CWRU'S TRANSVERSE ANALYSIS DEVELOPING NORMS

By

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DEDICATION

This thesis is dedicated to my loving husband, Jon. Thank you so much for your selflessness while helping me pursue my dreams. I will forever be grateful for your unconditional support.

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Abstract

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This study aims to develop a method to measure intercanine and intermolar angulation using cone beam computed tomography (CBCT); and to provide a descriptive analysis of intermolar/intercanine angulation, maxillary molar/canine and mandibular molar/canine buccolingual inclination in a sample deemed to have normal transverse dimensions. A survey was conducted asking orthodontic faculty to use pre-existing patient records to define a sample of acceptable transverse dimensions. Thirty adolescent patients, 15 males and 15 females, ages 10-16 participated in the study. On Demand3D software was used to measure buccolingual inclination of maxillary and mandibular first molars and canines. Dolphin3D Imaging was used to develop a method to measure intercanine and intermolar angulations. The mean buccolingual inclination of maxillary canines and first molars was 103.9±5.0° and 100.1±4.1°, and mandibular canines and first molars was 97.3±3.4° and 76.7±4.6°. The mean intercanine and intermolar angulations were 163.1±6.2° and 179.0±4.6°. In conclusion, we have established normal buccolingual

inclinations using CBCT that can be used in the differential diagnosis of transverse deficiency. We have defined intercanine and intermolar angulations, which can be reliably measured using CBCT.

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LITERATURE REVIEW

The concept that an ideal facial profile follows from an esthetic and stable relationship of the teeth, as presented by Haas (Haas, 1970), has long been a central tenet of orthodontics. The transverse dimension; however, has not historically attracted as much attention (Vanarsdall, 1994). Although the lateral cephalogram enables the clinician to evaluate patients in the sagittal and vertical dimensions, a proper diagnosis requires knowledge of the transverse dimension as well. Periodontal health, esthetics, stability, and patient satisfaction can all be increased by addressing problems of the transverse dimension (Graber 1994). Maxillary expansion is common, but there is currently little standardization of the true indications for its use. An accurate diagnosis of maxillary transverse deficiency is important, because there are profound benefits to be gained from expansion.

Nearly twenty years ago, Vanarsdall advocated for the study of the transverse dimension and the establishment of normative standards for use in clinical practice (Vanarsdall, 1994). Cephalometrics, which has been used for decades, allows clinicians to make measurements with respect to a patient's midline and compare them to established norms. However, until the advent of CBCT,

there were few tools to help orthodontists diagnose and treat patients in the transverse dimension. Orthodontic treatment must respect three dimensions, yet most clinicians continue to diagnose and treat based upon a two-dimensional lateral cephalogram.

At present, some orthodontists advocate a simple chairside assessment of symmetry and occlusal balance for the evaluation of the transverse dimension (Marshall 2005). However, when viewing the patient as a whole, if a dysplasia exists in either the sagittal and or vertical dimension, any additional transverse deficiency is often hidden, making a clinical evaluation of the transverse dimension of very limited diagnostic value (Betts, 1994). Others suggest differentiating skeletal and dental discrepancies by counting the number of teeth in crossbite, believing that larger crossbites indicate skeletal problems, and smaller crossbites (less than two teeth) indicate a dental discrepancy (Jacobs, 1980). This rule may cause problems when a patient manifests dental compensations without a crossbite, which then camouflages a true skeletal discrepancy (Marshall, 2005). McNamara believes that maxillary transverse deficiency may be camouflaged by laterally flared maxillary posterior teeth, which give the appearance of normal posterior occlusion

when the maxilla is, in fact, narrow (McNamara, 2000). In these cases, the lingual cusps of the upper posterior teeth are tipped below the occlusal plane, causing impaired function. Even though they lack a crossbite, these patients should be considered maxillary transverse deficient.

When determining maxillary transverse deficiency, many clinicians use plaster models to identify dental compensations. The American Board of Orthodontics (ABO) supports this model by providing a measuring gauge to evaluate buccolingual inclination of the posterior teeth on finished cases as one of their criteria on the clinical board exam. The ABO has instituted criteria for evaluation of finished cases on the clinical examination, which required four field tests and five years to completely develop. The development of this objective grading system began in 1995, when 100 cases were evaluated and 15 criteria were measured using casts and panoramic radiographs. Through a series of field tests and modifications, the 15 criteria were narrowed down to 8 (alignment, marginal ridges, buccolingual inclination, occlusal contacts, occlusal relationships, overjet, interproximal contacts, and root angulation) and in 1998 the fourth and final field test took place. This final

test refined the calibration and measuring system, and developed the passing criteria for the clinical exam. The establishment of proper buccolingual inclination requires that the examinee avoid balancing interferences, meaning that there should not be a significant difference between heights of the buccal and lingual cusps of the maxillary and mandibular molars and premolars. If the transverse occlusal plane is perpendicular to the axial inclination of the molars, the gauge rests across the right and left first molars, and the degree of molar inclination is appropriate. If, when resting the gauge on the lingual cusps of the maxillary molars, the buccal cusps are more than 1 mm from the straight edge of the gauge, one point is deducted per tooth. Similarly, if, when resting the gauge on the buccal cusps of the mandibular molars, the lingual cusps are more than 1 mm from the straight edge of the gauge, one point is deducted per tooth. If the maxillary buccal or mandibular lingual cusps are more than 1 mm from the straight edge of the gauge, a maximum of 2 points are deducted per tooth (ABO, 1998).

Another supporter of appropriate buccolingual inclination is Andrews, who defined six keys to normal occlusion using 120 study models of non-treated cases chosen by orthodontists, dentists, and a local university

to receive no greater benefit by undergoing orthodontic treatment. He compared these cases with 1150 cases treated by the nation's most talented orthodontists (Andrews, 1972). He listed buccolingual inclination of the dentition as number three in his criteria for proper occlusion. Ricketts also recognized the importance of the transverse dimension, and orthodontists' lack of information about it, which led him to advocate for the establishment of standards to accompany the rise of advanced treatments such as palatal widening and maxillary orthopedics, mandibular posturing devices such as the Frankel appliance, and extraoral traction (Ricketts, 1981).

Betts et al stated, "the postero-anterior (PA) cephalogram is the most readily available and reliable radiograph for identification and evaluation of transverse skeletal discrepancy." Although the authors recommended the use of the postero-anterior cephalogram for the evaluation of transverse discrepancy (Betts, 1995), it has been reported that only 13.3% of orthodontists take PA cephalograms for initial records (Gottlieb, 1991). Ricketts described landmarks and measurements to assess transverse discrepancy of the maxilla and mandible using the PA cephalogram, calling this the Rocky Mountain Analysis (Ricketts, 1981). In his analysis, he describes

the maxillomandibular transverse relationship as the expected maxillomandibular relationship (based upon his developed norms per age), minus the actual maxillomandibular amount. He defines the maxillary width as the linear measurement between jugale points, which are defined as the intersection at the maxillary tuberosity and zygomatic buttress; and the mandibular width as the linear measurement connecting bilateral points located at the lateral inferior margin of the antegonial protuberance. This analysis allows the clinician to determine the extent and location of deficiency (Vanarsdall, 1999). This analysis, however, is flawed.

A retrospective study by Allen et al. (2003) described skeletal and dental differences that existed between patients with and without a posterior crossbite. The study sample consisted of 93 children with a posterior crossbite, and 97 children without a posterior crossbite. Comparisons were made using measurements taken from dental casts, lateral cephalograms, and PA cephalograms. The maxillary intermolar width and mandibular intermolar width were measured on each dental cast, and the intermolar ratio was determined by dividing the maxillary width by the mandibular width. Postero-anterior cephalograms were measured according to the landmarks described by Ricketts'

Rocky Mountain Analysis, and lateral cephalograms were measured after being traced on acetate paper. The sagittal variables measured were upper incisor inclination, lower incisor inclination, mandibular plane angle, ANB angle, lower face height, maxillary unit length, and mandibular unit length. The authors found seven characteristics that were significantly different between the two groups: mandibular plane angle, lower face height, skeletal maxillary-to-mandibular width ratio, maxillary intermolar width, mandibular intermolar width, maxillary-to-mandibular intermolar width ratio, and mandibular unit length. They also discovered that the ratio of effective skeletal maxillary-to-mandibular width can only account for a small fraction of the discrepancy in the ratio of the intermolar dental width obtained from the dental casts. Marshall (2005) described this phenomenon as being due to the fact that the distant landmarks (jugale and antegonion) are inappropriate for a transverse analysis, as they do not involve the alveolar process bone, which is the bone that can be altered with treatment.

More recent studies have attempted to assess the buccolingual inclination of posterior teeth using plaster study models. One such study was performed by McNamara et al. in 2003, who examined the short- and long-term dental

arch dimensional changes in a longitudinal study of patients treated with Haas-type rapid maxillary expansion, followed by non-extraction fixed edgewise appliances. One-hundred and twelve treated patients followed a strict protocol of two expander turns per day, until the expansion screw reached 10.5mm, at which point it was retained for a mean of 65 days. Dental casts were gathered at three timepoints: pretreatment, post-expansion and comprehensive treatment, and long-term evaluation. Arch width, depth, perimeter, and molar angulation were all evaluated, and compared against an untreated control group of 41 patients. The authors discovered that gains of 6 mm in the maxillary arch perimeter, and 4.5mm in the mandibular arch perimeter, were found in the treated group. They also realized that the treatment group was capable of a stable change in the dental arch width, and an increase in arch depth. These authors evaluated molar angulation by drawing a line tangential to the mesiobuccal and mesiolingual cusp tips bilaterally, and then measuring the angle at which they intersected in each arch. An angle of less than 180 degrees was considered to be buccally flared, and an angle of more than 180 degrees indicated that the patient was lingually flared.

Conversely, Janson et al (2004) in a similar study, found that the measured angle between the mesiobuccal and mesiolingual cusps corresponds to the occlusal surface inclination, rather than the actual long axis inclination of the teeth. These authors felt that extrapolation of occlusal surface inclination to long axis inclination was invalid due to differences in dental crown anatomy. Their evaluation of buccolingual inclination of the posterior teeth in patients with a horizontal growth pattern, compared against patients with a vertical growth pattern, was performed to test the hypothesis that patients with long lower anterior facial height have a greater buccal inclination of the posterior teeth, and patients with short lower anterior facial height have greater lingual inclination of the posterior teeth. Two groups of 35 patients were evaluated by measuring buccolingual inclination of the first molar and second premolar by a method previously described by Ross et al (1990): First the posterior occlusal plane was determined by placing a piece of glass on a minimum of 3 of the following points: The most prominent cusp of the right and left mandibular molar and at the most prominent cusp of at least one of the second premolars. From this, the base of the model was trimmed and then cut in two through the maxillary midline.

Lines were placed through the mesiobuccal and mesiolingual cusps of the first molars, and through the buccal and lingual cusps of the second premolars. The models were trimmed posteriorly to the molar line, and anteriorly to the premolar line. Photocopies of the cut study models were taken and digitized with Dentofacial Planner 7.0 software, and the authors described the occlusal surface of the molars using a line tangential to the mesiobuccal and mesiolingual cusp tips, and the occlusal surface of the second premolars by a line placed tangent to the buccal and lingual cusp tips. By dropping a perpendicular line to the previously determined occlusal surface, the long axis of each tooth was determined. A line was also drawn perpendicular to the base of the model and the angulation of the molar and premolar were determined by the angle between the perpendicular line to the model and the line representing the long axis of the tooth. The tooth was determined to have a buccal inclination when the angle was positive, and a lingual inclination when the angle was negative. The authors determined with statistical significance that patients with a vertical growth pattern had greater buccal inclination of the maxillary posterior teeth compared to those with a horizontal growth pattern.

The advent of CBCT has allowed for precise measurement and precise patient evaluation. Halazonetis et al. (2005) felt that the increased precision offered by CBCT might lead to their widespread use within a short period of time, especially since the amount of radiation from CBCT may be similar to that incurred by the multiple radiographs often used in current treatment regimens. These authors recognized that CBCT would allow more precise measurement of tooth inclination and torque, and suggested that the axial inclination of the dentition may provide supplementary information to traditional models.

Podesser et al (2004) recognized the lack of information available regarding the transverse dimension, and designed a study aimed at developing a reproducible and reliable technique for the evaluation of maxillary structures using frontal CT scans. The authors felt that the PA cephalogram lacked information due to the superimposition of structures and the lack of precision in landmark identification. Their study involved only ten subjects who were chosen independent of occlusion and facial morphology, with the only requirement being that no restorations were present due to viewing difficulties of metallic interference. Eighteen registration points were identified, and these were then digitized so that linear

and angular variables could be calculated with a cephalometric program. They assessed intra-observer variation by repeating the process at a minimum of 10 days after the initial measuring, and they assessed inter-observer variation by evaluating the readings performed by one observer with that of another experienced observer. Maxillary alveolar width was found to have a statistically significant difference in measurement between the two observers. Despite several flaws of the study, which included measurements not being clearly described, small sample size, and sample chosen irregardless of crossbite status, expander status, or molar classification, the authors concluded that their method could be useful as a supplement to orthodontic diagnosis. However, a more carefully devised study is needed to highlight the importance of the lack of available information about the midface.

Recent studies of the buccolingual inclination of teeth have been performed at Case Western Reserve University. Shewinvanakitkul et al (2008) described a reliable method for the measurement of mandibular canine and first molar buccolingual inclination, and defined the mean and standard deviation as it pertains to molar classification, expander status, gender, and crossbite

status. Evangelinakis et al (2010) continued the study, using the method previously described by Shewinvanakitkul et al (2008), by focusing on the change in buccolingual inclination of mandibular molars and canines following orthodontic treatment in non-extraction patients treated with straightwire pre-torqued brackets. Karamitsou et al (2011) described a reliable method to measure the buccolingual inclination of maxillary canines and first molars, and also defined the range, mean and standard deviation as it pertains to molar classification, expander status, gender, and crossbite status prior to orthodontic treatment. From these research projects, the orthodontic community has gained a better understanding of the transverse dimension.

In addition, Tong et al (2012) recently introduced a custom root vector analysis program in Dolphin 3D to obtain the mesiodistal angulation and faciolingual inclinations for each whole tooth from 76 patients with near-normal occlusion. The authors found apparent patterns in these intra-arch relationships as well as inter-arch relationships. However, the authors did not use a sample with strict Class I molar relationship and they allowed a single tooth dental crossbite in what they described as being ”near-normal occlusion.” Moreover the author’s custom

analysis cannot currently be applied to all malocclusions, but rather was developed specifically for near-normal occlusions.

Vanarsdall, recounting the words of Edward Angle, once proposed that new information is often met with resistance before gaining acceptance, at which point those who have accepted the new idea will claim to have ”known it all along.” It is obvious that there is not only a place, but a need for an analysis on maxillary transverse deficiency. The emergence of CBCT allows orthodontists the unique ability to view a patient in the transverse dimension, and more specifically along the long axis of a tooth, rather than using occlusal anatomy as the basis for treatment. With the establishment of transverse dimensional norms, every orthodontic patient may finally be quantified in all three dimensions of space: sagittal, vertical, and *transverse*.

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STATEMENT OF THESIS

The goals of this study are: 1.) To identify a sample of individuals demonstrating normal transverse dimensions; 2.) To develop a reliable method to measure intercanine and intermolar angulation using cone beam computed tomography (CBCT); and 3. To provide a descriptive analysis of intermolar angulation, intercanine angulation, maxillary molar and canine buccolingual inclination, and mandibular molar and canine buccolingual inclination in this selected group deemed to have normal transverse dimensions.

We hypothesize that the method of measuring intercanine and intermolar angulation using CBCT will be reliable and reproducible.

We hypothesize that the CBCT measurement of intermolar angulation, intercanine angulation, maxillary molar and canine buccolingual inclination, and mandibular molar and canine buccolingual inclination in the sample identified will display mean angulations with a narrow range and small standard deviation, making these angles of value when evaluating the transverse dimension.

CWRU's Transverse Analysis Developing Norms

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Introduction: This study aims to develop a method to measure intercanine and intermolar angulation using cone beam computed tomography (CBCT) and to provide a descriptive analysis of intermolar/intercanine angulation, maxillary molar/canine and mandibular molar/canine buccolingual inclination in a sample deemed to have normal transverse dimensions. **Methods:** A survey was conducted asking orthodontic faculty to use pre-existing patient records to define a sample with acceptable transverse dimensions. Thirty adolescent patients, 15 males and 15 females, ages 10-16 participated in the study. On Demand3D software was used to measure buccolingual inclination of maxillary and mandibular first molars and canines. Dolphin3D Imaging was used to develop a method to measure intercanine and intermolar angulations. **Results:** The mean buccolingual inclination of maxillary canines and first molars was $103.9 \pm 5.0°$ and $100.1 \pm 4.1°$, and mandibular canines and first molars was $97.3 \pm 3.4°$ and $76.7 \pm 4.6°$. The mean intercanine and intermolar angulations were $163.1 \pm 6.2°$ and $179.0 \pm 4.6°$. **Conclusions:** We have established normal buccolingual inclinations using CBCT that can be used in the differential diagnosis of transverse deficiency. We have defined intercanine and intermolar angulations, which can be reliably measured using CBCT.

INTRODUCTION

Currently, there exists no standard upon which the diagnosis of a transverse deficiency is made; orthodontists use a variety of methods to assess a patient's transverse dimension. Some clinicians use plaster models to evaluate a patient's Curve of Wilson, with larger curves indicating that a patient has made dental compensations for a skeletal discrepancy[1]. Plaster models may also be used to count the number of teeth in crossbite to determine whether it is skeletal (large number) or dental (small number) in nature, or to evaluate whether there is a relative or absolute transverse discrepancy by hand articulating a patient into a Class I occlusion[2]. Measurement of the palatal width may be a strong criterion for another orthodontist who might base a transverse deficiency on a golden number. Moreover, other clinicians might place an emphasis on his or her chairside evaluation assessing dark buccal corridors in an animated smile[1], or evaluating the transverse by the degree of malar hypoplasia and presence of deep nasolabial folds in a patient's soft tissue profile[3]. These methods are all highly subjective. The use of a frontal radiograph is perhaps the most objective form of evaluation currently in use, with the Ricketts Rocky Mountain Analysis suggesting specific measurements of the maxilla and mandible to evaluate a patient's imbalance in the transverse dimension by comparing to proposed norms and differentials[4]. With recent imaging advances and as utilization of CBCT becomes more commonplace in diagnosis and treatment planning, the orthodontist is able to supplement these current diagnostic tools with a more quantitative approach.

Cephalometric analysis aims to illustrate where a patient may be out of balance by using measurements with respect to the midline and comparing them against established norms. For example, the differential diagnosis of a class II malocclusion may include: 1) prognathic maxilla, orthognathic mandible; 2) orthognathic maxilla, retrognathic mandible; 3) prognathic maxilla, retrognathic mandible; or 4) maxillary dental protrusion, mandibular dental retrusion; but by comparison to established cephalometric norms, the orthodontist can determine the precise diagnosis. Likewise, three-dimensional CBCT imaging now allows a similar evaluation of maxillary and mandibular buccolingual inclination to determine the etiology of a transverse discrepancy by having the unique ability to isolate the individual components (maxillary and mandibular molars and cuspids) to determine whether the discrepancy is dental, or skeletal in nature.

Orthodontic treatment must respect three dimensions, yet most clinicians continue to diagnose and treat based upon a two-dimensional lateral cephalogram. Periodontal health, esthetics, stability, and patient satisfaction are all increased by a proper transverse relationship[5], but the diagnosis of a transverse deficiency is usually based upon subjective findings rather than objective data. There are profound benefits to be gained from an accurate diagnosis of a transverse deficiency.

Normative data in the transverse dimension has only recently been published[6,7], and as a result these advanced tools remain underutilized for the non-syndromic orthodontic patient. Recent studies of buccolingual inclination using CBCT have been performed evaluating population norms: Shewinvanakitkul et al.[6]

described a reliable method for the measurement of mandibular canine and first molar buccolingual inclination, and defined the mean and standard deviation as it relates to molar classification, expander status, gender, and crossbite status prior to orthodontic treatment. Karamitsou et al.[7] described a reliable method to measure the buccolingual inclination of maxillary canines and first molars, and also defined the range, mean and standard deviation as it pertains to molar classification, expander status, gender, and crossbite status prior to orthodontic treatment. While these studies of population norms have greatly expanded the orthodontist's understanding of the transverse dimension, no study has yet examined a group of patients possessing normal transverse dimensions.

The purpose of this study was to measure maxillary and mandibular canine and molar buccolingual inclination using a group of patients selected for normal transverse dimensions. In addition, we endeavored to develop a reliable method to measure intercanine and intermolar angulation using CBCT. Such normative data will be useful to practicing orthodontists when evaluating patients in the transverse dimension.

MATERIALS AND METHODS

Approval for this study was obtained from the Case Western Reserve University Institutional Review Board (IRB). All patients had previously signed a consent form allowing their records to be used for research purposes. The study population consisted of patients who received pre-treatment records at the Case Western Reserve University School of Dental Medicine Department of Orthodontics during a two-year period from 2009 to 2011. The following selection criteria was applied:

1. Patient age between 10 and 16 years at initial records appointment with available pre-treatment images.
2. Posterior teeth were evaluated with ABO ruler: in maxillary arch the buccal cusp was within 1mm of the straight edge and in the mandibular arch, lingual cusps were within 1mm of the straight edge.
3. Study models confirm that first molars and canines are present and fully erupted into occlusion.
4. Landmarks were easily viewed on CBCT imaging.
5. Patients had not had any prior experience with orthodontics.
6. There was not greater than 90° rotation on first molars or canines.
7. Study models confirmed that no deciduous teeth were present.
8. There were not any missing or extracted permanent teeth.
9. There were not any supernumerary or congenitally missing teeth as determined using the CBCT.
10. The patient had not been diagnosed with any craniofacial anomalies or syndromes.

11. A posterior crossbite was not present.

12. Study models confirmed that the patient was Class I molar and canine.

13. The patient was not treatment planned for expansion or extractions.

A survey was then conducted which asked the orthodontic faculty to use pre-existing patient records (intraoral/extraoral photographs, study models, and frontal radiographs constructed from large volume CBCT images) to further define a sample considered to have normal transverse dimensions. The faculty were asked to independently examine each set of records and then to place each patient into one of two categories: "Transverse deficient" or "Not transverse deficient". Thirty of the fifty-four patients (55.6%) had universal agreement among examiners, and these patients were included in the measurement portion of the study. Using this sample, CBCT scans were used to measure the intercanine angulations, intermolar angulations, buccolingual inclination of the maxillary first molars and canines and mandibular first molars and canines.

The methods to measure maxillary buccolingual inclination and mandibular buccolingual inclination were defined in a previous study by Karamitsou et al.[7], and Shewinvanakitkul et al.[6], respectively. A single operator collected all data. Radiographic data was constructed from CBCT scans. OnDemand 3D software (Cybermed, Inc., Seoul, South Korea) was used to make maxillary and mandibular molar and canine buccolingual inclination measurements. Dolphin 3D imaging (Patterson Dental Supply, Inc., St. Paul, MN) was used to develop a method and then to measure intercanine and intermolar angulations. Intra-examiner reliability was

determined by repeating measurements for one-third of the study population three months after initial data collection.

Measurement of maxillary canine buccolingual inclination was made in the coronal view by the angle formed between a reference line drawn tangent to the inferior border of the nasal cavity and the inclination measured through the long axis of the tooth, cusp tip to root apex (Figure 1). Maxillary first molar buccolingual inclination was measured in the coronal view as the angle formed between a line connecting the apex of the palatal root and the mesiolingual cusp tip and a line tangent to the inferior border of the nasal cavity (Figure 2). Measurement of mandibular canine buccolingual inclination was made in the coronal view with a reference line drawn tangent to the base of the mandible and the inclination measured as the angle between the long axis of the canine and the reference line (Figure 3). Measurement of mandibular first molar buccolingual inclination was made in the coronal view with the angle being measured as that between a line passing through the central groove and root apex of the mandibular molar and a reference line drawn tangent to the base of the mandible (Figure 4).

Intercanine and intermolar angulation were then measured for all subjects using a novel method which we devised: Images were first prepared using the method described by Wu et al.[8] to orient three-dimensional images around nerve canals. The intercanine angulation was then measured by scrolling through coronal slices at a voxel setting of 10 until the maxillary and mandibular canine root apices and cusp tips could be visualized as landmarks. Two lines were drawn, the first connecting the maxillary canine root apex and cusp tip, and the second connecting

the mandibular root apex and cusp tip. The intersection of these lines formed the desired angle (Figure 5). The intermolar angle was measured by again scrolling through images in the coronal plane using a voxel setting of 10 until the maxillary first molar palatal root apex and mesiolingual cusp tip and mandibular first molar central fossa and mesial root apex were visualized. Two lines were drawn, the first connecting the maxillary first molar palatal root apex and mesiolingual cusp, and the second connecting the mandibular first molar central fossa and mesial root apex. The intersection of these lines formed the desired angle (Figure 6).

Statistical Analysis:

Statistical analysis was performed using Statistical Package for the Social Sciences (SPSS) software (IBM, Inc., New York, NY). The mean, median, mode, range, and standard deviation were calculated for each measurement. Reliability was determined using the Intraclass Correlation Coefficient (r^2) using 10 sets of measurements gathered randomly via a random number generator, resulting in re-measurement of one-third of the sample.

RESULTS:

All teen clinic pre-treatment records between years 2009-2011 were evaluated (N=760) for inclusion into the study. After applying the selection criteria, 54 subjects remained and were entered into the faculty survey. After examination by expert analysis, the final study population (N=30) consisted of 15 males and 15 females. The age of the study sample varied from 10-16 years, with a mean age of 13.8 $\pm$ 1.2 years. The study contained 25 Caucasian subjects and 5 African-American subjects (Table I). Intra-examiner reliability ranged from 0.933 to 0.996 (Table II). The mean buccolingual inclination of maxillary canines and first molars were 103.9$\pm$5° and 100.1 $\pm$4.1°, respectively. The mean buccolingual inclination of mandibular canines and first molars were 97.3 $\pm$3.4° and 76.7$\pm$4.6°. The mean intercanine and intermolar angulations were 163.1 $\pm$6.2° and 179 $\pm$4.6° (Table II).

DISCUSSION:

The goal of this study was to develop normative data. It is by comparing the patient in question to normative data that the orthodontist is able to see where a discrepancy exists. The Downs Analysis[9], relies on the skeletal and dental measurements of 20 adolescent patients who were believed to have ideal occlusions. In the Steiner Analysis[10], measurements are based upon a single Hollywood star that Cecil Steiner judged to be the definition of perfection. Such analyses give clinicians a guide as to the malocclusion they are presented with, and comparative values to assist with treatment. Nearly twenty years ago, Vanarsdall[11] advocated for study of the transverse dimension and the establishment of normative standards for its use in clinical practice. We have performed a study of thirty individuals possessing normal transverse dimensions in order to establish these norms, and these mean angular measurements will serve as normative standards for clinicians who choose to use CBCT in their practice.

While CBCT advanced imaging is relatively new to the practicing orthodontist, the importance of buccolingual inclination has long been recognized. The American Board of Orthodontics lists buccolingual inclination of posterior teeth as one of its eight criteria in evaluating the success of a finished case on the clinical board exam. The establishment of proper buccolingual inclination requires that balancing interferences are avoided and thus the heights of buccal and lingual cusps of the maxillary and mandibular posterior teeth remain within 1mm of one another[12]. Another advocate of attention to buccolingual inclination is Andrews[13],

who coined the Six Keys to Normal Occlusion, listing buccolingual inclination as number three in the criteria to consider when determining proper occlusion.

A patient's buccolingual inclination of maxillary and mandibular molars and cuspids can now be accurately measured and compared to established norms. This method can aid in detecting dental compensations for a skeletal discrepancy and provide scientific evidence as to when orthopedic expansion may or may not be indicated. As with cephalometrics, if a particular patient demonstrates buccolingual inclination measurements one or more standard deviations removed from the mean, it behooves the orthodontist to take a closer look. One must consider the effect of placing pre-torqued brackets on significantly flared teeth for the possibility of creating a "mysterious" crossbite is quite real when the posterior segments upright. Conversely, one must also realize when dental expansion may be the key to resolving a discrepancy that was in fact dental in nature. Furthermore, from this study, the following categories for clinical application of the transverse analysis have been suggested: 1) patient's with a crossbite, whether it be unilateral or bilateral may present with normal or abnormal angles 2) patient's without a crossbite may present with normal angles or abnormal angles with abnormal angles being due to excessive maxillary and/or mandibular tipping.

It is interesting to note that the means and standard deviations of the buccolingual inclinations measured in our ideal study population (selected norm) only differ slightly from those measured in a less-controlled study population (population norm) by Karamitsou et al.[7] and Shewinvanakitkul et al.[6] (Table II). It was assumed that angulations of this ideal sample would be accompanied by a much

smaller standard deviation. The significance of this finding is unclear. It could be the case that a wide variety of buccolingual inclinations produce cosmetically-appealing and functional anatomy. In this case, the establishment of normative data may be of less value than originally thought. It could also be the case that our study has identified the very problem with the use of commonly available tools for the diagnosis of transverse deficiency which CBCT might be expected to resolve: Even when expert orthodontists were asked to diagnose transverse deficiency using plaster models, frontal radiographs, and patient photographs, they were unable to produce an "ideal" population which differed greatly from a population norm. For example, certain individuals identified with unanimous agreement as having acceptable transverse dimensions, upon closer examination, still fell two standard deviations outside of the mean. Further study of the transverse dimension using CBCT is necessary to resolve this unexpected finding.

We have established protocols for the measurement of the intercanine and intermolar angles. These angles may provide information about the relative adaptations which have occurred during an individual's dental development, and may play a role in axial loading. We have provided information about these angles as they are found in ideal anatomy. Further study of abnormal anatomy using the intercanine and intermolar angles will provide information about whether adaptations differ in characteristic ways amongst malocclusions.

Limitations of our study relate to its small sample size and the use of a single observer to perform all measurements. The use of a screening process by orthodontic faculty to establish ideal anatomy necessitated a smaller population, as

the very concept of ideal anatomy dictates that an ideal group will be small, rather than large. Although intraobserver reliability was excellent, the use of a single observer in this study makes our measurements prone to systematic error, and these measurements should be validated in further studies.

CONCLUSION:

We have performed a study evaluating buccolingual inclination in patients demonstrating normal anatomy in the transverse dimension using CBCT, and we have established normative data in this regard, which may be useful to the practicing orthodontist in the differential diagnosis of transverse deficiency. We have also described and provided normative data for the intermolar and intercanine angles, which may be measured with CBCT. Further study of these angles in normal and abnormal anatomy, as well as the potential impact in diagnosis and treatment planning, is recommended.

Table I: Descriptive Summary of Demographics of CBCT subjects:

Variables (N=30)	Group	Total	Percent	Male	Female
Age	10-13 14-16	14 16	47% 53%	5 10	9 6
Ethnicity	Caucasian African-American	25 5	83% 17%	13 2	12 3
Sex	Male Female	15 15	50% 50%		
Molar and Canine Classification	Class I	30	100%	15	15

Table II: Descriptive Summary of Maxillary and Mandibular Canine and Molar Buccolingual Inclination and Intercanine and Intermolar Angulation

Variables	Streit Mean ± SD (N=30)	Median	Mode	Range	Intraclass correlation (r^2)	Karamitsou Mean ± SD (N=72)	Shewinvanakitkul Mean ± SD (N=156)
Maxillary Canine	103.9 ± 5°	104°	100.9°	92.2-114.5°	0.98	Right: 103± 6° Left: 105.9± 6.5°	
Maxillary Molar	100.1 ± 4.1°	99.9°	105.1°	92-105.6°	0.98	Right: 99.2± 5.3° Left: 101.7± 5.4°	
Mandibular Canine	97.3 ± 3.4°	97.4°	98.4°	90.8-106.4°	0.96		98.0±4.1°
Mandibular Molar	76.7 ± 4.6°	76.2°	74.9°	65.1-89.5°	0.97		74.6±4.7°
Intercanine	163.1 ± 6.2°	162.2°	160.2°	141-172.8°	0.96		
Intermolar	179 ± 4.6°	180°	180°	170.1-190.5°	0.95		

Figure 1:

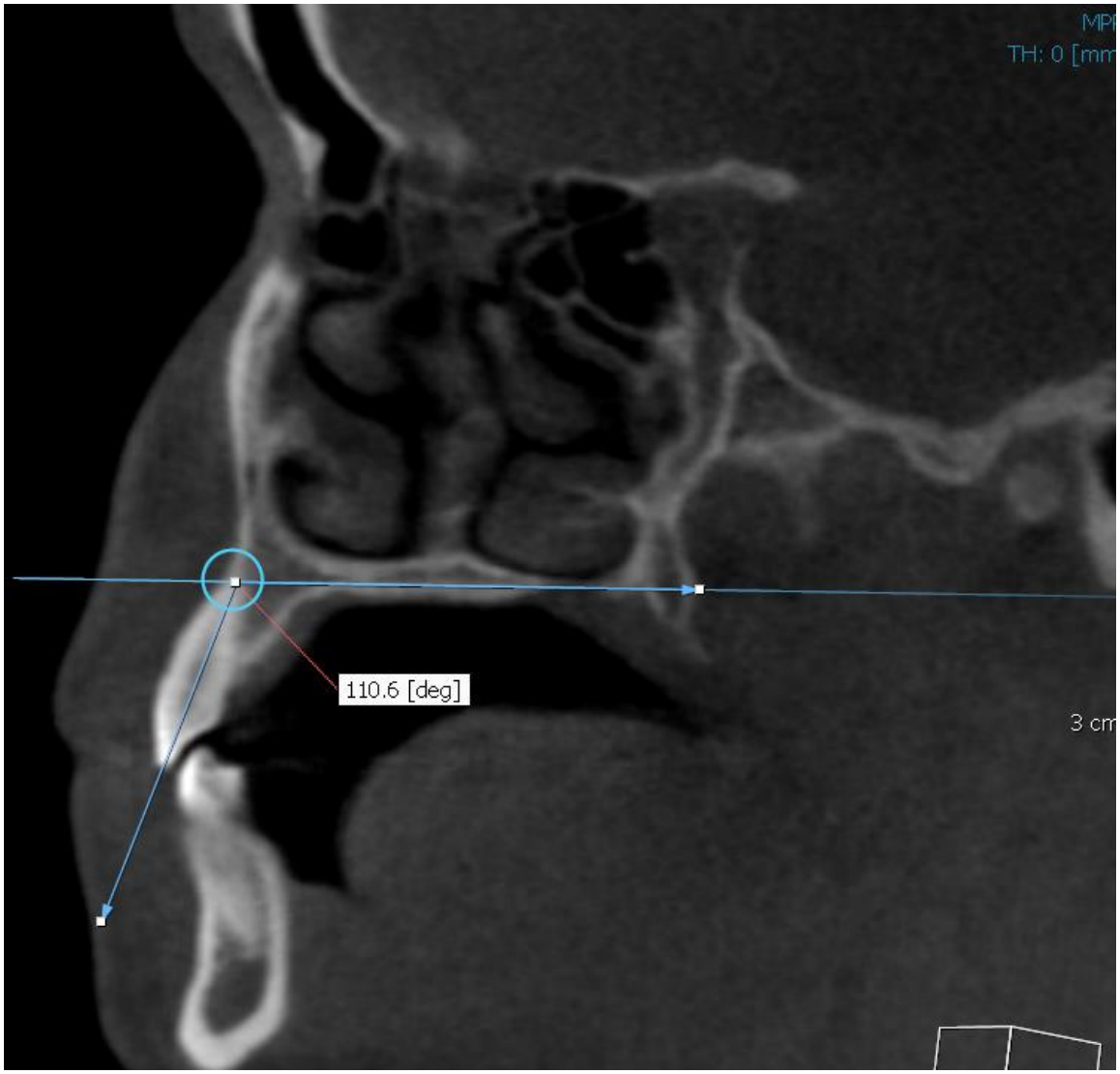


Figure 2:

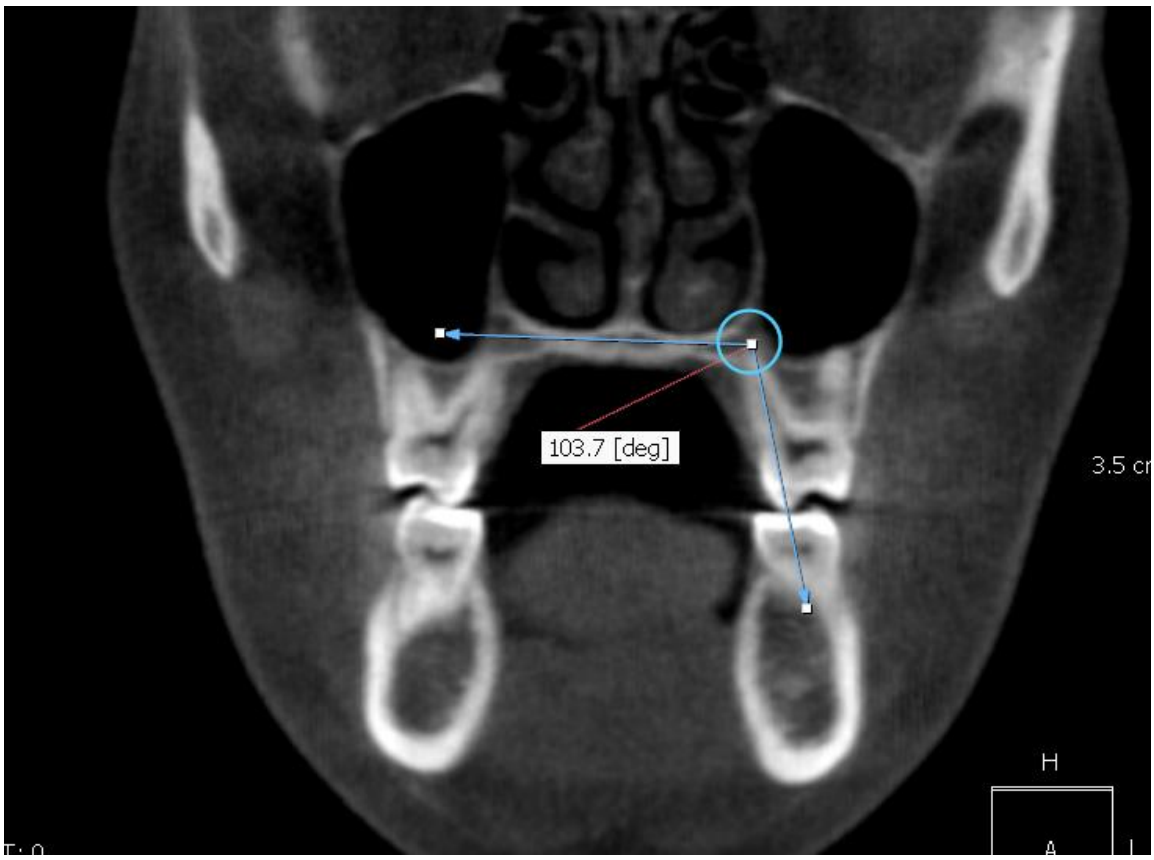


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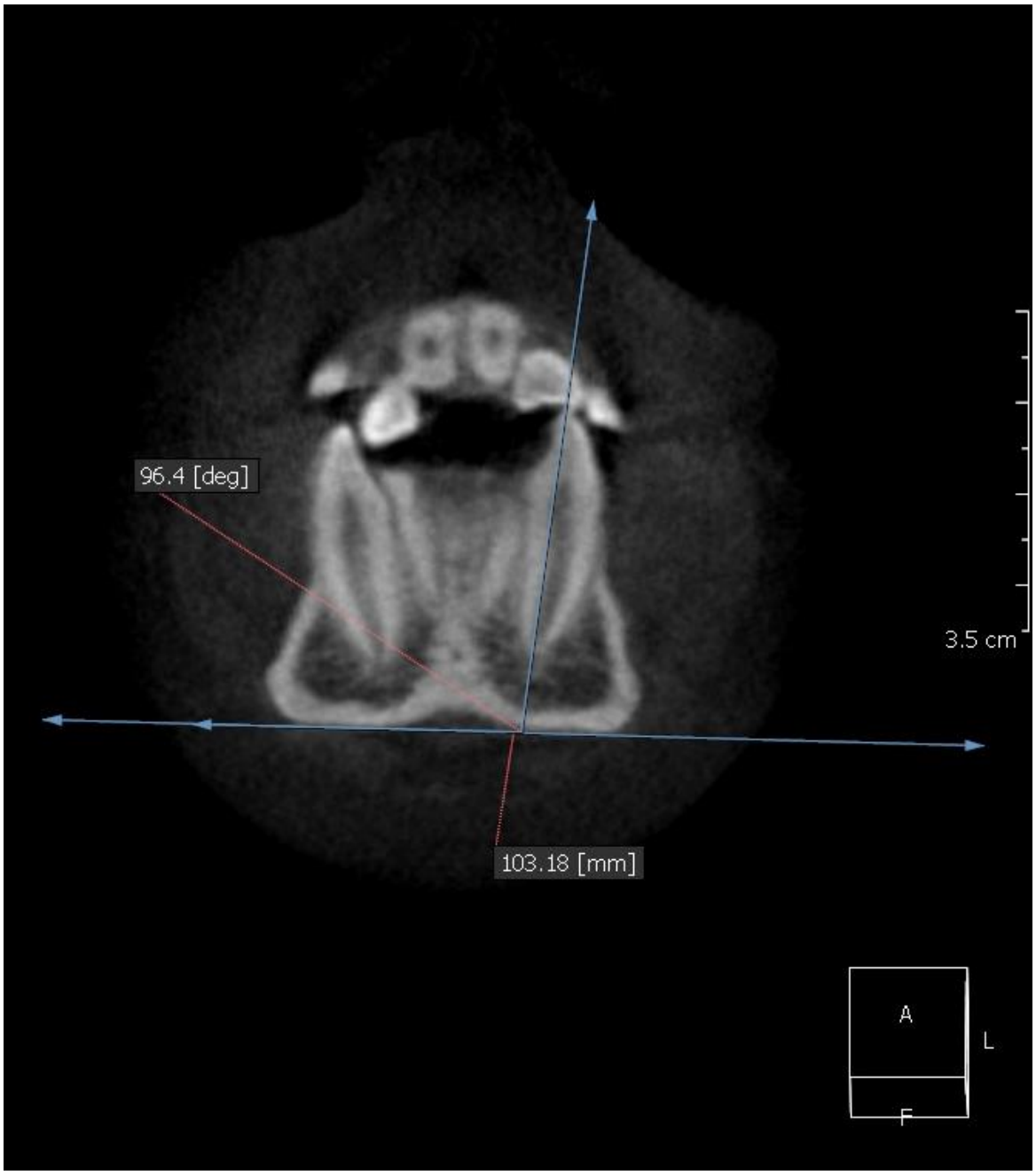


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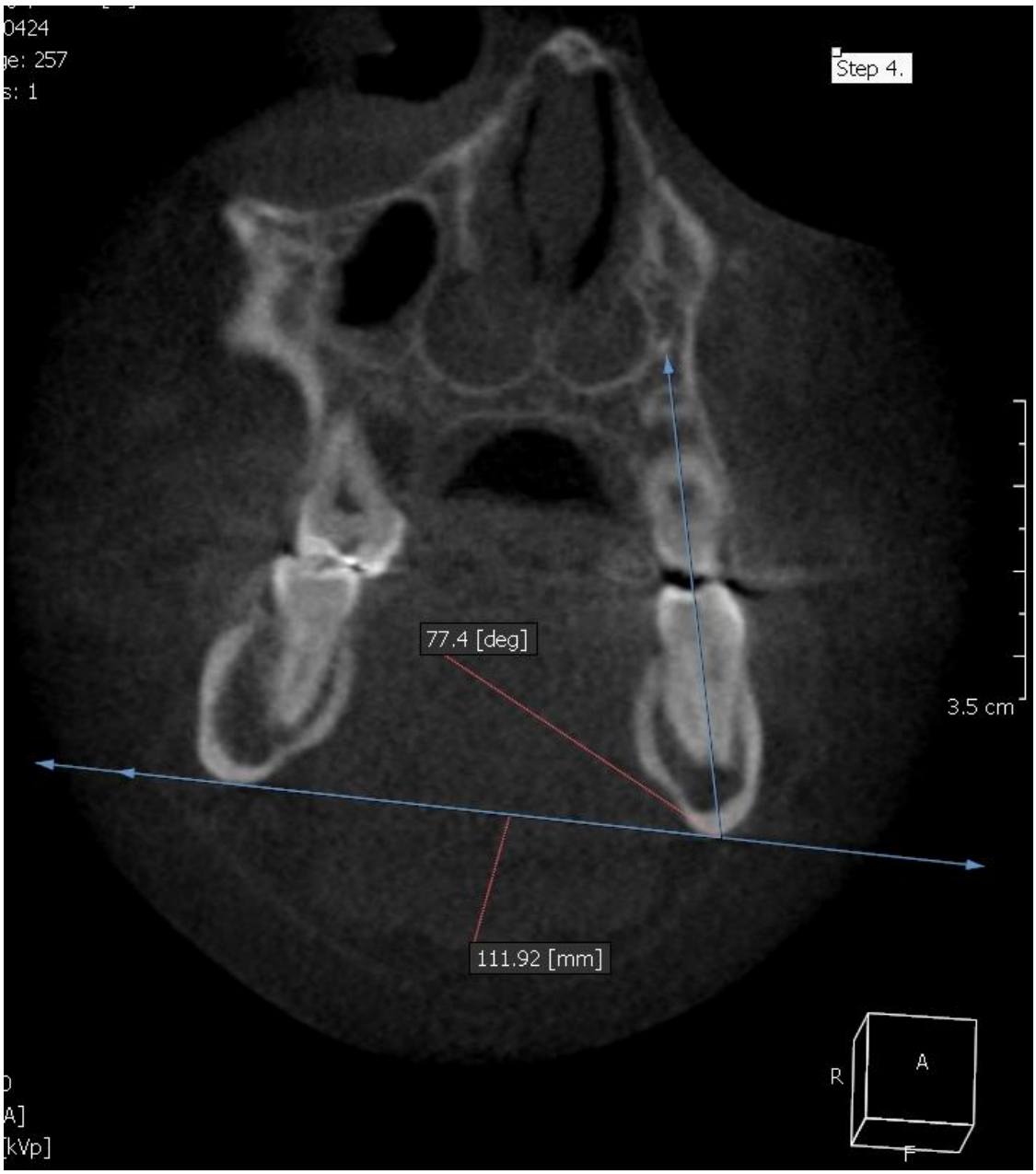


Figure 5a:



Figure 5b:

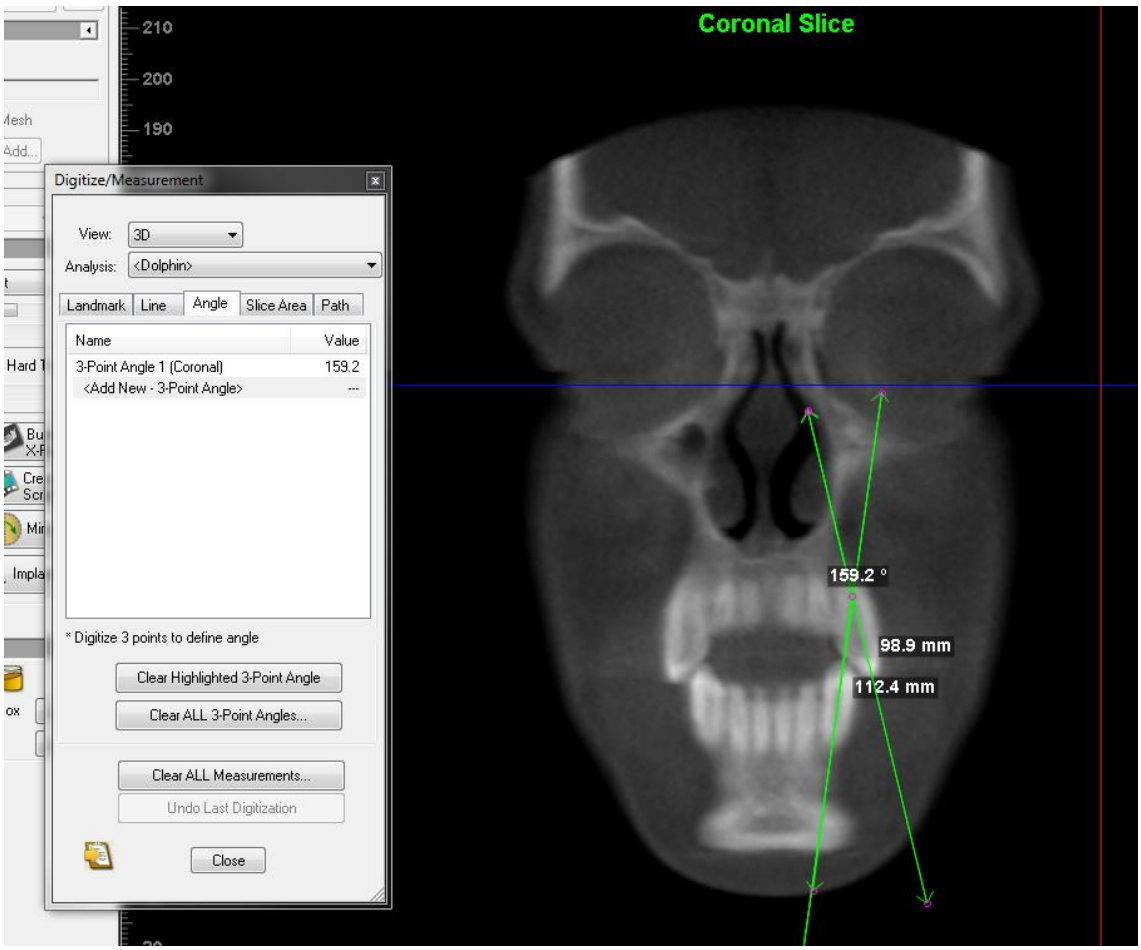

Coronal Slice
210
200
190
Digitize/Measurement
View:
3D
Analysis:
<Dolphin>
Landmark
Line
Angle
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Name
Value
3-Point Angle 1 (Coronal)
159.2
<Add New - 3-Point Angle>
* Digitize 3 points to define angle
Clear Highlighted 3-Point Angle
Clear ALL 3-Point Angles...
Clear ALL Measurements...
Undo Last Digitization
Close
159.2 °
98.9 mm
112.4 mm

Figure 6a:

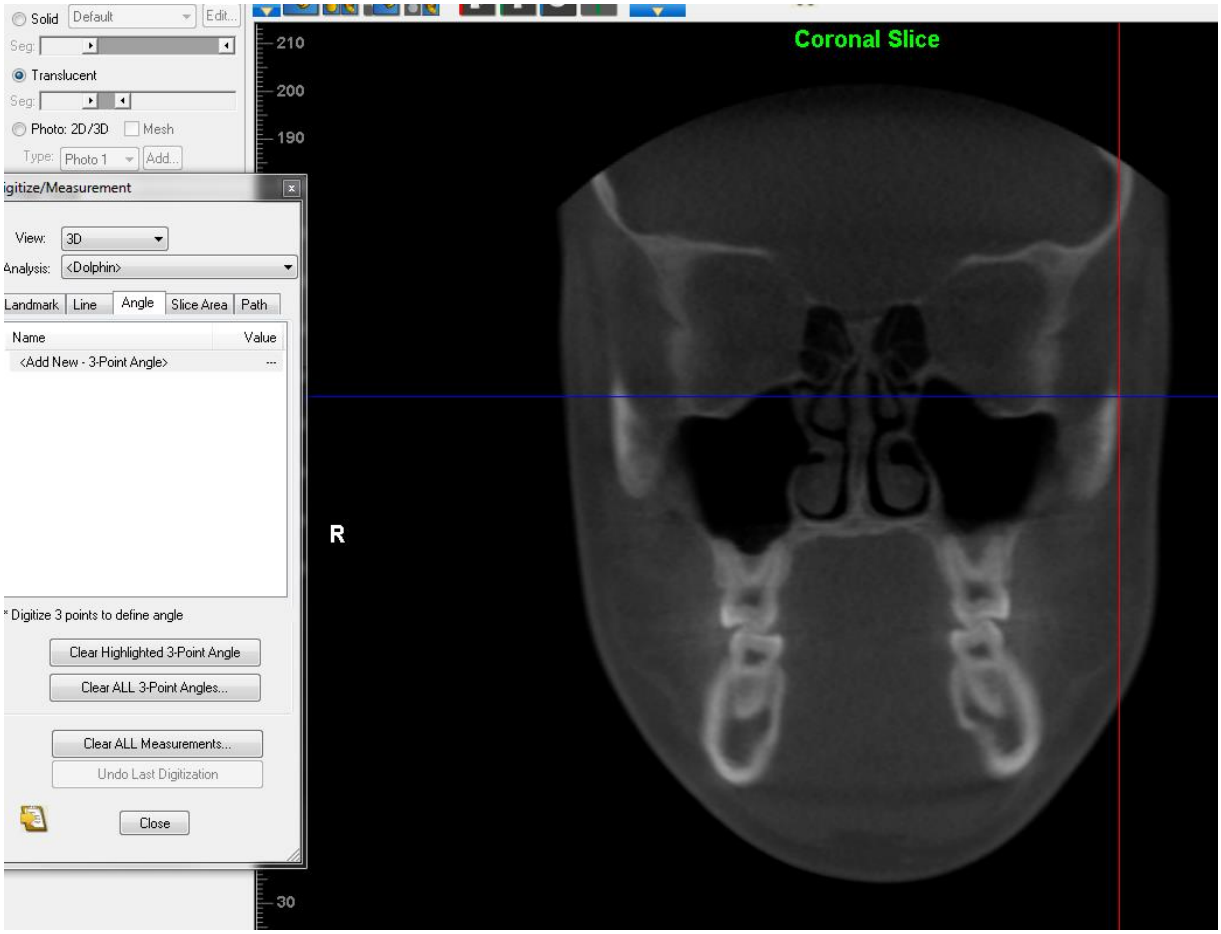
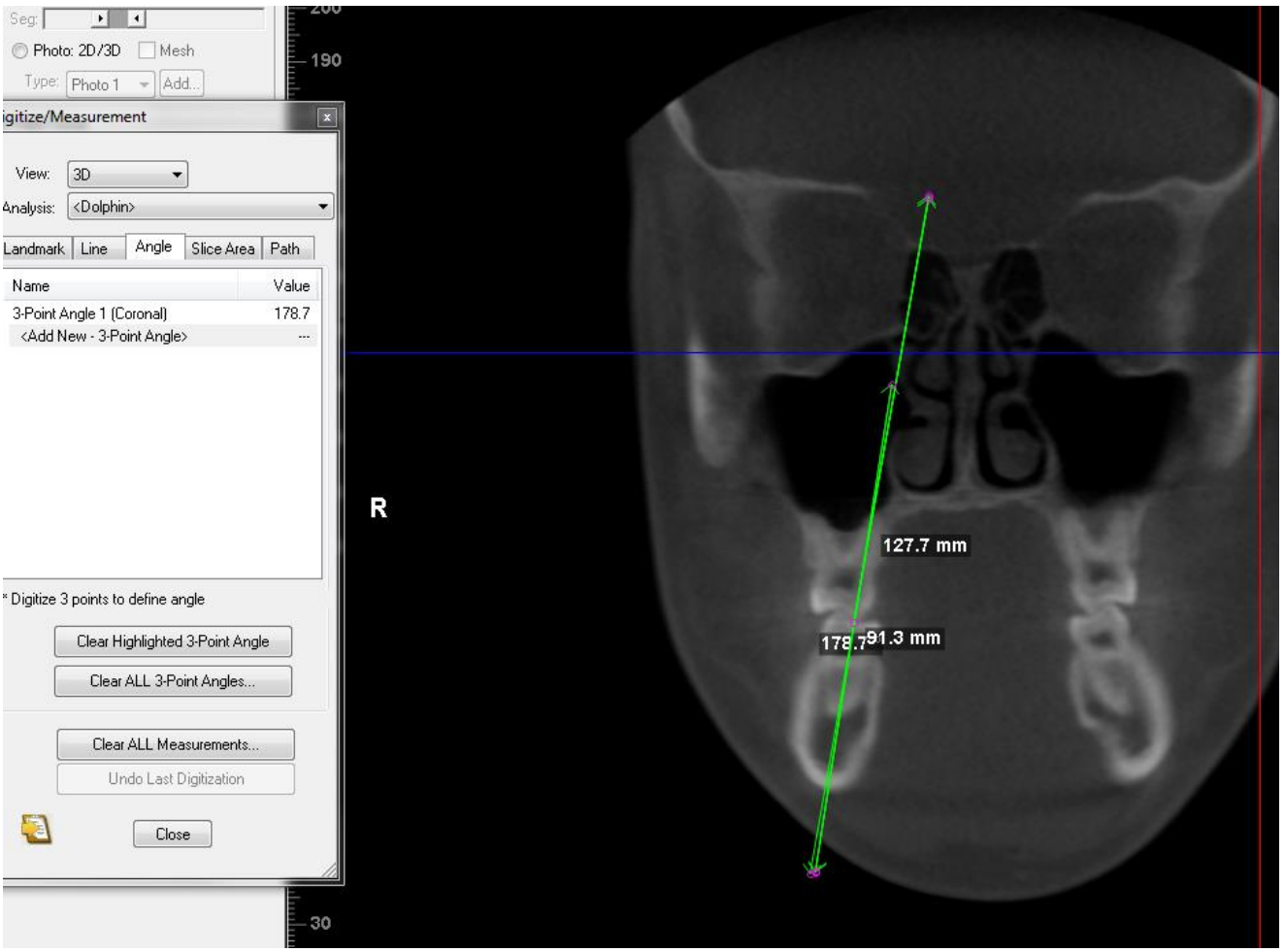

Solid
Default
Edit...
Seg:
Translucent
Seg:
Photo: 2D/3D
Mesh
Type:
Photo 1
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View:
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Analysis:
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* Digitize 3 points to define angle
Clear Highlighted 3-Point Angle
Clear ALL 3-Point Angles...
Clear ALL Measurements...
Undo Last Digitization
Close
210
200
190
30
Coronal Slice
R

Figure 6b:


Seg:
Photo: 2D/3D
Mesh
Type:
Photo 1
Add...
190
igitize/Measurement
View:
3D
Analysis:
<Dolphin>
Landmark
Line
Angle
Slice Area
Path
Name
Value
3-Point Angle 1 (Coronal)
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<Add New - 3-Point Angle>
* Digitize 3 points to define angle
Clear Highlighted 3-Point Angle
Clear ALL 3-Point Angles...
Clear ALL Measurements...
Undo Last Digitization
Close
30
R
127.7 mm
91.3 mm

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APPENDIX 1

IRB Approval



NOTICE OF EXEMPTION #4

Research involving the collection or study of existing data, documents, records, pathological specimens, or diagnostic specimens, if these sources are publicly available or if the information is recorded by the investigator in such a manner that subjects cannot be identified, directly or through identifiers linkedto the subjects.

Case IRB Protocol Number: IRB-2012-116

Protocol Title: Case Western Reserve University's Analysis on the Transverse Dimension

Responsible Investigator (RI): Juan Palomo

Co-Investigators (CI): Laura Streit

RI Department: Case Western Reserve University IBC and SBER IRB - DEN - Orthodontics

Exemption Date: February 27, 2012

This protocol is exempt under the #4 category because this involves EXISTING RETROSPECTIVE DE-IDENTIFIED data. Prospective data is included in this exemption. If you intend to collect prospective data for this study, then this study might not be eligible for an exemption and you must contact the Institutional Review Board (IRB) office as soon as possible.

De-identified pre-existing data collected after are not covered by this exemption.

The IRB has deemed the above protocol EXEMPT under 45 Code of Federal Regulations (CFR) part 46.101(b)(4). The IRB will not conduct subsequent reviews of this protocol

APPENDIX 2

Raw Data:

Subject	Age	Agreement	UL3	UR3	UL6	UR6	LL3	LR3	LL6	LR6	Left IM	Right IM	Left IC	Right IC	Upper IM	Upper IC	Lower IM	Lower IC
1	171.9	100	114.5	111.7	105.1	96.2	98.2	98.4	74.9	73.6	176.3	179	161.8	160.2	55.45	37.64	42.55	27.66
2	160.8	100	102	106	105.6	104.7	96.5	101.2	75.6	74.9	179.2	178	158.9	141	50.34	33.27	39.09	25.31
3	177.2	100	96.7	100.7	96	105.1	93.9	94.1	78.9	75.9	178.2	178.5	173.2	170	51.76	32.14	39.61	23.76
4	162.7	100	108	105.3	104.7	99	95.5	92.4	77.6	74	183.9	180	170.1	165.7	54	34.55	39.67	23.91
5	171.5	100	102.9	108.8	96	100.9	97.8	93.2	65.1	69.3	184.8	178.3	170.7	168.4	52.9	35.36	39.74	24.41
6	171.3	100	100.9	108.3	92.2	105.4	95.4	94.1	74.3	69.8	183.9	179.1	158.7	164.9	51.23	32.72	38.42	25.4
7	161	100	100.9	100.2	102.1	102.2	97.7	96.9	74.1	74.3	179.6	179.1	173.1	171.4	55.04	34.34	42.9	25.68
8	157.5	100	92.2	95.8	94.8	97.8	100.3	96	76.2	79	179.9	175.5	164.7	160.4	53.34	36.47	40.91	25.87
9	168.6	100	95.6	99	92	101.6	94.7	92.9	78.5	76.2	181.7	176.8	166.4	158.3	52.67	34.12	39.43	26.19
10	141.6	100	106.8	104.7	102.9	101.7	106.4	104.1	89.5	79.4	162.9	170.4	154.1	154.4	59.19	40.23	44.1	28.54
11	128.9	100	97.9	110.4	101.5	105.1	101.9	97	89.3	83.4	170.1	170.9	160.5	160.2	54.65	37.61	44.72	28.73
12	150.8	100	103.7	107.9	103.5	98.6	99.6	97.8	72.4	71.7	178.9	185.4	159.9	156.8	48.84	33.11	38.16	23.37
13	170.7	100	110.2	104.5	98	97	93.8	93.9	78.8	78.4	179.6	176.8	172.8	168.6	51.54	33.24	39.28	23.05
14	188.9	100	111.2	107.2	111	96.2	96.5	97.7	76	73.1	175.5	180	168.9	160	50.87	34.94	39.14	24.11
15	178.5	100	104.5	102.1	104.4	99.9	101.5	98	82	76.4	180	180	160.9	157.5	52.72	32.7	42.13	23.2
16	162.2	100	98.9	102.2	102.5	99.1	99.9	95	76.5	80.6	180	175.7	154.2	156.4	51.62	33.52	41.41	26.69
17	180.3	100	105.8	106.8	97.9	93.5	95.7	96	84.8	83.9	178.2	175	164	156.4	50.89	33.82	41.63	25.19
18	154.1	100	105.4	104.1	97.3	92.7	99.1	98.4	77.1	74.7	185.1	180	166	159.9	51.06	34.53	41.37	27.86
19	184.7	100	99.8	107.9	97	104.9	99.2	91.3	83.1	85.9	170.2	171.4	169.9	156.8	53.05	35.43	41.65	25.85
20	156.7	92	106.5	97.6	101.8	97.9	91.9	92.1	72.8	75.2	185	188.2	169.7	171.9	48.7	34.49	38.59	24.01
21	183.7	92	100.9	103.8	101.4	99.5	95.8	90.8	77.8	72.3	190.5	180	169.5	159.4	51.11	33.6	38.62	23.53
22	176.6	92	98.4	99.1	99.8	94.8	100.5	101	77.2	75.1	185.8	180	163.2	163.2	53.23	35.78	40.2	25.94
23	161.5	92	110.9	106.2	107	96.9	95.2	99.5	76.9	74.4	180	180	168.8	160.1	51.99	35.13	41.54	25.26
24	151	92	106.3	104.1	101.6	102.7	101.7	102.4	78.8	78.3	180	180	162.4	157.2	53.54	35.83	42.91	28.79
25	186.3	92	100.7	103.6	99.8	96.5	99.9	98.1	76.8	72.9	180	180	162.4	161.8	54.57	38.56	43.36	26.44
26	181.1	92	104.9	101.6	99.8	103.6	94.9	96.3	69.2	70.9	180	180	169.8	169.1	50.46	33.14	40.32	24.67
27	137	92	112.8	113.6	96.6	97.4	96.7	101.2	80.9	76.8	180	183.1	161.4	159	50.29	33.66	38.84	23.59
28	168.8	92	101.3	100.4	102.9	96.9	94.2	98.5	74.1	75.4	180	180	164.7	172.2	52.51	34.62	42.63	23.72
29	168.7	92	99	103.6	103.8	101.9	98.1	100.4	81.2	79.7	170.4	179.1	162	159.3	57.66	36.96	47.26	30.59
30	158.2	92	94.4	110.5	93.2	101.9	103.2	95.5	72.3	72.8	180	180	156	168.4	49.29	35.08	38.85	25.35

Key:

Age= (months)
UL3= Maxillary left cuspid buccolingual inclination (degrees)
UR3= Maxillary right cuspid buccolingual inclination (degrees)
UL6= Maxillary left first molar buccolingual inclination (degrees)
UR6= Maxillary right first molar buccolingual inclination (degrees)
LL3= Mandibular left cuspid buccolingual inclination (degrees)
LR3= Mandibular right cuspid buccolingual inclination (degrees)
LL6= Mandibular left first molar buccolingual inclination (degrees)
LR6= Mandibular right first molar buccolingual inclination (degrees)
Left IM= Left intermolar angulation (degrees)
Right IM= Right intermolar angulation (degrees)
Left IC= Left intercanine angulation (degrees)
Right IC= Right intercanine angulation (degrees)
Upper IM= Maxillary intermolar width (mm)
Upper IC= Maxillary intercanine width (mm)
Lower IM= Mandibular intermolar width (mm)
Lower IC= Mandibular intercanine width (mm)

Reliability Raw Data:

Subject	L IM	R IM	L IC	R IC
3	176.5	180.9	174.3	171.4
5	184.1	178.2	170.7	168.8
6	184.8	178.1	159.4	165.6
8	180	179	162.4	160.5
12	180	185.8	159.6	156.6
17	180	175	166.7	159
19	168.8	172.4	164.6	165.6
20	185.3	186.9	170.7	170.8
23	180	180	167.8	159.8
30	180	180	156.4	164.6

Subject	UL3	UR3	UL6	UR6	LL3	LR3	LL6	LR6
3	96.7	100.6	96	105.2	93.2	94.2	75.6	78.9
5	101.3	108.1	96.7	100.6	97.4	93.4	68.3	65.9
6	98.3	108	91	105.2	95.2	94.8	68.2	74.7
8	92.7	96.7	93.9	97.3	100.5	96.3	81.5	74.7
12	104.9	107.9	103.9	98.3	99.4	99.7	76.7	72.3
17	103.5	105.5	94.4	93.2	95.5	95.9	84.9	84
19	100.8	106.4	97.6	104.2	101.7	92.1	88.3	83.5
20	106.6	96	101.5	97.9	92.2	91.4	75.7	74.3
23	111	105	107.4	96.7	95	98.7	75.2	77.9
30	94.1	109.4	93.8	102.5	103.4	94.8	73	71.8

APPENDIX 3

EXPANDED METHODS

Method of Measuring Maxillary Canine Buccolingual Inclination:

1. Locate the canine in the axial view and place the line that represents the sagittal plane tangent to the buccal cortical plate of the canine. The same line should then be moved buccolingually until the longest root length in the sagittal slice view is visible. (Figure 7)
2. In the sagittal view, place the line representing the coronal slice along the long axis of the tooth. (Figure 8)
3. In the coronal view, draw the reference line tangent to the inferior border of the nasal cavity. (Figure 9)
4. Measure the inclination through the long axis of the canine (cusp tip to root apex).
5. Repeat steps for the contralateral canine.

Measurement of Maxillary Molar Inclination:

Measuring molar buccolingual inclination begins with proper orientation.

1. In the sagittal view, orient the line which represents the axial plane so that it passes through anterior nasal spine (ANS). (Figure 10)
2. Locate ANS in the axial view (the point where the coronal and sagittal planes meet). (Figure 11)
3. In the sagittal view, move the line which represents the axial view downward so that it passes through the center of atlas. (Figure 12)
4. In the axial view, rotate the line that illustrates the sagittal plane around ANS so that it passes through the center of the odontoid process. (Figure 13)
5. Locate the molar in the axial view, the point which the palatal root length is the longest in the sagittal view. (Figure 14)
6. In the saggital view, position the line representing the coronal slice through the palatal root apex and the mesiolingual cusp tip. (Figure 15)

7. In the coronal view, draw the reference line tangent to the inferior border of the nasal cavity. (Figure 16)
8. In the coronal view, measure the inclination through the long axis of the molar formed by a line connecting the apex of the palatal root and the mesiolingual cusp tip and a line parallel to the horizontal reference plane. (Figure 17)
9. Repeat steps for the contralateral molar.

Method of Measuring Mandibular Canine Buccolingual Inclination:

1. Locate the canine in the axial view, the point at which the root is longest in the sagittal view. (Figure 18)
2. Position the coronal line along the long axis of the tooth (cusp tip to root apex). (Figure 19)
3. Draw a reference line tangent to the base of mandible in the coronal view. (Figure 20)
4. Measure the inclination which is the angle between the line passing the long axis of the canine and the reference line. (Figure 21)

Method of Measuring Mandibular Molar Buccolingual Inclination:

1. Locate the molar in the axial view, the point at which the roots are longest in the sagittal view. (Figure 22)
2. Position the coronal line along the long axis of the tooth (mesial cusp tip to mesial root apex). (Figure 23)
3. Draw a reference line as the tangent at the base of mandible in the coronal view. (Figure 24)
4. Measure the inclination which is the angle between the line passing through the central groove and root apex and the reference line. (Figure 25)

Method of Measuring Intercanine and Intermolar Angulation:

Measuring intercanine and intermolar angulation begins with proper orientation. The method of orientation was defined in a previous study by Wu et al.

1. Set the axial plane by centering the right and left optical foramina in the coronal view. (Figure 26)
2. Set the coronal plane by centering the right and left foramina ovale in the axial view. (Figure 27)
3. Set the sagittal plane by viewing foramen cecum in the axial view and placing the axial plane along McRae's line (basion to opisthion). (Figure 28)

Method of Measuring Intercanine Angulation:

1. After the image is properly oriented, scroll through the coronal slices at a voxel setting of 10 until you can see all necessary landmarks: maxillary and mandibular canine root apices and cusp tips. (Figure 29)
2. Measure the angle formed by the intersection of these lines. (Figure 30)
3. Repeat steps above for contralateral canines.

Method of Measuring Intermolar Angulation:

1. After the image is properly oriented, scroll through the coronal slices at a voxel setting of 10 until you can see all necessary landmarks: maxillary first molar palatal root apex and mesiolingual cusp tip and mandibular first molar central fossa and mesial root apex. (Figure 31)
2. Measure the angle formed by the intersection of these lines. (Figure 32)
3. Repeat steps above for contralateral molars.

Figure 7: In the axial view position the line representing the saggital plane tangent to the buccal cortical plate of the canine. Move this line buccolingually until the longest root length is visible in the sagittal slice.



Figure 8: In the sagittal view, place the line representing the coronal slice along the long axis of the tooth.

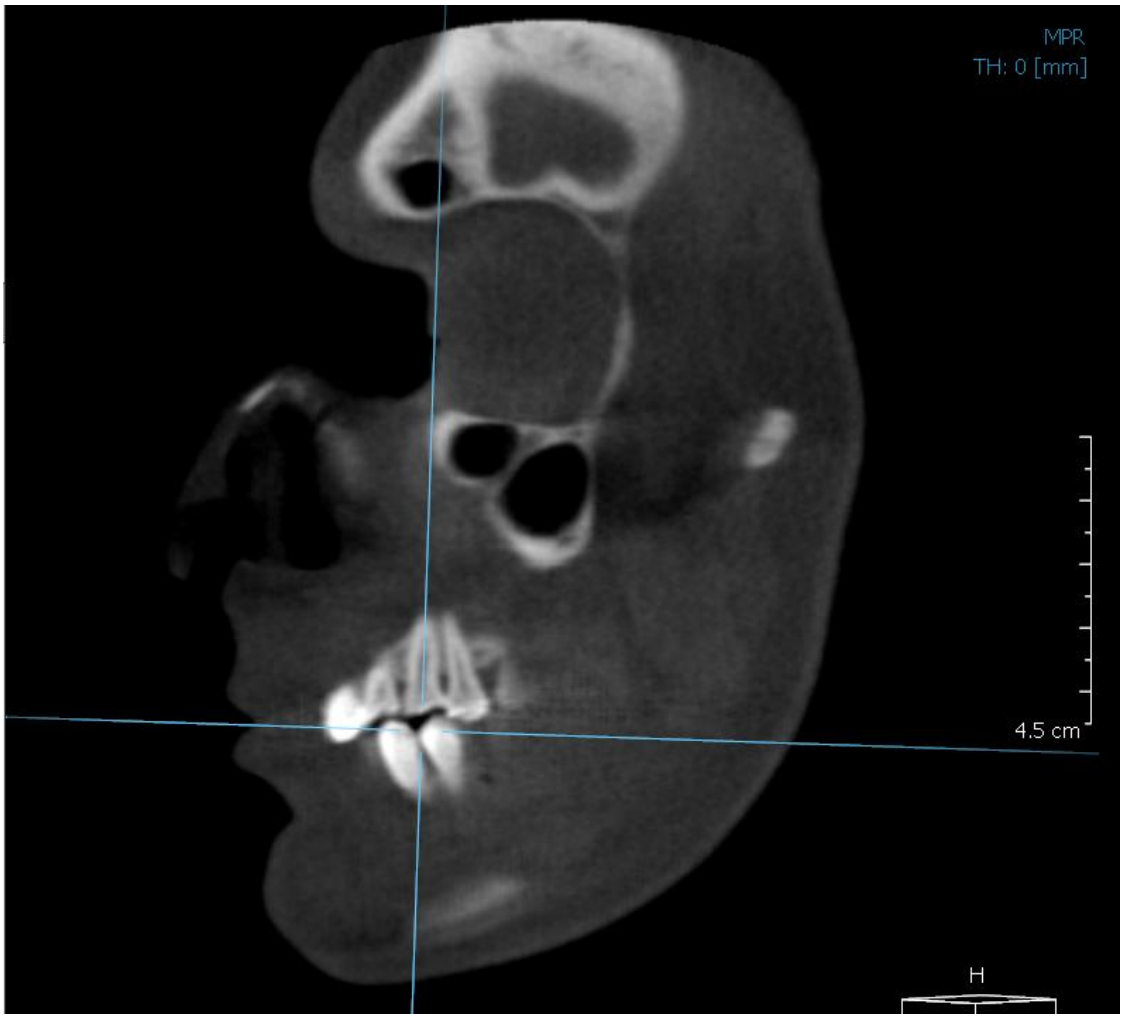


Figure 9: In the coronal view, measure the angle formed by the horizontal reference plane and the long axis of the canine.

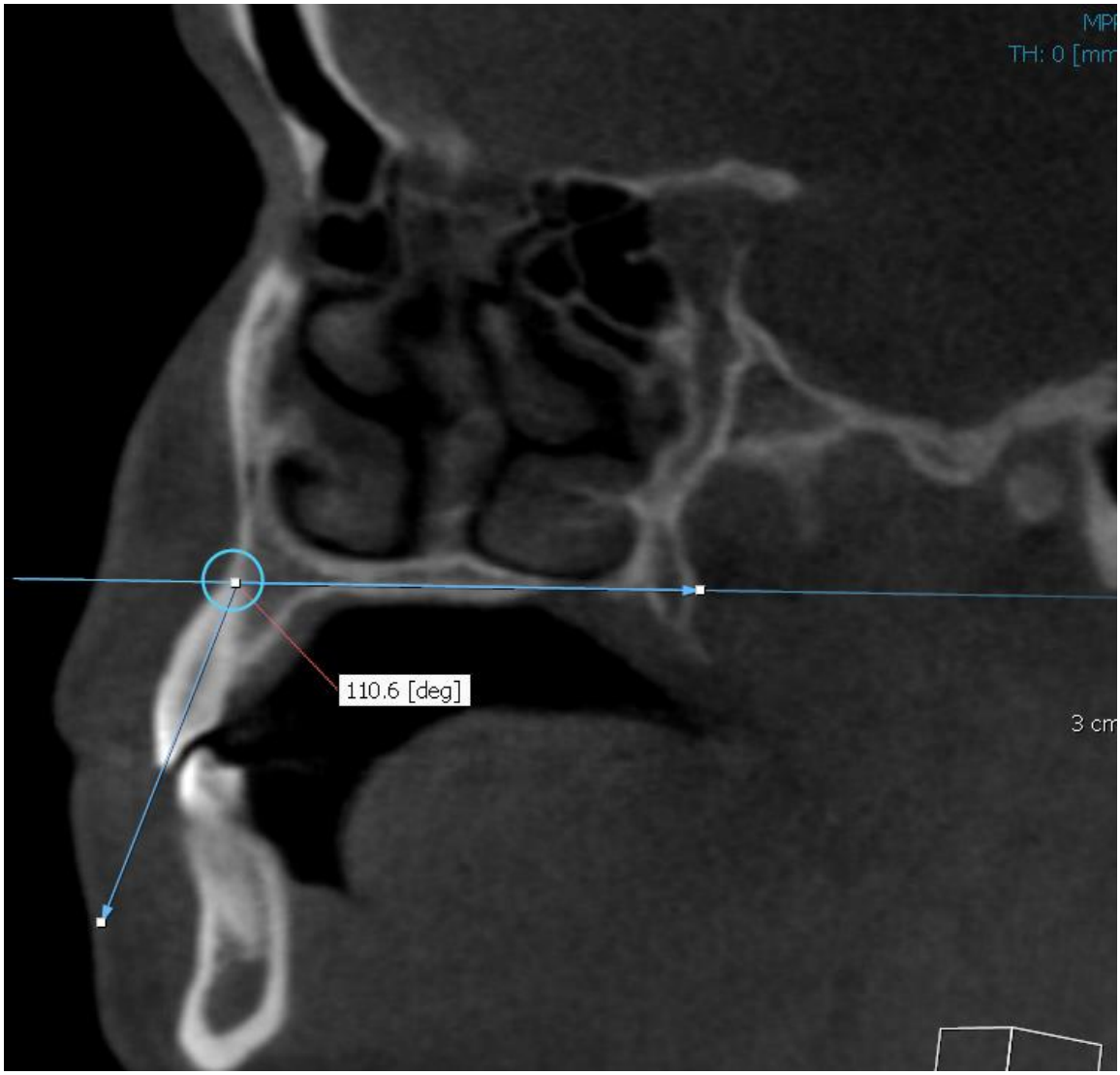


Figure 10: Orient the axial plane so that it passes through ANS in the saggital view.

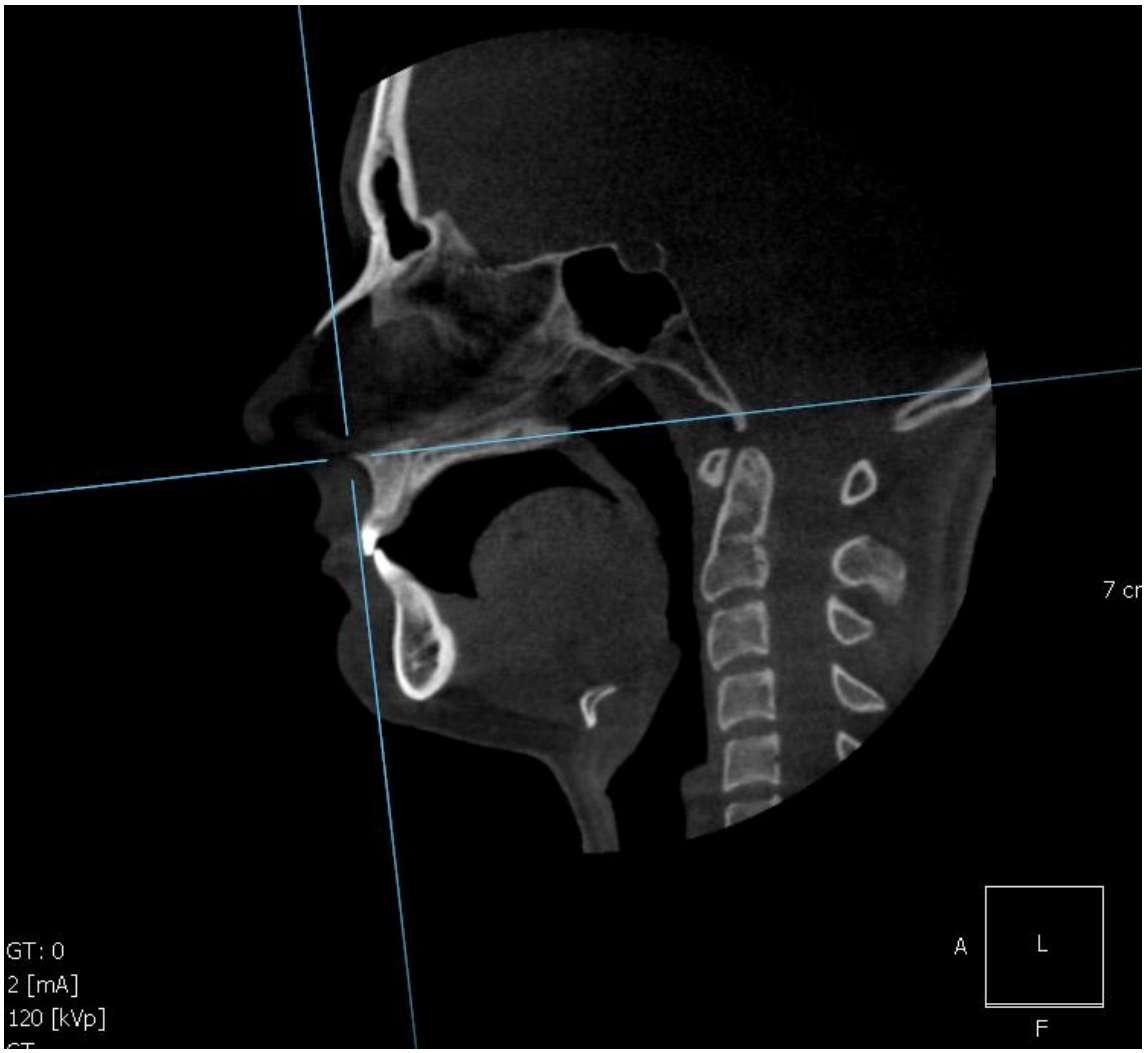


Figure 11: In the axial view place the intersection of the saggital and coronal plane at ANS.

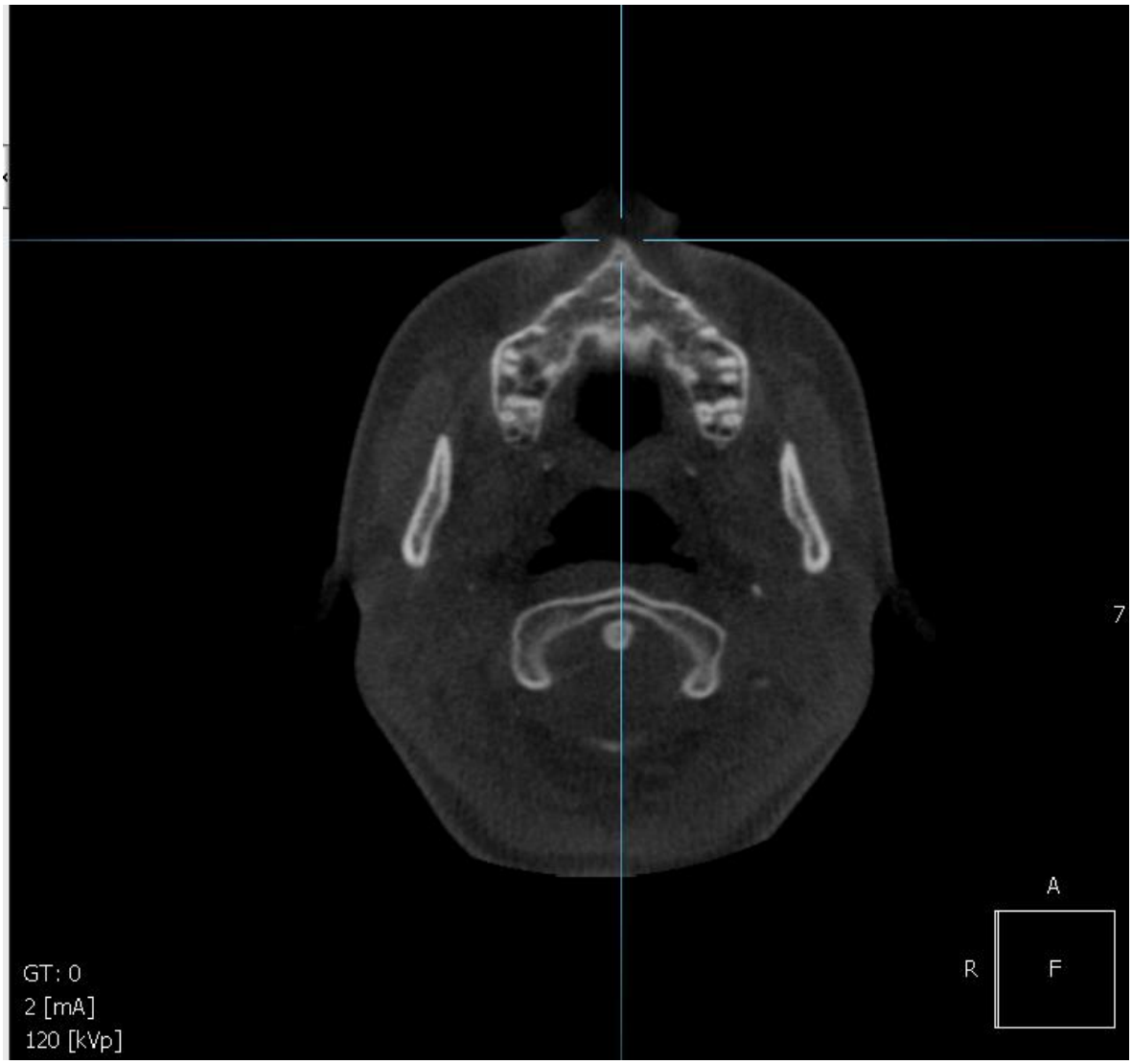


Figure 12: In the sagittal view, move the line which represents the axial view so that it passes through the center of atlas.

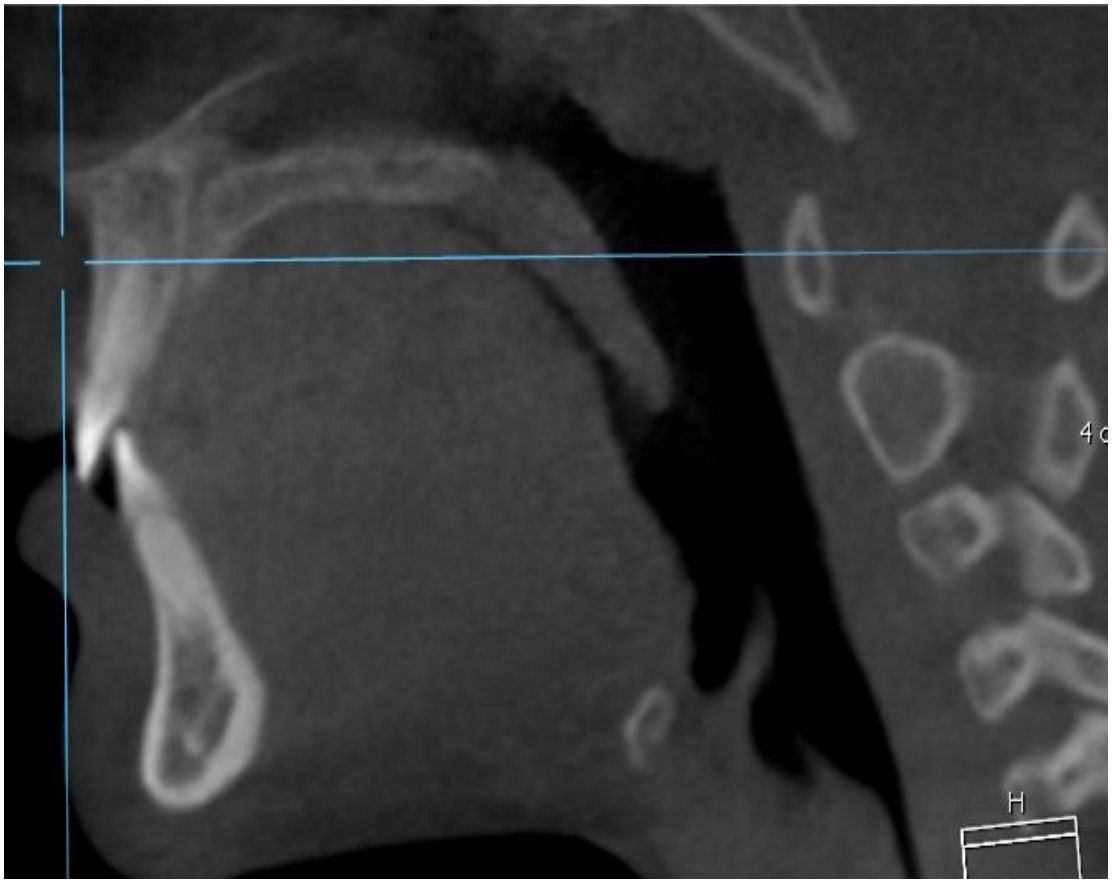


Figure 13: In the axial view, rotate the saggital plane around ANS so that it bisects the center of the odontoid process.

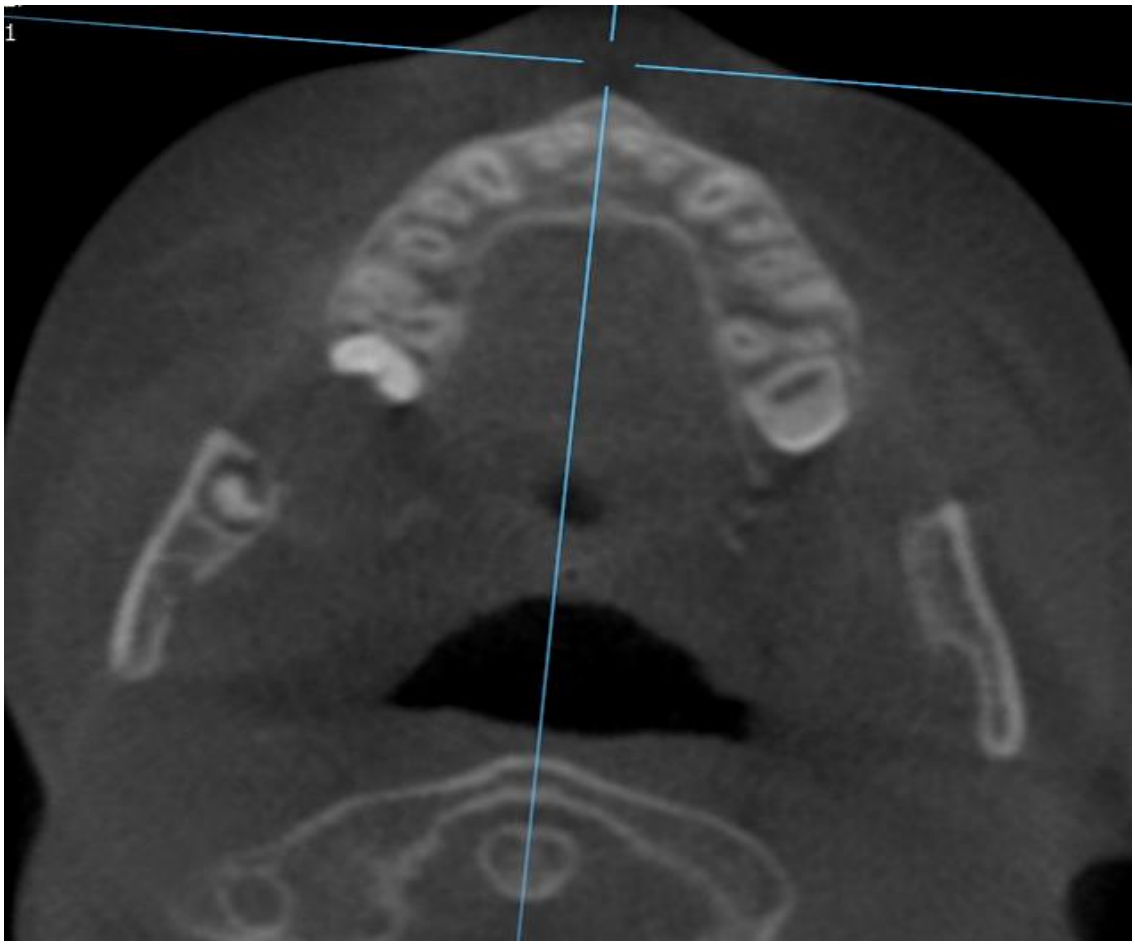


Figure 14: Locate the palatal root of the maxillary first molar in the axial view.

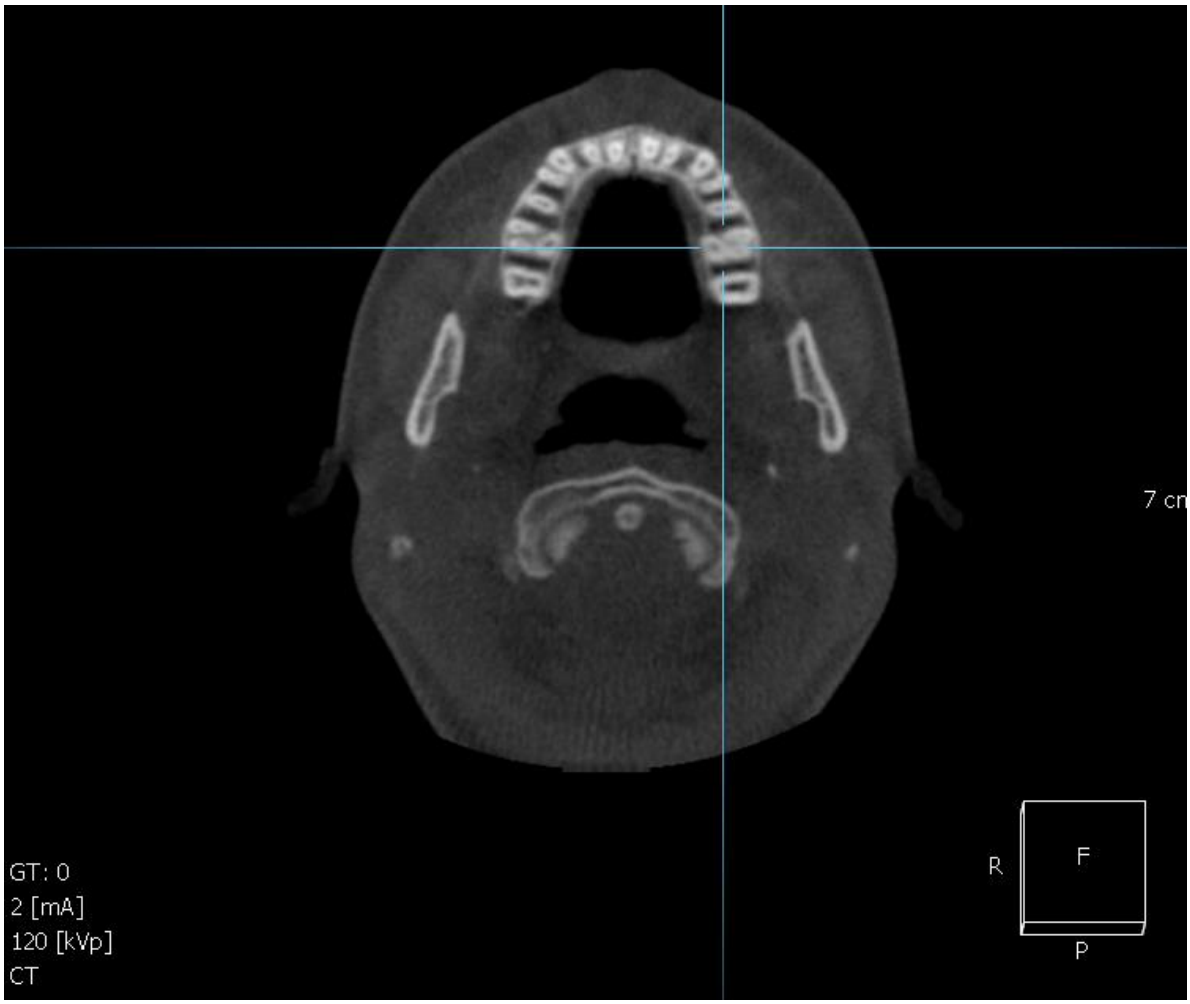


Figure 15: Locate the slice that shows the longest view of the palatal root and place the line representing the coronal plane through the root apex and the mesiolingual cusp tip.

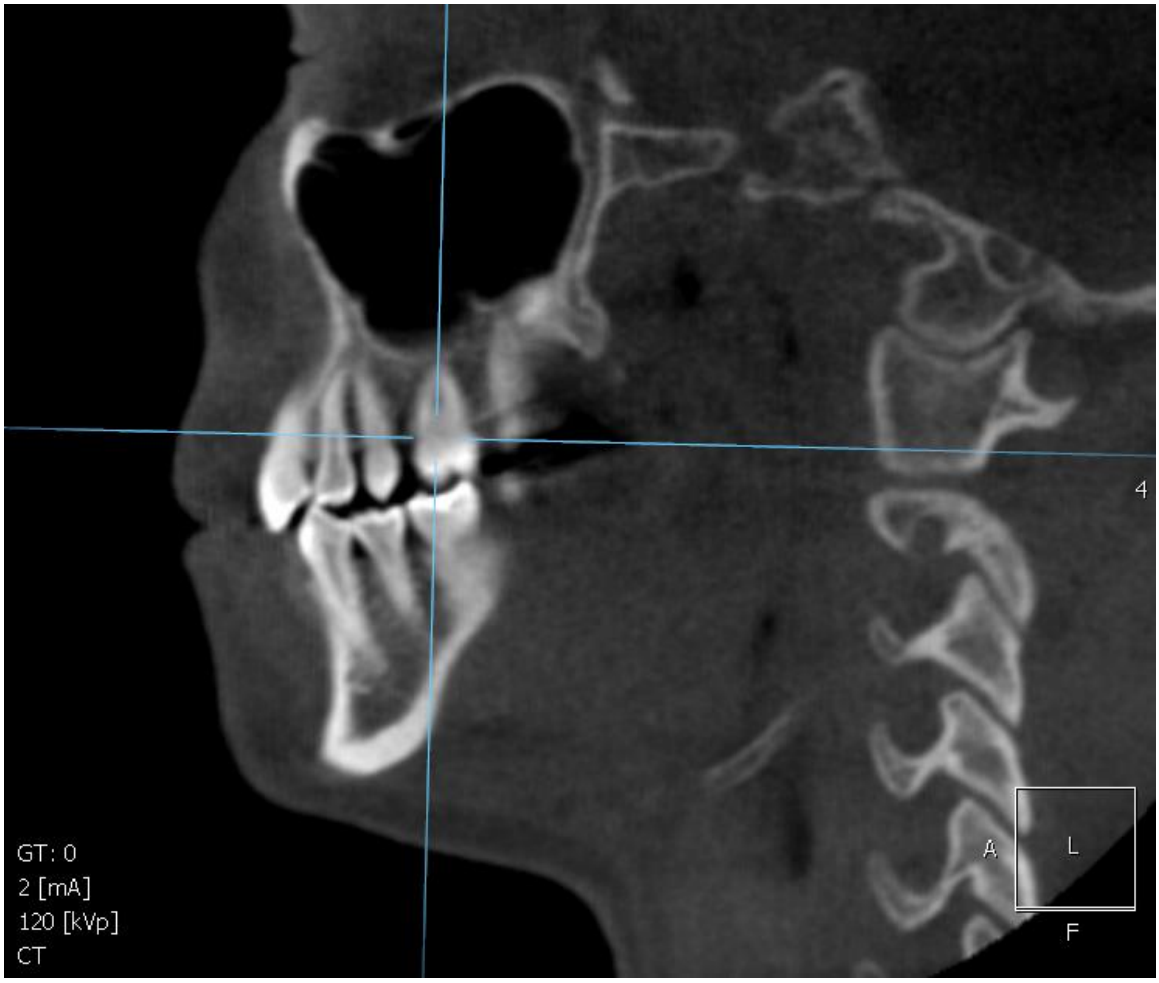


Figure 16: In the coronal view place a horizontal reference line tangent to the inferior border of the nasal cavity.

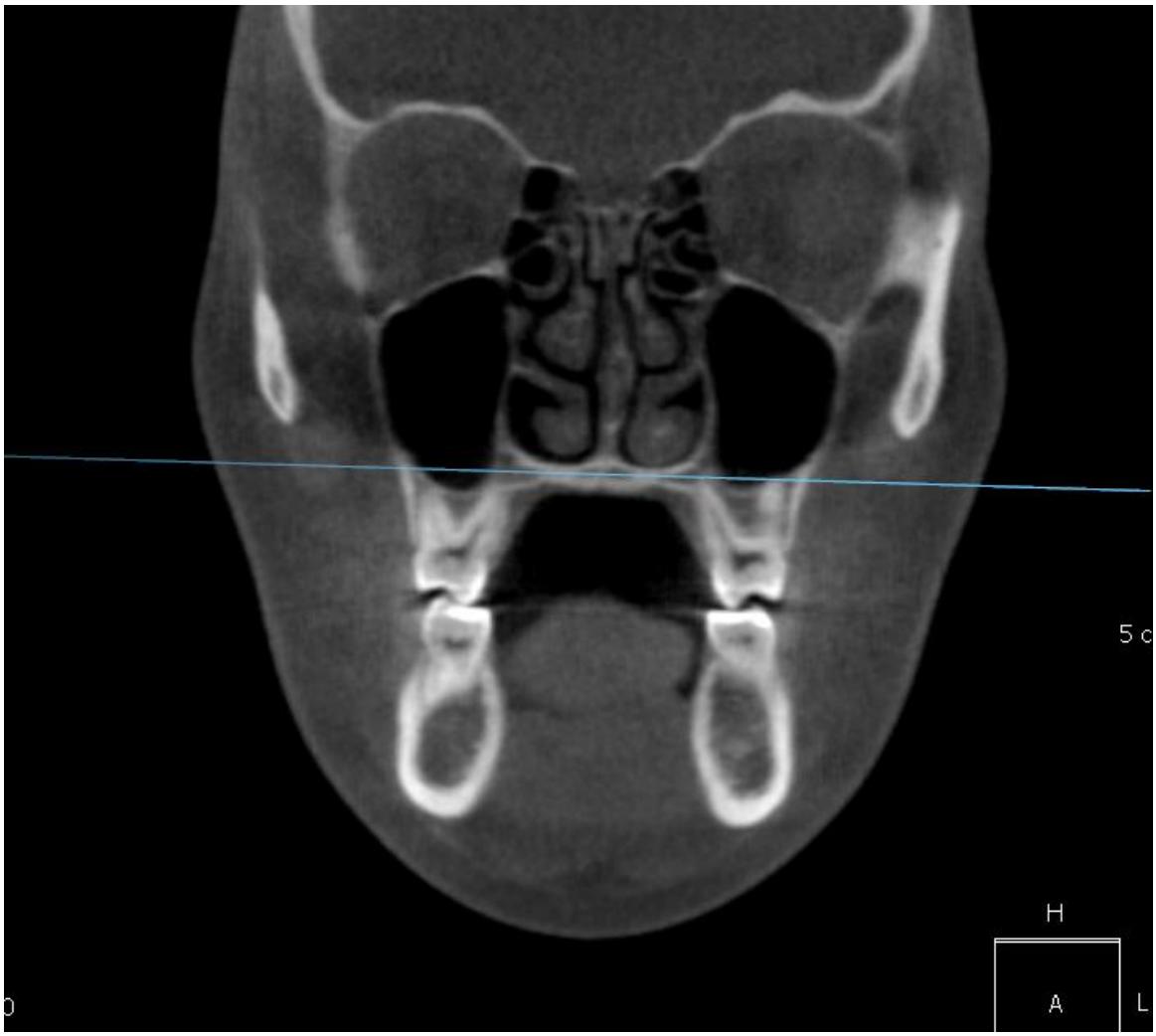


Figure 17: Angle measured by a line parallel to the horizontal reference plane and a line passing through the palatal root apex and the mesiolingual cusp tip.

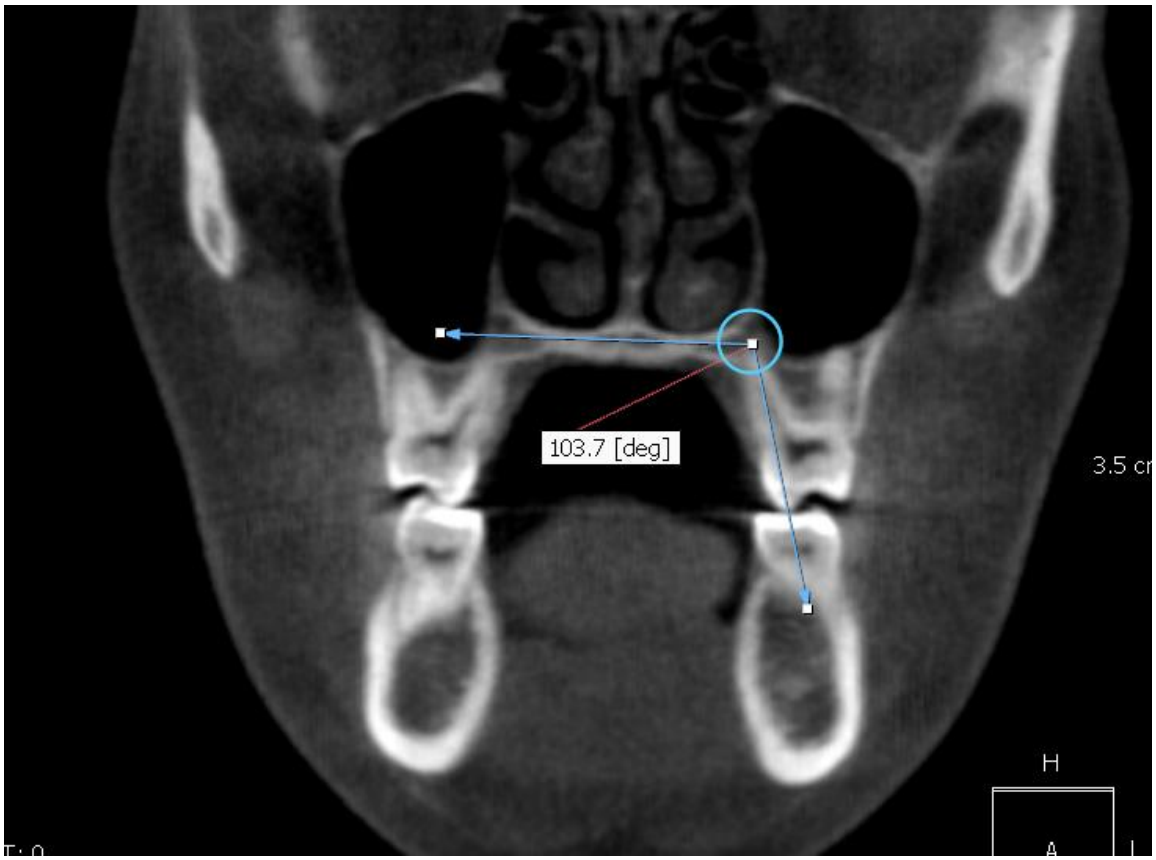


Figure 18: Locate the canine in the axial view, the point at which the root is longest in the sagittal view.

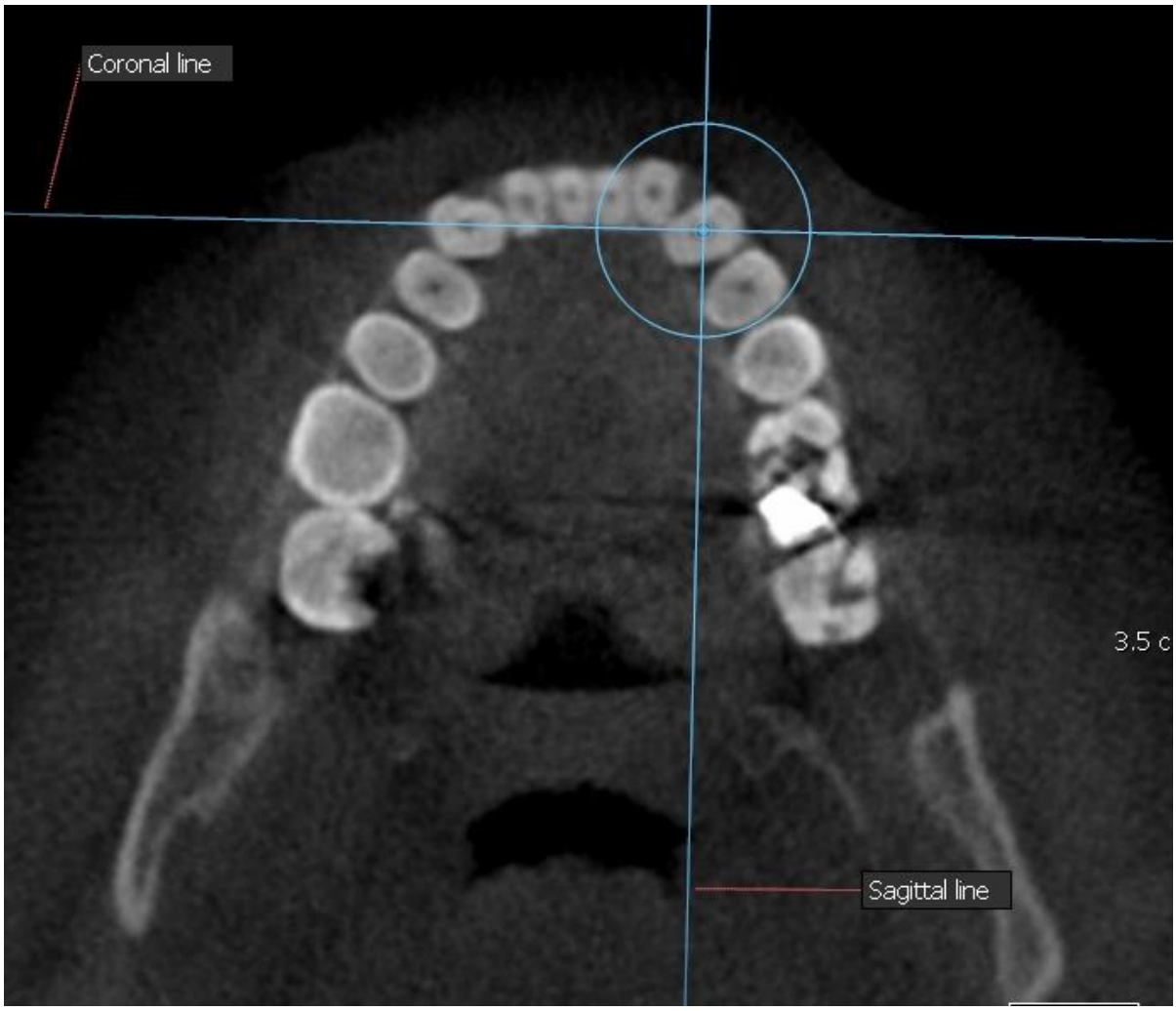


Figure 19: Position the coronal line along the long axis of the tooth (cusp tip to root apex).

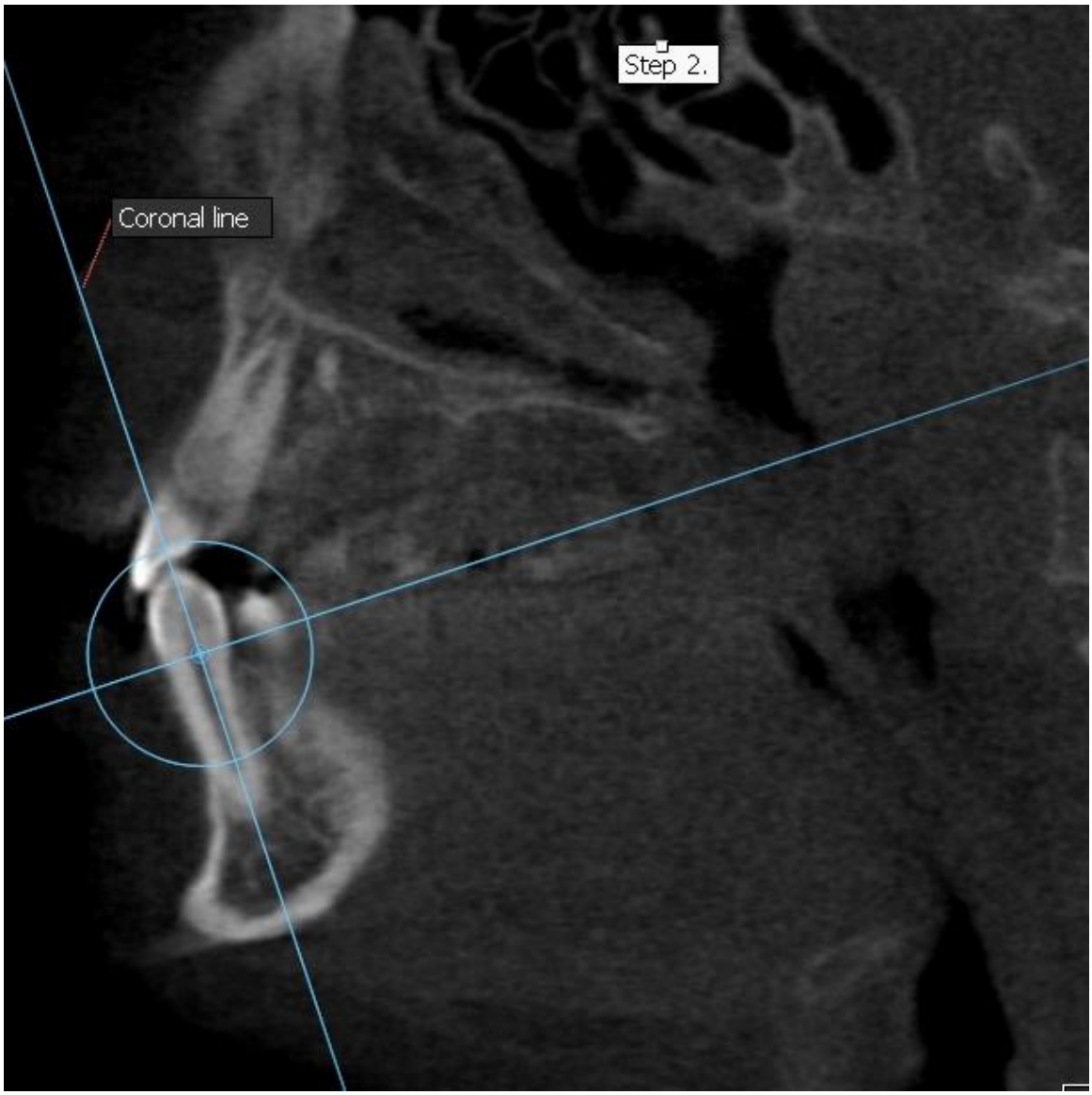


Figure 20: Draw a reference line as tangent to the base of mandible in the coronal view.



Figure 21: Measure the inclination which is the angle between the line passing the long axis of the canine and the reference line.

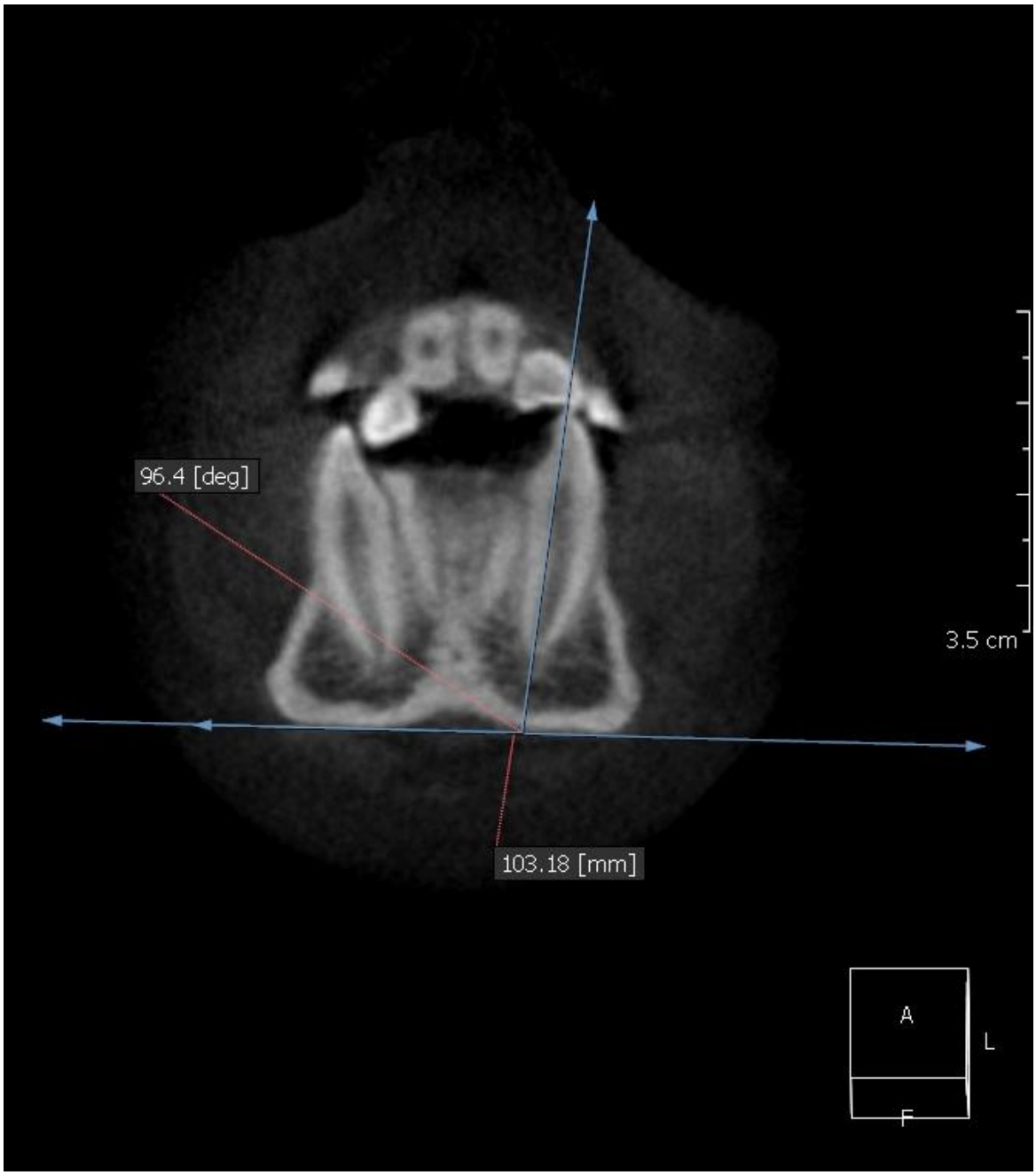


Figure 22: Locate the molar in the axial view, the point at which the roots are longest in the sagittal view.

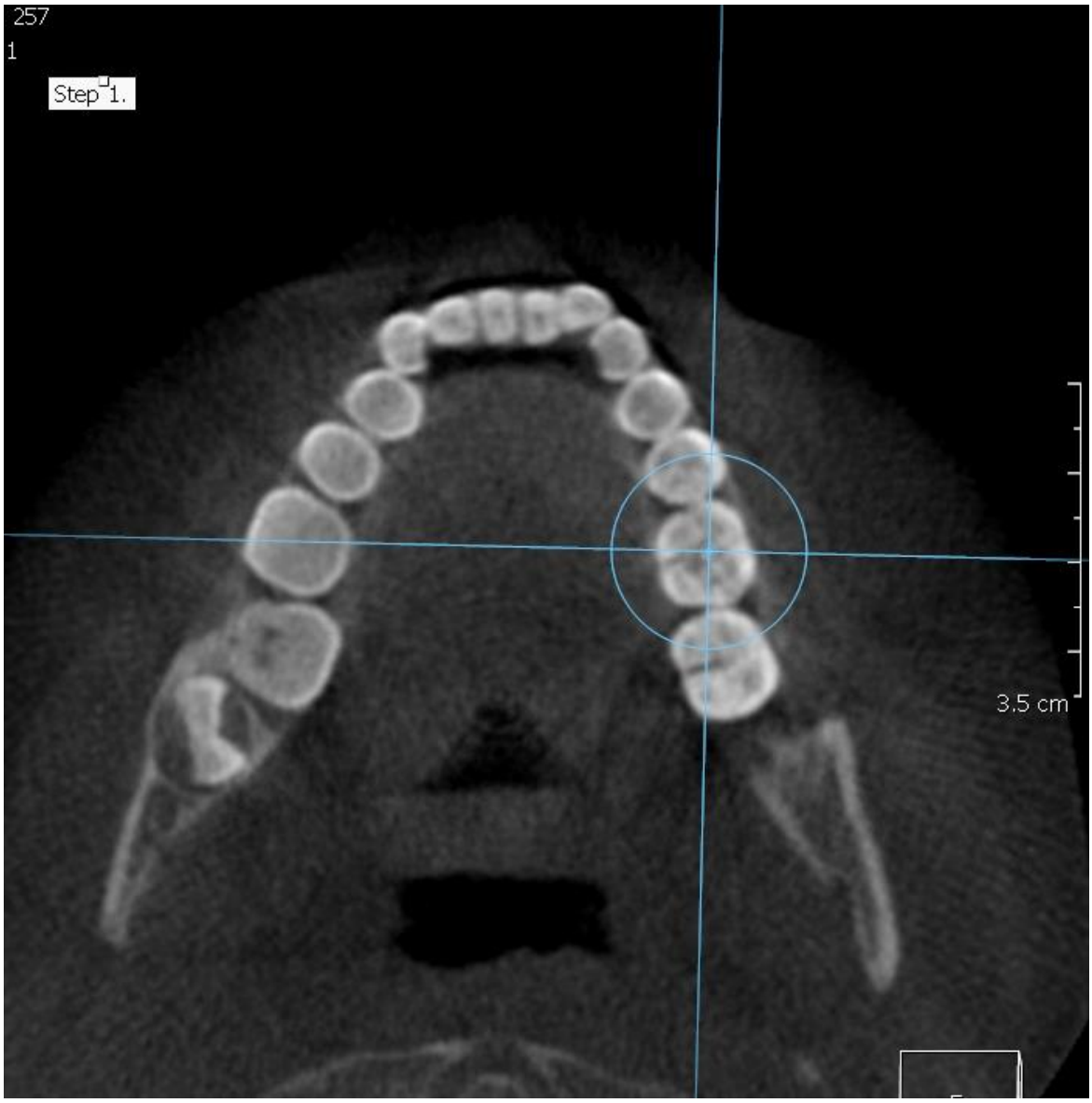


Figure 23: Position the coronal line along the long axis of the tooth (mesial cusp tip to mesial root apex).

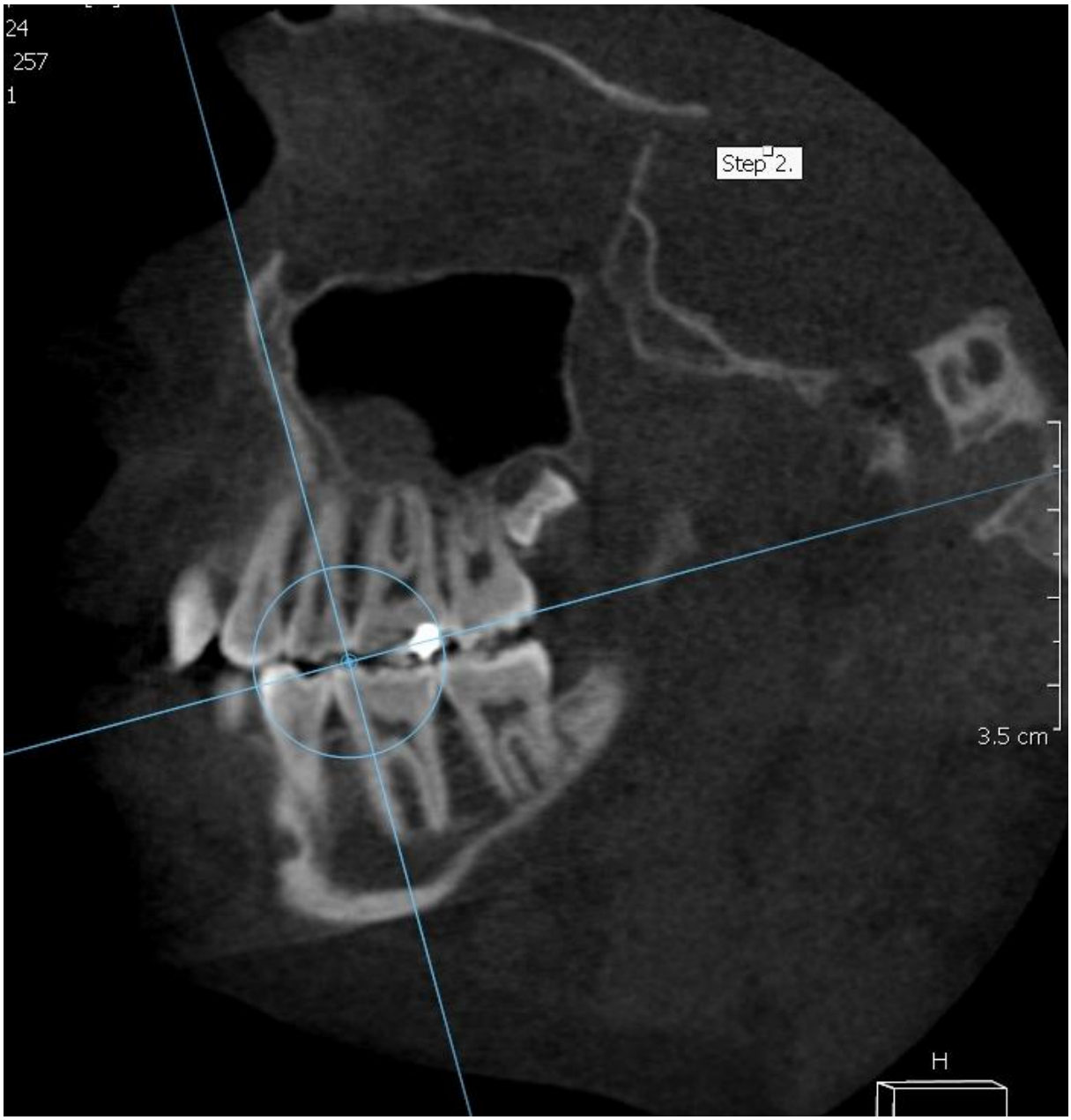


Figure 24: Draw a reference line as the tangent at the base of mandible in the coronal view.



Figure 25: Measure the inclination which is the angle between the line passing through the central groove and root apex and the reference line.

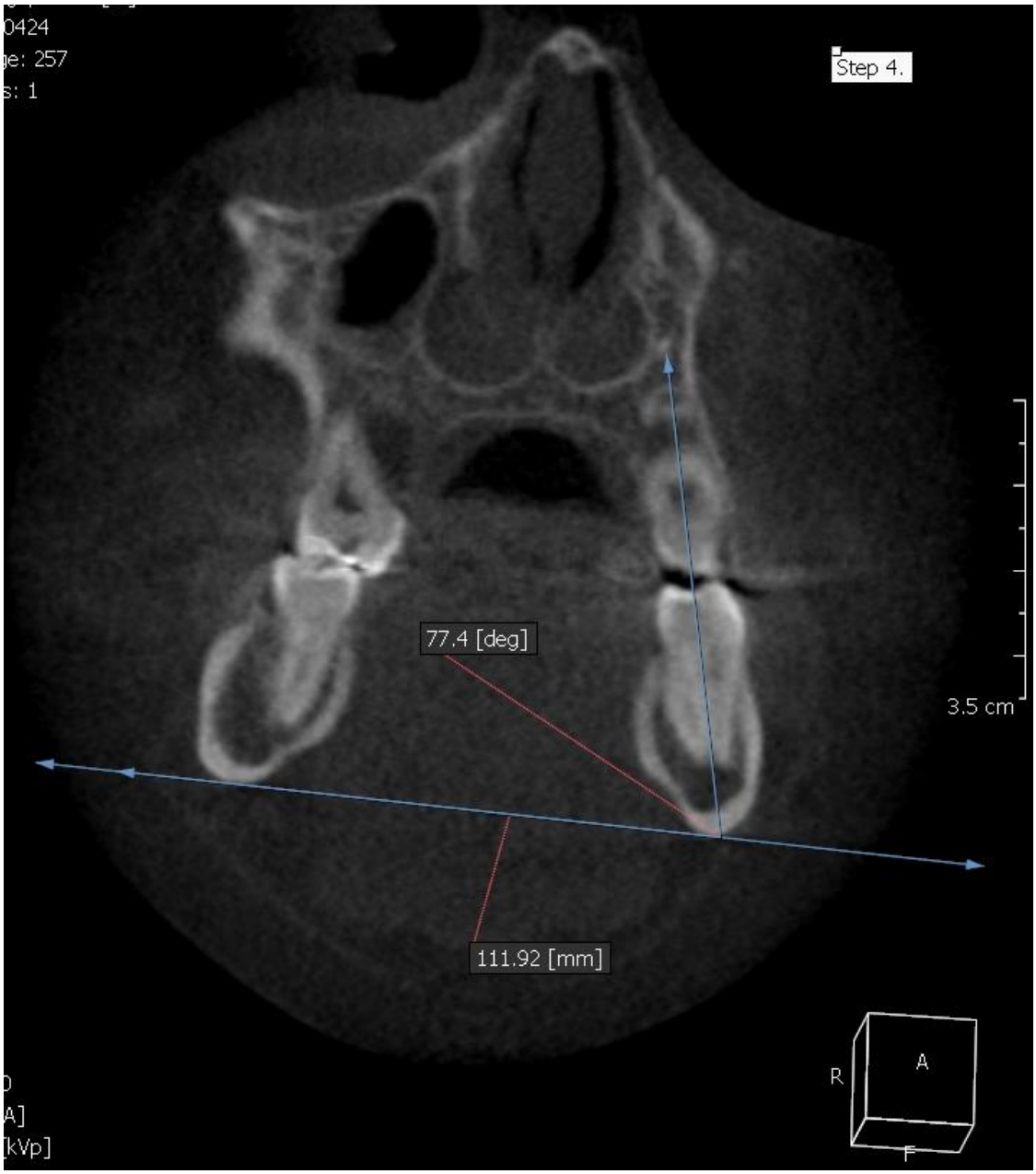


Figure 26: Set the axial plane by centering the right and left optical foramina in the coronal view.

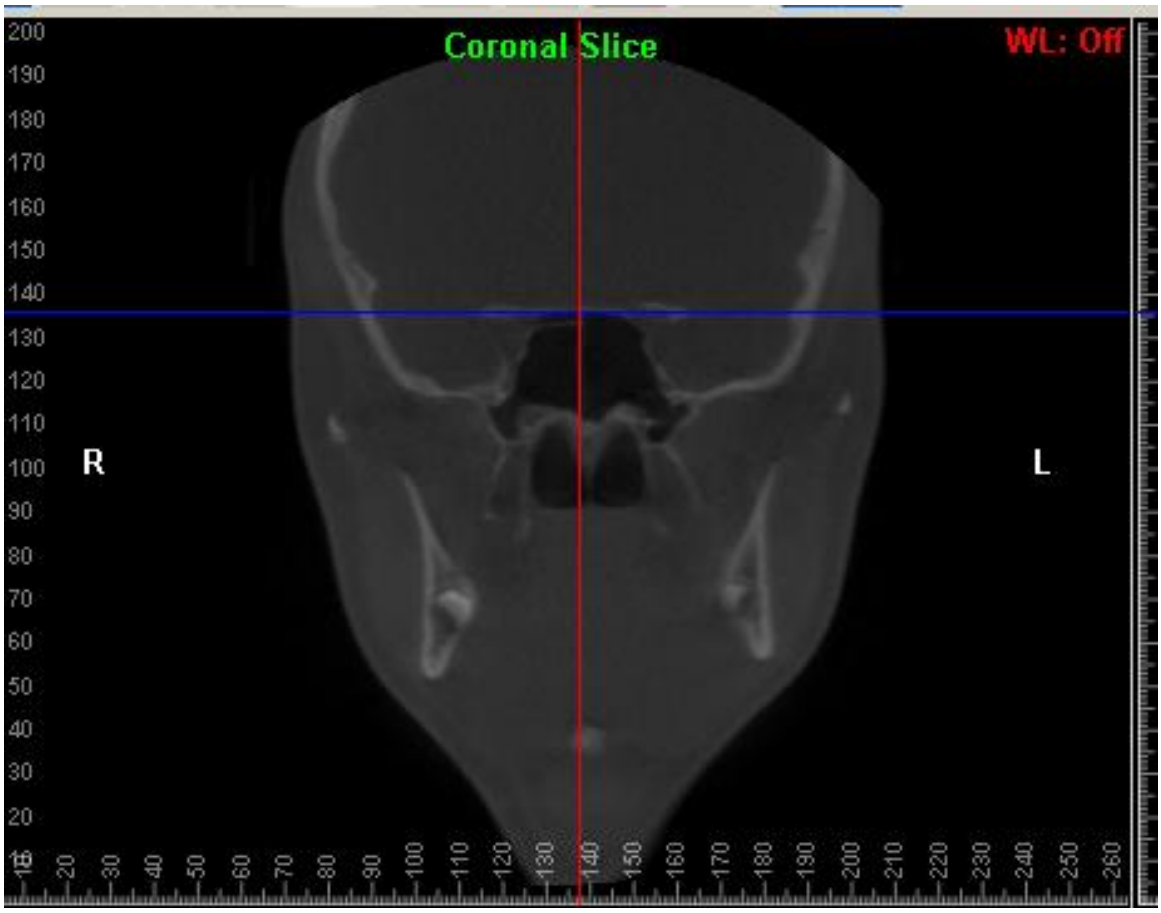


Figure 27: Set the coronal plane by centering the right and left foramina ovale in the axial view.

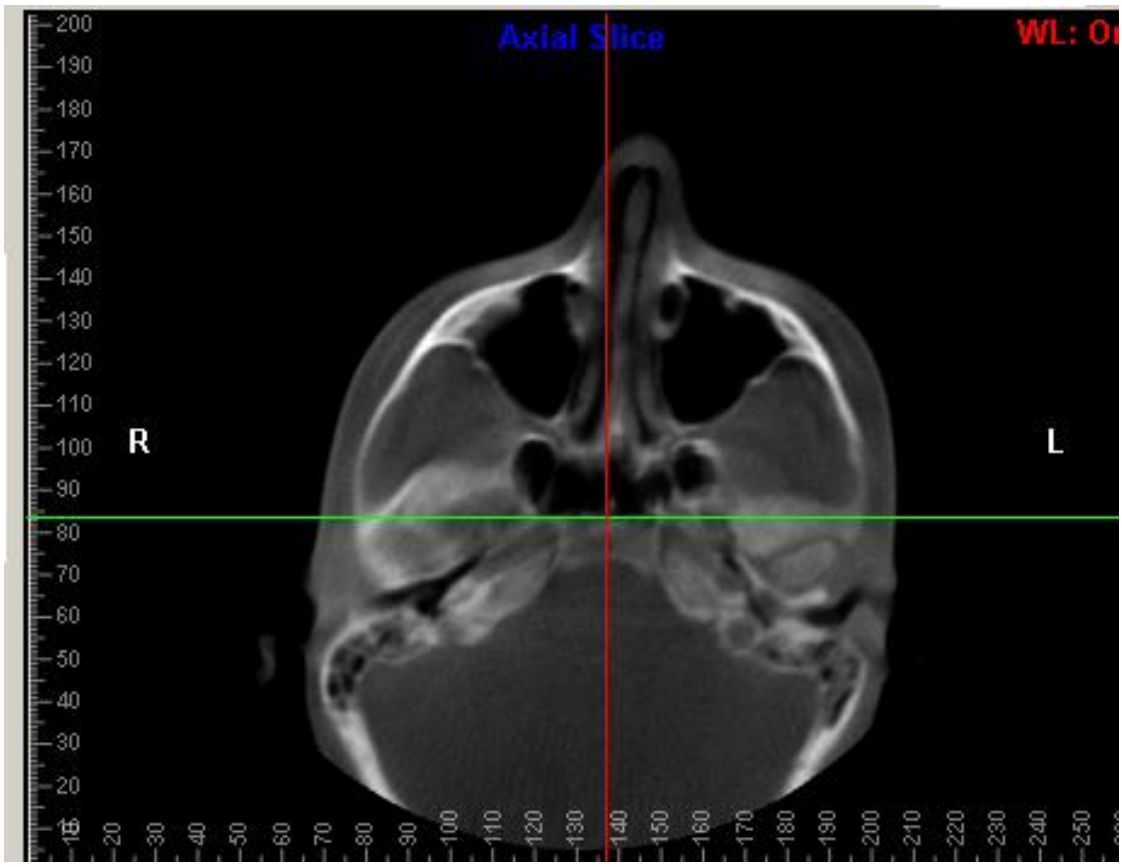


Figure 28: Set the sagittal plane by viewing foramen cecum in the axial view and placing the axial plane along McRae's line (basion to opisthion).

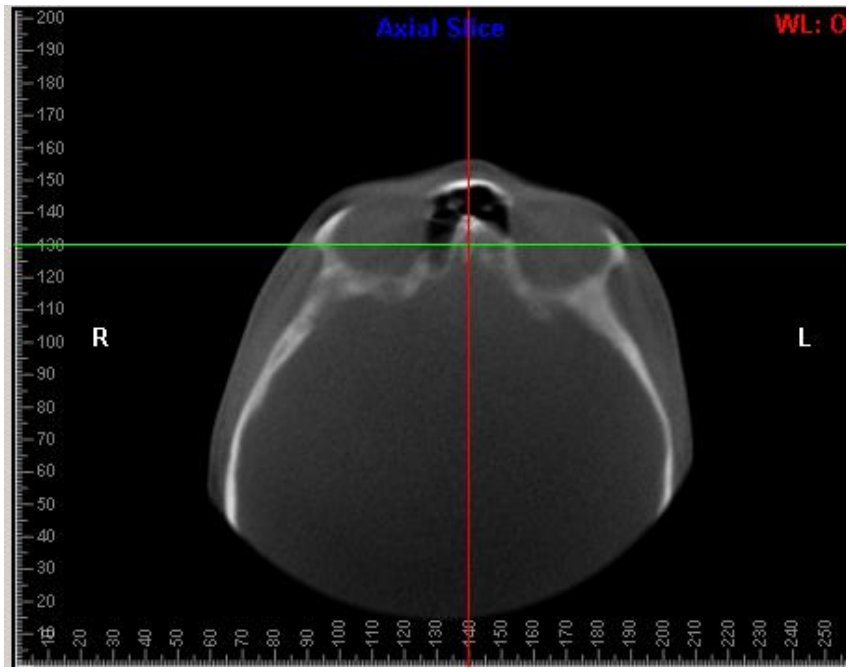




Figure 29: After the image is properly oriented, scroll through the coronal slices at a voxel setting of 10 until you can see all necessary landmarks: maxillary and mandibular canine root apices and cusp tips.



Figure 30: Measure the angle formed by the intersection of these lines.

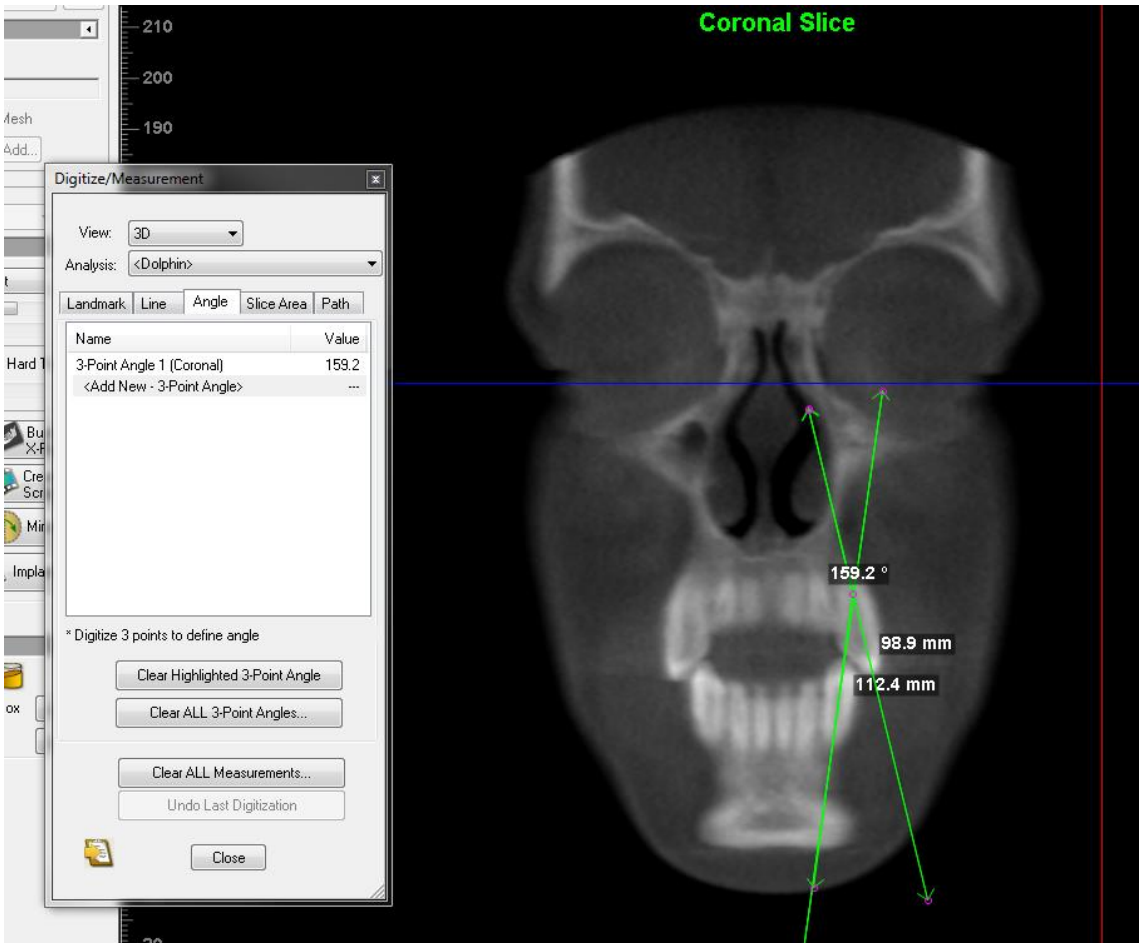


Figure 31: After the image is properly oriented, scroll through the coronal slices at a voxel setting of 10 until you can see all necessary landmarks: maxillary first molar palatal root apex and mesiolingual cusp tip and mandibular first molar central fossa and mesial root apex.

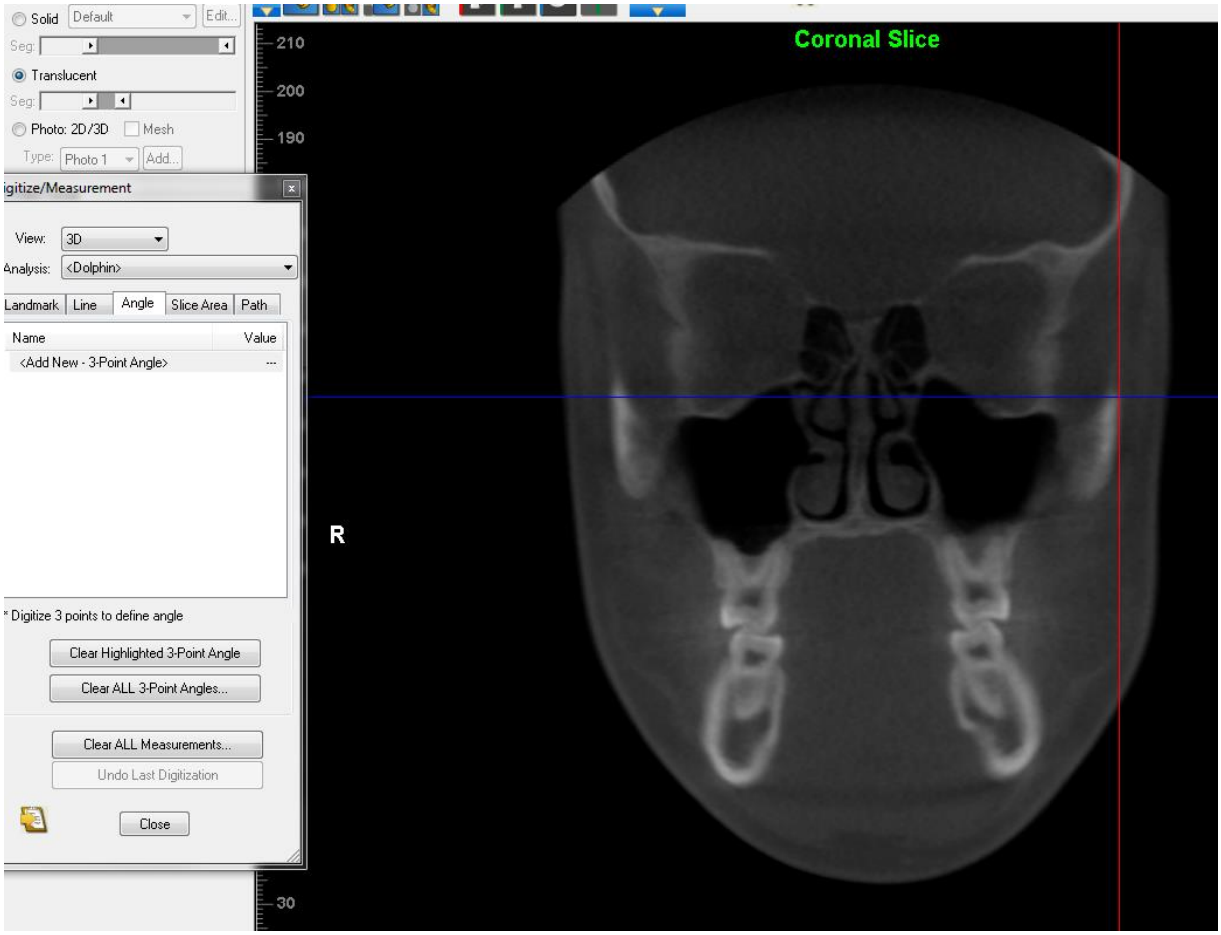


Figure 32: Measure the angle formed by the intersection of these lines.

