial Radiology resident comprehensively analyzed each scan using InVivo Dental software (Anatomage, Inc. San Jose, CA, USA) and generated a radiology report for each scan. Although all scans were not analyzed by the same resident, the reports followed a consistent format containing a list of all radiographic findings, impressions, and snapshots of scan findings. An example of the report format can be seen in Figure 3. All scans and reports were then reviewed by a board-certified oral maxillofacial radiologist. The resident and radiologist were both considered blinded to the study since the reports were made prior to the implementation of the study.



UCLA Dentistry
Oral & Maxillofacial Radiology

PATIENT:
DATE OF BIRTH:
EXAM DATE:
REFERRED BY:

Clinical Indications
Orthodontic Survey
Ectopic LL3

Radiographic Examination
18 X 16 CM NEWTOM 5G CONE BEAM CT SCAN

Image Quality
Optimal for diagnosis

Radiographic Findings
Dentition:
- Permanent dentition with missing teeth nos. 17 and 32. Teeth nos. 1 and 16 are developing in their follicles and exhibit normal follicular space.
- Prominently short root length is noted at nos. 7, 8, 9, 10, resulting in an unfavorable crown-to-root ratio.
  - External root resorption is noted at no. 7. The resorptive changes are noted along the distal aspect and appear to be communicating with the pulp canal.
  - Tooth no. 10 exhibits external root resorption, where it contacts impacted crown no. 11.
- Mesio-angularly impacted no. 11 is visualized with a hyperplastic follicle. The crown of no. 11 abuts the palatal aspect of nos. 10 and 11. The apex of no. 11 is open, and its apex is located inferior to the floor of the left maxillary sinus. The incisive canal is approximately 1.6 mm away from the follicle of no. 11, at its closest MD dimension.
- The lamina dura and PDL space around the roots of the other maxillary and mandibular teeth are consistent with developmental stages.
- Significant overjet with proclined maxillary anterior teeth.
- Ectopically erupted tooth no. 22, with lingual inclination.
- Bilateral class II dental relationship.

TMJ:
- The right and left TMJs demonstrate convex superior surfaces with normal underlying trabecular bone. The superior cortical outline of the condyles is not fully visualized, consistent with a phase of growth. The condyles are centrally positioned within the fossae bilaterally.

Cervical Spine:
- Normal morphology and alignment of the vertebrae.

Airway:
- The airway is patent without obstruction. Enlargement of the pharyngeal adenoids, palatine and lingual tonsils is observed, which is considered normal for the patient's age. However, there is a narrowing of the airway in these regions, and the minimum cross-section of the airway measures approximately 88.6 mm^2.

Other:
- The spheno-occipital synchondrosis has not been fused, consistent with the patient's age.

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Oral & Maxillofacial Radiology

PATIENT:
DATE OF BIRTH:
EXAM DATE:
REFERRED BY:

Nasal Cavity and Paranasal Sinuses:
- Patent nasal airway.
- Mild mucosal thickening is noted in the bilateral maxillary sinuses. The remaining paranasal sinuses are well-aerated.

The remaining bones, soft tissues, airway, and paranasal sinuses appear normal where visualized.

Impressions:
1. Mesio-angularly impacted tooth no. 11 with a hyperplastic follicle, as described.
2. External root resorption of nos. 7 and 10, as described.
3. Prominently short root length at nos. 7, 8, 9, 10, resulting in an unfavorable crown-to-root ratio.
4. No radiographic evidence of apical or osseous pathology involving the other maxillary or mandibular teeth.
5. Significant overjet with proclined maxillary anterior teeth.
6. Narrow oropharyngeal airway with a minimum cross-sectional area of approximately 88.6 mm*. This could be secondary to enlarged tonsillar tissues. Correlation with the patient's symptomatology of sleep apnea and/or snoring is suggested.

Date Signed: 9/1/23

Oral & Maxillofacial Radiology Resident

Diplomate, American Board of Oral & Maxillofacial Radiology

**The oropharyngeal airway is measured from the level of the hard palate to the vallecula. Assessment of airway dimensions is based on published methods. In general, airway constriction has been associated with obstructive sleep apnea. While there are no established norms, in our analyses, we categorize an airway as "narrow" when the minimum cross-sectional area is less than 90mm2 and as "severely narrow" when the minimum cross-sectional area is less than 50 mm2.*

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Figure 3: Example of CBCT report generated by the UCLA Oral Maxillofacial Radiology Department

Patient clinical information and orthodontic treatment information was accessed through axiUm dental software (Exan Group, Henry Schein, Melville, New York, United States). The clinical notes were reviewed to identify the primary indication for the CBCT, facilitating the identification of IFs in the report. IFs were defined as findings unrelated to the primary purpose for which the scan was taken. Additionally, the clinical notes were reviewed to assess whether the IFs had any influence on the orthodontic treatment.

ii. Data Collection

For each of the 256 CBCT reports included in the sample, key features from the reports were assessed, organized, and recorded in an Excel spreadsheet (Microsoft Corporation;

Washington, USA). Information collected included age, gender, date of scan, specific details of the IFs, and recommendations from the radiologist (if included). Patients were grouped into 6 different age categories and by gender. The 6 different age groups were (1) 1-10 years, (2) 11-15 years, (3) 16-20 years, (4) 21-25 years, (5) 26-30 years, and (6) >30 years. IFs were organized into 8 categories: (1) airway, (2) paranasal, (3) dentoalveolar, (4) TMJ, (5) calcifications, (6) nasal, (7) osseous, and (8) other and were recorded as categorical variables. For each patient, IFs were either counted as present or absent for each category. If an IF appeared more than once in a patient, the IF was documented as a single instance. IFs related to primary teeth or wisdom teeth were not recorded.

Each IF was given a clinical significance score of mild, moderate, or severe based on the radiologist's recommendations and supporting evidence in the literature. A "mild" score indicated that no further monitoring or management was recommended, a "moderate" score suggested that periodic evaluation, follow-up, or eventual referral of the IF was recommended, and "severe" score signified that immediate referral and/or treatment was recommended.

Lastly, to identify the reason for the CBCT referral and treatment influence, clinical notes were reviewed using axiUm dental software. As a resident of the UCLA Orthodontic Clinic, the primary researcher obtained access to all orthodontic patient charts and reviewed consult notes for each patient to determine the primary indication for the CBCT referral. If it was unclear as to why the CBCT was recommended, then the patient was excluded from the sample. Additionally, progress treatment notes were analyzed to determine whether the clinician adjusted the orthodontic treatment in response to the IFs documented in the patient's CBCT report. Adjustments to clinical treatment ranged from monitoring the condition or slowing orthodontic movements to delaying treatment until clearance from a specialist. This information was collected and noted for every report on the Excel spreadsheet.

iii. Statistical Analysis

Descriptive analysis of the data was performed to calculate the mean age of the sample size, evaluate the prevalence of the incidental findings, analyze the frequency of the various CBCT referrals, assess the proportion of IFs in the various clinical significance categories, and examine the proportion of patients whose treatment was affected by the IFs.

A chi-squared test was used to compare the influence of age and gender on the 8 IF categories. The statistical analysis was performed using the Statistical Package for Social Sciences (SPSS Inc Version 28,IBM). The level of significance was set at a level of $p \leq 0.05$.

RESULTS

i. Characteristics of the Study Sample

There was a total of 256 reports included in the study ranging from September 29, 2020 to December 7, 2023. The 256 patients included 131 males (51.17%) and 125 females (48.83%) with ages ranging from 5 to 65 years old. The mean age for males was 19.05 years (± 9.35) and 20.27 years (± 10.57) for females. The age distribution of the study sample is shown in Table 1.

The most common reason for CBCT referral was for orthognathic surgical planning (42.97%). The second most common referral was for impacted teeth (29.30%), followed by MARPE or SARPE consideration (7.81%), TMJ evaluation (5.47%), supernumerary teeth (3.91%), potential missing teeth (3.91%), root evaluation (1.95%), ectopic eruption (1.17%), airway analysis (1.17%), bone evaluation (0.78%), possible ankylosis (0.78%), syndromic evaluation (i.e. Gorlin Goltz Syndrome), and amelogenesis imperfect (0.39%). The distribution for CBCT referrals can be found in Table 2.

Table 1: Age Distribution of Study Sample

Patient Age Group	No. of Males	% of Males	No. of Females	% of Females	Total No. of Patients	% of Patients
1-10 years	15	65.22%	8	34.78%	23	8.98%
11-15 years	46	46.94%	52	53.06%	98	38.28%
16-20 years	33	56.90%	25	43.10%	58	22.66%
21-25 years	13	41.94%	18	58.06%	31	12.11%
26-30 years	9	60.00%	6	40.00%	15	5.86%
>30 years	15	48.39%	16	51.61%	31	12.11%
Total	**131**	**51.17%**	**125**	**48.83%**	**256**	**100%**

Table 2: Primary Indication for CBCT Referral

Reason for CBCT	No. of Patients	% of Patients
Orthognathic surgery	110	42.97%
Impacted Teeth	75	29.30%
MARPE or SARPE	20	7.81%
TMJ	14	5.47%
Supernumerary	10	3.91%
Missing Teeth	10	3.91%
Evaluation of Roots	5	1.95%
Ectopic Eruption	3	1.17%
Evaluation of Airway	3	1.17%
Evaluation of Bone	2	0.78%
Possible Ankylosis	2	0.78%
Syndromes (i.e. Gorlin Goltz)	1	0.39%
Amelogenesis Imperfecta	1	0.39%

ii. Characteristics of IFs

A total of 999 IFs were identified across the 256 analyzed CBCT reports. Of the 256 subjects, only 12 (4.69%) reports contained no IFs. The most prevalent IF was of the airway category (22.92%), followed by paranasal (20.12%), dentoalveolar (19.52%), TMJ (15.02%), calcifications (11.61%), nasal (6.51%), osseous (3.20%), and other (1.10%). A detailed distribution of IFs along with their clinical severity scores and information about treatment modification can be found on Table 3.

Table 3: Descriptive analysis and frequency of IFs, including their clinical significance and treatment influence, in 256 CBCT reports

Category	Incidental Finding (IF)	Number (N)	% of IFs	% of Patients	Clinical Significance	Influence on Orthodontic Treatment
I	**Airway**	**229**	**22.92%**	**89.45%**		
	Narrowed	109	10.91%	42.58%	Moderate	Yes
	Palatal Tonsil Hypertrophy	53	5.31%	20.70%	Moderate	No

	Adenoid/Pharyngeal Hypertrophy	49	4.90%	19.14%	Moderate	No
	Lingual Tonsil Hypertrophy	17	1.70%	6.64%	Moderate	No
	Thicken and elongated soft palate	1	0.10%	0.39%	Mild	No
II	**Paranasal**	**201**	**20.12%**	**78.52%**		
	Mucosal thickening	104	10.41%	40.63%	Mild	No
	- Maxillary	56	5.61%	21.88%	Mild	No
	- Ethmoidal	27	2.70%	10.55%	Mild	No
	- Sphenoid	12	1.20%	4.69%	Mild	No
	- Frontal	9	0.90%	3.52%	Mild	No
	Mucous retention cyst	46	4.60%	17.97%	Mild	No
	Hypoplastic/Aplastic sinus	18	1.80%	7.03%	Mild	No
	- Hypoplastic frontal	7	0.70%	2.73%	Mild	No
	- Hypoplastic maxillary	5	0.50%	1.95%	Mild	No
	- Hypoplastic sphenoid	2	0.20%	0.78%	Mild	No
	- Aplastic frontal	3	0.30%	1.17%	Mild	No
	- Aplastic sphenoid	1	0.10%	0.39%	Mild	No
	Opacified Sinuses / Aerosolized Secretions	14	1.40%	5.47%	Mild	No
	- maxillary	3	0.30%	1.17%	Mild	No
	- ethmoid	3	0.30%	1.17%	Mild	No
	- sphenoid	1	0.10%	0.39%	Mild	No
	- frontal	1	0.10%	0.39%	Mild	No
	- Complete opacification of paranasal sinuses	1	0.10%	0.39%	Severe	No
	- Aerosolized secretions in sphenoid sinus	3	0.30%	1.17%	Mild	No
	- Aerosolized secretions in maxillary sinus	2	0.20%	0.78%	Mild	No
	Opacified ostiomeatal units	10	1.00%	3.91%	Mild	No
	Pneumatization of Sphenoid or Frontal Sinuses	9	0.90%	3.52%	Mild	No
III	**Dentoalveolar**	**195**	**19.52%**	**76.17%**		
	Caries	42	4.20%	16.41%	Moderate	Yes
	Root resorption	25	2.50%	9.77%	Moderate	Yes
	Apical periodontitis	24	2.40%	9.38%	Severe	Yes
	Idiopathic sclerosis / Boney Island	16	1.60%	6.25%	Mild	No

	Dentigerous Cyst	15	1.50%	5.86%	Severe	Yes
	Supernumeraries	13	1.30%	5.08%	Moderate	Yes
	Thin alveolar ridge	12	1.20%	4.69%	Mild	Yes
	Root shortening	11	1.10%	4.30%	Moderate	Yes
	Irregular tooth/root morphology	9	0.90%	3.52%	Mild	Yes
	Missing teeth	8	0.80%	3.13%	Mild	Yes
	Bone loss	8	0.80%	3.13%	Moderate	Yes
	Impaction	6	0.60%	2.34%	Moderate	Yes
	Cemento-osseous dysplasia	4	0.40%	1.56%	Mild	No
	Enamel Pearl	2	0.20%	0.78%	Mild	No
IV	**TMJ**	**150**	**15.02%**	**58.59%**		
	Non-centric relation of condylar head	62	6.21%	24.22%	Mild	No
	Osteoarthritic	34	3.40%	13.28%	Moderate	No
	Bone remodeling	30	3.00%	11.72%	Moderate	No
	Osteophyte	15	1.50%	5.86%	Moderate	No
	Subchondral cyst formation	4	0.40%	1.56%	Moderate	No
	Loss of vertical due to remodeling/erosion	2	0.20%	0.78%	Moderate	No
	Hyperplastic condylar head	2	0.20%	0.78%	Moderate	Yes
	Bifid right condylar head	1	0.10%	0.39%	Mild	No
V	**Calcification**	**116**	**11.61%**	**45.31%**		
	Stylohyoid ligament	37	3.70%	14.45%	Mild	No
	Thyroid/Triticeous cartilages	30	3.00%	11.72%	Mild	No
	Tonsilloliths	18	1.80%	7.03%	Mild	No
	Pineal Gland	9	0.90%	3.52%	Mild	No
	Falx Cerebri	6	0.60%	2.34%	Mild	No
	Choroid Plexus	6	0.60%	2.34%	Mild	No
	Antrolith	5	0.50%	1.95%	Mild	No
	Petroclinoid ligament	3	0.30%	1.17%	Mild	No
	Internal Carotid Artery	2	0.20%	0.78%	Severe	No
VI	**Nasal**	**65**	**6.51%**	**25.39%**		
	Septum Deviation	36	3.60%	14.06%	Mild	No
	Boney Spurs	15	1.50%	5.86%	Mild	No
	Concha Bullosa	11	1.10%	4.30%	Mild	No
	Nasal turbinate hypertrophy	3	0.30%	1.17%	Mild	No
VII	**Osseous**	**32**	**3.20%**	**12.50%**		
	Degenerative changes of C-spine (i.e. erosions and subchondral cysts)	22	2.20%	8.59%	Moderate	No
	Craniofacial Asymmetry	10	1.00%	3.91%	Mild	No
VIII	**Other**	**11**	**1.10%**	**4.30%**		

Soft tissue opacities in external auditory canals	6	0.50%	2.34%	Mild	No
Expansion of incisive canal	3	0.30%	1.17%	Moderate	Yes
High riding jugular bulb	1	0.10%	0.39%	Mild	No
Thinning/expansion of the greater wing of sphenoid bone	1	0.10%	0.39%	Severe	Yes

Of the 999 IFs, 647 (64.76%) of IFs were of mild clinical significance, 402 (44.54%) were of moderate clinical significance, and 43 (4.30%) were of severe clinical significance. A distribution of these findings is shown in Figure 4. Only a total of 15 types of IFs influenced orthodontic treatment with 11 of them stemming from the dentoalveolar category.

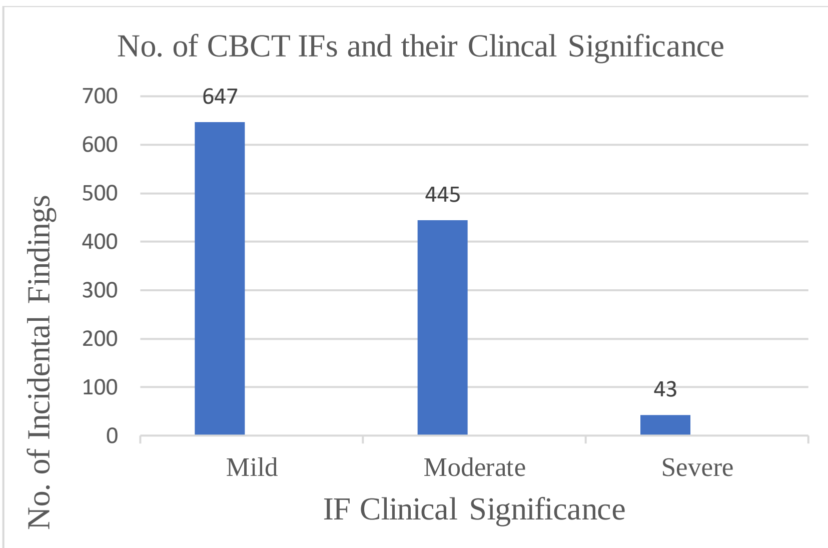

Figure 4: Distribution of CBCT IFs by clinical significance (mild, moderate, and severe)

When comparing the prevalence of IFs across gender (male or female), the chi-squared analysis demonstrated a statistically significant relationship between gender and the presence of calcification IFs (P value= 0.044). The linear-by-linear association test showed that females tend to have a higher proportion of calcification IFs compared to men (P value= 0.045) (Table 4a and 4b). There was no statistical significance found between gender and any other IF category.

Table 4a: SPSS Output Comparing Gender and Presence of Calcification IFs

			Sex		
			Male	**Female**	**Total**
Calcification	Absent	Count	98	79	177
		% within Calcification	55.4%	44.6%	100.0%
		% within Sex	74.8%	63.2%	69.1%
		% of Total	38.3%	30.9%	69.1%
	Present	Count	33	46	79
		% within Calcification	41.8%	58.2%	100.0%
		% within Sex	25.2%	36.8%	30.9%
		% of Total	12.9%	18.0%	30.9%

Table 4b: Chi-Square and Linear-by-Linear Association Significance between Gender and Calcification IFs

	Value	**df**	**Asymptotic Significance (2-sided)**
Pearson Chi-Square	4.040[a]	1	.044
Linear-by-Linear Association	4.025	1	.045

When analyzing the presence of IFs across the different age groups, the chi-squared analysis revealed a statistical significance between age and TMJ IFs (P value < 0.001), osseous IFs (P value < 0.001), and calcification IFs (P value < 0.001). The linear-by-linear association test suggests that as age increases, the presence of TMJ findings may also increase (P value < 0.001), the presence of calcification findings become more prevalent (P value < 0.001), and there is a higher presence of osseous IFs (P value < 0.001) (Tables 5-7). There was no statistical significance between age and the other IF categories.

Table 5a: SPSS Output Comparing Age and Presence of TMJ IFs

			Age					
			1-10	11-15	16-20	21-25	26-30	>30
TMJ	Absent	Count	20	77	33	12	10	14
		% within TMJ	12.0%	46.4%	19.9%	7.2%	6.0%	8.4%
		% within Age	87.0%	78.6%	56.9%	38.7%	66.7%	45.2%
		% of Total	7.8%	30.1%	12.9%	4.7%	3.9%	5.5%
	Present	Count	3	21	25	19	5	17
		% within TMJ	3.3%	23.3%	27.8%	21.1%	5.6%	18.9%
		% within Age	13.0%	21.4%	43.1%	61.3%	33.3%	54.8%
		% of Total	1.2%	8.2%	9.8%	7.4%	2.0%	6.6%
Total		Count	23	98	58	31	15	31
		% within TMJ	9.0%	38.3%	22.7%	12.1%	5.9%	12.1%
		% within Age	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
		% of Total	9.0%	38.3%	22.7%	12.1%	5.9%	12.1%

Table 5b: Chi-square and Linear-by-Linear Association Significance between Age and TMJ IFs

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	29.219[a]	5	<.001
Linear-by-Linear Association	19.120	1	<.001

Table 6a: SPSS Output Comparing Age and Presence of Calcification IFs

			Age					
			1-10	11-15	16-20	21-25	26-30	>30
Osseous	Absent	3.6%	22	80	42	14	5	14
		53.3%	12.4%	45.2%	23.7%	7.9%	2.8%	7.9%
		3.1%	95.7%	81.6%	72.4%	45.2%	33.3%	45.2%
		7	8.6%	31.3%	16.4%	5.5%	2.0%	5.5%
	Present	20.0%	1	18	16	17	10	17
		46.7%	1.3%	22.8%	20.3%	21.5%	12.7%	21.5%
		2.7%	4.3%	18.4%	27.6%	54.8%	66.7%	54.8%
		15	0.4%	7.0%	6.3%	6.6%	3.9%	6.6%
Total		Count	23	98	58	31	15	31
		% within Osseous	9.0%	38.3%	22.7%	12.1%	5.9%	12.1%
		% within Age	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
		% of Total	9.0%	38.3%	22.7%	12.1%	5.9%	12.1%

Table 6b: Chi-Square and Linear-by-Linear Association Significance between Age and Calcification IFs

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	40.758[a]	5	<.001
Linear-by-Linear Association	35.154	1	<.001

Table 7a: SPSS Output Comparing Age and Presence of Osseous IFs

			Age					
			1-10	11-15	16-20	21-25	26-30	>30
Osseous	Absent	3.6%	23	93	49	8	8	23
		53.3%	10.4%	42.1%	22.2%	3.6%	3.6%	10.4%
		3.1%	100.0%	94.9%	84.5%	53.3%	53.3%	74.2%
		7	9.0%	36.3%	19.1%	3.1%	3.1%	9.0%
	Present	20.0%	0	5	9	7	7	8
		46.7%	0.0%	14.3%	25.7%	20.0%	20.0%	22.9%
		2.7%	0.0%	5.1%	15.5%	46.7%	46.7%	25.8%
		15	0.0%	2.0%	3.5%	2.7%	2.7%	3.1%
Total		Count	23	98	58	31	15	31
		% within Osseous	9.0%	38.3%	22.7%	12.1%	5.9%	12.1%
		% within Age	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
		% of Total	9.0%	38.3%	22.7%	12.1%	5.9%	12.1%

Table 7b: Chi-Square and Linear-by-Linear Association Significance between Age and Osseous IFs

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	28.459[a]	5	<.001
Linear-by-Linear Association	21.358	1	<.001

DISCUSSION

CBCTs have become increasingly popular in orthodontics due to the many advantages they offer over traditional 2D imaging. However, IFs are more commonly found on a CBCT image than on a lateral or panoramic radiograph[15] and are often found outside the regions of interest for many orthodontists[5]. Our study found an average of 3.9 IFs per patient report. This finding is comparable to previous studies, which reported 3.2 IFs[9] and 3.6 IFs[16] per scan. This highlights the need to comprehensively review the entire scan to identify any possible pathological findings, even outside the regions of interest. Improved identification of these IFs can potentially prevent further complications or adverse outcomes if identified early. However, not all IFs may require a referral or immediate attention, which is why it is important for clinicians to understand the clinical severity of the IFs. Although all IFs should be disclosed to the patient, having a better understanding of the clinical severity can prevent unnecessary investigations, biopsies, patient anxiety, or financial burden when reporting insignificant IFs[13, 16, 17]. Each major IF category found in this study will be analyzed in detail to understand the prevalence of each IF, clinical significance, and the extent to which they may impact orthodontic treatment.

i. Airway

In this study, airway IFs were most prevalent (Table 3). This finding is consistent with other studies that found airway IFs to be the most prevalent[5, 7, 9, 16, 18]. Similar to the results of this study, Cha et al. found 18.2% of IFs in the airway area, while Price et al. reported 35.0%. However, other studies have reported higher incidences of airway findings, ranging from 42.3%[5] to 51.8%[7]. The reason for these differences can be attributed to the fact that previous studies further generalized the airway category to also include other categories, such as nasal and paranasal IFs. Our study categorized the IFs found into very specific categories to include IFs only of that category. As a result, the percentage of airway IF findings were smaller, but still consistent with being the most prevalent type of IF.

A narrowed airway was present in almost half of the study sample (Table 3). Given this high prevalence, it is important to understand the clinical impacts of such a finding. From the radiology reports reviewed in this study, four reports indicated a narrowed airway which was likely due to a retruded tongue (Figure 5). Therefore, it is important to understand how factors unrelated to a pathology may contribute to a narrowed airway. One important limitation of radiographic assessment of the airway space is that the pharyngeal airway is a dynamic space. The pharyngeal space is constantly changing in volume, area, and shape depending on tongue position, breathing route, swallowing phase, and head and neck position[19]. Therefore, it is essential for clinicians to correlate these CBCT findings with clinical assessments to distinguish between normal physiological variations in airway volume and potential pathologic conditions, such as obstructive sleep apnea. Due to the potential to have pathological effects, narrow airway was given a moderate clinical significance score. However, of the narrowed airways findings, no orthodontic treatment notes indicated an impact to the orthodontic treatment and only 1 patient was referred for a sleep study and required clearance prior to starting orthodontic treatment. Nonetheless, narrowed airway does have the potential to alter orthodontic treatment. For instance, when planning orthognathic surgery, it is important to keep in mind how alterations in the pharyngeal airway through jaw positioning may impact the patient's postoperative breathing and overall health[20].

A) B)

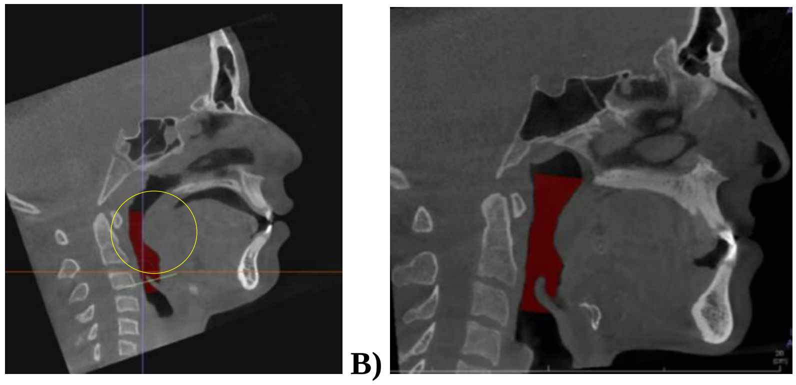

Figure 5: CBCT sagittal cross-sections depicting narrowed airway in a patient with A) retruded tongue position and B) normal (non-retruded) tongue position

Nearly all remaining airway IFs were related to tonsillar hypertrophy with palatal tonsillar hypertrophy being the most prevalent, followed by adenoid hypertrophy, and lingual tonsillar hypertrophy (Table 3). The size of the tonsils and adenoids can vary among individuals and may differ with age. Distinguishing between physiologic and pathological tonsillar hypertrophy can be challenging, and misinterpretation may result in unnecessary and inappropriate treatment[21]. During childhood, adenoids and tonsils intensely grow in size, as they are very immunologically active, and start to atrophy at about 17-20 years of age[22]. Tonsillar hypertrophy may also result from various factors, such as infections, allergies, genetic influences, and in rare cases neoplastic growth. Therefore, it is important to correlate the radiographic findings with clinical symptoms. For instance, in our study, 19 of the 109 of narrowed airway IFs were reported to be likely secondary to enlarged tonsils (Figure 6). Clinical correlation for symptoms of snoring, obstructive sleep apnea, mouth breathing, adenoidal face, throat infections, rhinorrhea, speech impairment, and secretory otitis media, are recommended to assess the need for treatment[22]. Overall, the CBCT should not be the sole determination for making a referral, the clinician must correlate these findings with patient symptoms. Due to the potential to have negative health effects, all tonsillar hypertrophy IFs were given a moderately clinically significant. However, based on the treatment notes reviewed, no patients in this study were referred to a medical specialist nor was there an influence on the orthodontic treatment.

Lastly, our study found no statistical significance when comparing airway IFs across age our gender.

Figure 6: CBCT sagittal cross-section demonstrating adenoid hypertrophy leading to a narrowed airway

ii. Paranasal

The second most common IF category in this study was paranasal IFs (Table 3). This is consistent to the reporting by Edwards et al. which also found paranasal sinus IFs to be the second most common IFs at a rate of 30.9%[5] and close to the reporting of Kadkohdayan et al. which found 15.0%[17] of IFs to be of paranasal sinus nature. However, the prevalence in our study was higher than the prevalence reported by Rheem et al., which found 51.70%[14] of all subjects to have IFs of sinus origin. This can be due the larger sample size in this study which analyzed 256 CBCT reports as opposed to 147 CBCT scans in Rheem et al.'s study. Of the paranasal sinus IF category, the most prevalent IFs were mucosal thickening, followed by mucous retention cyst, hypoplastic/aplastic sinus, opacified sinuses or aerosolized secretions, and pneumatization of sphenoid or frontal sinus (Table 3).

Evaluating sinus mucosa on CBCT scans is crucial in the field of dentistry, as it helps identify pathological changes that may impact treatment planning and overall health, particularly in relation to dental infections. Since periapical lesions may extend to the maxillary sinus it is important to be aware if the mucosal thickening observed on CBCT is odontogenic in nature. The rate of mucosal thickening in our study was comparable to the findings of other studies that demonstrated 30-50%[9, 23] of patients with mucosal thickening. With such a great prevalence, it is important to understand the clinical significance of mucosal thickening. Generally, according to previous studies, mucosal thickening of up to 3mm is common and lacks clinical significance[12, 13, 17, 24] in asymptomatic patients. However, clinical assessment is essential in the assessment of sinus disease. Given this information, mucosal thickening was assigned mild clinical significance, with the understanding that the mucosal thickening did not exceed 3mm. Additionally, none of the mucosal thickening IFs led to modifications in orthodontic treatment.

Another highly prevalent IF found in the paranasal category was mucous retention cyst (Table 3). Mucous retention cysts are common IFs found in 1.79% to 6.89% of IFs in CBCT scans[5, 9, 12, 16]. If an implant or sinus floor elevation procedure are planned, then differential diagnosis such as potential malignancy should be eliminated. However, most often, a “wait and see” approach is recommended for mucous retention cysts, since they often remain unchanged or totally disappear[5, 25] and require no clinical intervention. Thus, mucous retention cysts were given a mild clinical significance score, and no patients had a mucous retention cyst that led to a modification in orthodontic treatment.

Hypoplastic or aplastic sinuses had a smaller prevalence (Table 3). Only one additional study reported on the presence of hypoplastic or aplastic sinus and found them at a rate of 1.53% of all IFs in their study[26]. The clinical significance of such IFs is very mild as it relates to orthodontic treatment. Paranasal sinus hypoplasia and aplasia are rare conditions that mainly occur in the frontal sinus or maxillary sinus. The simultaneous absence of multiple sinuses, accompanied by hypoplasia of others, is an exceptionally rare occurrence[27]. Despite the rare occurrence, further evaluation would be necessary for a surgeon performing sinus surgery to avoid surgical complications[27, 28]. Due to the rarity of this finding and low clinical impact, this IF was given a mild clinical significance score and no effect on orthodontic treatment.

This study further divided opacified sinuses and aerosolized secretions in the paranasal category, but the same mild clinical relevance can be applied to these IFs if mild in nature. Opacification and aerosolized secretions are common findings, even in asymptomatic subjects[5]. Contrastingly, complete opacification of a sinus or even worse of several sinuses warrant further examination and/or referral[12, 13]. According to various studies, the pathology varies from inflammatory in nature to neoplastic. One study concluded unilateral maxillary and sphenoid sinus opacification are markers of neoplasia in 18% of patients and malignant in 7-10% of patients[29]. Therefore, clinicians should pay careful attention and make the appropriate referral to an otolaryngologist when coming across completely opacified sinuses. There was one case in this study with complete opacification of the right paranasal sinuses (Figure 7), but after reviewing the orthodontic treatment clinical notes, there was no influence on the treatment. Thus, although such findings warranted a referral, there were no immediate modifications made to the orthodontic treatment.

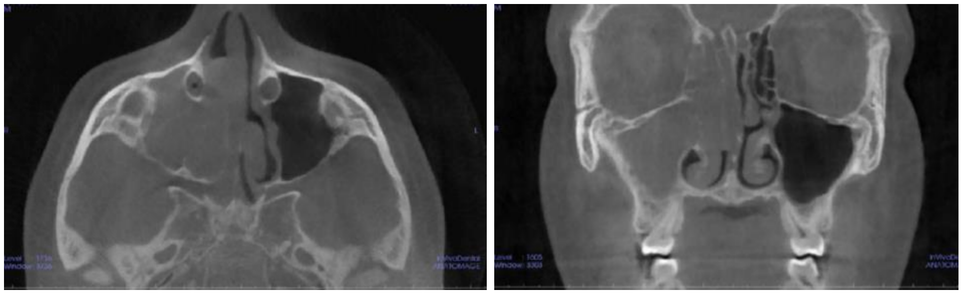

Figure 7: Axial (left) and coronal (right) CBCT cross-sections depicting complete opacification of the right paranasal sinuses, suggestive of sinusitis. Referral to an otolaryngologist is suggested for further evaluation.

The remaining paranasal sinus findings were pneumatization of sphenoid or frontal sinus. No other studies have reported on this occurrence, likely because of the rarity and clinical insignificance. Pneumatization of sinuses are anatomical variants that are necessary to understand when performing sinus surgeries[30]. Unless it is expected that the patient will undergo a sinus surgery, this finding is of very low clinical relevance and does not lead to any orthodontic treatment changes.

Similar to airway IFs, paranasal IFs showed no statistical significance with gender or age.

iii. Dentoalveolar

The third most common type of IF was dentoalveolar (Table 3). This finding is consistent with other studies which found the percentage of dentoalveolar IFs to range from 14.70%[5] to 27.32%[12]. The most common type of dentoalveolar IFs was caries (Table 3). Although CBCTs should not be utilized as a primary choice for caries diagnosis[31], incidental detection of carious lesions should prompt the clinician to refer the patient to a dentist for appropriate evaluation and treatment. Failure to do so can result in more severe dental and systematic complications. As a result, caries was given a moderate clinical significance since follow-up is recommended to ensure the caries has been removed. Based on the clinical orthodontic treatment notes reviewed in this study, caries IF had the potential to influence the orthodontic treatment. In this study specifically, the detection of caries influenced the decision to extract carious teeth versus healthy teeth in two orthodontic extraction cases.

Since there were many IFs in this dentoalveolar category, the following discussion will focus on grouping the IFs based on their clinical significance. The dentoalveolar IFs of mild clinical significance included idiopathic sclerosis, thin alveolar ridge, irregular tooth/root morphology, missing teeth, cemento-osseous dysplasia, and enamel pearl. Of this mild category, three IFs had an influence on the orthodontic treatment, which were thin alveolar ridge, irregular tooth/root morphology, and missing teeth.

Idiopathic sclerosis, commonly known as dense boney island, is a benign localized area of dense bone that is not a result of infection or systemic disease. Idiopathic sclerosis may remain asymptomatic and without any changes for long period of time and there is no need for routine monitoring[32]. However, orthodontic tooth movement through an idiopathic sclerotic lesion may be slower due to high bone density and may warrant lower force levels to avoid root resorption[32]. Despite this information, based on our patient sample, no orthodontic notes described altering orthodontic treatment based on this IF.

Although thin alveolar ridge, irregular tooth/root morphology, and missing teeth IFs were labeled as mildly clinically significant, since they do not pose a direct threat to the patient's health, they did have an influence on the orthodontic treatment. Having a thin alveolar ridge can lead to challenges with implant placement and orthodontic treatment. In a case with a thin alveolar ridge, moving the teeth too far buccally or lingually during orthodontic treatment can lead to bone loss around the teeth[33] and periodontal defects. Of the 12 cases with thin alveolar ridge IFs, there was 1 case in which no orthodontic treatment was recommended due to the severity of thin bone labial to the lower incisors and 11 cases where a non-extraction plan was avoided to prevent the risk of dehiscence and fenestration. In the 9 cases of irregular tooth/root morphology IFs, although altered tooth/root anatomy (i.e. dilacerated root or peg lateral) should not be too much of a concern, there was 1 case in which this IF influenced the clinician's decision to extract an impacted central incisor with a facially dilacerated root. Failure to assess the root morphology in this case could have resulted in an unexpected clinical challenge for the orthodontist. In the 8 cases of missing teeth, the orthodontist had to decide early on whether to close the spaces or maintain space for a future dental restoration. Therefore, orthodontists should pay careful attention to thinness of alveolar ridge, root/tooth morphology, and missing teeth when analyzing CBCTs for treatment planning purposes.

The remaining two IFs of mild clinical significance were cemento-osseous dysplasia and enamel pearl, which are usually asymptomatic and require no treatment. With cemento-osseous dysplasia there is no pain involved, and the diagnosis is often incidental as the lesions are noted when radiographs are taken for other purposes. Invasive procedures like extractions and biopsies should be avoided in the area to prevent secondary infection as the thick cortical margins surrounding the lesions can make it difficult for blood vessels to penetrate making antibiotic therapy obsolete[34]. The four cases of cemento-osseous dysplasia in this study did not require further management, referral, or treatment modifications, but orthodontists should be aware of negative effects a secondary infection can cause and should thus limit the use of extractions, temporary anchorage devices, etc. in the area[35]. Enamel pearls are usually asymptomatic but can be associated with periodontal pockets due to plaque retention and inadequate cleansing.

Nonetheless, no further monitoring, referral, or orthodontic treatment considerations need to be made for enamel pearls.

In addition to caries IFs, moderate clinical significance was also assigned to root resorption, root shortening, supernumerary, impaction, and bone loss IFs. All had an influence on the orthodontic treatment. The category of root resorption IFs included internal and external root resorption (Figure 8). Depending on the type of resorption and etiology of the resorption, different treatment regimens have been proposed, which include 1) No treatment with eventual extraction if/when the tooth becomes symptomatic, 2) extraction, or 3) endodontic treatment of the lesion[36]. Follow-up is recommended to assess whether the resorption has progressed or stabilized. Surprisingly, of the 25 root resorption IFs in our study, only 5 had an influence on the extraction decision and rate of orthodontic tooth movement. However, in the short root IF category (Figure 9), all 11 cases had an influence on orthodontic treatment. Clinicians either elected to extract teeth with short roots in extraction cases or limit the movement of teeth with short roots. Orthodontic treatment is contraindicated in severe root shortening cases, but in less severe cases, biomechanical adaptations and periodic monitoring are required[37]. Thus, extra consideration should be given to the roots when orthodontists are utilizing a CBCT and treatment planning.

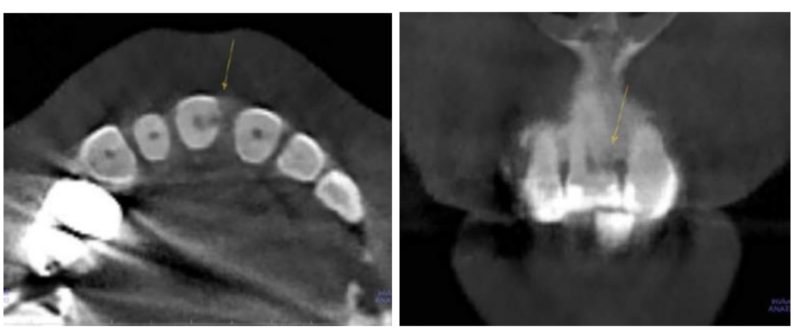

Figure 8: Axial (left) and coronal (right) CBCT cross-sections demonstrating external cervical resorption at the mesial aspect of the tooth #8 with pulpal involvement

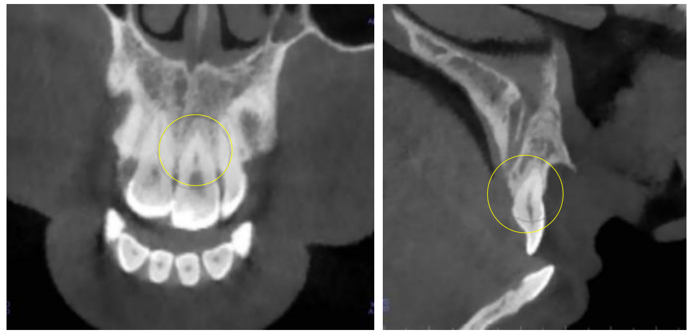

Figure 9: Coronal(left) and sagittal (right) CBCT cross-sections illustrating reduced crown to root ratio of tooth no. 9

Supernumerary and impacted tooth IFs also require follow-up and influence orthodontic treatment. If ignored, supernumerary (Figure 10) and impacted teeth (Figure 11) have the potential to create disturbances to adjacent teeth and even cyst formation[38]. Often, a referral to an oral and maxillofacial surgeon is placed to extract supernumerary teeth and, in some cases, expose and bond impacted teeth to help bring them in the arch. In all 13 supernumerary and 6 impacted cases, the orthodontist had to take these IFs into consideration for orthodontic treatment planning. A decision had to be made between extracting the teeth or attempting to align them within the arch. If alignment was chosen, the treatment plan required the incorporation of appropriate orthodontic mechanics.

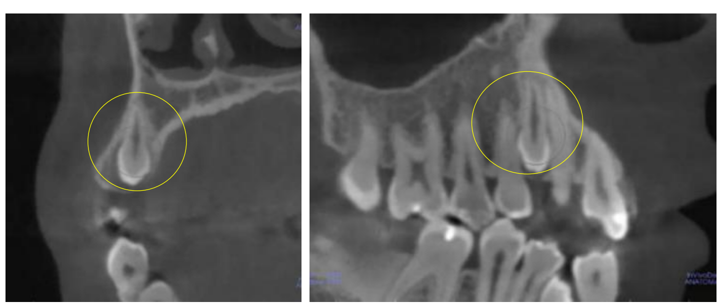

Figure 10: Coronal (left) and sagittal (right) CBCT cross-sections showing supernumerary tooth #5A is unerupted and vertically oriented at the palatal aspect of teeth #5 and 6

Figure 11: Axial (left) and sagittal (right) CBCT cross-sections demonstrating impacted tooth #29, which was previously believed to be missing

Bone loss was deemed moderately clinically significant, as clinicians should monitor the progression and make precautionary referrals to a periodontist to prevent further bone loss. Studies show in patients with severe bone loss, orthodontic therapy must always be preceded by periodontal therapy. The combination of periodontal regenerative procedures with orthodontic treatment represents the gold standard for treatment of intrabony defects[39, 40]. In 1 of the 8 cases with bone loss (Figure 12), the clinician referred the patient to a periodontist before initiating orthodontic treatment and took measures to shorten the treatment duration.

Figure 12: Panoramic reconstruction from a CBCT showing generalized bone loss

Apical periodontitis (Figure 13) and dentigerous cyst (Figure 14) were the two IFs in the dentoalveolar category classified as having severe clinical significance, necessitating immediate referral or treatment. Since many other conditions mimic the appearance of apical periodontitis, it is important for clinicians to interpret the radiographic findings with clinical symptoms to understand the nature and stage of apical disease. If apical periodontitis is suspected, it is important to send the patient for further evaluation by an endodontist since early detection can prevent complications, such as bone loss, abscess formation, or systemic effects. If left untreated, severe complications such as osteomyelitis, cellulitis, and life-threatening Ludwig's angina can occur[41]. Lastly, dentigerous cysts are generally asymptomatic and are often IFs on routine radiographs or radiographs taken to locate a tooth that has failed to erupt[42]. Dentigerous cysts are of severe clinical significance due to their ability to cause bone destruction, resorption of roots, infection, and jawbone fracture. If untreated, potential complications include transformation of the epithelial lining into an ameloblastoma[43]. Referral to an oral surgeon should be made immediately for biopsy and cyst removal.

Figure 13: Coronal CBCT cross section depicting apical periodontitis associated with tooth #8

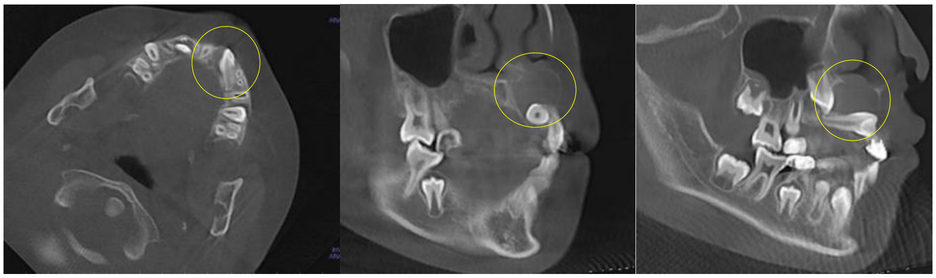

Figure 14: Axial (left), coronal (middle), and sagittal (right) CBCT cross-sections showing a dentigerous cyst associated with the crown of impacted tooth #9

Similar to airway and paranasal IFs, dentoalveolar IFs showed no statistically significant association with gender or age.

iv. TMJ

TMJ IFs were the fourth most common type of IFs in this study (Table 3). This is similar to the rate found in Price et al.'s study which found TMJ IFs in 14.3% of all IFs and 34.6% of patients[9]. However, the TMJ IF rates in this study were consistently higher than other studies which found TMJ IFs ranging from 5.71%-6.14%[5, 12] of all IFs and 11.10%-26.53%[7, 14] of all patients. This can be attributed to the fact that the highest number of TMJ IFs came from the non-centric relation of condylar head IF, which other studies did not report. The probable reasons this IF was not included in other studies are because IF studies typically prioritize structural abnormalities over positional variations that may not be clinically relevant or because centric relation is a physiologic concept that is best evaluated through clinical examination. However, in this study, if a patient did present with this IF, then clinical correlation with TMJ pain and/or dysfunction was recommended by the radiologist. Otherwise, no further follow-up was recommended and was thus given a mild clinical significance score. Similarly, no cases with this IF led to any orthodontic treatment plan changes.

Degenerative joint disease is characterized by the following changes and decreased in prevalence in the following order: osteoarthritic changes, osteophyte formation (Figure 15A), subchondral cyst formation (Figure 15B), and erosions (Figure 15C) (Table 3). Per the Diagnostic Criteria for Temporomandibular Disorders, degenerative joint disease was confirmed if erosions, sclerosis, osteophytes, or subchondral cysts were observed on CBCT imaging[44]. Once degenerative changes start, the pathology can be crippling and lead to functional deformities[45]. Therefore, if these IFs are present in a CBCT report, the clinician should monitor the patient for developing symptoms and/or make a referral to a TMJ specialist. In this study, orthodontic treatment plans remained unchanged in any case with degenerative joint disease IFs because the patients were asymptomatic, and thus only monitoring was necessary. If patients presented with symptoms (i.e. pain, limited opening, etc.) then it is very likely the clinician requested a CBCT to observe the TMJs and thus the findings were not considered incidental. Nonetheless, in symptomatic cases, a referral to a TMJ specialist is recommended along with a 6-9 month radiographic follow up to track degenerative changes.

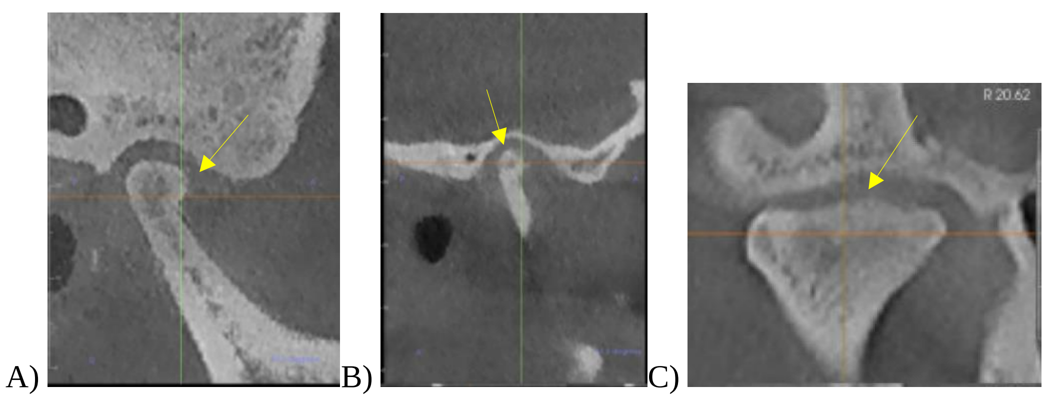

Figure 15: CBCT cross-sections depicting osteoarthritic changes of the TMJ A) Sagittal view showing osteophyte formation at the anterior aspect of the right condyle B) Sagittal view demonstrating subchondral cyst formation along the anterior surface of right condyle C) Coronal view depicting cortical erosion at the superior aspect of the right condyle

Remodeling of the TMJ IF can be considered either a physiological adaptation or pathological. Remodeling can occur as result of adaptation to altered joint forces or can be the beginning signs of degenerative joint disease[12]. Therefore, clinical correlation is recommended to determine the etiology. This IF has moderate clinical significance if asymptomatic, but would be classified as severe if symptoms are present, warranting referral to a TMJ specialist. There is no need to modify orthodontic treatment if TMJ remodeling is present.

Condylar hyperplasia (Figure 16) was reported in two patients, but these cases were mild in nature and thus did not have an influence on the orthodontic treatment. However, this may not always be the case. Condylar hyperplasia generally appears in subjects' growth phase where there is excessive growth in one condyle over the other. This leads to facial asymmetries and dental malocclusions[46]. Follow-ups are required to monitor the progression of the condylar growth. For moderate to severe cases involving dental malocclusions, such as crossbites or open-bites, the orthodontist should refer the patient to a TMJ specialist to assess whether the growth is active or inactive and determine the appropriate treatment approach. It is crucial for the orthodontist to obtain this information before initiating treatment to determine whether the asymmetry and malocclusion are likely to progress or remain stable. Therefore, condylar hyperplasia does have an influence on the orthodontist's treatment plan.

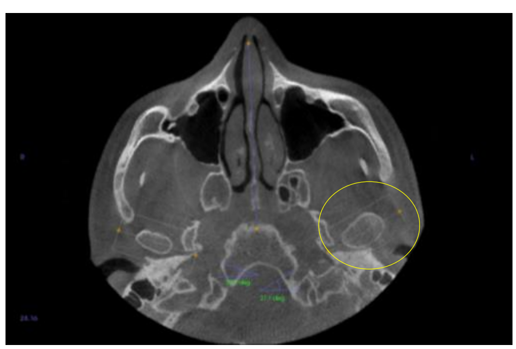

Figure 16: Axial CBCT cross-section demonstrating a hyperplastic left condylar head

There was one case of unilateral bifid condylar head in this study, which is of mild clinical significance and does not lead to any modifications in orthodontic treatment. Bifid mandibular condyle is an extremely rare anatomic variation, but can also be associated with trauma[47]. They are often asymptomatic and discovered as an IF[48]. Regarding symptomatic cases, monitoring and referral to a TMJ specialist is recommended.

Although TMJ IFs showed no statistical significance with gender, there was a statistical significance associated with age. The linear-by-linear association test indicated a potential increase in TMJ findings with advancing age (Table 5b). This is expected as it is consistent with the literature which states that TMJ disorders show a peak prevalence in 45-64 year olds and then only gradually decreases with age[49]. Since the final age group in this study included all subjects over 30, future research should further subdivide this category to determine whether the declining trend in TMJ disorders continues beyond age 64.

v. Calcification

The fifth most common type of IF found in this study was calcification IFs (Table 3). The prevalence in this study is close to previous IF studies which reported 7.32%[12] of IFs and 58.67%[9] of patients. The discrepancy in findings may be due to the varying sample sizes and which calcifications were recorded. Previous studies mainly focused on stylohyoid, tonsilloliths, thyroid/triticeous, and carotid artery calcifications, while this study included antroliths, pineal gland, falx cerebri, choroid plexus, and petroclinoid ligament calcifications. All, but antroliths, can be categorized as soft tissue or intracranial calcifications. Previous studies have classified antroliths in the airway category. However, since an antrolith is defined as a calcified mass within the maxillary sinus, this study categorized it under calcifications.

Antroliths present on the floor of the maxillary sinus. They are usually asymptomatic and incidentally discovered on routine radiographs. However, larger antroliths may present with symptoms of pain, nasal obstruction, and discharge. It is also very common for antroliths to be associated with sinusitis and if so, treatment is recommended along with treatment for the infection[50]. Unless symptomatic or performing any procedures that involve the sinus floor, no treatment is necessary. No modifications to orthodontic treatment are necessary.

The soft tissue calcifications identified in the 256 CBCT reports included the stylohyoid ligament, thyroid/triticeous cartilages and tonsilloliths, which were all considered mildly clinically significant and do not require orthodontic treatment changes. Calcification of the stylohyoid ligament had the highest prevalence of IFs in the calcification category. Most patients with a calcified stylohyoid ligament are asymptomatic. However, in some cases, the calcified ligament can compress adjacent nerves and vessels leading to symptoms such as, recurrent throat and facial pain, foreign sensation in neck, and dysphagia[51]. Therefore, clinical correlation is essential. If the patient exhibits symptoms, they should be referred to their primary care physician for further evaluation and treatment. Thyroid/triticeous cartilages were the second most prevalent calcified IFs. Calcification of the thyroid and triticeous cartilages starts upon reaching skeletal maturity and continues as a normal physiologic process[52]. They are incidental findings with no clinical relevance[53]. Last of the soft tissue calcifications, which were the third most common calcification IFs were tonsilloliths. Tonsilloliths are biofilm calcifications that form in the crypts of palatal tonsils. They give rise to increased halitosis and an unsettling foreign body sensation[54]. Removal can alleviate halitosis and discomfort; however, treatment is generally not required.

The intracranial calcification IFs found in this study were pineal gland, falx cerebri, choroid plexus, petroclinoid ligament, and internal carotid artery calcifications. All were categorized as mildly clinically significant with no influence on orthodontic treatment, except for internal artery calcifications which were considered highly clinically significant. Pineal gland calcifications present from fetal life to adulthood and increase in number and size with aging[55]. They are often physiological, but in very rare occurrences can be pathological if associated with symptoms. Similarly, falx cerebri calcifications are considered a physiological phenomenon and not clinically relevant[56]. However, studies have found that calcification of the falx cerebri is a pathognomonic feature of Gorlin-Goltz syndrome, which is a nevoid basal cell carcinoma syndrome[57]. Understanding this correlation can aid clinicians and physicians in making appropriate diagnoses. Choroid plexus calcifications are also age-related and common in adults. In most cases, no treatment is necessary. However, if exuberant calcification is present in young patients, then pathological calcification of the choroid plexus should be evaluated[58]. Studies have also found that choroid plexus calcifications may serve as potential markers for neurodegenerative conditions[59]. Recognizing this relationship can enhance communication with physicians and support an interdisciplinary approach to patient care. Petroclinoid ligaments are commonly asymptomatic, but very rarely may be symptomatic depending on the site and extent of the calcification. Typically petroclinoid ligament calcification is considered a normal physiologic process, but some studies state it has been seen as a radiographic feature of nevoid basal cell carcinoma and systemic fluorosis[60]. However, most do not lead to any clinical concern. Last of the intracranial calcification IFs is calcification of the internal carotid artery (Figure 17), which unlike the previous intracranial calcifications, does pose a potential risk to patients and is therefore assigned a severe clinical significance score. Calcification of the intracranial carotid arteries plays a role in the progression of atherosclerosis. Atheromatous plaques arise because of intimal calcification and can give rise to vascular stenosis, occlusion, and secondary degenerative alternations[61]. Due to the proven correlation between carotid stenosis and ischemic stroke, it is imperative that the clinician evaluating the CBCT refers the patient to their primary care doctor to prevent major cardiovascular events[17]. Although this may not directly have an influence on orthodontic treatment, it is important for orthodontists to know how to evaluate the severity and make referrals in a timely manner.

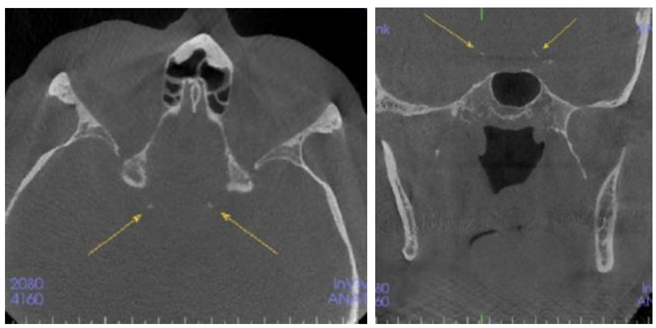

Figure 17: Axial (left) and coronal (right) CBCT cross-sections showing circumferential calcifications within the cavernous segments of the internal carotid artery

This study identified a statistically significance association between calcification IFs with gender (Table 4b) and age (Table 6b). The linear-by-linear association test suggested that females tend to have a higher proportion of calcification IFs compared to men (Table 4b). This finding contrasts the results of previous studies, which have found vascular calcifications to have a higher prevalence in males than females[62-64]. However, these studies were assessing the association between gender and vascular calcifications while this study analyzed a variety of calcifications. More research needs to be done comparing the association between serval types of calcification IFs with gender. However, it is important to note that the results were borderline significant, so it is possible that the relationship was not truly statistically significant as other studies have reported[65, 66].

However, the association between calcification IFs and age was strongly significant (Table 6b). The linear-by-linear association test suggested that as age increases, there is a higher presence of calcification IFs. This is supported by research stating calcifications of soft tissues is an age-related pathology that primarily occurs within vascular tissue[67]. Similar studies have also found that the older the patient, the greater the number of calcifications[12].

vi. Nasal

Nasal IFs were the sixth most common type of calcifications found in this study (Table 3). These results come very close to the results reported in other studies where nasal IFs ranged from 7.38-12.11%[5, 9] of all IFs and 21.67-27.60%[5, 7, 9] of all patients. All nasal IFs were classified as normal anatomical variants, requiring referral to an otolaryngologist only if the patient exhibited symptoms[13, 16]. As a result, none of the nasal IFs had an influence on the orthodontic treatment.

Nasal septum deviation was the most prevalent IF in the nasal category, followed by boney spurs (Table 3). Boney spurs are frequently associated with nasal septum deviation[68]. Depending on the severity, presence of nasal septum deviation and/or boney spurs can impact nasal airflow, leading to obstruction or a diminished sense of smell[69]. However, it is of little clinical concern considering they are normal developmental variations found in most of the population[68].

Concha bullosa was the third most common nasal IF (Table 3). The middle nasal turbinate is essential for effective drainage of the maxillary sinus, but when it becomes pneumatized, it is referred to as concha bullosa. In rare cases, an enlarged concha bullosa can lead to sinusitis by blocking the ostiomeatal complex[70]. If a patient does present with concha bullosa and is planning for implants in the sinus area, clinicians must be aware of the predisposition concha bullosa has to postoperative conditions. However, in most cases no pathology results[71].

Hypertrophy of the nasal turbinate was the least common IF found in the nasal category. Similar to the previous nasal IFs, the nasal turbinates have the potential to cause nasal obstruction if they become hypertrophied[72]. Treatment is typically pursued only in cases of severe symptoms, at which point an otolaryngologist would provide care.

Nasal IFs showed no statistically significant association with gender or age.

vii. Osseous

Osseous IFs included degenerative changes of the cervical spine and craniofacial asymmetry (Table 3). Studies by Theodoridis et al., Edwards et al., and Rheem et al., reported similar prevalences of osseous IFs representing 1.07% of IFs, 1.31% of IFs, and 15.64% of patients, respectively[5, 14, 16]. However, Barghan et al. and Kadkohdayan et al. reported a higher prevalence of osseous IFs, at 20.06% and 18.00%, respectively[17, 73]. A possible explanation for this discrepancy can be due to a difference in the mean age of the sample population. The mean age for the subjects in Barghan et al. and Kadkohdayan et al.'s study was 47.08 and 53.90 years, respectively[17, 73]. Whereas the mean age in this study was 19.66 years. Previous studies have found a significant association between age and increased degenerative vertebral changes. One study found that the prevalence of disk degeneration increased from about 70% of individuals younger than 50 years to greater than 90% in individuals greater than 50 years[74]. Having a younger sample population is a possible explanation for why this study did not identify more osseous IFs. However, this study did find a significant correlation between age and osseous IFs

(Table 7b). More than half of the osseous IFs in this study were related to degenerative changes of the cervical spine (Figure 18) and in one case a referral was generated for further analysis. However, this highlights the need for clinicians to be well versed in understanding the impact of these moderate type of IFs to make referrals in a timely manner. Disc degeneration is frequently observed incidentally in asymptomatic individuals, becoming nearly universal after age 45 and typically progress over time[75]. While degenerative cervical spine disorders are often benign, cervical disorders may become debilitating resulting in pain and possibly neurologic sequelae[76]. This highlights the importance of clinicians being able to assess the severity of IFs and exercise their judgment in determining when a referral may be beneficial to help mitigate the progression and impact of degenerative changes[5].

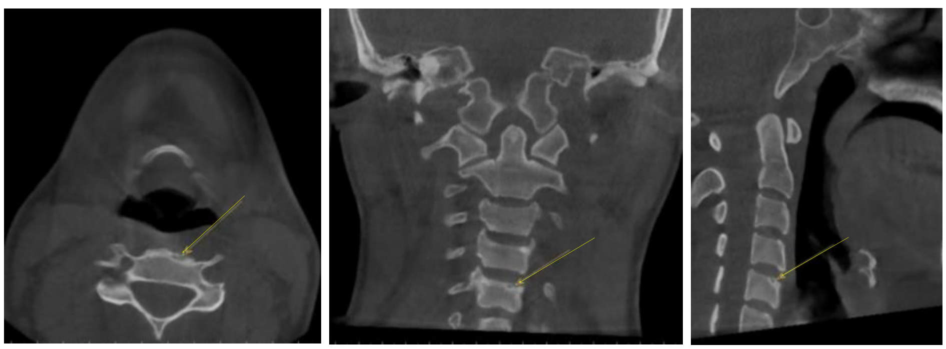

Figure 18: Axial (left), coronal (middle), and sagittal (right) CBCT cross-sections illustrating erosions and subchondral cyst formation at the anterior body for the C5 cervical spine vertebra

The second type of osseous IF was craniofacial asymmetry (Table 3). Since all patients were orthodontic patients presenting for initial evaluation and records, it is highly likely that those with significant craniofacial asymmetry would have been referred for CBCT imagining to assess the asymmetry and possibly plan for orthognathic surgery. Therefore, the low prevalence observed is likely because most craniofacial asymmetries can be detected clinically and thus not considered incidental. Minor craniofacial asymmetries and not clinically relevant, but moderate to severe asymmetries may be associated with morphologic, esthetic, and stomatognathic problems that require further investigation into the cause of the asymmetry and orthognathic correction[77]. None of the craniofacial symmetries in this study were significant enough to warrant orthognathic correction.

viii. Other

There were 4 other IF categories which did not fit into one of the 8 other categories and were thus categorized as “other” (Table 3). One was soft tissue opacities in the external auditory canals, likely representing accumulated cerumen. These were categorized as having low clinical significance, requiring neither monitoring nor referral. However, if symptomatic, referral may be necessary to rule out lesions, such as cholesteatoma and malignant otitis externa[78].

There were 3 cases with expansion of the incisive canal. Expansion of the incisive canal (Figure 19) usually represent incisive canal cysts. Incisive canals are usually under 6mm in diameter, but when they exceed 6mm, cystic changes should be considered[79]. One study found incisive canals were frequently larger than 6mm in patients over the age of 60. Therefore, they concluded the need to consider age differences when diagnosing incisive canal cysts[80]. However, referral to an oral surgeon should be made on suspicion of incisive canal cyst due to their ability to cause pain, swelling, infection, and/or impaction of teeth[81]. Therefore, expansion of the incisive canal has the potential to alter orthodontic treatment if a cyst and impaction are involved.

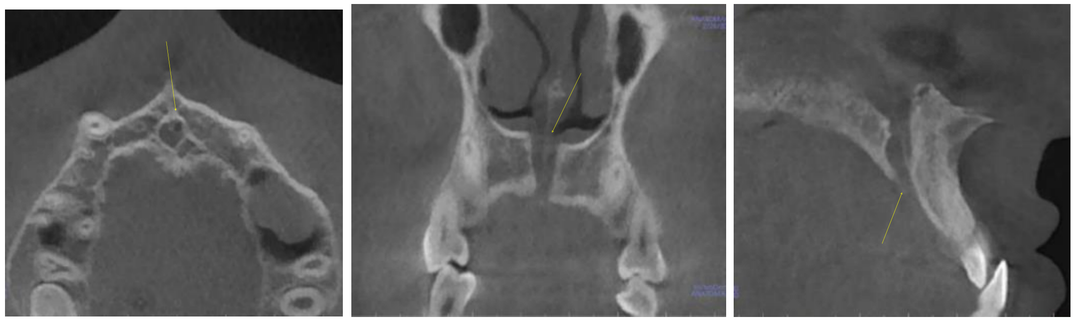

Figure 19: Axial (left), coronal (middle), and sagittal (right) CBCT cross-sections showing expansion of the incisive canal

High riding jugular bulb was observed in one report, which is a common venous anomaly and of low clinical significance. Most cases will be asymptomatic, but the high riding jugular bulb can cause pressure on the surrounding structures and cause tinnitus and conductive hearing loss[82]. In such cases, referral should be made for possible surgical planning.

The final and most significant IF in the study was expansion and thinning of the greater wing of the sphenoid (Figure 20) which led to the most urgent and severe referral. The CBCT radiology report reported the IF to be suggestive of a benign neurologic lesion with potential diagnoses including a ganglioglioma or an arachnoid cyst. It is critical to differentiate between the two as a ganglioglioma is cancerous in nature and an arachnoid cyst is a non-cancerous fluid collection. However, both have the potential to cause headaches, seizures, and nausea[83]. Most arachnoid cysts do not require treatment unless symptomatic, in which surgery is almost always curative[84]. On the contrary, gangliogliomas are slow growing, often appear late and age, have a high rate of progression, and thus optimal treatment is complete resection[85]. This IF is of the most severe clinical significance and requires immediate referral to a specialist. Orthodontic treatment should be postponed until clearance from the specialist. In this study, the patient with this IF, was immediately notified and referred to their primary care doctor. Orthodontic treatment was postponed until clearance from their physician was obtained. The physician recommended no immediate treatment but advised follow-up with another radiograph in one year for monitoring.

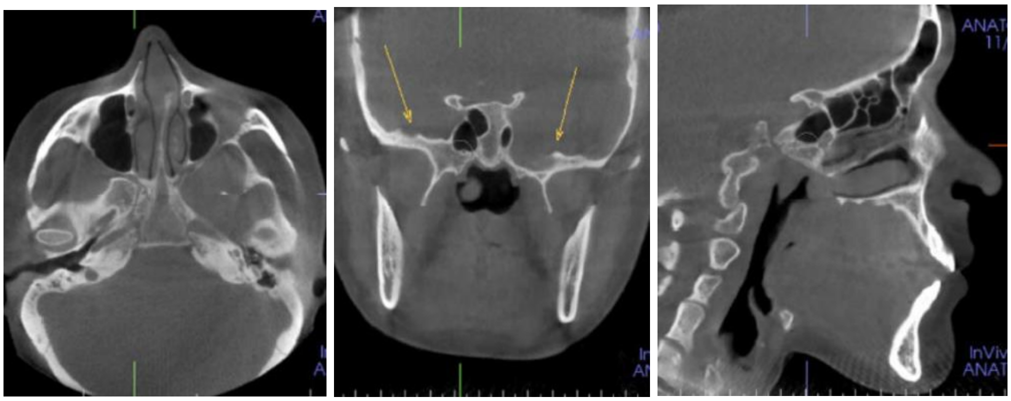

Figure 20: Axial (left), coronal (middle), and sagittal (right) CBCT cross-sections demonstrating asymmetric skull base. There is thinning and expansion of the greater wing of the sphenoid bone. The orbital surface of the greater wing of the sphenoid is expanded.

Of the 999 IFs found in this study, most IFs were of mild clinical significance, followed by moderate clinical significance, and only a small percentage of severe clinical significance (Figure 4). These findings are consistent with previous studies that demonstrate most IFs found on CBCTs are of minor clinical concern[12, 13]. Despite the high prevalence of CBCT IFs often being of low clinical significance, it is crucial for clinicians to recognize and interpret the scan in its full entirety to ensure that no clinically relevant abnormalities are overlooked. Although the prevalence of moderate and severe IF were lower, management or referral of these IFs, can be lifesaving, such as in the cases of calcified carotid arteries or possible ganglioglioma identification. Proper evaluation allows for early identification of potentially significant pathologies, ensures comprehensive patient care, and helps in making informed treatment decisions while maintaining medico-legal responsibility. If a clinician lacks expertise in interpreting CBCTs, a referral to an oral and maxillofacial radiologist is advised for a comprehensive assessment of the scan[5, 7-10].

Unlike previous studies that have not correlated CBCT IFs with clinical information, our study uniquely analyzed orthodontic treatment charts to determine which IFs influenced treatment decisions—an aspect not explored in prior research. This study found a total of 15 different IFs that influenced orthodontic treatment, most of which were of dentoalveolar origin. The 15 IFs were narrowed airway, caries, root resorption, apical periodontitis, dentigerous cyst, supernumeraries, thin alveolar ridge, root shortening, irregular tooth/root morphology, missing teeth, bone loss, impaction, hyperplastic condylar head, expansion of incisive canal, and thinning/expansion of the greater wing of the sphenoid bone. It is important to note that while not every patient with these IFs required modifications to their orthodontic treatment, for those who did, these findings were important for orthodontists to further investigate when treatment planning.

This study had limitations, including the lack of consistency in having the same two radiology residents or board-certified radiologists evaluate all CBCTs, as well as the absence of intra- and inter-rater reliability assessments. Since the CBCTs had been collected over the years and the residents change from year to year, it is not possible to have all the CBCT reports written by the same residents. Similarly, approximately three different board-certified radiologists reviewed the reports, leading to potential variability. This limitation could not be addressed in our study, as the reports were generated before the study was implemented. Additionally, another pitfall may be that there may be missing or incomplete clinical notes from which it may be difficult to determine whether there was a modification/alteration made to the patients' treatment plan. Lastly, inconsistencies exist across studies regarding the classification of each IF. Future studies can address this pitfall by establishing standardized classification criteria for IFs to ensure consistency across research. This could be achieved through consensus guidelines developed by a panel of experts, including radiologists, orthodontists, and other relevant specialists.

The growing use of artificial intelligence (AI) in healthcare presents an opportunity to enhance CBCT interpretation by integrating the findings of this and other similar studies into AI algorithms, enabling automated detection and classification of IFs with greater accuracy and efficiency. Some studies have already begun to use AI for dental diagnosis with CBCT; however, clinicians must still know how to review the output. For instance, AI may accurately detect a narrowed airway, but as this study showed, narrowed airway can be a result of a retruded tongue or tonsillar hypertrophy. Therefore, AI may be a useful tool; however, clinicians should still confirm the results with diagnostic tools already at their disposal, such as sectioning CBCT images and evaluating the slices in closer detail.

Although a valuable diagnostic asset, AI may have the potential to lead to overdiagnosis. For instance, AI may be very useful and accurate in detecting common IFs, such as mucosal thickening, caries, septum deviation, etc., but may have low specificity for more rare IFs, such as internal carotid artery calcifications of thinning/expansion of the greater wing of the sphenoid. The high rate of false positives can result in unnecessary patient anxiety and additional costs from further diagnostic investigations. This is why it is imperative a clinician still be able to read and interpret a CBCT or refer to an oral and maxillofacial radiologist instead of fully relying on AI for diagnostic purposes. While AI can enhance the detection of IFs on CBCTs, orthodontists still have a moral obligation to thoroughly review and accurately report all relevant findings to ensure the well-being and informed care of their patients.

CONCLUSIONS

- Our results demonstrated that of all the IFs in this study, airway IFs were most prevalent (22.92%), followed by paranasal (20.12%), dentoalveolar (19.52%), TMJ (15.02%), calcification (11.61%), nasal (6.51%), osseous (3.30%), and other (1.10%) IFs.
- The chi-squared analysis revealed a statistically significant difference in the distributions of IFs in the calcifications category across different genders (P value= 0.040). Additionally, statistical significance was found between age and TMJ IFs (P value < 0.001), osseous IFs (P value < 0.001), and calcification IFs (P value < 0.001).
- Most IFs (64.76%) were of mild clinical significance, followed by moderate clinical significance (44.54%), and only a small percentage (4.30%) of severe clinical significance.
- This study found a total of 15 different IFs that influenced orthodontic treatment, most of which were of dentoalveolar origin.
- The 15 IFs were narrowed airway, caries, root resorption, apical periodontitis, dentigerous cyst, supernumeraries, thin alveolar ridge, root shortening, irregular tooth/root morphology, missing teeth, bone loss, impaction, hyperplastic condylar head, expansion of incisive canal, and thinning/expansion of the greater wing of the sphenoid bone.
- Orthodontists must be proficient in interpreting CBCT scans and recognizing IFs to ensure comprehensive patient care and early detection of clinically significant abnormalities. A thorough understanding of these findings allows for appropriate referrals and informed treatment planning, ultimately prioritizing the patient’s overall well-being.
- Future directions include feeding the results of this study and other similar studies into AI algorithms, enabling automated detection and classification of IFs with greater accuracy and efficiency.

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