PATHOLOGY OBSERVED ON CONE BEAM COMPUTED TOMOGRAPHIC SCANS: A COMPARISON OF PREVALENCE AND TYPE OF INCIDENTAL FINDINGS FOR CHILD/ADOLESCENTS AND ADULTS

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DEDICATION

This thesis is dedicated to my grandfather, who at 98 years young, inspires me to this day. Also thanks to my Lord and Savior Jesus Christ for his countless blessings.

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ABSTRACT

Introduction: Cone beam computed tomography (CBCT) has gained popularity in the field of dentistry and orthodontics. The increased use of CBCT raises the likelihood of incidental findings outside of the primary area of interest. This study compared the prevalence, type, and percent of referral for incidental findings observed on CBCTs between child/adolescent and adult patients. **Method**: 267 CBCT scans from child/adolescent patients (≤18 yo) and 254 from adults (≥19 yo) were evaluated by one radiologist and findings were placed into seven categories for comparison. All findings were categorized as 1) requiring referral to a healthcare provider, 2) requiring referral, if symptomatic, and 3) those requiring no referral. The groups were compared using Chi Square analysis. **Results**: 97.3% of all 521 scans had at least one incidental finding. Adults were more likely to incur at least one finding ($p<0.001$) in every category studied; the airway category revealed a greater ($p=0.0001$) number of findings in the child/adolescent group. Adults were more likely ($p=0.0001$) to have findings that required referral to a healthcare provider. Referrals for dental ($p=0.0001$), osseous structures ($p=0.0084$), and other findings ($p=0.0062$) were more prevalent for adults. **Conclusions**: CBCTs of adults revealed more incidental findings in all, but one category. The airway category was the only one in which child/adolescent patients exhibited more findings. CBCTs of adults revealed a higher percentage of incidental findings that required referral (42%) to a healthcare provider, compared to child/adolescents (17%). The high prevalence of findings observed in this study, supports routine review of CBCT scans by a radiologist.

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I. BACKGROUND AND LITERATURE REVIEW

A. Background

Cone beam computerized tomography (CBCT) was introduced into the European market in 1998 and first entered the US market in 2001 (Hatcher, 2010). This technology ultimately originates back to Godfrey Hounsfield and his invention of what he called computerized axial transverse scanning in the 1970's. He used a moving fan-shaped beam of x-rays that rotated about the head of the subject and the remnant of radiation that existed after passing through the patient was detected by a scintillation crystal sensor. This sensor relayed the info to a computer that using mathematical algorithms was able to reconstruct two-dimensional images that could be viewed in the axial, coronal, or sagittal planes, via multiplanar reformatted imaging. The image volume was actually a compilation of individual rectangular-shaped volumes of data called voxels (*vo*lume *el*ements) (Fig 1, C).

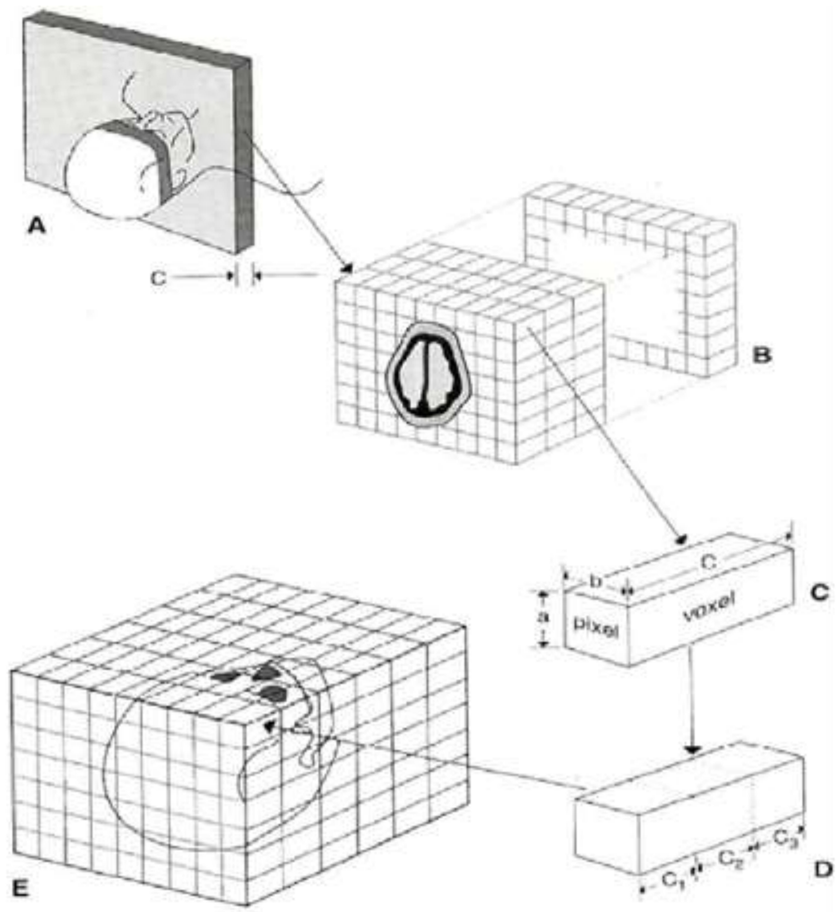


Figure 1: CT Composition (Source Oral Radiology: Principles and Interpretation 4th Ed. 2000)

The size of the voxel is a product of the computer program used to construct the image as well as the width of the x-ray beam. Each voxel is also assigned a value that comes from the amount the beam was attenuated in that volume element as the radiation passed through the subject. For conventional CT, this value is called a Hounsfield unit (HU), named in the honor of Godfrey Hounsfield, and they ranged from -1000 for air, 0 for water, and +1000 for dense bone. Being able to detect a vast array of densities allowed CT to have an inherently high-contrast resolution.

While conventional radiography needed a 10% difference in physical density to detect a difference, CT needed a less than 1% change in density, allowing for images with higher resolution and also allowed a view of soft tissues. As computer programs advanced they were able to take the data gained from the CT scan to form three-dimensional images. This required that each voxel be divided into multiple cuboidal-shaped voxels by a process called interpolation (Fig 1, D). Over time companies began to change the shape of the beam in attempts to shorten the scan time needed and thus decrease the radiation dose to the patient. This led to the production of both spiral and cone-beam CTs [White & Pharoah, 2000].

In cone beam CT, as the name implies, the beam is conical in shape as opposed to the original fan-shaped beam (Fig 2). CBCT was originally developed with angiography in mind (Farman & Scarfe, 2009). It was not until the late 1990's that the computer technology and the ability to produce x-ray tubes capable of continuous radiation production that were small and inexpensive enough for use in a dental office. Two additional advancements further increased the reality of CBCT. These were the development of two-dimensional detector arrays and refinement of cone-beam algorithms. Detectors were initially produced using a combination of scintillation screens, image intensifiers (II), and charged couple device (CCD) detectors. These detectors were subject to a number of issues. They were large and bulky, had a tendency to not capture the complete volume of the scan, and their sensitivity was affected by magnetic interferences from both the image intensifiers and the earth itself. These bulky detectors were replaced by high-resolution, inexpensive flat panel detectors (FPD), composed of hydrogenated amorphous silicon (a-Si) thin film transistors. With these new detectors a scintillator made up of terbium-activated gadolinium oxysulphide or thallium-doped cesium iodide, detects the x-rays and converts them into visible light that is registered by a photo diode array. This type of detector offers greater dynamic range and reduced distortion, offset by a slightly greater radiation exposure. Flat panel detectors do have their limitations though related to linearity of response to the radiation spectrum, uniformity of the response throughout the detector, and bad pixels. These limitations are overcome by making the detectors linearized piecewise to cause nonuniformity that can be identified by the software and calibrated. Another way to increase image detail is to reduce the size of the pixels in the detector. Conventional CT imaging had its voxel size determined by the slice thickness, but CBCT imaging is dependent upon pixel size on the area detector. In CBCT imaging, the area of the detector is less than a millimeter, ranging from 0.07 mm to 0.4 mm. This comes at a price though as the detector panel has two components, the photodiodes that record the image and the thin-film transistors that act as carriers of the information. Therefore a portion of the detector is not actually recording the image. Fill factor is the percentage area of the detector that is actually registering information within an individual pixel. The fill factor may be as low as 35%, therefore more radiation is needed to make more photons available to activate the smaller pixels and reduce image noise. However it is the reduction in pixel size that allows for more resolution in the CBCT image. This leads to a situation where the gains in resolution have to be weighed against increases in radiation exposure [Scarfe & Farman, 2008].

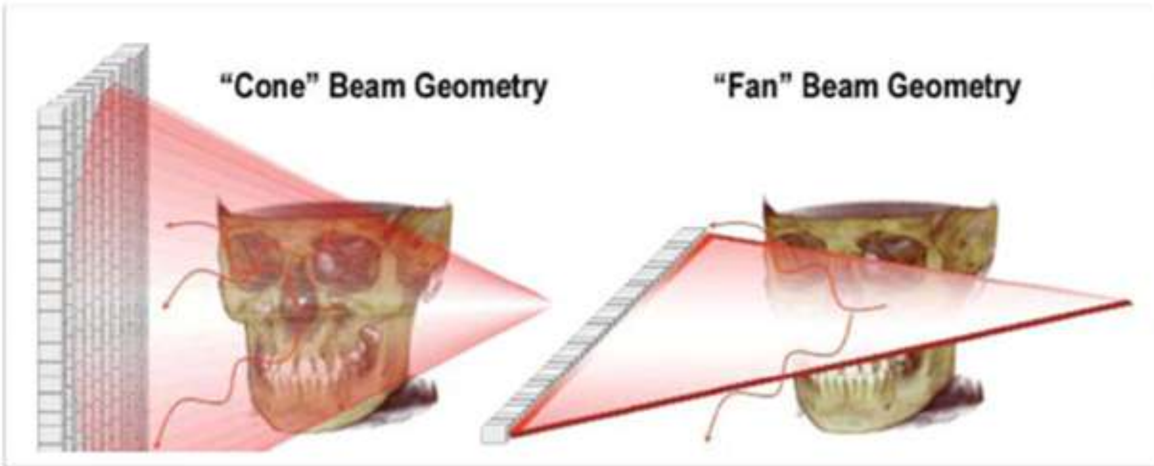


Figure 2: X-ray Beam Geometry (Source Scarfe and Farman 2008)

According to Scarfe and Farman, the refinement of the algorithms, as stated earlier, also had a role in making today's CBCT a reality. Conventional fan-shaped CT uses filtered back projection to reconstruct individual axial slices. Cone-beam however has two-dimensional x-ray area detectors with a different geometry applied to the beam and thus relies on cone-beam reconstruction. The first and most popular reconstruction algorithm was referred to as the Feldkamp, Davis, and Kress (FDK) method uses a convolution-back projection method. The FDK has positives and negatives to it. It is good at reconstructing images at the center of the beam, but provides approximations that cause distortion in noncentral planes. The time to reconstruct can vary depending on acquisition parameters (voxel size, FOV, number of projections), hardware (processing speed, data throughput from detector to computer) and software (algorithm) used.

As with other radiography techniques, the x-ray beam of the CBCT is characterized by different parameters. The beam can either be continuous or pulsed. When continuous it obviously exposes the patient to greater doses of radiation. When pulsed it is done so to coincide when the detector is active, thus not exposing the patient to unnecessary radiation. Beam *quality* is defined by the voltage peak (kVp), anode material, and filtration. Beam *quantity* on the other hand is determined by anode current (mA) and exposure time (s). The beam is collimated to define its width and height and thus helping to define the field of view [Scarfe & Farman, 2008].

The complete determination of the field of view (FOV) depends on the detector size and shape, the beam projection geometry, and the degree of collimation. Each machine has different FOV settings that enable either partial or complete exposure of the object of interest. Cone beam allows the acquisition of two-dimensional images throughout the scan allowing a complete dataset in one scan or less. Multiple single exposures at certain degree intervals are made throughout the scan, each providing an individual two-dimensional image known as a “basis,” “frame,” or “raw” image that are similar to a traditional cephalogram. These multiple “frames,” each offset from the next by a certain degree make up a complete set of images known as the “projection data,” and the number of images comprising that set is determined by the frame rate, the trajectory arc, and the speed of the rotation. The number of images in a scan can be fixed or variable and that is dependent on the machine used. Increasing the projection data though provides more information from which to reconstruct the image and this leads to greater resolution, less noise, and reduced artifacts. This gain in data though must be measured against increased radiation exposure for the patient [Scarfe & Farman, 2008].

The detector, which is much less expensive than traditional CT detectors, receives the data and the computer algorithm compiles it via primary reconstruction into volumetric data. This reconstruction process consists of two stages, the acquisition stage and the reconstruction stage (Fig 3). The acquisition stage involves image collection and detector preprocessing, where varying sensitivities and imperfections of the photodiodes are accounted for. Next is the reconstruction stage where the corrected images are related to each other and assembled. A common method is the use of a composite image that relates each row of each projection image into a sinogram. These corrected sinograms are then converted into a complete two-dimensional CT slices. The FDK algorithm is then used to reconstruct volumetric data. This can then be manipulated as two-dimensional multi-planar reformatted slices or in three dimensions by surface reconstruction or volume rendering [Scarfe & Farman, 2008].

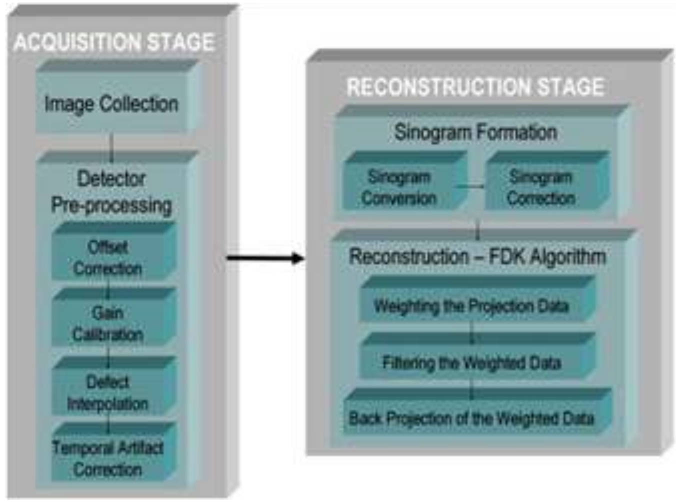


Figure 3: Image Acquisition and Reconstruction (Source Scarfe and Farman 2008)

One difference in CBCT is the way in which value is assigned to the voxels. In CBCT each voxel is assigned a grey value as opposed to the HU in traditional CT. The grey value is determined by the reconstruction algorithm, by combining information from all obtained projections. This leads to one of the disadvantages of CBCTs. Because the density value of the voxels is determined by the algorithm which partly uses the voxel's position in the scan to determine its value it is not always reliable (Swennen 2006). Traditionally because dental CBCT scans do not use a standardized system for scaling the grey values that represent the reconstructed density values, they are essentially arbitrary and do not allow for assessment of bone quality between different machines (Norton, 2001). However, recently proposed techniques have offered ways of using linear regression to derive HUs from the grey values of CBCT machines (Reeves et al., 2012). CBCT built upon Dr. Hounsfield’s original invention has gained much popularity in the dental community.

The CBCT machines being used in the dental field today consist of a scanner that is made up of an x-ray source and a tightly coupled sensor that usually rotates 360 degrees around the head of the patient. During this rotation it obtains between 150 to 600 unique images, which the software reconstructs into viewable formats. The scan time can range from five to forty seconds. The cuboidal voxels generated from the scan can range in size from 0.07 to 0.40 millimeters per side, and each is assigned a grey-scale value. The latest generation of CBCT units produces 12 or 14 bit images, which translates to 4,096 or 16,384 shades of grey respectively. This is substantially more than most computer monitors which are usually 8 bit or 256 shades of grey, but through a process called “windowing and leveling” the software enables the operator to visualize all the data (Hatcher, 2010). The data can be visualized through multiplanar mode (MPR), shaded surface display (SSD), and volume rendering (VR). Shaded surface display is a software technique that bases visualization on each voxel’s attenuation value and this technique is useful to visualize soft tissue or bone. The other technique is volume rendering which allows the operator to see both soft and hard tissues at the same time by letting the operator assign transparency values to voxels based on their attenuation values. This allows some unique views of the bony structures through the soft tissues. Both SSD and VR modes require that surface contours be estimated and thus leads to measurement errors (Kapila et al., 2011). Visualizing in the MPR mode though allows for highly accurate measurements when compared to physical skull measurements. MPR mode is a nonaxial two-dimensional image that should be used when precision is needed, such as in implant site assessment and orthodontic evaluation.

In terms of radiographic imaging CBCT provides many advantages over other techniques. CBCT offers a rapid scan time that acquires all projection images in one rotation around the patient. This makes the time to acquire an image close to that of a conventional panoramic radiograph. Another advantage is the collimation of the primary x-ray beam limiting patient exposure. Next with voxel size of less than a millimeter, CBCT allows for images with a high level of spatial accuracy. In comparison to conventional CT, which also has high level of accuracy, CBCT allows it at a greatly reduced radiation dose. Using the 1990 International Commission on Radiological Protection calculations CBCT provides a dose reduction of 76.2% to 98.5% in comparison to conventional CT. Another advantage to CBCT is that it is accessible via a personal computer which allows a higher degree of manipulation by the operator. All these features have made for the increase in popularity of CBCT [Scarfe & Farman, 2008].

There are also some innate disadvantages and limitations to CBCT. The first is the presence of artifacts, which are any distortions or errors in the image, unrelated to the subject being examined. These artifacts can be classified according to the etiology and are grouped into four categories: Acquisition, patient-related, scanner-related, and cone beam-related. Acquisition artifacts arise from the limitations in the physical process of acquiring the data and are related to beam hardening. Beam hardening results from lower energy photons in the x-ray beam being absorbed preferentially. This results in two types of artifacts one of which is cupping, where metallic structures, such as a patient's crown, are distorted due to this differential absorption of the beam. The other artifact linked to beam hardening is streaks and dark bands between dense objects (Fig 4). Next patient-related artifacts are due to the subject moving during the scan or not removing jewelry prior to the scan. Another category of artifacts called scanner-related present as circular or ring streaks resulting from poor calibration or imperfections in the detector. These types of artifacts will be reproducible and occur consistently in images. The last category of artifacts is cone beam-related and there are three types: Partial volume averaging, undersampling, and cone beam effect. Partial volume averaging occurs as a result of an individual voxel containing both hard and soft tissue. The value of that voxel then becomes an average of the two tissue values. The next type of cone beam-related artifact is undersampling. Undersampling occurs when too few basis projections are provided for the reconstruction. The reduced data sample leads to misregistration, sharp edges, and noisier images. The final cone beam-related artifact is the cone beam effect. This results because of the divergence of the x-ray beam and leads to streaking artifacts; as well as, peripheral distortion and noise [Scarfe & Farman, 2009].

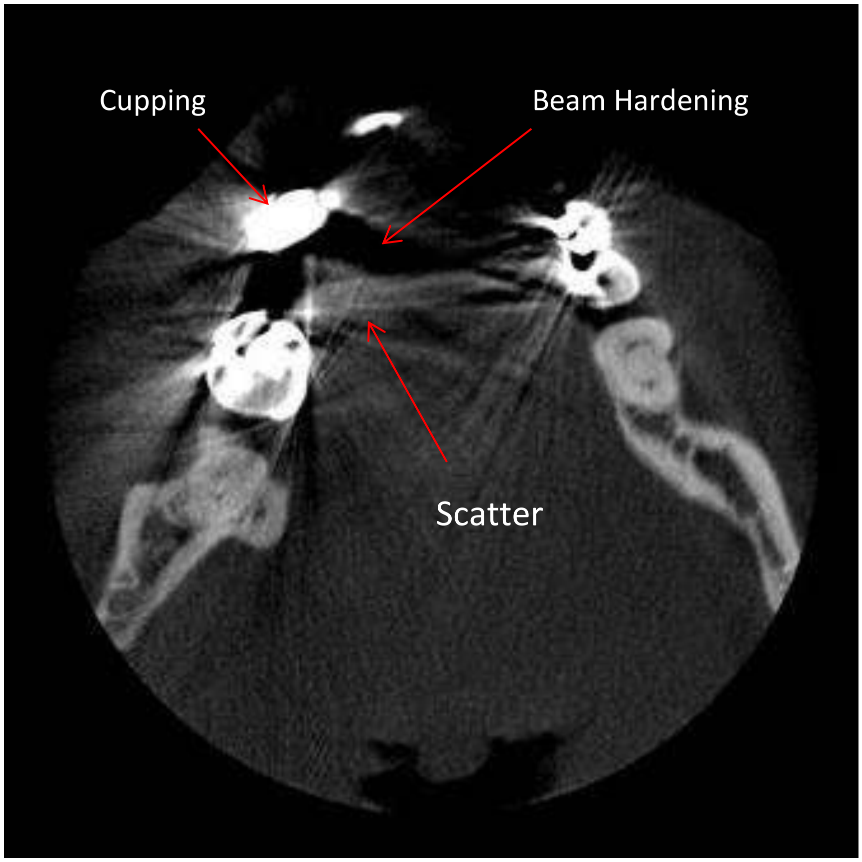


Figure 4: CBCT Artifacts (Source Scarfe and Farman 2008)

The next limitation of CBCT is this image noise. Due again to the geometry of the beam a large number of photons undergo Compton scattering interactions leading to scatter radiation that becomes recorded by the detector. This scattered radiation though is not a true reflection of the attenuation in that given area. The amount of scatter radiation that is produced is proportional to the total mass of the object in the beam and can be 200 times higher than conventional CT. Additional sources of noise are from variations in the x-ray beam intensity and inherent flaws in the detector system [Scarfe & Farman, 2008].

Another limitation of CBCT is poor soft tissue contrast. The scatter radiation that leads to image noise also contributes to poor contrast by inaccurately adding radiation to areas that should have been poor in attenuation. The second factor leading to decreased contrast in CBCT images is the nature of the flat panel detectors, which are subject to saturation, dark current, and bad pixels. These factors are encountered randomly throughout the detectors to various degrees and thus making the detector non-uniform in its reception of radiation [Scarfe & Farman, 2008].

The radiation dose of the CBCT machines is variable and is affected by a number of variables, to include machine type, scan time, voxel size, FOV, etc. When comparing different machines it is useful to use the effective dose which is measured in units of energy absorption per unit mass (joules/kg) called Sieverts. Most often the microSievert is used which is one millionth of a Sievert. Effective dose is calculated by measuring the energy absorption in a number of organs/tissues in the body. Each organ dose is multiplied by a weighting factor that is a reflection of that tissue's radiosensitivity. These values for the organs/tissues are then added up to get a "whole body" detriment (SEDENTEXCT, 2009). These tissue weighting factors were updated in 2007 by the International Commission on Radiological Protection and many new studies are using them; however, many older studies used the previous 1990 factors when examining earlier CBCT machines. This makes comparing various newer machines to older ones quite difficult. Knowing the range of dosage a machine may have though, whether it is based on the 1990 or 2007 standards still allows us to determine a radiation risk to the patient. The risk of developing cancer or other hereditable effects is affected by exposure to radiation. SEDENTEXCT found that the probability of radiation-induced cancer and hereditable effects for the whole population to be 5.7 X 10^{-2} Sv^{-1} (SEDENTEXCT, 2009). Risk is age dependent and is highest for the young with those under the age of ten being three times higher. Those between the age of ten and twenty are two times the risk. The elderly are at a reduced risk since the latent period between x-ray exposure and clinical presentation may exceed the patient’s life span. There is also a risk in relation to gender with females at a slightly higher risk than males. Patients are exposed to radiation daily from all kinds of sources. The annual per-capita dose from all sources of ionizing radiation is 6.2 mSv, while annual background dose alone is 3.0 mSv (Grunheid et al., 2012). With this value in mind, a panoramic radiograph can be associated with an additional 0.5-2 days of additional background radiation, while the dental CBCT adds up to a few days up to an additional couple months’ worth of radiation (SEDENTEXCT, 2009). Figures 5 and 6, show the effective dose ranges for some popular CBCTs and other conventional dental imaging techniques from SEDENTEXCT 2009.

Table 1: Effective Doses of Dental CBCT Units

Dental CBCT unit	Effective dose (μSv)		References	
	Dento-alveolar	Craniofacial	Dento-alveolar	Craniofacial
NewTom	41-75	30-78	Ludlow et al 2003	Ludlow et al 2006 Okano et al 2009 Silva et al 2008 Ludlow et al 2003 Ludlow et al 2008 Mah et al 2003 Tsiklakis et al 2005
Accuitomo/ Veraviewepocs	11-102		Okano et al 2009 Loftag-Hansen et al 2008 Hirsch et al 2008 Loubele et al 2008	
Galileos		70-128		Ludlow et al 2008
Promax	488-652		Ludlow et al 2008	
Prexion	189-388		Ludlow et al 2008	
i-CAT	34-89	48-206	Roberts et al 2009 Loubele et al 2008	Ludlow et al 2006 Roberts et al 2009 Loubele et al 2008 Ludlow et al 2008 Mah et al 2003
CB MercuRay	407	283-1073	Ludlow et al 2008	Ludlow et al 2006 Okano et al 2009 Ludlow et al 2008
Illuma		98-498		Ludlow et al 2008

Source SEDENTEXCT 2009

Table 2: Effective Doses of Conventional Dental Readiographs

	Effective dose (μSv)	References
Intra-oral radiograph	<8.3*	European Commission 2004*
Panoramic radiograph	2.7 - 23	Ludlow et al 2006 Okano et al 2009 Silva et al 2008 Palomo et al 2008 Garcia-Silva et al 2008
CT maxillo-mandibular	180 - 2100	Ludlow et al 2006 Okano et al 2009 Silva et al 2008 Loubele et al 2005
CT maxilla	1400	Ludlow et al 2006

*no data available calculated subsequent to ICRP2007

Source SEDENTEXCT 2009

The introduction of cone beam computerized tomography (CBCT) into dentistry has enhanced diagnostic capabilities and aided treatment planning in multiple disciplines. This technology can help image implant sites for a prosthodontist, lay out bone topography for the periodontist, or show a canal's shape to an endodontist. It has been shown to be very effective for oral surgeons in detecting pathology in the maxillary sinus when images are taken for implant placement (Ritter et al., 2011). It also has a substantial role in orthodontics today. CBCT has a number of valuable applications and offers advantages for imaging in orthodontics (Mah et al., 2010). These include comprehensive evaluation of the developing dentition with an undistorted view. This allows the orthodontist to see in three dimensions the relationship of erupted and unerupted teeth to each other. It also provides enough clarity to evaluate and classify root resorption, and its representation of the dentition is accurate enough to allow measurements to be made from its images. The technology has also allowed for the volumetric analysis of airways and the ability to use new three dimensional landmarks in the evaluation of growth and development that were previously impossible with traditional two-dimensional images (Mah et al., 2010). All these capabilities have increased the popularity of CBCT imaging. In a recent survey of sixty-nine United States and Canadian dental schools, 73.3% of those that responded reported regular usage of a CBCT and 18.2% used CBCT as the radiographic record of choice for every patient (Smith et al., 2011). CBCT has gained much popularity in the dental field over the last decade.

Few would dispute the advantages of CBCT imaging, but there is a mindset that the radiation dose it imparts on the patient is not worth what is gained diagnostically across the board. The patient effective dose though varies greatly and is largely dependent on the machine used (Cattaneo & Melsen, 2008). There is much debate in and out of the dental community on when CBCT should be used.

This debate on the use of CBCT was highlighted in the April 2012, American Journal of Orthodontics and Dentofacial Orthopedics (AJO-DO) in a Point-Counterpoint segment (Larson, Halazonetis, 2012). In this article, Dr. Brent Larson from the University of Minnesota spoke on the stance that CBCT was the imaging technique of choice for orthodontic assessment, while Dr. Demetrios Halazonetis from the University of Athens defended the position that it was not. The benefits laid out by Dr. Larson focused on the increased diagnostic abilities of cone-beam. He talked of the localization of impacted teeth, assessment of root resorption, TMJ visualization, and identifying asymmetries; as well as, seeing periodontal and endodontic problems. He felt all this diagnostic ability was gained at a small increase in radiation dose compared to the standard digital panoramic and cephalometric films. He stated though it is elevated slightly compared to today's standards, it is still an 80% reduction in dose from the standard record taken 15 years ago. Dr. Halazonetis responded by acknowledging the diagnostic benefits of CBCT's, but was not convinced that the treatment outcome would be better in all cases or even the majority. The larger voxel size used to reduce the radiation dose to the patient made thin structures difficult to detect, reduced resolution in regards to periodontal assessment made it less than optimal, and though the TMJ could be better visualized there is no evidence to show it led to better treatment. He felt that cone-beam computed tomography had its uses in those cases with impacted teeth and possible associated root resorption. He also felt it was a benefit when the practitioner was considering temporary skeletal anchorage to assess bone quality and allow better placement. His overall feelings in regards to CBCT mirrored that of the AAO which in its clinical guidelines stipulates," that while there may be clinical situations where a cone-beam computed tomography (CBCT) radiograph may be of value, the use of such technology is not routinely required for orthodontic radiography (AAO, 2012)." The debate is sure to continue as radiation doses will continue to decrease. Even more so is the growing popularity of customized treatment appliances. Being that the CBCT scan can be used to fabricate a customized orthodontic appliance, this streamlined treatment process when efficient enough may then outweigh the cost of a slightly increased radiation dose. Despite the debate on when it is appropriate to utilize this technology, it is hard to understate CBCT's usefulness as a diagnostic tool.

The greater visualization of the patient in three dimensions via CBCT has also made pathology visible in areas that normally fall outside a dentist's comfort zone. CBCT is known for its ability to visualize suspected pathology; but that same ability must be recognized each time it is used to help diagnose a patient. One may not be looking for pathology, just the need to do an orthodontic work-up; however, the diagnostic capability remains the same. It will show a carotid artery calcification or a nasal polyp that was far removed from the intent of taking the image. CBCT's taken for orthodontic treatment can lead to other discoveries such as an atlas cleft, an enamel pearl, a bifid condyle, or foreign bodies (Rogers et al., 2011). Because of the capability to find this unexpected pathology and potentially life-threatening conditions we are obligated to our patients to have the images thoroughly read.

The American Academy of Oral and Maxillofacial Radiology (AAOMR) released an executive opinion statement on performing and interpreting diagnostic cone beam computed tomography in 2008. In the paper they made a number of important recommendations to help guide the dental practitioner. Though not a legal standard of care, the document is intended to assist the practitioner in responsible use of CBCT. One of their first recommendations is that the technology be used with the ALARA principle in mind, to minimize patient exposure and to use only for valid diagnostic reasons. Next they stress the responsibilities of the practitioner ordering the image. They state, "It is the responsibility of the practitioner obtaining the CBCT images to interpret the findings of the examination (Carter et al., 2008)." They feel the dental practitioner needs to be trained to a level where they can comfortably interpret the full image volume, even the areas outside of his/her area of practice, for they are the ones who are ultimately responsible for the image. The committee feels it is "erroneous" to assume no responsibility for findings outside of the area of initial focus (Carter et al., 2008). The American Association of Endodontists joined with the AAOMR in 2010 to develop a position paper to help guide endodontists in the safe and responsible way to utilize CBCT. A similar collaboration between the

American Association of Orthodontists (AAO) and the AAOMR would be useful in guiding today's orthodontists in the responsible use of CBCT. The clinical practice guidelines put out by the AAO briefly touch on the subject when addressing diagnostic records. They state, "Technological advances such as CBCT scans … should be assessed/read in their entirety by a qualified professional; the entire area encompassed by the scan may be the responsibility of the practitioner (AAO, 2008)." Viewing and interpreting the entire image of a CBCT must be embraced by the practitioner, if one is to use the technology responsibly. As the AAOMR suggested and the AAO reiterated this may call for specific training in order to train the orthodontist in proper examination of the images they are taking. If one is looking for the advantage of higher diagnostic capabilities one also accepts the increased responsibility to the patient in terms of diagnosing occult pathology or anatomical variations.

The diagnosis of occult pathology in CBCTs has been demonstrated in a number of recent studies. A study by Cha, et al. had one board certified oral radiologist read 500 CBCTs taken at the University of Southern California. Out of those 500, 252 were orthodontic patients. They took the findings and characterized them between airway, TMJ, endodontic, and other. The overall rate of findings was 24.6%, with the airway having the highest rate of occurrence. The orthodontic group itself had a rate of 21% for incidental findings. The top three locations of pathology for the orthodontic patients were airway, TMJ, and then endodontic (Cha et al., 2007). A study by Pazera at the University of Bern in Switzerland looked at incidental maxillary sinus findings in orthodontic patients. They looked at 139 consecutive CBCTs read by two individuals independently. One reader was an orthodontist and the other a board-certified radiologist, but any disagreements in diagnosis were discussed and resolved by consensus. They recorded all incidental pathology found in the maxillary sinus and grouped them into three types: flat mucosal thickening, polypoid mucosal thickening, and signs of acute sinusitis. They found that 46.8% of the CBCTs had incidental maxillary sinus pathology. They did not however find any correlation between gender, season of imaging, or field of view. A statistical link to the frequency of findings and age though was found (Pazera et al., 2011). Another study at the University of Minnesota School of Dentistry looked at 194 patients starting orthodontic care. All the scans were read by one of two board certified radiologists and the findings characterized by gender, age, and lesion location. The findings were then characterized by severity. They reported a 65.5% incidental finding rate with the airway being the most common location. In terms of severity, 37.6% had findings that they felt required immediate follow-up in patients starting orthodontic treatment. These lesions were mostly of TMJ and endodontic origin. Finally they found a significant positive correlation between age and lesions of the TMJ and endodontic origin (Pliska et al., 2011). The discovery of incidental pathology is a part of using CBCT for orthodontic evaluation.

There appears to be a disparity between orthodontists and radiologists in terms of recognizing pathology on radiographs. A study by Moffitt looked at the frequency of significant pathologies discovered by orthodontists throughout their career. The study used a mail-in survey that questioned the practitioner in regards to how many times they discovered significant pathology on the lateral cephalograms they had taken for orthodontic treatment. The survey also asked the orthodontists to estimate the number of patients they had seen in their career, to get an idea of how often they saw pathology. 201 surveys were returned and from these it was tallied that out of over one million patients treated by those practitioners, that they had discovered significant pathology in 268 of them. This turned out to be a discovery rate of about 0.02% (Moffitt, 2011). The disparity between orthodontists and radiologists becomes evident when you compare this number to a study by Tetradis, et al. that looked at pathology discovered on radiographs taken for orthodontic treatment and reviewed by an oral and maxillofacial radiologist. Out of a sample of 325 patients, significant pathology that required referral to a physician was found in six cases, for an incidence of 1.8%. Nine patients required referral to an oral and maxillofacial surgeon for further evaluation of dental abnormalities, for an incidence of 2.7% (Tetradis & Kantor, 1999). This difference in discovery rates raises the question of how much pathology is potentially being missed by the orthodontist on lateral cephalograms. As evidenced by the studies discussed above, the incidence of pathology discovered on CBCTs is probably even higher. This could be a point of concern, if orthodontists are not discovering pathology at a higher rate as well. It is not surprising then that in June 2009, the AAO advised practitioners to refer their CBCT images to a radiologist. The data shows that there is a difference in terms of discovering incidental pathology on radiographs between orthodontists and radiologists.

This difference in identifying pathology was highlighted in a study at the University of Michigan where they looked at the efficacy of orthodontists and orthodontic residents in identifying incidental findings. They showed the two groups ten CBCT scans to see if they could identify lesions in three different categories; dentomaxillofacial, extragnathic, and temporomandibular. After letting them view the first group of ten images they gave them a three hour seminar by an oral and maxillofacial radiologist on normal and variations of normal anatomy, and various head and neck lesions. The groups were then given the other set of ten CBCT scans to evaluate to see if they improved in identifying lesions after training. The detection rate improved significantly to 56.7% after the training, up from 41.1% initially. The detection of extragnathic and TMJ lesions improved in kind; however, the detection of dentomaxillofacial lesions remained largely unchanged. In addition to looking at successful identification of lesions the study also looked at the number of false positives before and after training. The training also helped to lower the number of false positives. Though training helped to lower the number of missed lesions as well as the number of false positives, just under a half of the lesions were still being missed (Ahmed et al., 2012). This study showed and reiterated the need for a radiologist to read and interpret CBCT scans.

Today there is a wide range of individuals seeking orthodontic care. The majority of our patients are still adolescents, but more recently there are a larger number of adults seeking orthodontic care as well. Many of whom were unable to get care as kids. This adult population has been the fastest growing type of orthodontic treatment and comprise 30% of all patients receiving comprehensive orthodontic treatment (Proffit et al., 2013). Fifty years ago few adults were seeking treatment, but over the years the idea has become more popular with the older generation. Young adults from age 19 to thirty comprise the largest group, single females making up a high percentage. Though only about 1% of the adult population in the United States is seeking care, this corresponds to approximately 2.05 million people and they are a growing segment of the average orthodontic practice (Whitesides et al., 2008)

This older population presents with some unique features and usually present with a different state of oral disease when compared to adolescents. Nattrass and Sandy layed out some of these differences in a 1995 publication. The first difference highlighted was in regard to the periodontium. Adults are more likely to have or had periodontal disease, and thus should be carefully screened prior to orthodontic treatment to ensure it is not active. Active disease in an adult can be exacerbated by orthodontic treatment. The next difference they touched upon was the lack of growth. Since the adult patient is past their peak growth phase, the clinician has to be cautious of undesired extrusive mechanics. Adults are also more likely to have restorative considerations in their problem list and well as restorations present in their mouth. It is not uncommon to find porcelain and gold restorations in the adult dentition and the orthodontist must address these to get proper bonding. Another feature of adult treatment can be the presence of TMD. Some adults may present for treatment in the hope their ailment can be corrected with orthodontic care.

Finally the closure of old extraction spaces can be challenge to accomplish in the older population. All of these factors, some would say, make the older population a harder one to treat (Nattrass & Sandy, 1995).

One could postulate that being at a later stage in life, the adult population would have higher rates of incidental pathology on CBCTs taken for orthodontic care. One study demonstrated a positive correlation between age and findings in the TMJ and in endodontic lesions (Pliska et al., 2011). This being the case it would be helpful to know if other areas or certain lesions were more prevalent in adults. Knowing this practitioner would have an idea of where to look and pay closer attention to those areas shown to have higher incidents of pathology. This is true of the adolescent population as well. A few studies now have looked at incidental findings on CBCT and most of them have had both adolescents and adults, but a detailed comparison of findings in these two groups has not been done. The goal of this paper is to explore that topic and see which age group, adolescents or adults, has the higher rate of incidental pathology, where pathology is most likely to be found and in what form from a full head CBCT scan.

II. OBJECTIVES

A. Overall Objective

The overall objective of this study was to determine if the prevalence and type of incidental findings found on cone beam computed tomography (CBCT) differs between child/adolescents and adults. We wanted to evaluate seven different locations and determine where findings were most likely to be located in the two groups and determine if any differences between the groups were significant. The second objective of this study was to determine what types of findings were recommended for referral to a healthcare provider, either a physician or dentist, and whether there was a statistical difference in the prevalence of referrals between the two age groups.

B. Specific Hypotheses

It is hypothesized that there will be an increased prevalence of findings in the adult population. It is hypothesized that in each of the seven different locations the adult population will have more findings. Finally it is hypothesized that the adult population with have more findings for which a referral is suggested by the radiologist.

III. MATERIALS AND METHODS

A. Experimental Design

The project protocol was reviewed and approved by the Wilford Hall Ambulatory Surgical Center Institutional Review Board (IRB) for human-exempt research due to its retrospective nature. The sample population consisted of 553 consecutive CBCTs taken at the Tri-Service Orthodontic Residency Program (TORP) and Wilford Hall Oral Surgery Department between June 2008 and December 2011 for orthodontic or oral surgery purposes. These images were taken on either the: ICat Classic (Imagining Sciences International, Hatfield, PA) using a 13cm x 16cm (height x diameter) field of view at120 kVP, 5 mA, and a scan time of 20 seconds; or the ICat Platinum (Imagining Sciences International, Hatfield, PA) using a 17cm x 23cm field of view at 120 kVP, 5 mA and a scan time of 17.8 sec. A resolution of a 0.3 voxel was attained on each machine. The patient was seated completely back in the chair with their head rested back against the head rest and their hands on their lap. The laser line was centered on the middle of the chair. The patient was then positioned with the alignment lines, with the horizontal line coincident with the occlusal plane between the lips and the vertical component 1.5" in front of the condyle. Once positioned the patients head was secured in position with the Velcro strap on the head rest. They were then instructed to bite on their back teeth and to keep them together throughout the scan. They were also told to stay as still as possible, to breathe through their nose, and not to swallow during the acquisition of the image. Before the image was captured, the positioning of the patient was confirmed with the Preview mode. The operator ensured the patient was centered in the frame with their nose a quarter inch from the front border of the screen. Once proper positioning was confirmed the image was captured.

The images were read at Lackland Air Force in San Antonio, Texas by one oral and maxillofacial radiologist. The CBCTs were read using Dolphin Software, because of its ease of use and availability in the radiology clinic, on a HP DC5850CMT Compaq computer with a dual core processor and Windows XP 32 bit operating system. Two Dell 22 flat panel LCD 20.8 inch wide screen monitors one set up as landscape and the other as portrait view with resolutions of 1680 x 1050 and 1050 x 1680, respectively. Both monitors were set up with 32 bit True Color and a 59 Hz refresh rate. The monitors were turned on about an hour before use and a SMPTE (Society of Motion Pictures and Television Engineers) pattern was used to calibrate the monitors quarterly and periodically. High brightness was preferred by the radiologist for better contrast. In order to reduce reader fatigue no more than ten images were viewed per day. The radiologist sat directly in front of the monitor and at a viewing distance of about 30 inches. The radiologist first reviewed any panoramic reconstructions if they were present; as well as, any previous CBCTs. After reviewing these prior radiographic records the new CBCT was analyzed. A slice thickness of 0.5mm was used in viewing the images. The radiologist used the following viewing sequence to read them. First the axial perspective was viewed and the radiologist scrolled through the entire image looking for gross anomalies and/or variants. Next the coronal image was viewed with finer detail in areas identified in the axial images. Finally the sagittal view was scrolled through again looking more closely at areas previously identified. After all the views had been exhausted, the radiologist correlated the findings with the purpose of the scan and checked the availability of any comparison scans like previous CBCT, CT, or MRI images that were also reviewed. Previous radiography reports and the medical history were examined for anything of significance. Any pathology that was found was then grouped into seven main areas: the paranasal sinuses, nasal cavities, airway, temporomandibular joints, osseous structures, dental findings, and other. The reports were received by the author after they had been de-identified such that only the age of the patient and the report itself remained. The 553 radiology reports consisted of images taken at both the orthodontic and oral surgery residencies at Lackland AFB, San Antonio, TX. All the scans taken at TORP (330) were for orthodontic purposes. Scans taken at the oral surgery department were taken for a number of reasons; Implant placement (71), pathology follow-up (12), prosthodontics treatment (1), post-orthognathic evaluation (12), TMJ evaluation (8), orthodontic evaluation (19), and oral surgery evaluation (100).

Out of the initial 553 radiology reports, 521 were included in the study. This consisted of 267 who were 18 and younger and 254 who were over the age of 19. The twelve reports on images taken for known pathology were dropped from the study. An additional, twelve reports from images taken after oral and maxillofacial surgery had been performed were dropped. Finally, eight reports on scans taken to follow up on known TMJ symptoms were also dropped from the study. It was felt that in all of these excluded scans one would have been expected to find some degree of findings and thus those findings would not be incidental.

The radiology reports from the two groups, child/adolescent and adult, were read by the author. All findings discovered by the radiologist in each report were noted. The severity of a finding was based on the radiologist's recommendation for follow-up. This decision to refer was based on what the radiologist had seen on the scan as well as any pertinent medical history. Overall the reports were classified as i) Referral needed to healthcare provider (ie. Physician or Dentist) ii) Referral needed to healthcare provider, if symptomatic iii) Normal variations, no referral needed.

There were a large number of findings when all the reports had been examined. The sheer number of unique and individual findings led to the need to consolidate findings into groups to aid in statistical comparison. This was done as little as possible to try and maximize the data and not generalize a broad group of findings. After grouping though there were 89 different findings compared between the two groups. Specific findings that would be unable to be diagnosed solely from a radiograph, like a dentigerous cyst or endplate erosion, were derived from the review of existing radiologic or medical reports. The groups that include a number of unique findings will be laid out below addressing each category at a time. The grouping of these various findings was done with the consent and oversight of the radiologist, using the original radiographic reports as reference.

A few findings were grouped for the paranasal sinus category. Findings that said polyp or soft tissue density were grouped together as soft tissue density. Findings of high densities in the paranasal sinuses were grouped together under osteoma.

More findings were grouped in the nasal cavity category. Findings of bilateral pneumatization of middle turbinate, pneumatization of left or right middle turbinate, and low density in middle turbinate were all grouped as concha bullosa. Swollen turbinates, unilateral swelling of right inferior turbinates, and obliterated left nasal canal were grouped under hypertrophy of turbinates. Findings of polyps and soft tissue densities in nasal cavity were grouped together as polyps.

Minor condensing was needed in the airway category. Findings of enlarged lingual tonsil, enlarged tonsillar tissue, and soft tissue at base of the tongue were all included into an already existing group of tonsillar hypertrophy. Asymmetric soft tissue in nasopharynx was added into the group hypertrophy of nasopharyngeal tissues.

For the TMJ category, a number of findings were grouped. Degenerative changes in the TMJ includes findings of flattening of the condylar head, erosion of the condylar head, osteophytes, ely cyst, asymmetric condyle, and decreased disc space. The finding of pneumatized skull bones consisted of pneumatizations seen in the sphenoid or temporal bones. This pneumatizaton when seen in the sphenoid was not in reference to the sphenoid sinus, but to a separate area of bone.

A number of findings were also grouped in the osseous structures category. Degenerative changes in the cervical spine consisted of suspected arthropathy, osteophytes, endplate erosion, sclerotic dens and/or atlas, as well as, facet arthropathy. Lesion in mandible consists of suspected cemental lesions, odontomas, abnormal bone/fibrous tissue, ostoid osteoma, odontokeratocyst, simple bone cyst, paradental cyst, and cemento-osseous dysplasia. Lesion in maxilla consists of suspected large nasopalatine foramen, nasopalatine cyst, and odontoma. Density changes in skull bones consists of sclerotic area of mastoid process, stippled lucency in sphenoid, and low density lesion in clivus. Osteomas in the maxilla along with tori, to include torus palatinus, and idiopathic osteosclerosis were grouped under high density in maxilla. High density in mandible consisted of osteomas, tori, enostoses, and idiopathic osteosclerosis. The findings put into both of the high density categories were suspected to be benign in nature, while those in the lesion categories were thought to be more pathologic in nature.

Not as much grouping was need for the dental category. Dentigerous cysts and enlarged follicles were grouped together as coronal lesions. While apical lesions consisted of apical periodontitis, apical cyst, granuloma, and condensing osteitis. The impacted teeth category consisted of all types of impacted teeth.

The last category named, other, consisted of a collection of findings that were outside of the previous six and were quite diverse. Two broad groupings were established to entail findings that were not common. A group called intracranial findings was established and consisted of things like middle ear infections, an asymmetric sella turcica, fewer than normal air cells in the mastoid, a high density in the choroid plexus, opacification of mastoid air cells, and a high density in the area of the pituitary gland. The second broad grouping in this category was named extracranial findings and consisted of a cleft in the dens of C2, debris in the skin, a sialolith in the submandibular gland, a vertebral artery calcification, a bur head in the mandibular body, an oro-nasal communication, a perforated implant, and a missing auricle.

B. Statistical Management of Data

The data was examined using descriptive statistics. The sum of all the findings for each age group and location were examined. The occurrence of findings, both normal variations and suspected pathology, between these two groups for the seven categories were evaluated for statistical significance using Chi Square contingency tables. If any cells had a value of zero or no findings then Fisher's exact test was used instead.

IV. RESULTS

In our sample of 521 patients, 507 patients had incidental findings in their radiologic report. That is 97.3% of the total sample with at least one finding. In all 2,000 findings were noted in the sample. That comes to 3.8 findings per scan. If you only included those scans that had findings, the findings per scan rises slightly to 3.9. Fourteen (2.7%) patients had no findings in their scan. Table 3 shows all the findings that were noted in the seven categories.

Table 3: Total Number of Findings and Percent Overall

Location	Findings	Number of findings	%
Paranasal Sinuses	Antral pseudocyst	62	3.10%
	Debris noted at max ostia	2	0.10%
	Hypoplastic antrum	5	0.25%
	Mucosal thickening(MT) of antrum	75	3.75%
	MT of antrum & ethmoid	35	1.75%
	MT of antrum, ethmoid, frontal	3	0.15%
	MT of atrum,ethmoid, sphenoid	20	1.00%
	MT of atrum, ethmoid, sphenoid, frontal	2	0.10%
	MT of atrum & sphenoid	8	0.40%
	MT of ethmoid	28	1.40%
	MT of ethmoid & frontal	1	0.05%
	MT of ethmoid & sphenoid	5	0.25%
	MT of frontal	1	0.05%
	MT of sphenoid	7	0.35%
	No sphenoid sinus	1	0.05%
	Obstructed mucocilliary pathway	3	0.15%
	Opacified antrum	14	0.70%
	Opacified frontal, ethmoid, and antrum	2	0.10%
	Opacified sphenoid sinus	1	0.05%
	Osteoma	3	0.15%
	Pneumatization of antrums	2	0.10%
	Pneumatization of sphenoid laterally	100	5.00%

	Severe rhinosinusitis	1	0.05%
	Sinus lift of left antrum	1	0.05%
	Soft tissue density in antrum	8	0.40%
	Soft tissue density in sphenoid	6	0.30%
Nasal Cavity	Cleft in nasal floor	1	0.05%
	Concha bullosa	147	7.35%
	Crenulated nasal septum	2	0.10%
	Deviated septum	179	8.95%
	Hypertrophy of turbinates	6	0.30%
	Nasal polyp	9	0.45%
	Rhinolith	1	0.05%
	Foreign body	1	0.05%
Airway	Adenoid calcifications	1	0.05%
	Adenoid hypertrophy	170	8.50%
	Decreased airway due to calcified ligaments C1-C2	1	0.05%
	Decreased airway due to patient positioning	2	0.10%
	Hypertrophy of nasopharyngeal tissues	3	0.15%
	Prevertebral thickening	4	0.20%
	Tonsillar calcifications	19	0.95%
	Tonsillar hypertrophy	141	7.05%
TMJ	Bifid condyle	4	0.20%
	Degenerative changes bilaterally	15	0.75%
	Degenerative left TMJ	7	0.35%
	Degenerative right TMJ	10	0.50%
	Hyperplastic unilateral condyle	1	0.05%
	Hypoplastic condyle bilaterally	4	0.20%
	Hypoplastic unilateral condyle	10	0.50%
Osseous Structures	C1 posterior arch defect	17	0.85%
	C2 defect	1	0.05%
	Cleft palate	4	0.20%
	Degenerative changes in upper C-spine	82	4.10%
	Density changes in skull bones	7	0.35%
	Displacement of the dens due to trauma	1	0.05%
	Fusion of cervical vertebrae	5	0.25%
	High density in mandible	70	3.50%
	High density in maxilla	56	2.80%
	Lesion in mandible	16	0.80%
	Lesion in maxilla	6	0.30%
	Pneumatization of skull bones	5	0.25%
	Ponticulous ponticus	9	0.45%
	Soft tissue mass left zygomatic arch	1	0.05%

Dental Findings	Apical lesion	46	2.30%
	Apical resorption	3	0.15%
	Coronal fracture	1	0.05%
	Coronal lesion	9	0.45%
	Foreign debris in alveolar crest	5	0.25%
	Impacted teeth	24	1.20%
	Macrodont	1	0.05%
	Mesiodens	7	0.35%
	Microdont	3	0.15%
	Missing teeth	27	1.35%
	Retained permanent root	11	0.55%
	Retained primary tooth	5	0.25%
	Root fracture	1	0.05%
	Supernumerary	9	0.45%
	Transposition	1	0.05%
Other	Asymmetric, large jugular foramen	43	2.15%
	Calcification in the area of the pineal gland	53	2.65%
	Calcification of petroclival ligaments	11	0.55%
	Calcification of stylomandibular ligaments	3	0.15%
	Calcifications of stylohyoid ligaments	239	11.95%
	Carotid artery calcifications	26	1.30%
	Debris in external auditory canal	13	0.65%
	Dural calcifications	5	0.25%
	Extracranial finding	9	0.45%
	Intracranial finding	10	0.50%
	Radiodense upper borders of thyroid cartilage	21	1.05%
		2000	100.00%

The major findings in the paranasal sinuses were antral pseudocysts (3.1%), mucosal thickenings of the various sinuses (9.4%), and pneumatization of the sphenoid sinus laterally (5%).

Concha bullosa (7.35%) and deviated septums (8.95%) were the predominant findings in the nasal cavity.

The major types of findings in the airway were adenoid hypertrophy (8.5%), tonsillar hypertrophy (7.05%), and tonsillar calcifications (0.95%).

The TMJ finding with the highest prevalence was degenerative changes in the joint either unilateral (0.85%) or bilaterally (0.75%). When combined degenerative changes of the joint made up 1.6% of the total findings.

When it came to osseous structures the major findings were degenerative changes in the upper cervical spine (4.1%), high density findings in the mandible (3.5%) or maxilla (2.8%), C1 posterior arch defects (0.85%), and lesions in the mandible (0.80%).

The major types of findings in the dental category were apical lesions (2.3%), missing teeth (1.35%), and impacted teeth (1.2%).

Finally for the other category, which had the most findings, the predominant discoveries were calcifications of stylohyoid ligament (11.95%), calcifications in the area of the pineal gland (2.65%), asymmetric large jugular foramen (2.15%), carotid artery calcifications (1.3%), and radiodense upper borders of the thyroid cartilage (1.05%).

As mentioned the highest prevalence of findings fell in the other (21.65%) category, followed by paranasal sinuses (19.80%), nasal cavity (17.30%), airway (17.05%), osseous structures (14.00%), dental (7.65%), and then TMJ (2.55%). See Table 4 and Figure 5 below.

Table 4: Number of Findings by Category

Category	No. of Findings	Percentage
Paranasal Sinus	396	19.80%
Nasal Cavity	346	17.30%
Airway	341	17.05%
TMJ	51	2.55%
Osseous Structures	280	14.00%
Dental	153	7.65%
Other	433	21.65%
Totals	2000	100.00%

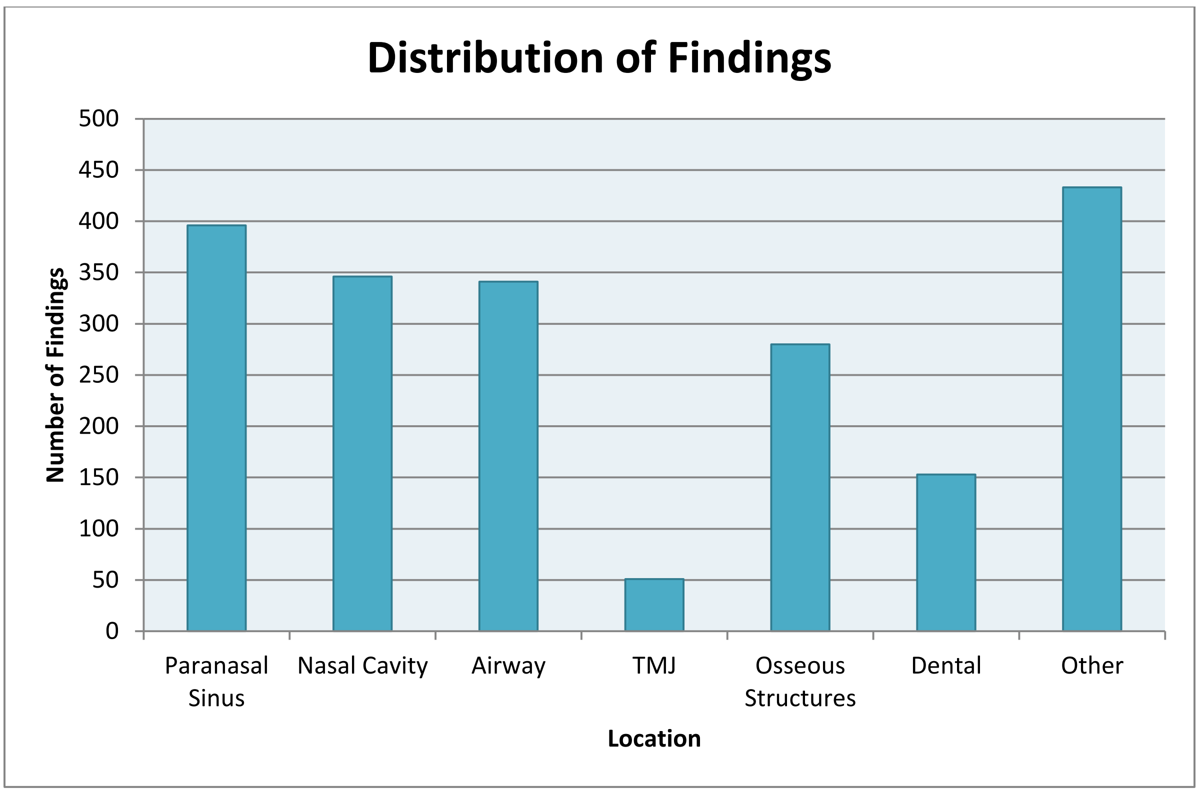


Figure 5: Distribution of Findings

In this study, we really wanted to examine the differences between child/adolescents and adults in and across these seven categories. The patients' mean age overall was 27.0 years. The distribution of the overall sample is shown below in Figure 6.

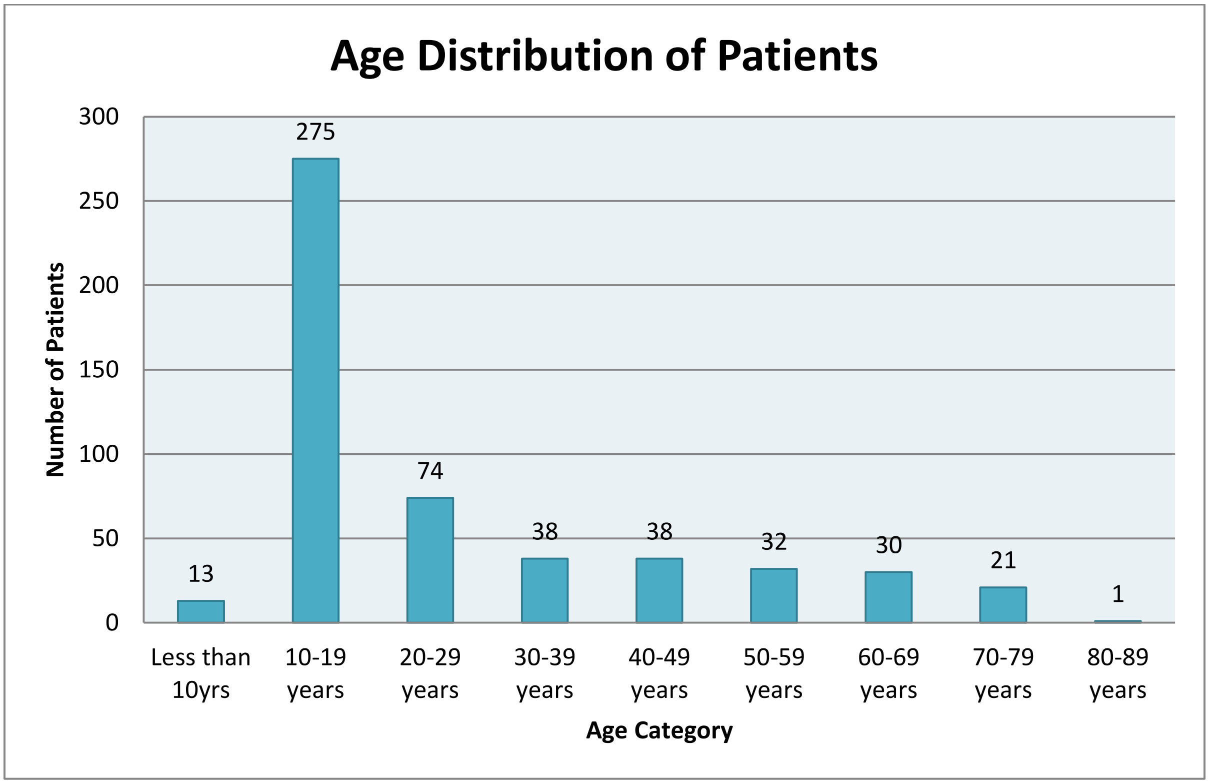


Figure 6: Age Distribution of Patients

The child/adolescent group had a mean age of 13.7 years and the adult group had a mean age of 41.0 years.

In each of the seven categories there was a statistically significant difference in the number of individuals who had findings between the two groups. In every category except airway the adult group had more individuals with a finding. The child/adolescent group had more individuals with a finding in the airway category. See Table 5 below.

Table 5: Number of Individuals with Findings by Age Group

Category	Child/Adolescents		Adults		p
Paranasal Sinus	149	55.81%	175	68.90%	0.0021
Nasal Cavity	133	49.81%	159	62.60%	0.0033
Airway	170	63.67%	67	26.38%	0.0001
TMJ	10	3.75%	40	15.75%	0.0001
Osseous Structures	63	23.60%	163	64.17%	0.0001
Dental	51	19.10%	92	36.22%	0.0001
Other	133	49.81%	192	75.59%	0.0001

When it came to the total number of findings in each category the adult group again had more findings except for airway. The difference was not significant in each category though as it was above. The difference in the total number of findings was statistically significant in the airway (p=0.0001), TMJ (p=0.0005), osseous structures (p=0.0001), dental (p=0.0245) and other (p=0.0428) categories. See Table 6.

Table 6: Incidence of Findings by Age Group

Category	Child/Adolescents		Adults		p
Paranasal Sinus	174	20.09%	222	19.57%	0.7743
Nasal Cavity	154	17.78%	192	16.94%	0.6178
Airway	238	27.47%	103	9.08%	0.0001*
TMJ	10	1.17%	41	3.61%	0.0005*
Osseous Structures	68	7.85%	212	18.70%	0.0001*
Dental	53	6.13%	100	8.82%	0.0245*
Other	169	19.51%	264	23.28%	0.0428*
Totals	866	100.00%	1134	100.00%	

Table 7 below shows the distribution of findings when the categories are broken down by individual findings, between child/adolescents and adults.

Table 7: Total Number of Findings by Age Group and Percent Overall

Location	Findings	# of Findings 18 & younger	% of Adolescent Findings	# of Findings 19 & older	% of Adult Findings	p-value
Paranasal Sinuses	Antral pseudocyst	26	3.00%	36	3.18%	
	Debris noted at max ostia	2	0.23%	0	0.00%	
	Hypoplastic antrum	4	0.46%	1	0.09%	
	Mucosal thickening(MT) of antrum	29	3.34%	46	4.06%	0.019*
	MT of antrum & ethmoid	17	1.96%	18	1.59%	
	MT of antrum, ethmoid, frontal	2	0.23%	1	0.09%	
	MT of atrum,ethmoid, sphenoid	6	0.69%	14	1.24%	
	MT of atrum, ethmoid, sphenoid, frontal	2	0.23%	0	0.00%	
	MT of atrum & sphenoid	3	0.35%	5	0.44%	
	MT of ethmoid	21	2.42%	7	0.62%	.0097*
	MT of ethmoid & frontal	0	0.00%	1	0.09%	
	MT of ethmoid & sphenoid	2	0.23%	3	0.26%	
	MT of frontal	1	0.12%	0	0.00%	
	MT of sphenoid	4	0.46%	3	0.26%	
	No sphenoid sinus	1	0.12%	0	0.00%	
	Obstructed mucocilliary pathway	2	0.23%	1	0.09%	
	Opacified antrum	7	0.81%	7	0.62%	
	Opacified frontal, ethmoid, and antrum	1	0.12%	1	0.09%	
	Opacified sphenoid sinus	1	0.12%	0	0.00%	
	Osteoma	0	0.00%	3	0.26%	
	Pneumatization of antrums	0	0.00%	2	0.18%	
	Pneumatization of sphenoid laterally	34	3.92%	66	5.83%	.0001*
	Severe rhinosinusitis	1	0.12%	0	0.00%	
	Sinus lift of left antrum	0	0.00%	1	0.09%	
	Soft tissue density in antrum	3	0.35%	5	0.44%	
	Soft tissue density in sphenoid	5	0.58%	1	0.09%	

Nasal Cavity	Cleft in nasal floor	1	0.12%	0	0.00%	
	Concha bullosa	77	8.88%	70	6.18%	
	Crenulated nasal septum	0	0.00%	2	0.18%	
	Deviated septum	69	7.96%	110	9.71%	.0001*
	Hypertrophy of turbinates	3	0.35%	3	0.26%	
	Nasal polyp	4	0.46%	5	0.44%	
	Rhinolith	0	0.00%	1	0.09%	
	Foreign body	0	0.00%	1	0.09%	
Airway	Adenoid calcifications	1	0.12%	0	0.00%	
	Adenoid hypertrophy	131	15.11%	39	3.44%	.0001*
	Decreased airway due to calcified ligaments C1-C2	0	0.00%	1	0.09%	
	Decreased airway due to patient positioning	1	0.12%	1	0.09%	
	Hypertrophy of nasopharyngeal tissues	1	0.12%	2	0.18%	
	Prevertebral thickening	1	0.12%	3	0.26%	
	Tonsillar calcifications	3	0.35%	16	1.41%	.0016*
	Tonsillar hypertrophy	100	11.53%	41	3.62%	.0001*
TMJ	Bifid condyle	2	0.23%	2	0.18%	
	Degen changes bilaterally	2	0.23%	13	1.15%	.0029*
	Degenerative left TMJ	0	0.00%	7	0.62%	
	Degenerative right TMJ	1	0.12%	9	0.79%	
	Hyperplastic unilateral condyle	0	0.00%	1	0.09%	
	Hypoplastic condyle bilaterally	1	0.12%	3	0.26%	
	Hypoplastic unilateral condyle	4	0.46%	6	0.53%	
Osseous Structures	C1 posterior arch defect	10	1.15%	7	0.62%	
	C2 defect	0	0.00%	1	0.09%	
	Cleft palate	2	0.23%	2	0.18%	
	Degenerative changes in upper C-spine	3	0.35%	79	6.97%	.0001*
	Density changes in skull bones	2	0.23%	5	0.44%	
	Displacement of the dens due to trauma	1	0.12%	0	0.00%	
	Fusion of cervical vertebrae	2	0.23%	3	0.26%	
	High density in mandible	23	2.65%	47	4.15%	.0009*
	High density in maxilla	14	1.61%	42	3.71%	.0001*

	Lesion in mandible	3	0.35%	13	1.15%	.0083*
	Lesion in maxilla	1	0.12%	5	0.44%	
	Pneumatization of skull bones	4	0.46%	1	0.09%	
	Ponticulous ponticus	2	0.23%	7	0.62%	
	Soft tissue mass left zygomatic arch	1	0.12%	0	0.00%	
Dental Findings	Apical lesion	5	0.58%	41	3.62%	.0001*
	Apical resorption	0	0.00%	3	0.26%	
	Coronal fracture	0	0.00%	1	0.09%	
	Coronal lesion	3	0.35%	6	0.53%	
	Foreign debris in alveolar crest	0	0.00%	5	0.44%	
	Impacted teeth	11	1.27%	13	1.15%	
	Macrodont	0	0.00%	1	0.09%	
	Mesiodens	3	0.35%	4	0.35%	
	Microdont	2	0.23%	1	0.09%	
	Missing teeth	20	2.31%	7	0.62%	.0148*
	Retained permanent root	1	0.12%	10	0.88%	.0047*
	Retained primary tooth	4	0.46%	1	0.09%	
	Root fracture	0	0.00%	1	0.09%	
	Supernumerary	3	0.35%	6	0.53%	
	Transposition	1	0.12%	0	0.00%	
Other	Asymmetric, large jugular foramen	29	3.34%	14	1.24%	.0266*
	Calcification in the area of the pineal gland	26	3.00%	27	2.38%	
	Calcification of petroclival ligaments	3	0.35%	8	0.71%	
	Calcification of stylomandibular ligaments	2	0.23%	1	0.09%	
	Calcifications of stylohyoid ligaments	87	10.03%	152	13.42%	.0001*
	Carotid artery calcifications	0	0.00%	26	2.29%	.0001*
	Debris in external auditory canal	11	1.27%	2	0.18%	.0148*
	Dural calcifications	2	0.23%	3	0.26%	
	Extracranial finding	2	0.23%	7	0.62%	
	Intracranial finding	7	0.81%	3	0.26%	
	Radiodense upper borders of thyroid cartilage	0	0.00%	21	1.85%	.0001*
		866		1134		

Each of the categories showed between one to five findings that were significantly different between the two age groups. In the paranasal sinuses, three findings were significantly different between them. These three findings were mucosal thickening of the antrum (p=0.019), mucosal thickening of the ethmoid (p=0.0097), and pneumatization of the sphenoid sinus laterally (p=.0001). The nasal cavity had one finding that was significantly different and that was deviation of the nasal septum (p=0.0001). Three findings in the airway showed significance, adenoid hypertrophy (p=0.0001), tonsillar calcifications (p=0.0016), and tonsillar hypertrophy (p=0.0001). Degenerative bilateral changes of the TMJ (p=0.0029) was the only significantly different finding in that location. For the osseous structures, four findings showed significance; degenerative changes in the upper cervical spine (p=0.0001), high density in mandible (p=0.0009), high density in maxilla (p=0.0001), and lesion in mandible (p=0.0083). The dental findings showed significant variance in three findings which were apical lesions (p=0.0001), missing teeth (p=0.0148), and retained permanent root (p=0.0047). The final category of other, had the highest percentage of findings and also the most significantly different findings with asymmetric large jugular foramen (p=0.0266), calcifications of stylohyoid ligaments (p=0.0001), carotid artery calcifications (p=0.000), debris in the external auditory canal (p=0.0148), and radiodense upper borders of the thyroid cartilage (p=0.0001).

The severity of the incidental findings varied. The majority, 312 (59.9%), had findings that were considered variations of normal by the radiologist. 153 (29.4%)

had findings severe enough for referral to a healthcare provider, either their physician or dentist. When comparing the two groups, forty-six individuals in the younger group (17%) were referred for findings, while 107 adults (42%) were referred for findings on their CBCT. The remaining fifty-six (10.7%) had findings of moderate significance that could be referred considering their medical history and/or pending symptoms. The data was examined in two ways to see the impact of those with findings of moderate significance. In Table 8 below, those with findings of moderate significance were left in the normal group.

Table 8: Incidence of Severe Findings Alone by Age Group

Age	Paranasal Sinuses	Nasal Cavity	Airway	TMJ	Osseous Structures	Dental	Other	Totals
Child/Adol	18	3	0	3	6	11	5	46 (17%)
Adults	11	4	2	6	18	49	17	107 (42%)
p	0.2308	0.6548	0.4744	0.2793	0.0084	0.0001	0.0062	0.0001
Total, No of patients	29	7	2	9	24	60	22	153 (29%)

There were twenty-nine individuals referred to a healthcare provider for findings in the paranasal sinuses, the second highest total. Seven individuals had concerning pathology in the nasal cavity, two in the airway, and nine had severe findings in the TMJ. Twenty-four patients had concerning findings in their osseous structures, while twenty-two had some in other locations. The highest area of referral had to do with dental findings, where sixty individuals (11.5%) were referred to the dentist for findings on the CBCT. Referrals for dental (p=0.0001), other (p=0.0062), and osseous structures (p=0.0084), were all more prevalent for the adult population.

Eleven individuals (4.1%) in the younger population were referred for dental findings on their scan, while forty-nine adults (19.3%) were referred. Five individuals (1.9%) in the younger population were referred for findings belonging to the other category on their scan, while seventeen adults (6.7%) were referred. In the last category with significant difference, six individuals (2.2%) in the younger population were referred for osseous structure findings, while nineteen adults (7.5%) were referred. There were no differences between the age groups in the incidences of referral for the remaining categories. Overall though there were significantly more adults referred for findings than child/adolescents (p=0.0001).

Table 9 below shows what was found when those with moderate findings were included in with the referrals. There are still significantly more adults (53%) who need referrals than child/adolescents (27%). Adding those with moderate findings increased the number of referrals for the paranasal sinuses and the other categories the most, with little effect on the remaining categories. In fact, the number of referrals for dental was completely unaffected. With those findings added, dental (p=0.0001), osseous structures (p=0.0019), and other (p=0.0292) were still the only categories with significant differences between the two groups. The number of referrals overall increased to 40%.

Table 9: Incidence of Severe & Moderate Findings Combined by Age Group

Age	Paranasal Sinuses	Nasal Cavity	Airway	TMJ	Osseous Structures	Dental	Other	Totals
Child/Adol	37	4	2	3	6	11	10	73 (27%)
Adults	31	5	2	7	21	49	21	136 (53%)
p	0.5756	0.6408	0.96	0.1749	0.0019	0.0001	0.0292	0.0001
Total, No of patients	68	9	4	10	27	60	31	209 (40%)

The average age of the referred child/adolescent was 14.0 years and the average adult age was 43.8 both slightly increased from the average age of their respective groups.

The findings that led patients to be referred to their physician are listed in Table 10 by location. Opacified antrums, mucosal thickening of the paranasal sinuses, nasal polyps, degenerative changes in the upper cervical spine, C1 posterior arch defects, and carotid artery calcifications were the highest causes for referral.

Table 10: Severe Findings by Location

Location	Findings	# of Findings
Paranasal Sinuses	Opacified antrum	6
	MT^ of antrum, ethmoid, sphenoid	5
	MT of antrum & ethmoid	3
	Soft tissue density in antrum	2
	Soft tissue density in sphenoid	2
	Severe rhinosinusitis	1
	MT of antrum	1
	No sphenoid sinus	1
	Opacified sphenoid sinus	1
	Opacified frontal, ethmoid, and antrum	1
	MT of antrum, ethmoid, sphenoid, frontal	1
	Hypoplastic antrum	1
	Debris noted at max ostia	1

	Antral pseudocyst	1
Nasal Cavity	Nasal Polyp	6
	Hypertrophy of turbinates	1
Airway	Hypertrophy of nasopharyngeal tissues	1
	Adenoid hypertrophy	1
Osseous Structures	Degenerative changes in upper C-spine	3
	C1 posterior arch defect	3
	Density changes in skull bones	2
	Cleft palate	2
	Fusion of cervical vertebrae	1
Other	Carotid artery calcifications	14
	Intracranial finding	4
	Extracranial finding	3
	Debris in external auditory canal	1
		69

^ MT=Mucosal thickening

The findings that led patients to be referred to have dental care are laid out in Table 11. The most common finding that led to referral to a dental provider was the presence of an apical lesion (38). Lesions in the mandible, impacted teeth, coronal lesions, retained permanent roots, and degenerative changes in the TMJ were also common reasons for referral.

Table 11: Severe Dental Findings

Location	Findings	# of Findings
Paranasal Sinuses	Mucosal thickening (MT) of antrum	1
	Osteoma	1
TMJ	Degenerative right TMJ	3
	Degenerative left TMJ	2
	Degenerative changes bilaterally	2
	Hypoplastic unilateral condyle	1
	Hyperplastic unilateral condyle	1
Osseous Structures	Lesion in mandible	9
	Lesion in maxilla	3
	Cleft palate	1
Dental Findings	Apical lesion	38
	Impacted teeth	8
	Coronal lesion	4

	Retained permanent root	4
	Apical resorption	3
	Mesiodens	2
	Supernumerary	2
	Root fracture	1
	Coronal fracture	1
	Foreign debris in alveolar crest	1
		88

Table 12 below shows the findings that were considered moderate in severity and were recommended for referral if the patient was symptomatic. The majority of these findings as stated earlier were in the paranasal sinuses and involved mucosal thickening of the various sinuses. There was one finding that recommended referral to the dentist pending TMJ symptoms.

Table 12: Number of Findings that May Require Referral to PCM or Dentist*

Location	Findings	# of Findings
Paranasal Sinuses	MT^ of antrum & ethmoid	9
	MT of antrum, ethmoid, sphenoid	7
	Opacified antrum	5
	MT of antrum	5
	Antral pseudocyst	4
	MT of antrum & sphenoid	2
	MT of sphenoid	2
	MT of ethmoid & sphenoid	2
	Soft tissue density in antrum/ sphenoid	1
	MT of antrum, ethmoid, sphenoid, frontal	1
	MT of ethmoid	1
Nasal Cavity	Concha bullosa	1
	Nasal Polyp	1
Airway	Tonsillar hypertrophy	1
	Adenoid hypertrophy	1
TMJ	Degenerative changes bilaterally	1*
Osseous Structures	Density changes in skull bones	2
	Degenerative changes in upper C-spine	1
Other	Asymmetrically large jugular foramen	3
	Intracranial finding	2

	Debris in external auditory canal	1
	Calcification of stylohyoid ligaments	1
	Extracranial finding	1
	Dural calcifications	1
		56

^ MT=Mucosal thickening

V. DISCUSSION

The diagnostic capabilities and sensitivity of CBCT were again demonstrated by the results of this retrospective study. Two-thousand findings across 521 patients were discovered, a rate of 3.8 findings per scan. This was very similar rate to a study by Price et al who found 3.2 findings per scan while using a smaller field of view (Price et al., 2012). As in their study the majority of the findings were not severe and were variations of normal. One-hundred and fifty-three (29.4%) scans in this study had findings that did necessitate referral to a healthcare provider. Pliska, et al. looking at CBCTs taken for orthodontic purposes felt 37.6% of their population had findings deemed worthy of a follow-up (Pliska et al., 2011), while another study showed a lower percentage of 16.1% of scans needing referral (Price et al., 2012). This variability in referral rate could in part be linked to the comfort level of the radiologist in calling a finding unworthy of referral. It was interesting that the radiologist in the Price study was blinded to additional clinical, radiographic, and histologic information, while the radiologist in this study had access to the patient's medical history and previous radiographs. Having access to such baseline images may have contributed to this difference in referral rate. The radiologist in this study being able to see changes or differences in appearance from previous images may have been quicker to suggest referral or feel comfortable not doing so. The number of findings and need for referral varies amongst studies due to differences in population, age, and how categories are broken up (Price et al., 2012). The present study showed differences between two age groups as well and that was the major area of interest for this study.

The number of individuals who had a finding in each age group was significantly different for each category examined (Table 5). In fact the differences were highly significant. The adults had more individuals with findings in every category except for airway. This leads one to believe that adults are more likely to have a finding of some sort in each category examined here besides airway. The fact that more younger patients had airway findings than adults could be linked to the types of findings in that category. Adenoid and tonsillar hypertrophy were two main findings in the airway category and both could be linked to the increased lymphatic tissue one would expect to see in a younger population group. The adenoids usually peak in size around the age of five and then atrophy, but chronic infection can keep the adenoid pad enlarged into adulthood (Kenna et al., 1996). Inflamed tonsils are also a common finding in the younger population, with the tonsillectomy being the second most common performed procedure among children in the United States (Clayburgh et al., 2011). It appears in the other categories that as age increases so does the likelihood of findings. Pliska et al found this to be true in their study in two categories, TMJ and endodontic. Their endodontic group being analogous to our dental category. They found that as age increased so did the incidental findings in the TMJ and endodontic categories (Pliska et al., 2011). The present study found this as well, but also felt it occurred in three additional categories as well.

When the total number of findings across the seven categories were compared there was not as quite a clear difference between the two age groups. The adults again had more overall findings in every category except airway, but the difference was no longer significant in the paranasal and nasal cavity categories, and barely significant in the other category (Table 6).

Each category had findings that showed significant differences between the two groups. The individual categories and their findings will be addressed below.

Paranasal Sinuses

As mentioned in the previous section mucosal thickening of the antrum, mucosal thickening of the ethmoid, and pneumatization of the sphenoid laterally were the three findings that displayed significant differences between the two age groups. The paranasal sinuses all originate as evaginations from the nasal fossae and are lined by a pseudostratified columnar ciliated epithelium that is directly attached to bone (Som & Curtin, 2003). The antrum is the first of the paranasal sinuses to form and is present at birth. Initially lying medial to the orbit, its lateral growth is usually complete by age 14 at which time it reaches laterally underneath the orbit. The antrums' growth is not complete until the third molar has completely erupted and the sinus completes its descent. The ostiums that drain the antrums lie superiorly on the medial walls and receive a mucous stream that is propelled by the cilia of the sinus lining. Obstruction of the drainage system can lead to mucosal swelling, which further impairs clearance of the sinus. Mucosal thickening of the antrum(s) can be associated with both acute and chronic sinusitis (Momeni et al., 2007). Sinusitis is one of the most commonly diagnosed illnesses in the United States and is estimated to affect over 30 million individuals, young and old alike. In the present study, the thickening of the antrum alone was more common in the adult population. This may be due to the fact that the maxillary antrum is not fully developed until later in childhood, thus making it less susceptible to infection until a little later in life.

The ethmoid sinus also develops by evaginations from the nasal fossae, which begin to form in the third to fifth fetal months. It is composed of a group of posterior and anterior cells, and reaches adult size by age 12 (Som & Curtin, 2003). This is a slightly younger age than seen with the maxillary antrums. This lends support to the thought that the sooner the sinuses develop the sooner they are susceptible to infection. In this study the adolescents were more likely to experience mucosal thickening of the ethmoid alone and being that more adolescents would have this sinus completely developed they were more likely to have the infection localized there.

The last significant difference seen in the paranasal sinuses had to do with the lateral pneumatization of the sphenoid sinus. The sphenoid sinus starts its major growth in the third to fifth year of life, usually reaching its adult configuration by the age of twelve. The degree of pneumatization is relevant when it comes to surgical approaches to tumors of the sellar region and gaining access. The sphenoid sinus can be classified by the degree to which it is pneumatized posteriorly and there are known frequencies in that direction, but the lateral pneumatization is considerably more variable (Som & Curtin, 2003). The difference seen between the two groups in this study is probably due to just more time for pneumatization in the adult population, and that as this younger population aged the numbers would be similar to the adult population.

Nasal Cavity

The only finding to exhibit a difference between the two groups in this category was a deviated septum. A deviated septum can be caused by a genetic disorder, but the most common cause is impact trauma to the face. The most common causes are contact sports, roughhousing, or automobile accidents (Mayo Clinic, 2012). Normal aging may also cause a nasal tip cartilage to deteriorate, which can aggravate a deviated septum over time (Haug et al., 2009). It is not surprising then that the adult population had a significantly higher number of deviated septums. They have had more life experiences that could have caused facial trauma and also with increased age more deterioration of nasal tip cartilage.

Airway

There were three findings exhibiting differences in the airway, two of which, adenoid and tonsillar hypertrophy, were discussed earlier in this section with the third being tonsillar calcifications. As stated earlier it was not surprising to see an increase in adenoid and tonsillar hypertrophy in the younger age group. The third finding of tonsillar calcifications or tonsilloliths was more numerous in the adult population. This too is not surprising as they are known to occur more frequently in adults.

When large enough they can cause a host of problems like halitosis, dysphagia, ear aches, and tonsillar swelling (Pruet & Duplan, 1987).

TMJ

This category had one finding that was significantly different between the two groups and it was bilateral degenerative changes of the TMJ. This finding was higher in the adult group and was one of the findings that consisted of a group of findings to include flattening of the condylar head, erosion of the condylar head, osteophytes, ely cyst, asymmetric condyle, and decreased disc space. This finding was not surprising as an unusually large amount of individuals diagnosed with osteoarthritis of the TMJ are about age 35 (Gremillion et al., 1994).

Osseous Structures

Four findings showed significant differences in this category. The first finding was degenerative changes in the cervical spine which was higher in the adult group. This is not surprising as age is the biggest factor in degenerative changes of the spine, and the changes signify an imbalance between synthesis and degradation of the matrix of intervertebral disks or articular cartilage (Bogduk, 2012). The next two significant findings involved the occurrence of high density lesions in the maxilla or mandible. These two were individual groups were composed of a number of different lesions. Osteomas in the maxilla along with tori, to include torus palatinus, and idiopathic osteosclerosis were grouped under high density in maxilla. High density in mandible consisted of osteomas, tori, enostoses, and idiopathic osteosclerosis. The groups were intended to be composed of high density findings that are benign in nature. These lesions are slow growing in nature and often not detected until young adulthood (Neville et al., 2002). Reports show that the highest incidence is in the sixth decade for osteomas and that they may be some type of an inflammatory reaction (Huvos, 1991). This would coincide with the lower incidence in the younger population. The last finding in this category showing significant difference was lesions in the mandible. This was a grouping that consisted of suspected cemental lesions, odontomas, abnormal bone/fibrous tissue, osteoid osteoma, odontokeratocyst, simple bone cyst, paradental cyst, and/or cemento-osseous dysplasia. As opposed to the high density grouping, findings here were suspected to be more pathologic in nature. The majority of the suspected findings have an age range that could include adolescents, but the ranges often carry over into adulthood more so. Odontomas do have a younger age range being they occur often in the first two decades of life. This though is offset by cement-osseous dysplasia which is not often seen until an individual's twenties (Neville et al., 2002). It was not surprising then to see the adult group with more of the findings. Lesions in maxilla were showing a similar trend as well, but there was not a large enough sample to state there was a significant difference.

Dental Findings

Three findings in this category showed a significant difference between the two groups. Apical lesions were more likely to be found in the adult population. Grouped in the apical lesion category were apical periodontitis, apical cyst, granuloma, and condensing osteitis. For this category to be higher in adults could be anticipated as adults have had more time for their teeth to be exposed to carious insults or trauma that can lead to such findings. This is also true of the next significant finding, retained permanent root. Adults again had the majority and to be expected as they have had more of a chance to develop the need for an extraction. In addition, an adult's more rigid bone may lend to the chances of breaking a root while attempting an extraction. The last finding in this category that showed difference was the absence of teeth. It was a bit shocking to see that the younger population was more likely to be missing teeth, but this we feel is an anomaly of our population base. The patients treated here at the residency must meet a certain score of difficulty to gain entry into the program and one feature that can raise their score is crowding. Often times then extractions are needed to manage these patients and thus some of the images were probably taken post-treatment in an extraction case. Thus premolars were mistakenly recorded as missing when they had been present, but extracted for treatment.

Other

The final category had five findings that were significantly different. Two of these findings, asymmetric large jugular foramen and debris in the external auditory canal, showed predilection for the younger group. The asymmetric large jugular bulb is a developmental variation that can on occasion erode into the inner ear and present with hearing loss, vestibular disturbance, and pulsatile tinnitus (Friedmann et al., 2011). It is most common on the right side of individuals and becomes apparent around the age of two. The size will enlarge through adulthood before stabilizing around the age of sixty, with large size in the male population (Friedmann et al., 2011). With all that is known about the variation, no studies have shown it to be more common in children. It did have a lower level of significance than some of the other findings, but it was still strong at p=0.026. This difference could have been caused by the differences in field of view between the two CBCT machines. The scans from the ICat Classic, 13cm x 16cm, were not as large as the ICat Platinum which were 17cm x 32 cm. The majority of the older population had scans taken on the ICat Classic and the smaller FOV may have led to an under diagnosis in that population group. Either way this anomaly is a feature to be aware of on CBCTs. The second finding more common in the younger population was debris in the external auditory canal. This is most likely linked to build up of ear wax or cerumen. Cerumen is produced in the outer third of the ear canal and acts as a self-cleaning agent with protective, lubricating and antibacterial properties. The cerumen is normally self-cleaned as it is transported to the ear opening, assisted by jaw motion. However improper cleaning attempts with cotton swabs and/or continuous insertion of hearing aids or earplugs and cause an impaction of cerumen. Cerumen impaction is more common in the elderly and in patients with cognitive impairment (Roland et al., 2008). Approximately 10% of children and 5% of normal healthy adults can be expected to present with cerumen impaction. Older patients in nursing homes can be as high as 57% (Roland et al., 2008). Our study results seem as expected then as our adult population was healthy and few were elderly, thus one would expect the younger population to have higher amounts of cerumen impaction. Another factor that could have contributed to higher cerumen impaction is the high frequency use of ear plugs or ear buds by the younger population to listen to music or while watching shows on a mobile device. This is a common sight these days and could contribute to a higher frequency in the younger population.

The remaining findings were higher in the adult population and included carotid artery calcifications, radiodense upper borders of the thyroid cartilage, and calcification of the stylohyoid ligaments. Stylohyoid calcification has been shown to increase with age and most often seen in the sixth decade (Oztas & Orhan, 2012). It occurs more often in females and those with systemic diseases (Oztas & Orhan, 2012). When the calcification is long enough to interfere with adjacent anatomical structures and function the condition has been called Eagles syndrome.

The thyroid cartilage is part of the laryngeal cartilaginous complex and can undergo calcification or endochondral ossification. Calcification of the thyroid cartilage has been known to increase with age, especially in the third decade and beyond (Mupparapu & Vuppalapati, 2005). It is no shock then that this finding was only seen in adults.

The final finding, carotid artery calcification, was also only seen in adults. These calcifications can be an indicator of potential stroke or metabolic disease (Price et al., 2012). Willeit and Kiechl showed a high correlation between age and the presence of carotid artery atherosclerosis with the highest incidences in the sixties and seventies (Willeit & Kiechl, 1993). Though a potential indicator, Fanning et al. showed that future stroke risk could not be predicted from carotid artery calcium scores from conventional CT scans (Fanning et al., 2006). With the older demographic being more prone to this finding it is not unexpected that the younger population was free of such calcifications.

The data shows that more adult patients will have a finding in one of the categories except airway, but the number of findings they have may not always be significantly different when it comes to the paranasal sinuses and nasal cavity. More child/adolescents had a finding when it came to the airway and they approximated the adult population in total number of findings in the paranasal and nasal cavity categories.

Another objective of this study was to see how many individuals would be referred to see a health care provider based on findings in their CBCT scan. Again the idea was to compare child/adolescents to adults. To review, there were three variations of findings; i) Referral needed to healthcare provider (ie. Physician or Dentist) ii) Referral needed to healthcare provider, if symptomatic iii) Normal variations, no referral needed. The question of what should be done with the middle group where referral was needed if the patient was symptomatic, needed to be addressed. The options were to leave them out, add them to the normal variation group, or add them into the need referral group. It was decided to look at it once with them left in the normal group and then look at it again when they were added into the severe group. What we found was that it made no difference which group they were in as both ways showed that the adults had significantly more referrals than the younger population. It also turned out that the same three categories were different between adolescents and adults. The osseous structures, dental, and other categories were the only ones to show significant differences between the two age groups, with adults more likely to need referral (Table 8 & 9). The remaining categories showed no statistical differences between the two groups.

When looking at Table 8 and considering the possible referrals as normal variations, the findings in the dental category were most often the cause for referral. When looking at what dental findings led to referral (Table 11) it can be seen that apical lesions were the primary cause accounting for almost half (38 of 88 referrals). The next two common findings leading to referral were lesions in the mandible (9) and impacted teeth (8). An interesting finding was that, although overall dental findings only composed 7.65% of all the findings (Table 4), the second lowest percent, they led to the most referrals (Table 8).

This opens the door to inquire if CBCT is better than traditional dental radiographs to screen for dental pathology in a new patient. A study by Bondemark looking at orthodontic patients with a mean age of 11.2 years found that 8.7% had findings on their panoramic radiographs and that 3.6% overall required referral before the start of treatment (Bondemark et al., 2006). The most common findings were radiopacities in alveolar bone, mucosal thickening of the sinuses, and periapical lesions. Another study looking mainly at adolescents found 6% of orthodontic patients had significant findings on their radiographs, but overall 0.5% required referral for their findings (Kuhlberg & Norton, 2003). Other studies looked at older populations. A study by Rushton et al. out of the UK, when looking at almost 2000 patients, showed that 44% of new adult patients (18 years and older) had findings on a panoramic radiograph that were relevant to treatment (Rushton VE et al., 2002). Another study that examined edentulous patients found that 51.7% of those patients had at least one finding on their panoramic radiograph (Awad EA & Al-Dharrab A, 2011). Masood et al. also found that about 42% of edentulous patients had at least one finding on their panoramic radiograph and that 3.8% had significant findings requiring referral (Masood et al., 2007). The sensitivity of CBCT is demonstrated in this study by the fact the 97.3% of the patients had at least one finding. This is double what was seen in the adult patients in previous studies with traditional radiography. This number is hard to compare though as the FOV in the CBCT scans is much broader than a traditional panoramic radiograph. When looking solely at dental findings though, the numbers are comparable. In this study, we found 36.2% of adults having dental findings and 19.1% of those in the younger age group. When talking about findings that warranted referral we found that 19.3% of adults and 4.1% child/adolescents had such findings. The adult population having more referrals is also seen with traditional radiographs. The types of findings are very similar as well to what was seen the panoramic radiographs; ie. apical lesions, radiopacities, etc. So though the number of findings needing referral were higher in both age groups there was not a drastic increase, nor were the findings severe enough to warrant CBCT in every patient for pathology alone. It is hard to say that much is gained from the CBCT in terms of finding pathology in the dentoalveolar realm. Where the big difference is seen is outside of the jaws and dentoalveolar complex, since the panoramic does not image these areas as well. Though many more findings are found and at a much higher rate on a CBCT (97.3%) than traditional radiographs (4.5%) (Tetradis et al., 1999), the majority of these are outside of the focus of the dentist. Plus the majority of what is found are variations of normal anatomy and development. To search out this pathology outside of the dental realm would not be prudent, nor would it follow the ALARA principle. This would be especially true for the younger population when as stated earlier those under ten are three times as sensitive and those between ten and twenty are twice as sensitive to radiation-induced cancers and hereditable effects (SEDENTEXCT, 2009). So, though the number of dental findings are slightly higher than what is seen on traditional radiographs it is not enough to warrant the increased radiation exposure to solely discover pathology in the dentoalveolar complex.

The second most common category that led to referral was paranasal sinuses. The primary findings in this category that led to referral (Table 10) were opacified antrums (6) and mucosal thickening involving three of the sinuses (5). The next two categories that led to referral were osseous structures and other (Table 8). The osseous findings that led to referral were pretty diverse, but degenerative changes in the upper c-spine and C1 posterior arch defects were equal at three apiece. Carotid artery calcifications (14) were the primary reason for referral from the other category (Table 10). Nine individuals were referred to the dentist for TMJ issues with degenerative changes accounting for the majority of the referrals (7) (Table 11). Nasal cavity was next for referrals with seven individuals and nasal polyps (6) were the primary reason (Table 10). Finally two individuals were referred for airway and the reason was hypertrophy of airway tissues (Table 10).

Taking a closer look at the possible referrals reveals that most of them fell in two categories; paranasal sinuses and other (Table 12). When looking at the paranasal sinuses, mucosal thickening involving the various sinuses was a predominant reason referral was considered, as was opacification of the antrum. The other category was fairly equally spread as to why referral was being considered, though an asymmetrically large jugular foramen was most common (3).

So looking at Table 9 where the possible referrals were added in with the definite referrals, the paranasal sinuses became the category with the most, followed by dental. As stated earlier mucosal thickening was a major finding that led to a consideration of referral related to the paranasal sinuses. This is easy to understand as mucosal thickening is known to be a changing phenomenon, showing potential acute rhino sinusitis one week while normalizing the next. This constantly changing appearance makes it prudent to not refer on appearance alone, but to correlate findings with clinical symptoms.

The other category moves up in prevalence as well with thirty-one individuals. However the makeup of this category being from a smattering of left-over findings that did not fit into the other categories brings its usefulness as a category into question. Because the findings here are so diverse to compare the category itself between the two groups is probably erroneous. It is probably better viewed by looking at the individual findings within it, then as a category in general.

When looking at individual findings outside of the dental realm, the dental realm being the maxilla, the mandible, and their associated teeth, there were a number of findings that were seen frequently (>1%) and it would benefit the clinician to be aware of these commonly seen findings. Most are simply variations in growth and development, while others can be associated with the aging process. The most frequently seen finding was adenoid and/or tonsillar hypertrophy at 15.6% in this population. As stated above the younger population was more likely to be seen with this. Calcification of the stylohyoid ligaments (11.95%) on the other hand was more common in adults. Mucosal thickening in any one of the sinuses was seen in 9.25% of this population and when looked at overall was evenly distributed between the two age groups. Deviated septums were more common in adults and seen in about 9% of this population. Another common finding was concha bullosa at 7.35% of the population and was evenly distributed between the age groups. The next two common findings pneumatization of the sphenoid laterally (5%) and degenerative changes in the c-spine (4.1%) were more common in adults. Antral pseudocysts (3.1%) were a frequently seen finding and were so in both age groups. Calcification in the area of the pineal gland was seen in 2.65% of this population and fairly evenly spread between the young and old. The younger group had the finding of asymmetric, large jugular bulb slightly more often, but it was seen in about 2.15% of this population overall. The last finding that was seen more than one percent of the time in this population overall was carotid artery calcifications (1.3%) and they were seen exclusively in the older population. This list gives the clinician some common findings that they are bound to see while examining CBCT's, but it is not an extensive list and does not allow the clinician to focus on any one area. The findings are spread across the various categories used here and across the head and neck of actual patients. The clinician has to be cognizant of the entire scan and not just a few areas. The diversity and disperse nature of the findings only reinforces the need to have CBCT images read by a trained radiologist.

There were a number of limitations in this study. One was the subjective interpretation of the radiographic images in regards to some of the findings that are normally classified or graded clinically. One example is the finding of tonsillar and/or adenoid hypertrophy. This is a finding that is normally graded by a clinical scale using a Friedman score. In this study though it was a determination made by the radiologist by their appearance on the scan. Without seeing volumetric results of these structures it is hard to differentiate one that is normal from one that is hypertrophic, as there is a continuum in size that has clinical impact. This same kind of issue plays into the previously discussed mucosal thickening of the sinuses as they are continuously changing and there is a scale of thickening that exists. The radiologist is again forced to make a determination of what they perceive as thickening from scan appearance alone. So while the CBCT is very sensitive in finding the disease it is not always as specific to allow one describe the degree to which disease exists.

The different fields of view of the two machines are another weakness in this study. Though not having much impact on many of the categories, it did come into play we believe when looking at some findings that may have been more on the peripheral of the images. The majority of these types of findings would have been in the other category, like the asymmetric jugular bulb discussed earlier. The smaller FOV potentially could have artificially lowered the number of findings in some of the scans and could be considered a shortcoming in the study.

Having only one radiologist reading the scans and not having a second reader or reviewer could also be seen as a study weakness. This could have led reports that focused more heavily on some areas more than others. Any bias of the radiologist though would have been applied to all the scans in the study equally though, so having one reader has benefits as well. Finally, it would have been ideal to have a pathology report for all the lesions that were referred to allow less grouping, that may translate into a loss of information. The pathology reports would provide a definitive diagnosis of some of the lesions as opposed to just the description provided by the radiologist and would have strengthened the results.

VI. CONCLUSION

1. The adult orthodontic patient can be expected to have more incidental findings in their CBCT scans. When breaking the findings down into categories, they can be expected to have more findings in each category except for airway. The difference in number of findings between child/adolescents and adults is statistically significant in the airway, TMJ, osseous structures, dental, and other categories. The differences in the number of findings in the paranasal sinuses and nasal cavity categories were not statistically significant.
2. An adult orthodontic patient is more likely to have an incidental finding in every category except for airway. A child/adolescent patient is more likely to have a finding in the airway, with these being adenoid or tonsillar hypertrophy. The differences were statistically significant in each category.
3. The adult orthodontic patient can be expected to have more findings that require referral for further evaluation. This is true whether the findings of possible referrals are included or not. The categories that showed significant differences were dental, osseous structures, and other. The rate of referral for findings in the paranasal sinuses, nasal cavity, airway, and TMJ did not differ significantly between the two groups.
4. Overall, the other category had the greatest percentage of findings at 21.6%. The paranasal sinuses were next at 19.8%. Nasal cavity and airway were similar with 17.3% and 17.05% respectively. Osseous structures made up

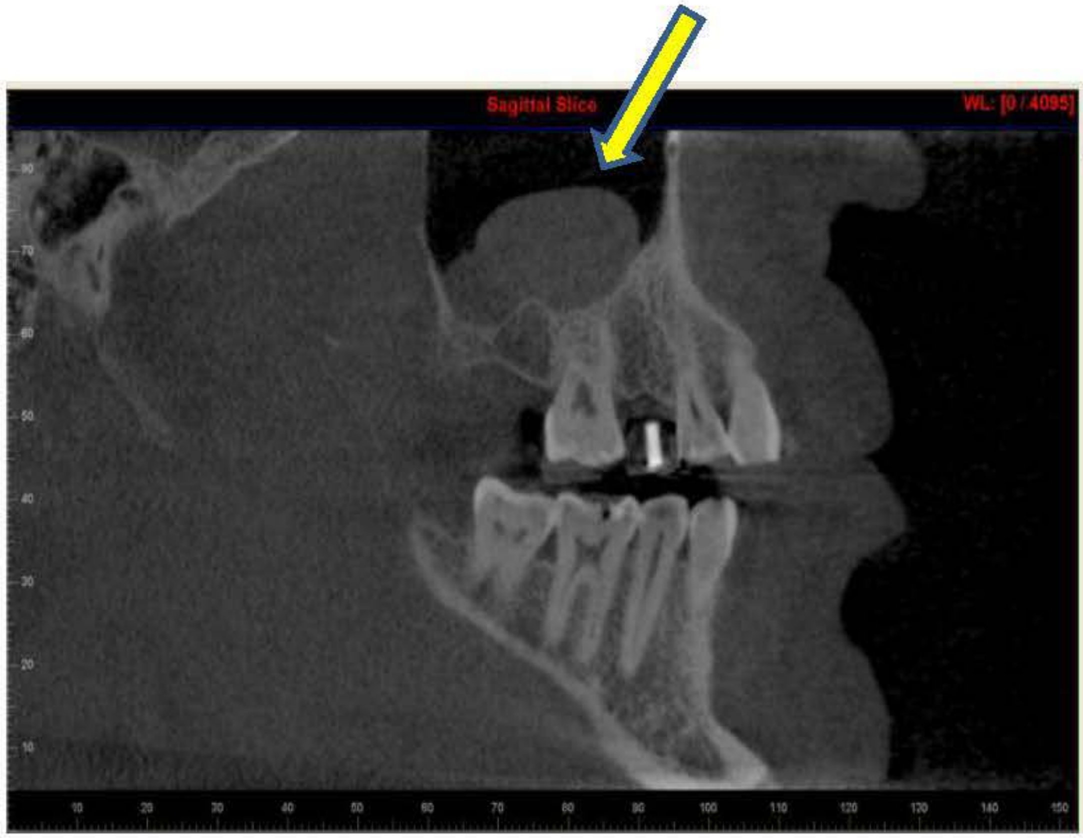
14% of the findings, dental 7.65%, and finally the lowest percentage was the TMJ at 2.55%. The disperse nature of the findings does not allow the clinician to focus on certain areas, and the entire scan needs to be examined by a radiologist.

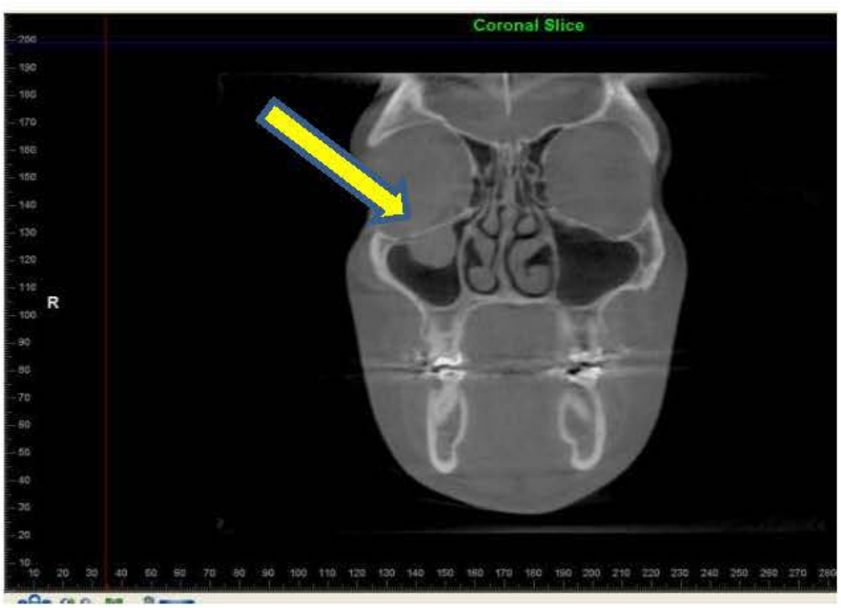
5. When looking at findings that should be referred combined with those that could be the paranasal sinuses had the most. Dental findings had the next highest. The other and osseous structure categories were half as likely to cause a referral. TMJ was next, then nasal cavity and finally airway.
6. CBCT is highly sensitive to variations to normal and potential pathology throughout its FOV with 97.3% of individuals having at least one finding in this study. This at least double the prevalence of findings typically found on traditional radiographs.
7. The findings seen most often (>1%) were tonsillar and/or adenoid hypertrophy (15.6%), calcification of the stylohyoid ligaments (11.95%), mucosal thickening of any of the sinuses (9.25%), deviated septum (9%), concha bullosa (7.35%), pneumatization of the sphenoid laterally (5%), degenerative changes in the c-spine (4.1%), antral pseudocysts (3.1%), calcification in the area of the pineal gland (2.65%), asymmetric, large jugular bulb (2.15%), and carotid artery calcifications (1.3%).
8. Though CBCT is very sensitive to discovering variations to normal throughout its field of view, it does not greatly add to the findings of traditional radiographs in regards to pathology in the dentoalveolar complex. So unless advanced diagnosis of a known condition, ie. impacted teeth, facial

asymmetry, etc. is required, it is more prudent to use traditional radiographs and lessen the radiologic exposure of the patient.

Appendix A. Images of Relevant Findings

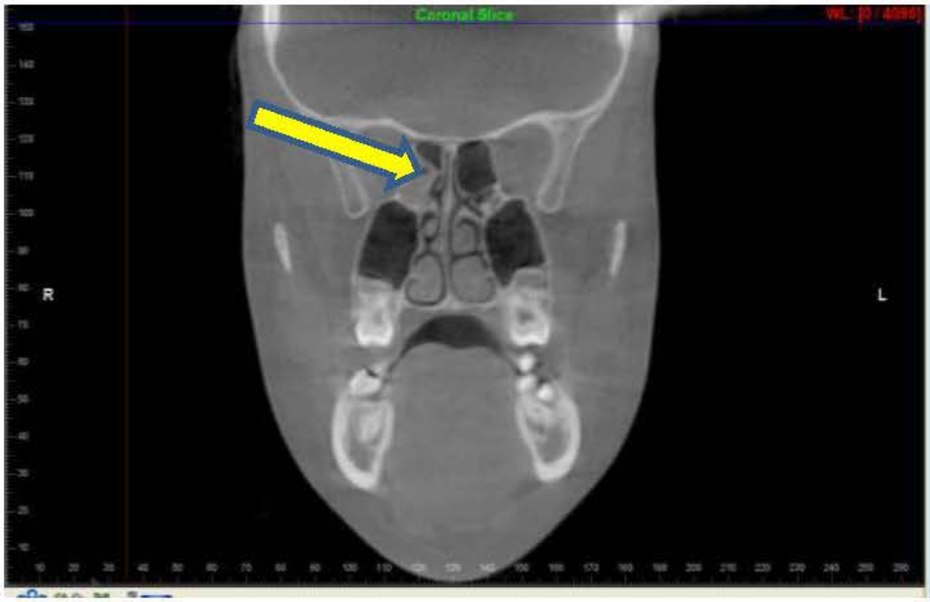
Antral Psuedocyst



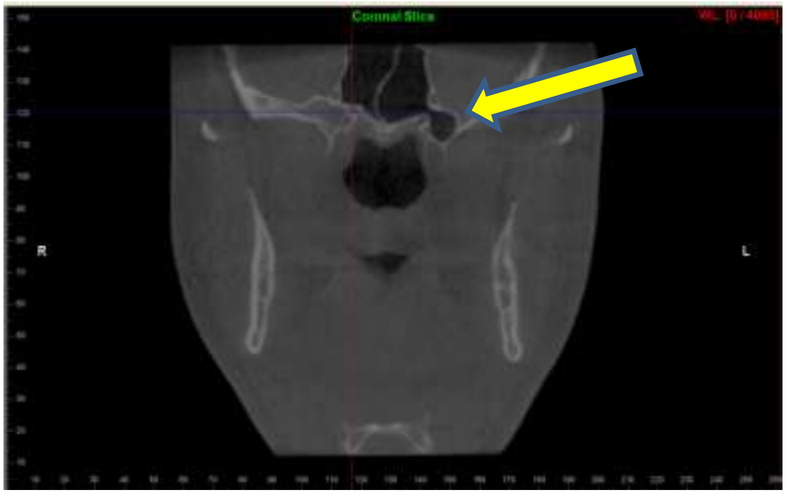


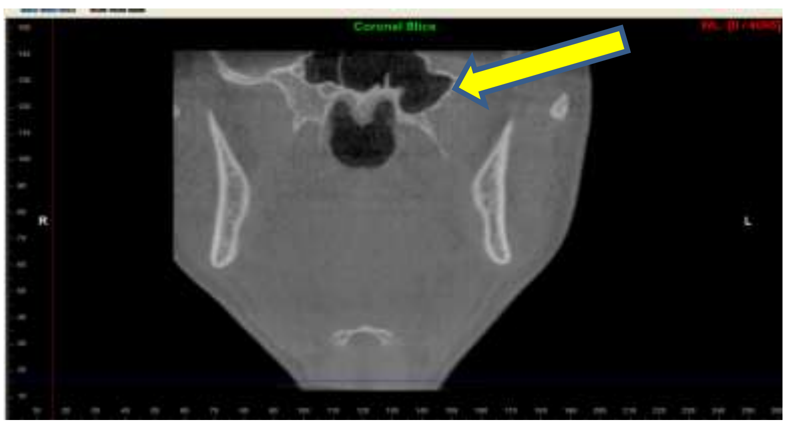
Mucosal Thickening of Antrum

Mucosal Thickening of Ethmoid

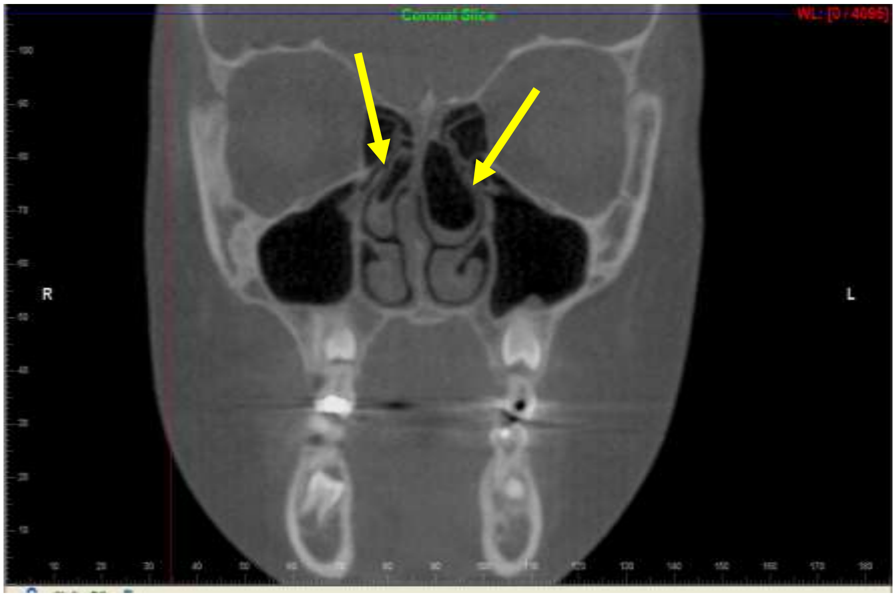


Pneumatization of Sphenoid Laterally

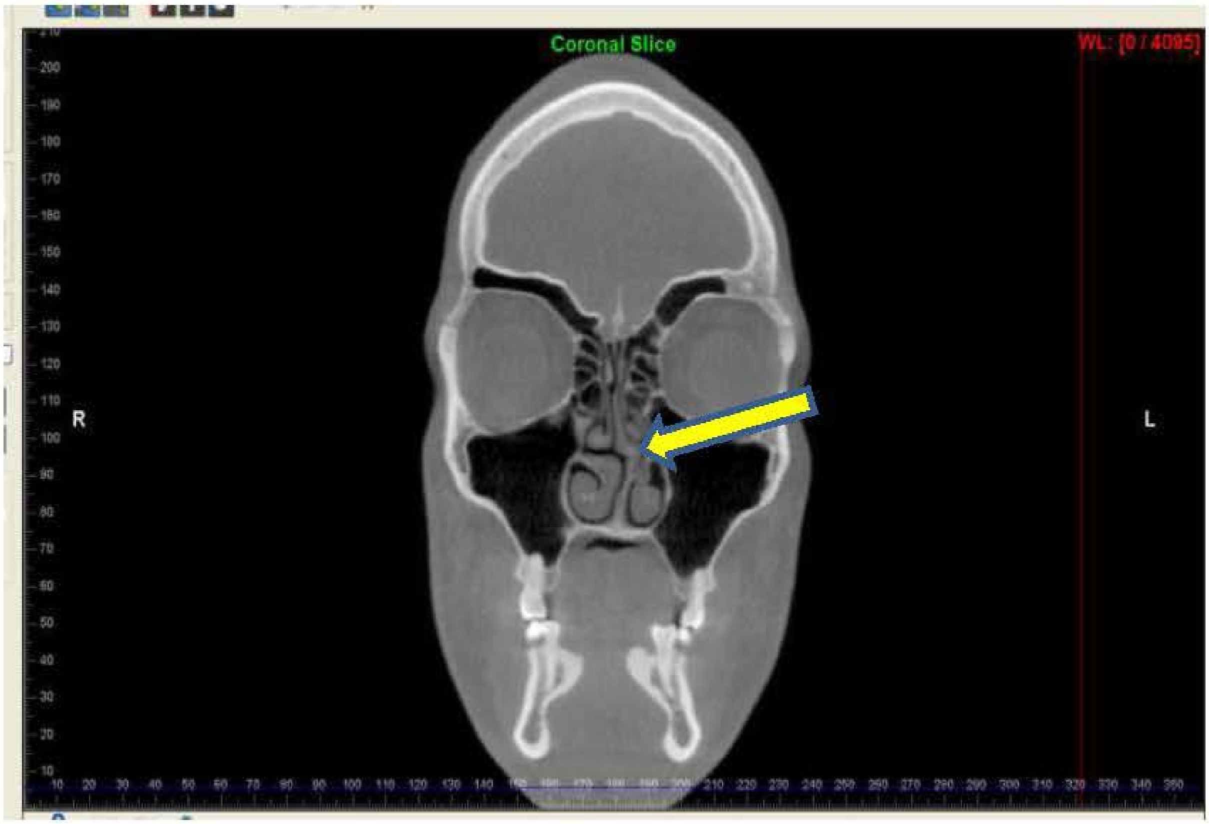


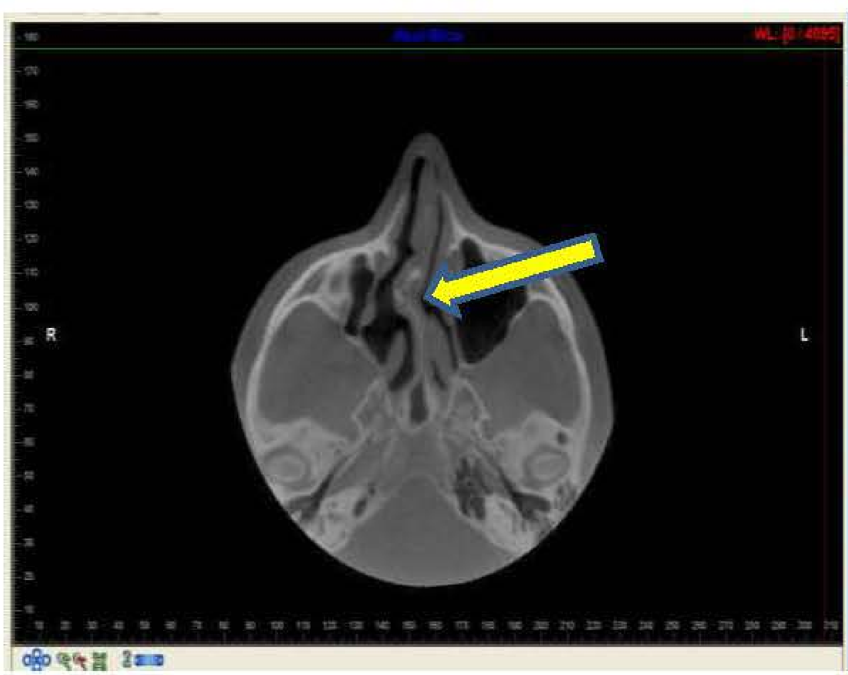


Concha Bullosa

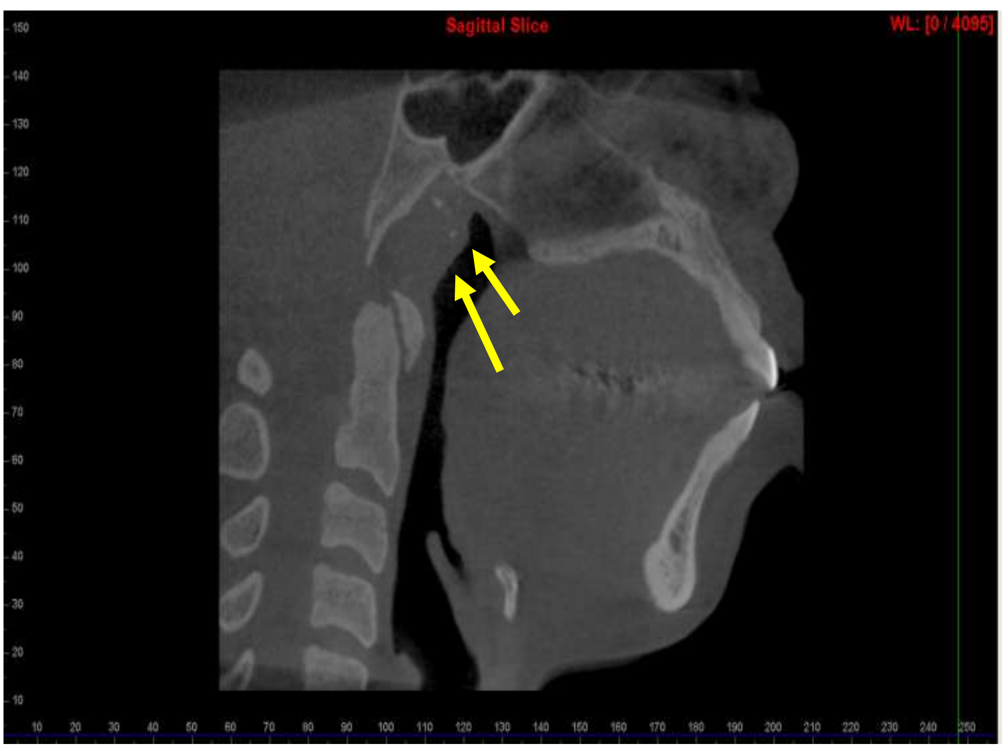


Deviated Septum

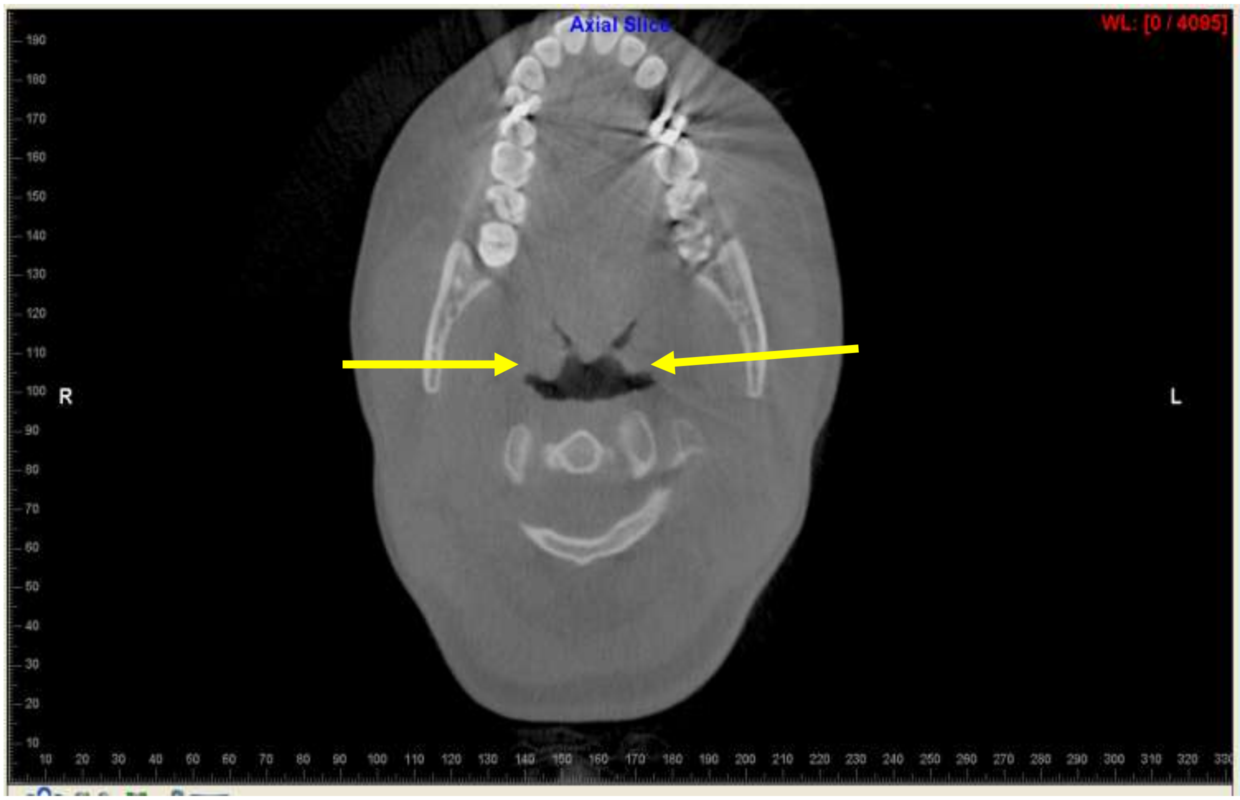


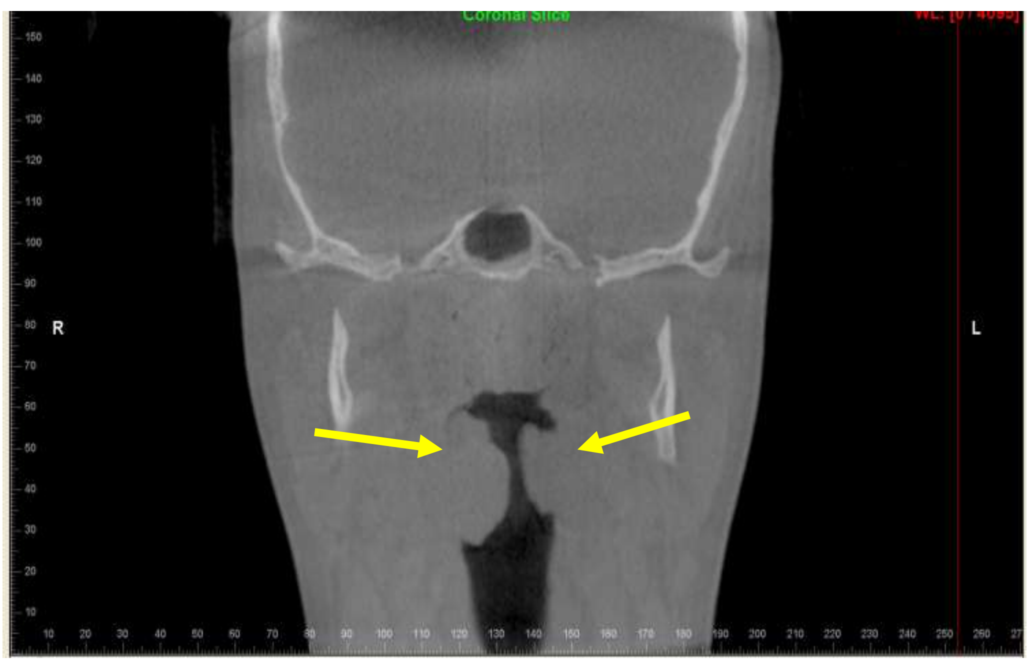


Adenoid Hypertrophy

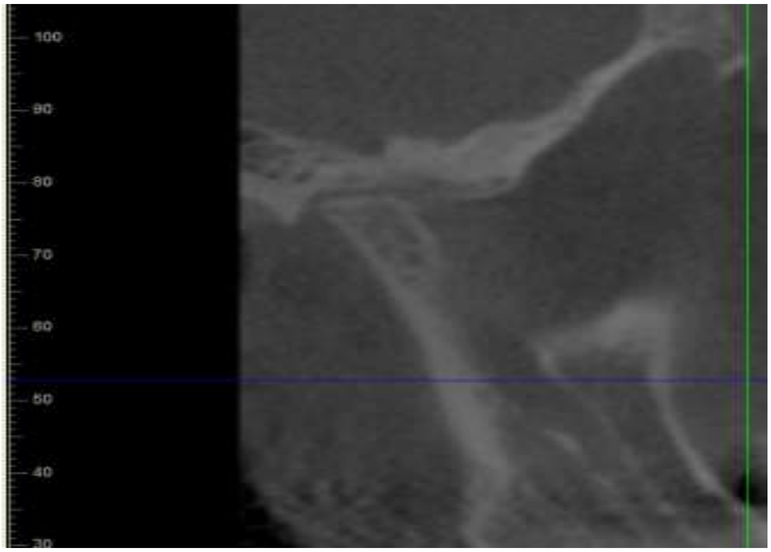


Tonsillar Hypertrophy

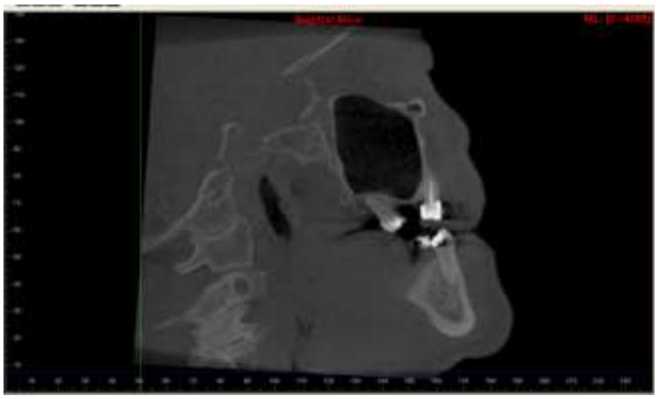


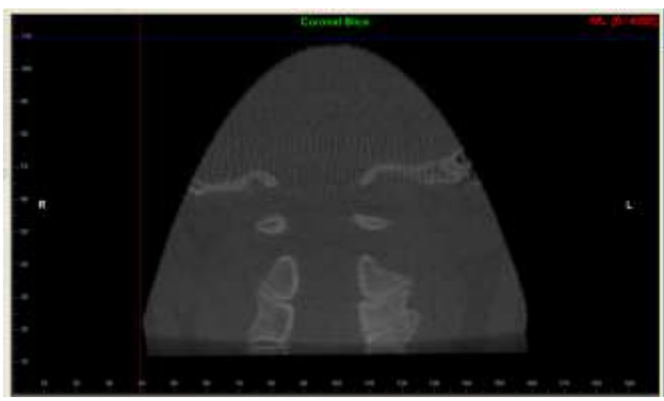


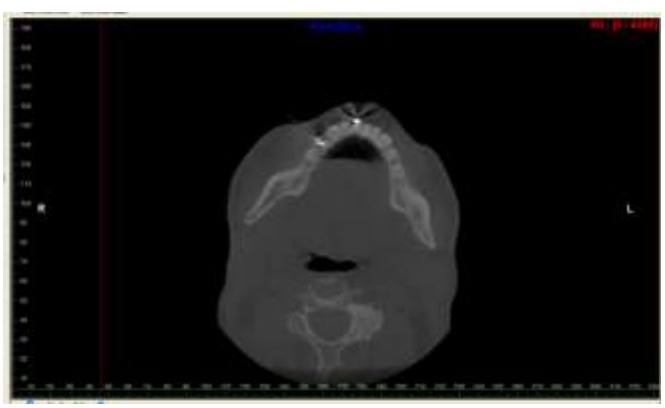
Degenerative Joint Changes



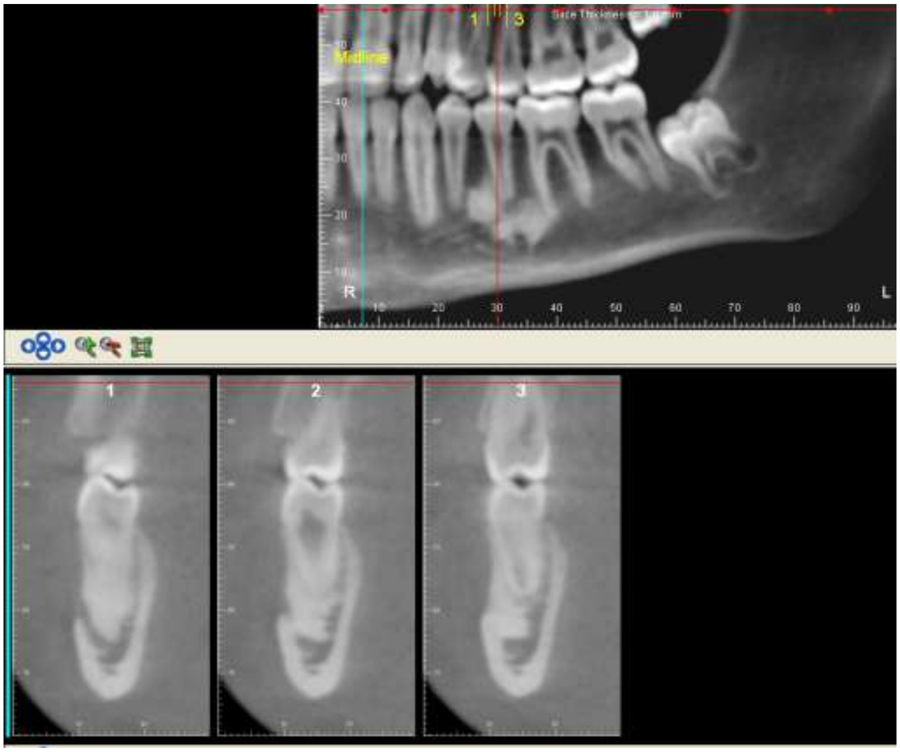
Degenerative Changes in Upper C-spine



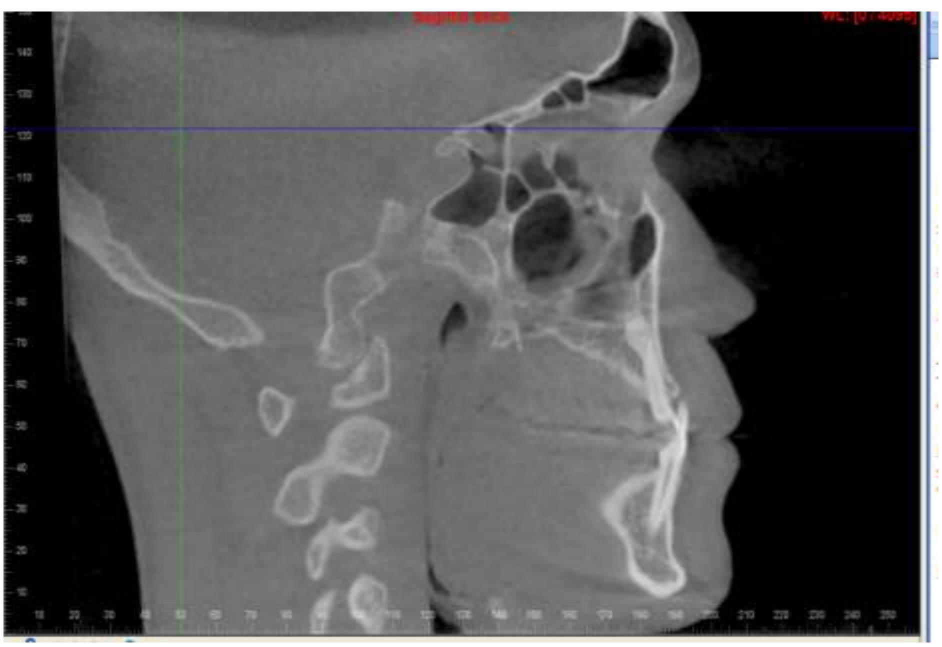




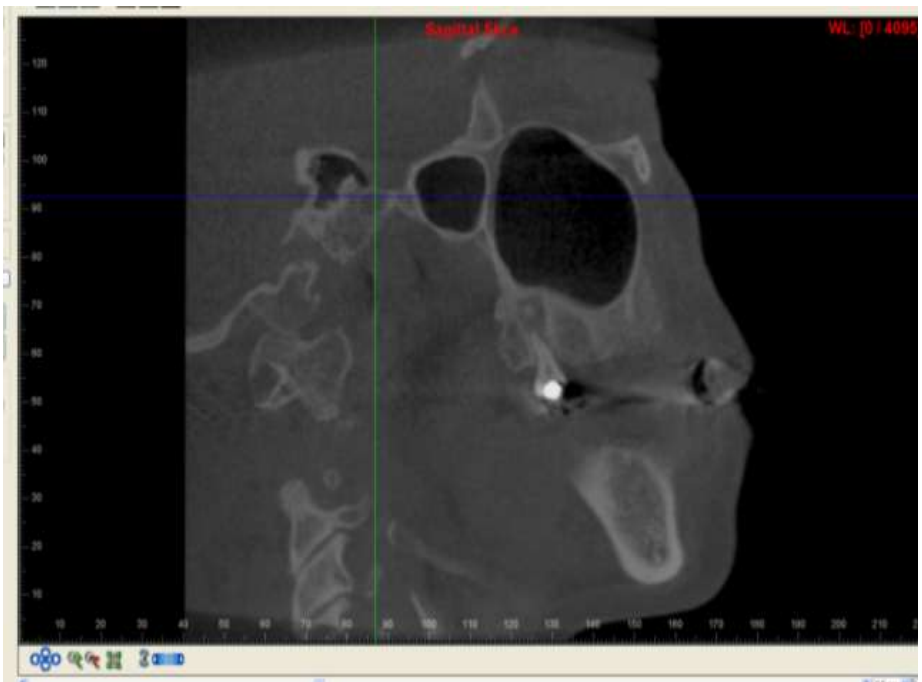
High Density in Mandible



High Density in Maxilla

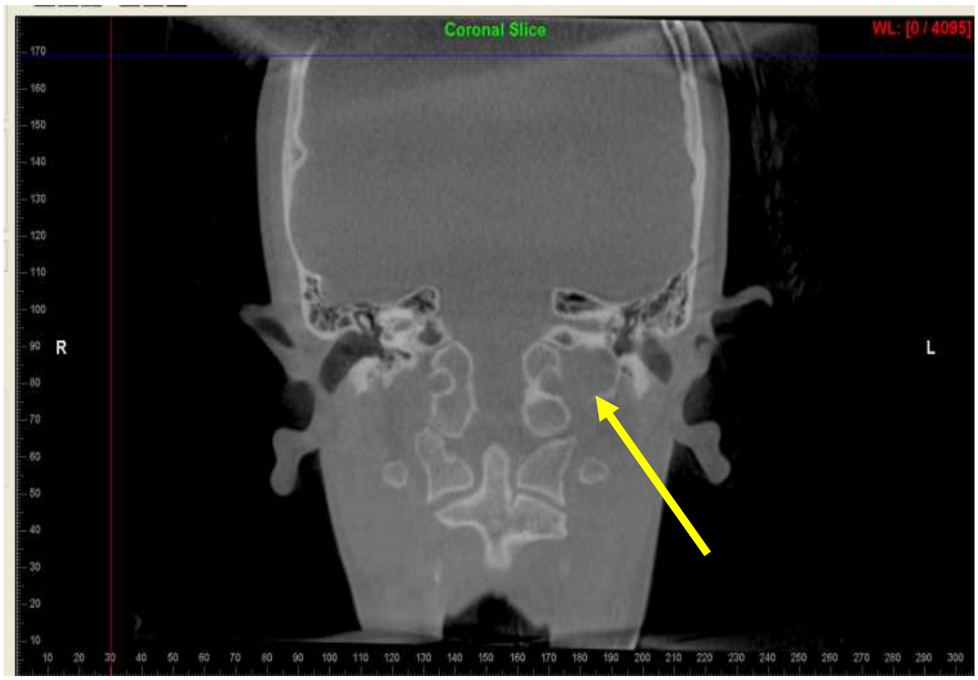


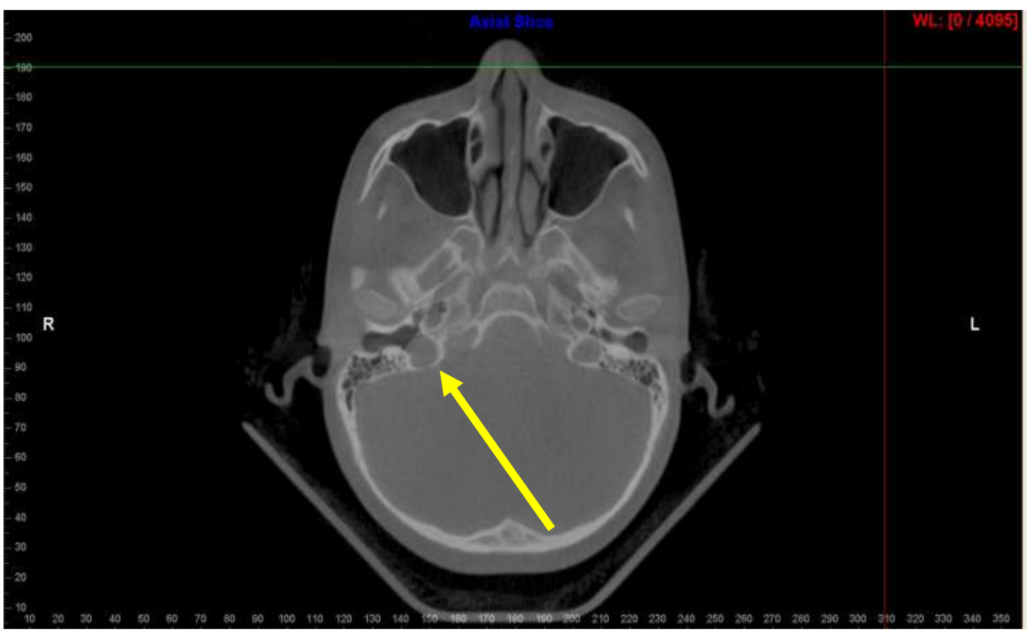
Apical Lesion



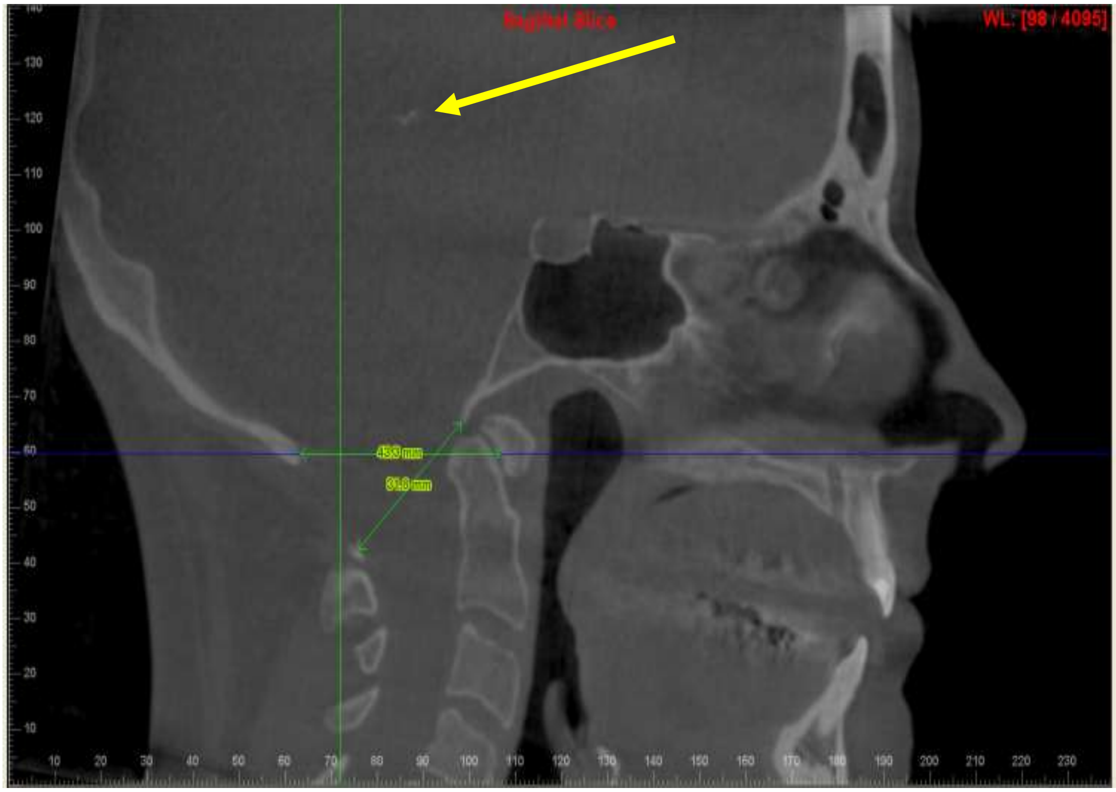
Impacted Teeth

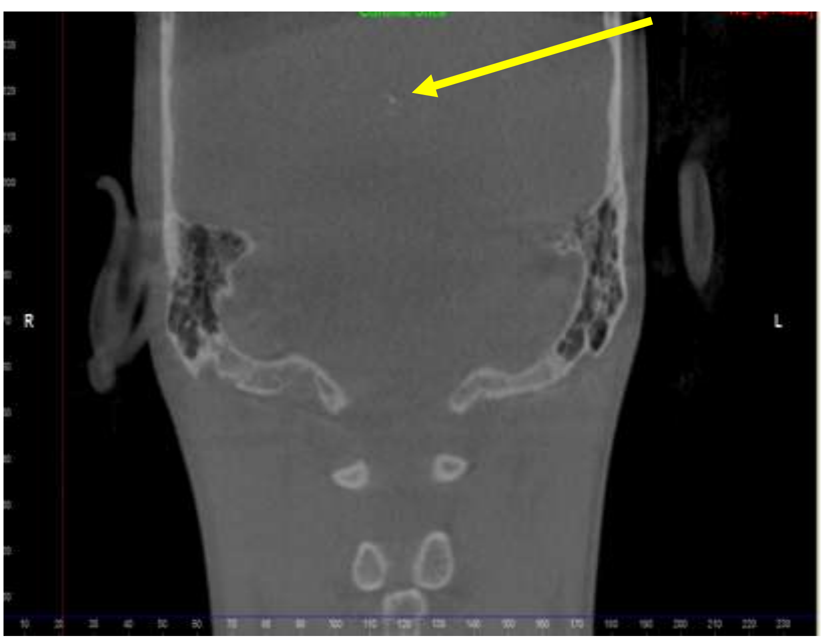
Asymmetrically Large Jugular Foramen



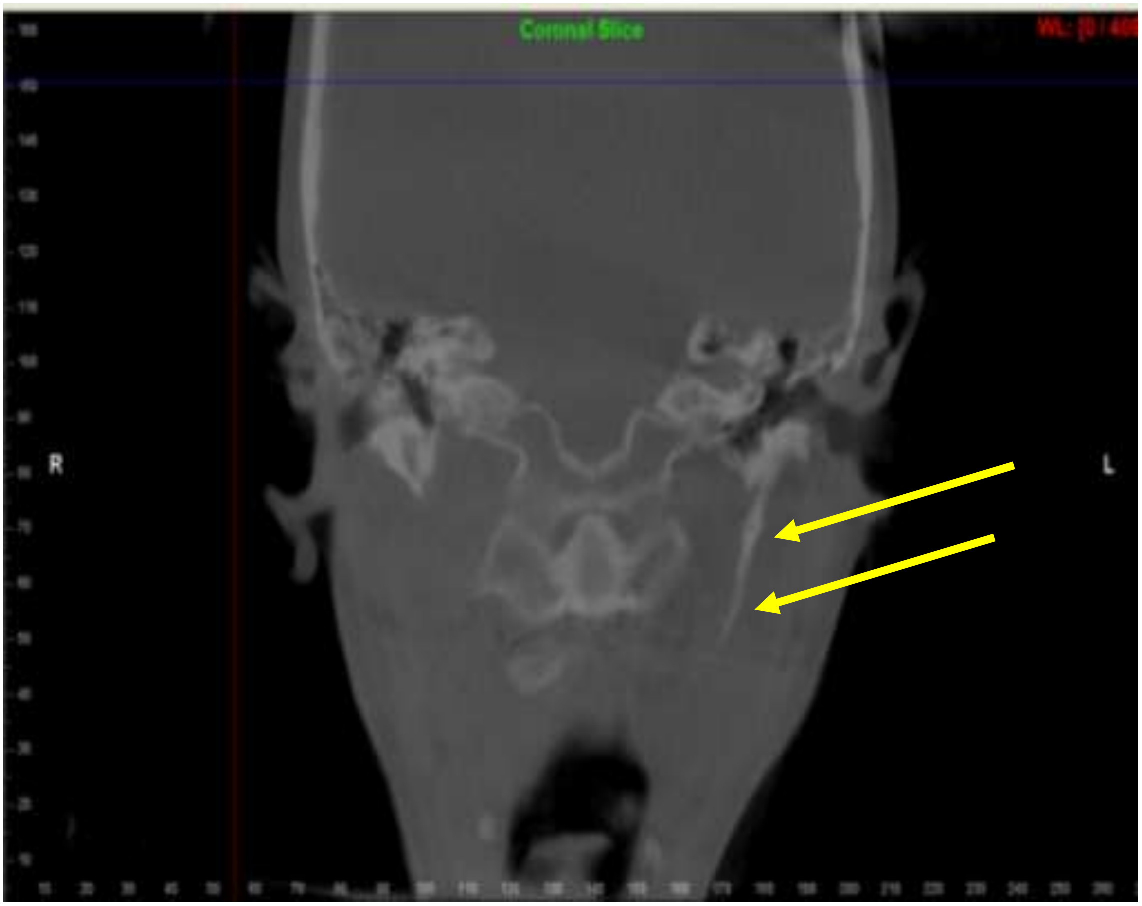


Calcification in Pineal Gland



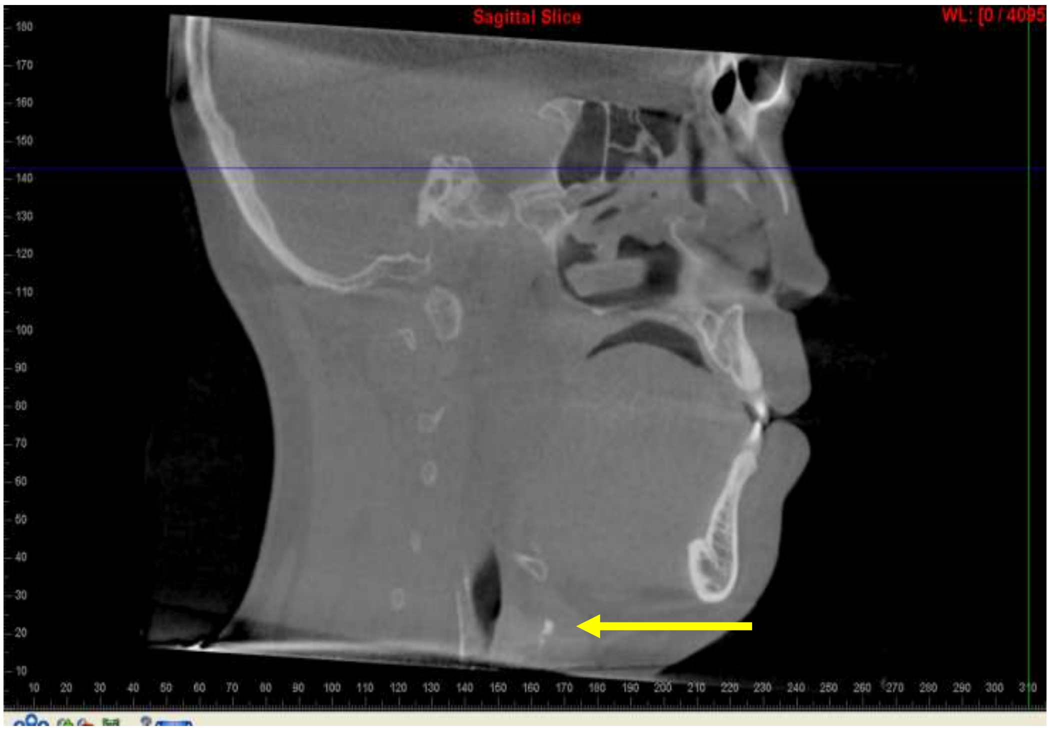


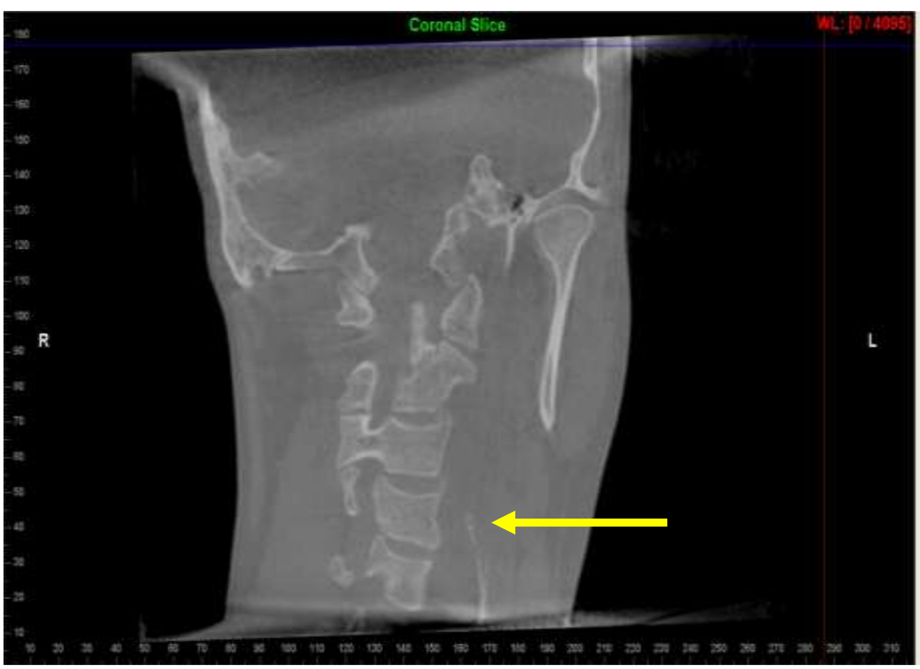
Calcification of Stylohyoid Ligaments



Carotid Artery Calcifications

Radiodense Greater Horns of Thyroid Cartilage





LITERATURE CITED

1. Ahmed F, Brooks SL, Kapila SD. Efficacy of identifying maxillofacial lesions in cone-beam computed tomographs by orthodontists and orthodontic residents with third party software. Am J Dentofacial Orthop. 2012 Apr;141(4):451-459.

2. American Association of Orthodontics. Statement on the role of CBCT in orthodontics (26-10H). eBulletin; May 2010. Available at: www.aaomembers.org/resources/publications/ebulletin-05-06-10.cfm. Accessed on August 25, 2012.

3. American Association of Orthodontists. Clinical Practice Guidelines for Orthodontics and Dentofacial Orthopedics. St. Louis: American Association of Orthodontists; 2008.

4. Awad EA, Al-Dharrab A. Panoramic radiographic examination: a survey of 271 edentulous patients. Int J Prosthodont. 2011 Jan-Feb;24(1):55-7.

5. Bogduk N. Degenerative joint disease of the spine. Radiol Clin North Am. 2012 Jul;50(4):613-28.

6. Bondemark L, Jeppsson M, Lindh-Ingildsen L, Rangne K. Incidental findings of pathology and abnormality in pretreatment orthodontic panoramic radiographs. Angle Orthod. 2006 Jan;76(1):98-102.

7. Carter L, Farman AG, Geist J, Scarfe WC, Angelopoulos C, Nair MK, Hildebolt CF, Tyndall D, Shrout M; American Academy of Oral and Maxillofacial Radiology. American Academy of Oral and Maxillofacial Radiology executive opinion statement on performing and interpreting diagnostic cone beam computed tomography. Oral Surg Oral Med Oral Pathol Oral Radiol Endod. 2008 Oct;106(4):561-2. doi: 10.1016/j.tripleo.2008.07.007.

8. Cattaneo PM, Melsen B. The use of cone-beam computed tomography in an orthodontic department in between research and daily clinic. World J Orthod. 2008 Fall;9(3):269-82.

9. Cha JY, Mah J, Sinclair P. Incidental findings in the maxillofacial area with 3-dimensional cone-beam imaging. Am J Orthod Dentofacial Orthop. 2007 Jul;132(1):7-14.

10. Clayburgh D, Milczuk H, Gorsek S, Sinden N, Bowman K, MacArthur C. Efficacy of tonsillectomy for pediatric patients with Dysphagia and tonsillar hypertrophy. Arch Otolaryngol Head Neck Surg. 2011 Dec;137(12):1197-202.

11. Fanning NF, Walters TD, Fox AJ, Symons SP. Association between calcification of the cervical carotid artery bifurcation and white matter ischemia. AJNR Am J Neuroradiol. 2006 Feb;27(2):378-83.

12. Farman AG, Scarfe WC. The basics of maxillofacial cone beam computed tomography. *Semin Orthod* 15 (2009). pp. 2–13.

13. Friedmann DR, Eubig J, McGill M, Babb JS, Pramanik BK, Lalwani AK. Development of the jugular bulb: a radiologic study. Otol Neurotol. 2011 Oct;32(8):1389-95.

14. Gremillion H, Bates R, and Stewart C. Degenerative Joint Disease. Part II: Symptoms and Examination Findings. 1994. 12(2):88-90.

15. Grunheid T, Kolbeck-Schieck JR, Pliska BT, Ahmad M, Larsen BE. Dosimetry of a cone-beam computed tomography machine compared with a digital x-ray machine in orthodontic imaging. Am J Dentofacial Orthop. 2012 Apr;141(4):436-443.

16. Halazonetis DJ. Cone-beam computed tomography is not the imaging technique of choice for comprehensive orthodontic assessment. Am J Orthod Dentofacial Orthop. 2012 Apr;141(4):403,405,407,409,411.

17. Hatcher DC. Operational principles for cone-beam computed tomography. J Am Dent Assoc. 2010 Oct;141 Suppl 3:3S-6S.

18. Haug MD, Witt P, Kalbermatten FD, Rieger UM, Schaefer DJ, Pierer G. Severe respiratory dysfunction in a patient with relapsing polychondritis: should we treat the saddle nose deformity? J Plast Reconstr Aesthet Surg. 2009 Feb;62(2):e7-10. Epub 2008 Oct 7.

19. Huvos A. Bone Tumors: Diagnosis, Treatment and Prognosis. W.B.Saunders, Co., 1991.

20. Kapila S, Conley RS, Harrell WE Jr. The current status of cone beam computed tomography imaging in orthodontics. Dentomaxillofac Radiol. 2011 Jan;40(1):24-34.

21. Kenna MA, Bluestone CD, Stool SE. Pediatric Otolaryngology. 3rd ed. Philadelphia: Saunders; 1996.

22. Kuhlberg AJ, Norton LA. Pathologic findings in orthodontic radiographic images. Am J Orthod Dentofacial Orthop. 2003 Feb;123(2):182-4.

23. Larsen BE. Cone-beam computed tomography is the imaging technique of choice for comprehensive orthodontic assessment. Am J Orthod Dentofacial Orthop. 2012 Apr;141(4):402,404,406,408,410.

24. Mah JK, Huang JC, Choo H. Practical applications of cone-beam computed tomography in orthodontics. J Am Dent Assoc. 2010 Oct;141 Suppl 3:7S-13S.

25. Masood F, Robinson W, Beavers KS, Haney KL. Findings from panoramic radiographs of the edentulous population and review of the literature. Quintessence Int. 2007 Jun;38(6):e298-305.

26. Mayo Clinic Fact Sheet. http://www.mayoclinic.com/health/deviated-septum/ds00977/dsection=treatments-and-drugs. Accessed November 14, 2012.

27. Moffitt AH. Discovery of pathologies by orthodontists on lateral cephalograms. Angle Orthod. 2011;81:58-63.

28. Momeni AK, Roberts CC, Chew FS. Imaging of chronic and exotic sinonasal disease: review. AJR Am J Roentgenol. 2007 Dec;189(6 Suppl):S35-45.

29. Mupparapu M, Vuppalapati A. Ossification of laryngeal cartilages on lateral cephalometric radiographs. Angle Orthod. 2005 Mar;75(2):196-201.

30. Nattrass C, Sandy JR. Adult Orthodontics – a review. Br J Orthod. 1995;22:331-7.

31. Neville BW, Damm DD, Allen CM, Bouquot JE. Oral and Maxillofacial Pathology. 2nd ed. Philadelphia: Elsevier; 2002.

32. Norton MR, Gamble C. Bone Classification: an objective scale of bone density using the computerized tomography scan. Clin Oral Implants Res. 2001 Feb;12(1):79-84.

33. Öztaş B, Orhan K. Investigation of the incidence of stylohyoid ligament calcifications with panoramic radiographs. J Investig Clin Dent. 2012 Feb;3(1):30-5. doi: 10.1111/j.2041-1626.2011.00081.x. Epub 2011 Aug 5.

34. Pazera P, Bornstein MM, Pazera A, Sendi P, Katsaros C. Incidental maxillary sinus findings in orthodontic patients: a radiographic analysis using cone-beam computed tomography (CBCT). Orthod Craniofac Res. 2011 Feb;14(1):17-24.

35. Pliska B, DeRocher M, Larson BE. Incidence of significant findings on CBCT scans of an orthodontic patient population. Northwest Dent. 2011 Mar-Apr;90(2):12-6.

36. Price JB, Thaw KL, Tyndall DA, Ludlow JB, Padilla RJ. Incidental findings from cone beam computed tomography of the maxillofacial region: a descriptive retrospective study. Clin Oral Implants Res. 2012 23:1261-1268.

37. Proffit WR, Fields, Jr HW, Sarver DM. Contemporary Orthodontics. 5th ed. St. Louis: Mosby; 2013:17,621.

38. Pruet CW, Duplan DA. Tonsil concretions and tonsilloliths. Otolaryngol Clin North Am. 1987 May;20(2):305-9.

39. Reeves TE, Mah P, McDavid WD. Deriving Hounsfield units using grey levels in cone beam CT: a clinical application. Dentomaxillofac Radiol. 2012 Sep;41(6):500-8. doi: 10.1259/dmfr/31640433. Epub 2012 Jun 29.

40. Ritter L, Lutz J, Neugebauer J, Scheer M, Dreiseidler T, Zinser MJ, Rothamel D, Mischkowski RA. Prevalence of pathologic findings in the maxillary sinus in cone-beam computerized tomography. Oral Surg Oral Med Oral Pathol Oral Radiol Endod. 2011 May;111(5):634-40.

41. Rogers SA, Drage N, Durning P. Incidental findings arising with cone beam computed tomography imaging of the orthodontic patient. Angle Orthod. 2011 Mar;81(2):350-5.

42. Roland PS, Smith TL, Schwartz SR, Rosenfeld RM, Ballachanda B, Earll JM, Fayad J, Harlor AD Jr, Hirsch BE, Jones SS, Krouse HJ, Magit A, Nelson C, Stutz DR, Wetmore S. Clinical practice guideline: cerumen impaction. Otolaryngol Head Neck Surg. 2008 Sep;139(3 Suppl 2):S1-S21.

43. Rushton VE, Horner K, Worthington HV. Routine panoramic radiography of new adult patients in general dental practice: relevance of diagnostic yield to treatment and identification of radiographic selection criteria. Oral Surg Oral Med Oral Pathol Oral Radiol Endod. 2002 Apr;93(4):488-95.

44. Scarfe WC, Farman AG. What is cone-beam CT and how does it work? Dent Clin North Am. 2008 Oct;52(4):707-30, v.

45. Scarfe WC, Farman AG. Cone-beam computed tomography. In: White SC, Pharoah, MJ. Eds. Oral Radiology: Principles and Interpretation. 6th ed. St. Louis: Mosby; 2009:Ch 14.

46. SEDENTEXCT project. Radiation protection: cone beam CT for dental and maxillofacial radiology. Evidence based guidelines 2011. Available at: http://www.sedentexct.eu/files/guidelines_final.pdf. Accessed on August 25, 2012.

47. Smith BR, Park JH, Cederberg RA. An evaluation of cone-beam computed tomography use in postgraduate orthodontic programs in the United States and Canda. J Dent Educ. 2011 Jan;75(1):98-106.

48. Som PM, Curtin HD. Head and Neck Imaging. 4th Ed., St. Louis: Mosby; 2003: Ch 2.

49. Swennen GR, Schutyser F. Three-dimensional cephalometry: spiral multi-slice vs cone-beam computed tomography. Am J Orthod Dentofacial Orthop. 2006 Sep;130(3):410-6.

50. Tetradis S, Kantor ML. Prevalence of skeletal and dental anomalies and normal variants seen in cephalometric and other radiographs of orthodontic patients. Am J Orthod Dentofacial Orthop. 1999; 116:572-7.

51. White SC, Pharoah, MJ. Eds. Oral Radiology: Principles and Interpretation. 4th ed. St. Louis: Mosby; 2000.

52. Whitesides J, Pajewski NM, Bradley TG, Iacopino AM, Okunseri C. Socio-demographics of adult orthodontic visits in the United States. Am J Orthod Dentofacial Orthop. 2008,133:489.e9-489.e14.

53. Willeit J, Kiechl S. Prevalence and risk factors of asymptomatic extracranial carotid artery atherosclerosis. A population-based study. Arterioscler Thromb. 1993 May;13(5):661-8.