CASE WESTERN RESERVE UNIVERSITY

SCHOOL OF DENTAL MEDICINE

GRADUATE STUDIES

We hereby approve the thesis of

Garrison Copeland

Candidate for the degree

Master of Science in Dentistry

Signed: _____ (Chairperson)

_____

_____

_____

_____

Date: 12/3/12

Case Western Reserve University Transverse Analysis – Clinical Application

By Garrison Copeland, D.D.S.

Submitted in partial fulfillment of the requirements for the degree of Masters of Science in Dentistry

Thesis Advisor: J. Martin Palomo, D.D.S., M.S.D.

Committee Members: Mark Hans, D.D.S., M.S.D., Manish Valiathan, D.D.S., M.S.D., Alfredo Hernandez, D.D.S., M.S.

Department of Orthodontics

School of Dental Medicine

CASE WESTERN RESERVE UNIVERSITY

July 2012

Dedication

This thesis is dedicated to my mother, father, sister, brother, extended family and friends for all their love and support over the years.

Acknowledgements

I would like to thank God for His continued blessings in my life for without Him I would not be where I am today.

Secondly, I would like to thank Dr. J. Martin Palomo, Dr. Mark Hans and Dr. Manish Valiathan for giving me the opportunity to attend one of the greatest orthodontic programs in the nation. In addition, I would like to thank the entire orthodontic faculty for providing me with the skills to excel in the field of orthodontics.

Abstract

Title: Case Western Reserve University Transverse Analysis - Clinical Application

Objective: To determine if the use of Case Western Reserve University Transverse Analysis will have an effect on orthodontic treatment planning. **Methods:** The sample was comprised of 100 randomly selected cases started in 2010 at CWRU's orthodontic clinic (44 males and 56 females). Maxillary and mandibular molar angulations were measured using OnDemand3D software (version 1.0.1.8407, CyberMed, Seoul, Korea). In addition, initial records (including CBCT scans), treatment plans and progress notes were reviewed to determine if CWRU Transverse Analysis would have had an effect on the initial treatment plan. **Results:** Intraclass correlation coefficient (r^2) was greater than .93. Maxillary molar angulations were 98.5° +/- 5.8° and 101.7° +/- 6.1° for right and left side, respectively. Similarly, mandibular molar angulations were 72.8° +/- 5° for the right first molar and 72.0° +/- 4.9° for the left first molar. Nineteen subjects had one molar angulation outside one standard deviation from the norm, twenty-four had two, twenty-eight presented with three and ten with all four. Three cases treated with rapid maxillary expansion had one molar angulation outside the norm, two cases had two, three cases had four, and three cases had all four molars outside one standard deviation from the norm. Similarly, the cases treatment planned for archwire expansion had one case had one molar angulation outside one standard deviation from the norm, one had two and one had three. **Conclusion:** Twenty eight cases should have been treated with rapid palatal expansion that were not. Thirty-two cases should have been treatment planned for archwire expansion that were not, and ten cases presented with a cant in the floor of the nasal cavity making it difficult to gauge true skeletal or dental disharmony. Therefore, the CWRU Transverse Analysis would have altered many of the cases reviewed in this study.

Keywords: Case Western Reserve University Transverse Analysis, cone beam computed tomography (CBCT), buccolingual inclination.

TABLE OF CONTENTS

DEDICATION.....2

ACKNOWLEDGEMENTS.....3

ABSTRACT.....4

LIST OF FIGURES.....7

LIST OF TABLES.....10

REVIEW OF THE LITERATURE.....11

LITERATURE REFERENCES.....31

STATEMENT OF THESIS.....33

MANUSCRIPT FOR PUBLICATION.....34

INTRODUCTION.....35

MATERIAL AND METHODS.....40

RESULTS.....44

DISCUSSION.....46

CONCLUSION.....57

REFERENCES.....59

APPENDICES

IRB APPROVAL.....114

INFORMED CONSENT DOCUMENT.....115

RAW DATA.....121

RAW DATA INTRACLASS CORRELATION.....124

List of Figures

Figure 1. Orientation: In the sagittal view orient the line which represents the axial view so that it passes through ANS.

Figure 2. In the axial view locate the ANS (point where coronal and sagittal plane meet).

Figure 3. In the sagittal view move the line which represents the axial view downwards so that it passes through the center of the atlas.

Figure 4. Go back to the axial view rotate the line that represents the sagittal plane around the ANS so that it passes through the center of the odontoid process.

Figure 5. Locate molar in axial view, the point at which the palatal root length is the longest in the sagittal view.

Figure 6. In sagittal view, position the line representing the coronal slice along the mesiopalatal cusp tip and the palatal root apex.

Figure 7. In coronal view, draw the reference line tangent to the inferior border of nasal cavity.

Figure 8. Measure the inclination through the long axis of the molar (represented by a line through the apex of the palatal root and the cusp tip) in the coronal view.

Figure 9. Locate the molar in the axial view, the point at which the roots are longest in the sagittal view.

Figure 10. Position the coronal line along the long axis of the tooth (mesial cusp tip to mesial root apex).

Figure 11. Draw a reference line tangent to the inferior border of the mandible in the coronal view.

Figure 12. Measure the inclination which is the angle between the line passing the long axis of the molar and the reference line.

Figure 13. Example of dental compensation for a skeletal discrepancy in the anteroposterior dimension.

Figure 14. CWRU Transverse Analysis

Figure 15. Case #87 composite

Figure 16. Molar Angulations

Figure 17. Case #13 composite

Figure 18. Case #13 CBCT Scan

Figure 19. Case #13 Molar Angulations

Figure 20. Case #99 composite

Figure 21. Molar Angulations

Figure 22. Case#24 Composite

Figure 23. Case#24 Molar Angulations

Figure 24. Case #75 Composite

Figure 25. Case #75 Molar Angulations

Figure 26. Molar Angulations

Figure 27. Case #7 composite

Figure 28. Case #21 Composite

Figure 29. Case #21 Frontal Photo

Figure 30. Case #21 CBCT Scan

Figure 31. Case #21 Molar Angulations

Figure 32. Case #20 Composite

Figure 33. Case #20 Molar Angulations

Figure 34. Case #59 Composite

Figure 35. Case #59 Molar Angulations

List of Tables

Table 1: Descriptive Summary of Demographics, Expander Status and Crossbite Status (N=100)

Table 2: Intra-Examiner Reliability of Maxillary and Mandibular Molars

Table 3: Descriptive Summary of Maxillary and Mandibular Molar Buccolingual Inclination

Table 4: Molar Angulations of each subject

LITERATURE REVIEW

The use of rapid maxillary expansion (RME) is both a useful and predictable tool for the orthodontic clinician. Researched has shown that desired effects can be reliably obtained. Dr. McNamara et. al. conducted a longitudinal study assessing changes in dental arch dimension through the use of rapid maxillary expansion followed by fixed appliances. The study consisted of two groups. The treated group was comprised of 112 subjects in which 61 were female and 51 were male, and 41 untreated subjects of whom 24 were male and 17 were female. Records were taken at three different time intervals: (1) pretreatment, (2) after expansion therapy and fixed appliances and (3) post-treatment (six years in retention). Dental casts from all three time intervals were analyzed. Measurements of arch depth, width and molar angulation were performed on each series of dental casts. The study found that RME with fixed functional appliances are an effective means in which to gain arch perimeter in situation of mild to moderate tooth size/arch size discrepancies. The use of rapid palatal expanders produces stable, long-term changes in arch dimension in both depth and width. In comparison to the untreated group, arch perimeter increased 6mm in the maxilla and 4.5mm in the mandible.

Depending on treatment objectives, different types of expanders may be indicated. In a study entitled "Maxillary Adaptation to Expansion in the Mixed Dentition," Dr. Lawrence M. Spillane et. al. assessed the amount of maxillary expansion and changes in the maxilla through the use of a bonded expander during the mixed dentition. The parent sample consisted of 224 consecutively treated patients during a five year period from the author's private practice. Due to strict exclusion criteria, the group was reduced to 162 subjects. The average age was 8 years 8 months, 73 were male and 89 were female. In addition, there were 37 subjects that presented with unilateral crossbites and 6 with bilateral crossbites. Study models were used to assess the effects of bonded expanders on the maxilla and measurements were taken before expansion, immediately post-expansion, one year post-expansion, two years post-expansion, and after the eruption of the first premolars. The study determined that RME produced 5 to 6mm of arch width change, after a five year follow up, 72-90% change remained, and rapid maxillary expansion produced bodily movement rather than tipping of posterior teeth. When comparing initially narrower arches to initially wider arches, narrower arches retained expansion more. Similarly, lingually inclined molars tended to retain expansion more than facially inclined molars. Arch depth and palatal vault height decreased with use of rapid palatal expanders, and

there were no correlations found between amount of residual expansion and gender, age at start of treatment, pretreatment crossbite, initial arch width, or length of post-treatment interval.

Although expansion may be a means to avoid extraction, certain instances call for removal of teeth. Despite the fact that the number of extraction cases have decreased over the years, clinicians still cannot agree on when to extract 100% of the time. Dr. Baumrind et. al. assessed this topic in a study entitled "The Decision to Extract: Part 1 - Inter-clinician Agreement." The sample consisted of 148 subjects with completed initial records. There were 100 adolescents and 48 adults in the group. Patients were selected based on the presence of class I or II occlusion, age appropriateness (20 years or older for adults and children between 10 and 15 years old), normal complement of permanent teeth, no medical conditions or history of prior orthodontic treatment. Five clinicians participated in the study. Each clinician agreed to extract in 40% of cases, and not extract in 26% of cases. However, they could not agree on whether to extract or not in 34% of cases. Of the 740 patient evaluations, nine percent suggested orthognathic surgery in conjunction with orthodontic treatment. Drawbacks from the study were that it lacked the clinician's criteria for

extraction, information on how the cases finished, and whether or not the group of clinicians were representative of orthodontists in general. In a similar study, "The Decision to Extract: Part II. Analysis of Clinicians' Stated Reasons for Extraction," attempts were made to address some of the previous study's shortcomings. Each clinician was given the freedom to list reasons for extraction vs. non-extraction. The most common responses were crowding, incisor protrusion, need for profile correction, class II severity, and achievement of stable result. A subset of 72 subjects were randomly selected from the initial sample (N=148). Clinicians decided to treat with extraction in 31 cases, non-extraction in 21 cases and disagreed on whether or not to extract on 20 cases. The study assessed reasons for extraction in adolescents and whether that differed from those for adults (no statistical difference). Similarly, whether reasons were different between unanimous cases and "borderline" cases (statistical difference with regard to crowding), to what extent were reasons different for each clinician ("crowding" most common response), were reasons the same in unanimous cases (all cited "crowding" first) and how frequently different answers were given in combination with each other.

For years clinicians have varied in their approach to the correction of malocclusion. Although some treatments may

produce better results than others, a good result can be achieved with many different treatment modalities. Consistency in diagnosis and treatment planning was evaluated by Dr. Luke et. al. in a study published in 1998. Thirty-nine clinicians were asked to diagnose and treatment plan cases. Participants were either a member of the Pacific Coast Society of Orthodontists and/or faculty at dental schools. Each participant was interviewed for at least two hours prior to being in the study. Six test cases were assessed in which study models, photographs, radiographs, and examination information was provided. Results demonstrated that "There was little consistency regarding the appropriateness of extraction of premolars or molars for crowding, the use of headgear and/or functional appliances, or the use of surgery." More specifically, there was a lack of continuity in diagnosing overbite, method of assessing skeletal discrepancy, crowding, and molar and canine classification. Similarly, the decision to extract was not unanimous amongst all clinicians. "The primary finding of this study was that 39 orthodontists recommended 39 different treatment plans."

The advent of cone beam computed tomography (CBCT) may aid in improving consistency amongst clinicians. It is well accepted that the use of 3D imaging has created a new and better

means in which to diagnose and treatment plan orthodontic cases. Dr. Halazonetis released a paper in TechnoBytes addressing some of the many advantages of CBCT. He touches on the fact that it enables practitioners to better assess alveolar bone from any view, tooth inclination and torque, position of impacted teeth, airway, early onset root resorption, surgical cases, and soft tissue relationships. All in all, orthodontists are constantly searching for ways to ameliorate clinical treatment, and this type of imaging modality will drastically improve their ability to do so.

The accuracy of CBCT far exceeds that of two dimensional imaging (2D). Dr. Haney et. al evaluated the difference between diagnosis and treatment planning of impacted maxillary canines using traditional radiographs versus cone beam computed tomography. The study consisted of 18 consecutively treated patients presenting with impacted maxillary canines (25 impacted canines total) at the School of Dentistry, University of California at San Francisco. For each patient, traditional 2D radiographs and CBCT scans were taken. The 2D radiographs consisted of an occlusal radiograph, panorex and 2 periapicals. Seven faculty members were asked to assess position the cuspid(s) and draw up a treatment plan for each case using only 2D imaging. Once complete, evaluation of each case was

performed again by the faculty using 3D imaging. The study found there to be a difference in the diagnosis both mesiodistally and labiopalataly of the maxillary canine cusp tip. In addition, "twenty-seven percent of the teeth that were planned to be left, recovered, or extracted with the 2D radiographs had different treatment plans when the judges viewed the 3D CBCT images." Ultimately, evaluation of cases with 2D imaging versus 3D imaging can produce different treatment plans for the same patient. The use of 3D imaging not only improves a clinician's ability to diagnose and treatment plan certain cases, it also enhances the quality of care for the patient. Similarly, Dr. Lucia H. S. Cevidanes et. al. assessed mandibular changes after orthognathic surgery with CBCT. The study consisted of 21 subjects recruited from University of North Carolina's Dentofacial Deformaties Program at the School of Dentistry. Of the 21 subjects, 10 received maxillary surgery and 11 both maxillary and mandibular surgery. CBCT scans were taken 1 week before and 1 week after orthognathic surgery. The study found that condylar displacement was not significant when compared with maxillary only surgery. Therefore, by using 3-D imaging, quantification of the vertical, transverse, and anteroposterior changes were made possible.

The standard cephalogram, panorex, study models and photographs provide limited means to evaluate the transverse dimension. However, three dimensional imaging has enabled clinicians to better diagnosis skeletal and dental discrepancies in this plane. Dr. Podesser et. al. investigated parameters used to assess the maxilla via CBCT in a study released in 2004 in the European Journal of Orthodontics. The aim of the study was to evaluate a reproducible means in which to diagnose skeletal disharmonies in the maxilla. There were 10 subjects included in the study (three males and seven females). Subjects were selected irrespective of occlusion and the average age was 26 years 3 months (minimum 22 years 1 month; maximum 31 years 6 months). Slices through the maxillary canines and first molars were assessed for each subject. Seventeen points were identified. From these landmarks, various measurements were determined: width of maxillary base, maxillary alveolar width, inter-molar width - apex, intermolar width - crown, nasal width, inter-canine width - crown, inter-molar width - apex, right molar angulation, left molar angulation, right canine angulation and left canine angulation. Ultimately, the study determined that this method is a reasonable means in which to assess the morphology of maxillary structures, however, the difference in inter-class correlation indicates that all measurements should be performed by one observer.

Case Western Reserve University also developed a means in which to evaluate the transverse dimension with three dimensional imaging. Measuring buccolingual inclination of molars and canines provides an added component to the differential diagnosis of transverse deficiencies. Dr. Karamitsou et. al. produced a reliable way to measure maxillary first molars and canines. The study sample size consisted of 97 subjects ranging in age from 12 to 15. All measurements were recorded using OnDemand3D software. The average molar angulations for the right and left were 99.2° +/- 5.3° and 101.7° +/- 5.4°, respectively. The range for the maxillary left molar was 88.5° to 117.5°, and the range for the maxillary right first molar was 86.6° to 112.8°. Similarly, it was determined that the mean maxillary right canine angulation is 103° +/- 6° and 105.9° +/- 6.5° for the left maxillary canine (the range was 91.8° to 123.8° for the left and 89.5° to 123.4° for the right). Similarly, Dr. Shewinvanakitkul et. al. developed a reliable method of measuring buccolingual inclination of mandibular first molars and canines. The sample size consisted of 108 subjects (56 male and 52 female). It was discovered that mean mandibular canine inclination is 98.0° +/- 4.1°, and mean mandibular molar inclination is 74.6° +/- 4.7°. The study also determined that there is a significant difference in molar angulations between class I and class II patients. Class II patient's average molar

angulation is 73.5° +/- 3.7° degrees, while class I patients were found to have an average molar angulation of 75.7° +/- 4.9°. Similarly, there was a significant difference in mandibular molar angulation for subjects treated with expansion and those treated without expansion. Those treated with expansion averaged 73.3° +/- 4.8° and those treated without expansion measured at 75.3° +/- 4.6°.

In addition, Dr. Miyamoto et. al. assessed changes in buccolingual inclination of maxillary first molars and canines pre- and posttreatment. The study consisted of 70 randomly selected subjects treated at CWRU graduate orthodontic clinic. The group was made up of 43 females and 27 males between the ages of 11 and 16. Patients were excluded from the study that (1) were not between the ages of 11 and 16 during the time of initial records, (2) did not have complete pre- and post-orthodontic records, (3) had received previous orthodontic treatment, (4) did not present with fully erupted canines and molars, (5) had no deciduous maxillary teeth or extraction permanent teeth, (6) no severe rotations, (7) no craniofacial anomalies or syndromes, and (8) landmarks that are not clearly visible on a CBCT scan. It was discovered that buccolingual inclination before and after orthodontic treatment can be measured reliably, canines decreased in inclination while molars

increased in inclination pre- and posttreatment, changes in buccolingual inclination was not strongly associated with changes in intermolar width, and those changes in buccolingual inclination greater than one standard deviation from the norm could have clinical significance. Similarly, changes in mandibular first molar and canine angulations were assessed pre- and post-treatment by Dr. Evangelinakis et. al. The study consisted of 70 patients between the ages of 11 and 14 that received CBCT scans before and after treatment. It was discovered that mandibular molar angulation increased a statistically significant amount posttreatment. Despite changes in torque, intermolar width did not significantly change and was not strongly correlated with buccolingual inclination.

Further analysis of the transverse dimension was conducted in a study by Dr. Streit et. al. entitled "Case Western Reserve University Transverse Analysis - Developing Norms." The sample consisted of subjects deemed to have the "ideal" arch in the transverse dimension. Orthodontic faculty at CWRU were surveyed in order to collect the appropriate sample. Ultimately, thirty subjects were selected (15 males and 15 females). Molar and canine angulations were measured using On Demand3D software. In conclusion, the study found that maxillary canine and molar angulations were 103.9° and 101.1° +/- 4.1° for the ideal

patient, respectively. Similarly, mandibular canine and molar angulations were 97.3° and 76.7° +/-4.6°, respectively. Therefore, the study established buccolingual inclinations of molar and canines that can be reliably used in the differential diagnosis of transverse deficiencies.

Similarly, Dr. Miner et. al. assessed the transverse dimension with CBCT. In a study consisting of 241 selected subjects, norms of maxillary and mandibular molar angulations and maxillary and mandibular widths were established. Although the study was similar in nature with Dr. Streit et. al., landmark identification varied greatly. As a reference line for molar angulation determination, the functional occlusal plane was used. In addition, maxillary molar angulations were established via the central groove and the furcation. Ultimately, the study determined that skeletally the bilateral and unilateral crossbite groups had narrower maxillary and wider mandibular widths than the control group (subjects with class I occlusion and no crossbites). Patients with unilateral crossbites had upright molars on the non-crossbite side, and some subjects presented without crossbite despite a transverse deficiency.

Buccolingual inclination of posterior teeth is a significant component to the ideal occlusion. In 1998, the

American Board of Orthodontics developed a means in which to assess panoramic radiographs and dental casts for phase III clinical examinations. The initiative was put in place to enable candidates to evaluate the adequacy of their finishes and provide examiners with a reliable means to grade cases. Although the PAR Index serves the same purpose, it does not address minor inadequacies of tooth position that are found in ABO case reports. Therefore, a new system was put in place. Spanning between 1994 and 1998, four field tests were done to determine a means in which to reliably evaluate dental casts and radiographs. Throughout the testing seven categories (alignment, marginal ridges, buccolingual inclination, overjet, occlusal relationships, occlusal contacts, and root angulation) consistently produced unreliable scores by various examiners. However, through the use of a new measuring instrument and extensive training sessions, an objective means of analyzing dental casts and radiographs was established. Ultimately, eight categories are evaluated: alignment, marginal ridges, buccolingual inclination, occlusal relationships, occlusal contacts, overjet, interproximal contacts and root angulations. An example of this is the assessment of buccolingual inclination: "In order to establish proper occlusion in maximum intercuspation and avoid balancing interferences, there should not be a significant difference between the heights of the

buccal and lingual cusps of the maxillary and mandibular molars and premolars."

In a study conducted between 1960 and 1964, Dr. Lawrence Andrews discovered what he felt to be the six keys to normal occlusion. One hundred and twenty subjects not having received previous orthodontic treatment were selected for the study. Other inclusion criteria consisted of subjects whose teeth "were straight and pleasing in appearance, had a bite which looked generally correct, and in my judgment would not benefit form orthodontic treatment." The six significant characteristics commonly found in all cases were molar relationship, crown angulation (the mesiodistal tip), crown inclination (labiolingual or buccolingual inclination), rotations, spaces and occlusal plane. Each category was clearly defined as to what was considered ideal. Dr. Andrews felt as though "the distal surface of the distobuccal cusp of the upper first permanent molar made contact and occluded with the mesial surface of the mesiobuccal cusp of the lower second molar." Similarly, as it pertains to crown angulation mesiodistally, "the gingival portion of the long axis of each crown was distal to the incisal portion, varying with the individual tooth type." In addition, "a lingual crown inclination existed in the upper posterior crowns….lingual crown inclination in the lower

posterior teeth progressively increased from the canines through the second molars." Lastly, no rotations or spaces existed, and the occlusal plane varied from flat to slight curve of spee. Ultimately, Dr. Andrews felt as though each of the six keys is paramount to an ideal occlusion, and if any one of the six were missing it would result in an occlusion "proportionally less than normal."

In a longitudinal study performed by Steve Marshall et. al., transverse molar movements during growth was assessed. The sample was collected from the Iowa Facial Growth Study in which 36 subjects fit the inclusion criteria (18 men and 18 women). All subjects needed to have "study models available from age 7 to 30, untreated class I occlusion, no distortion or abrasion of the tooth portion of the dental casts, no excessive enamel wear or restorations of the dental cusps of measured teeth, and no missing or extracted permanent teeth." Dental casts were evaluated for molar torque and inter-molar width. Five different time intervals were used in which the average age were 7.5, 10.3, 12.9, 16.5 and 26.4. It was determined that maxillary first molar torque changed 3.3° and maxillary second molar torque changed 5.9°. Mandibular first molars uprighted 5.0°, and second molars 7.5°. In addition, maxillary first and second intermolar width increased 2.8 and 2.0mm, respectively.

Mandibular intermolar width increased by 2.2 mm according the first molars, and .78mm according the second molars. Ultimately, inter-molar width for maxillary and mandibular first and second molars increased between the ages of 7.5 and 26.4. Also, maxillary molars erupt with buccal crown torque and upright with age, while mandibular molars erupt with lingual crown torque and upright with age.

Dr. Ross et. al. looked at whether or not vertical growth pattern has an effect on faciolingual inclination of molars and incisors. The study included both untreated, ideal occlusions and malocclusion of three different vertical skeletal growth patterns. Dental casts were evaluated for 72 subjects ranging in age from 9.5 to 41.5 (20 males and 52 females). Subjects were broken into four groups: subjects with ideal occlusion, subjects with SN-MP < or = 26°, SN-MP = 32° and SN-MP > or = 38°. Molar occlusal surface inclination was assessed by forming an angle between the occlusal table of the tooth being measured and the total occlusal plane, "the three most occlusally located cusps of the two first molars and one or both of the premolars." Similarly, incisor angulation is assessed by the angle formed from the cephalometric tracing of the long axis of the most anterior incisor and the occlusal plane. Ultimately, the study found that there is no mean difference in faciolingual

inclination of first molars between varying facial growth patterns. Similarly, lower incisor angulation did not differ, however, maxillary incisor angulation did (positively correlated with change in SN-MP).

In a study published in 2004 by Jansen et. al., buccolingual inclination of posterior teeth was assessed in subjects with different facial patterns. Seventy subjects were chosen from an initial sample of 120 subjects who voluntarily sought orthodontic care at the Department of Orthodontics at Bauru Dental School, University of Sao Paulo, Brazil. The group represented the extremes in measurement of upper anterior facial height to lower anterior facial height. Upper anterior facial height was determined by a line from Nasion to ANS, and lower anterior facial height was measured from ANS to Menton. Ultimately, thirty-five subjects deemed to have a horizontal facial pattern, and thirty-five had a vertical facial pattern. Study models were used to determine angulations of posterior teeth. Inclination was measured by the angle formed from a line drawn perpendicular to the base of the model and a second through the long axis of the tooth. The maxillary posterior teeth of subjects with a horizontal facial pattern had a significant lingual inclination compared with those of subjects

with a vertical pattern. However, mandibular posterior teeth were not statistically different between the two groups.

Appropriate assessment of the transverse dimension can aid in the diagnosis of skeletal asymmetries. The prevalence of skeletal discrepancies was assessed by Dr. Kyrkanides et. at. in a study entitled "Skeletal Asymmetries of the Nasomaxillary Complex in Noncleft and Postsurgical Unilateral Cleft Lip and Palate Individuals." The sample consisted of 36 unilateral cleft lip patients and 36 noncleft patients (control group) undergoing orthodontic treatment at Eastman Dental Center. The entire group was made up of 39 males and 33 females ranging in age from 6 to 16. Hand-wrist and posteroanterior x-rays were taken on all subjects. Along with analysis in the anteroposterior dimension, subjects were grouped based on skeletal maturation. Ultimately, "the measurements depict asymmetries of the nasal cavities, deviations of the bony nasal septum and of the premaxilla in the transverse dimension." In addition, these asymmetries occur most frequently in the pubertal growth spurt. Similarly, there was no statistically significant difference in asymmetries between the control group and unilateral cleft lip and palate patients indicating that asymmetries in the nasomaxillary complex occur to a greater degree than expected. Similarly, a review of the literature on

facial asymmetries performed by Dr. Bishara evaluated etiology, diagnosis and treatment of these cases. It was determined that causes of asymmetry include genetic or congenital malformations, environmental factors, and functional deviations. Diagnosis of these types of cases should be broken down into a thorough clinical examination assessing the dental midlines in centric occlusion and centric relation, vertical occlusal evaluation, transverse and anteroposterior occlusal evaluations, and skeletal/soft tissue assessment. Similarly, a radiographic examination should include a lateral cephalogram, panoramic film, and posteroanterior projection. Ultimately, successful management of asymmetries should be broken up into four categories: dental asymmetries, functional asymmetries, skeletal asymmetries, and soft tissue asymmetries.

Proper diagnosis and treatment planning is key to successful treatment. Understanding all components of a patient's malocclusion may reduce treatment time. Dr. Skidmore et. al. assessed the factors influencing treatment duration in orthodontic patients. The convenience sample consisted of 366 subjects treated by one orthodontist. There were 220 females and 146 males ranging in age from 10 - 20 years. Exclusion criteria were as such: (1) Patients younger than 10 and older than 20, (2) treatment in two phases (expansion or surgical),

(3) presented with missing teeth or treated solely with removable appliances. Factors such as sociodemographic status, malocclusion, treatment methods and patient cooperation were used, and progress notes were reviewed. Noted were treatment method variables such as extraction versus no-extraction, bracket prescription, bracket position, repositioned brackets, time in which second molars were bonded, wire bending, root position, oral hygiene, elastic wear, failed appointments, trouble visits, total visits and broken brackets. It was determined that 38% of cases with extended treatment were due to 9 variables: class II molar relationship, treatment plans involving extractions, delayed extractions, crowding of 3mm or more, poor oral hygiene, poor elastic wear, bracket breakage and brackets rebonded for repositioning. However, the greatest increase in treatment time was due to extractions and delayed extractions.

REFERENCES

McNamara et. al., Rapid Maxillary Expansion Followed by Fixed Appliances: A Long Term Evaluation of Changes in Arch Dimension. Angle orthod. 2003 Aug;73(4):344-53.

Spillane et. al., Maxillary Adaptation to Expansion in the Mixed Dentition. Seminars in orthodontics 1995; Vol. 1, No. 3: 176-187.

Baumrind et. al., The Decision to Extract: Part I - Interclinician Agreement. Am J Orthod Dentofacial Orthop 1996; 109:297-309.

Baumrind et. al., The Decision to Extract: Part II. Analysis of Clinicians' Stated Reasons for Extraction. Am J Orthod Dentofacial Orthop 1996;109:393-402.

Luke et. al., Consistency of Patient Classification in Orthodontic Diagnosis and Treatment Planning. The Angle Orthodontist 1998; 68:513-20.

Halazonetis et. al., From 2-Dimensional Cephalograms to 3-Dimensional Computed Tomography Scans. Am J Orthod Dentofacial Orthop. 2005 May;127(5):627-37.

Haney et. al., Comparative Analysis of Traditional Radiographs and Cone Beam Computed Tomography Volumetric Images in the Diagnosis and Treatment Planning of Maxillary Impacted Canines. AM J Orthod Dentofacial Orthop 2010;137 (5):590-7.

Cevidanes et. al., Three-Dimensional Cone-Beam Computed Tomography for Assessment of Mandibular Changes after Orthognathic Surgery. Am J Orthod Dentofacial Orthop 2007;131:44-50.

Podesser et. al., Quantitation of Transverse Maxillary Dimensions Using Computed Tomography: A Methodological and Reproducibility Study. Eur J Orthod. 2004 Apr;26(2):209-15.

Karamitsou et. al., Pretreatment Buccal Inclination of Maxillary First Molars and Canines. Master's Thesis, Case Western Reserve University, 2010.

Shewinvanakitkul et. al., Using CBCT to Measure Buccolingual Inclination of Mandibular Canines and First Molars. Masters Thesis, Case Western Reserve University, 2008.

Miyamoto et. al., Changes in Buccolingual Inclination of Maxillary Canines and First Molars after Orthodontic

Treatment. Masters thesis, Case Western Reserve University, 2011.

Evangelinakis et. al., Changes in buccolingual inclination of mandibular canines and first molars after orthodontic treatment using CBCT. Masters thesis, Case Western Reserve University, 2010.

Streit et. al., Case Western Reserve Transverse Analysis-The Norms. Masters thesis, Case Western Reserve University, 2012.

American Board of Orthodontics. Objective Grading System for Dental Casts and Panoramic Radiographs. Am J Orthod Dentofacial Orthop 1998; 114:296-309.

Andrews LF, The Six Keys to Normal Occlusion. Am J Orthod 1944;30:196-205.

Miner et. al., Cone-Beam Computed Tomography Transverse Analysis. Part I: Normative Data. Am J Orthod Dentofacial Orthop 2012; 142: 300-307.

Marshall et. al., Transverse Molar Movements During Growth. Am J Orthod Dentofacial Orthop 2003; 124:615-24.

Ross VA et. al., Influence of vertical growth pattern on faciolingual inclinations and treatment mechanics. Am J Orthod Dentofacial Orthop 1990;98:422-9.

Janson et. al., Buccolingual inclinations of posterior teeth in subjects with different facial patterns. Am J Orthod Dentofacial Orthop 2004;125:316-22.

Kyrkanides et. al., Skeletal Asymmetries of the Nasomaxillary Complex in Noncleft and Postsurgical Unilateral Cleft Lip and Palate Individuals.

Bishara et. al., Dental and Facial Asymmetries: A Review. The Angle Orthodontist 1994;64(2):89-98.

Skidmore et. al., Factors Influencing Treatment Time in Orthodontic Patients. Am J Orthod Dentofacial Orthop 2006; 129:230-8.

STATEMENT OF THESIS

The objective of the study is to determine if the use of Case Western Reserve Transverse Analysis will have an effect on orthodontic treatment planning.

It is hypothesized that:

The Case Western Reserve University Transverse Analysis will have an effect on orthodontic treatment planning.

Case Western Reserve Transverse University Analysis - Clinical Application

Authors: Garrison Copeland, D.D.S.[1]

Mark G. Hans D.D.S., M.S.D.[2]

Manish Valiathan D.D.S., M.S.D.[3]

Alfredo Hernandez D.D.S., M.S.[4]

J. Martin Palomo D.D.S., M.S.D.[5]

1. Resident, Department of Orthodontics at Case School of Dental Medicine in Cleveland, OH
2. Professor and Chairman, Department of Orthodontics at Case School of Dental Medicine in Cleveland, OH
3. Associate Professor, Department of Orthodontics at Case School of Dental Medicine in Cleveland, OH
4. Assistant Professor, Department of Prosthodontics at Case School of Dental Medicine in Cleveland, OH
5. Associate Professor and Program Director, Department of Orthodontics at Case School of Dental Medicine in Cleveland, OH

INTRODUCTION

As specialists in the field of dentistry, patients entrust appropriate alignment of bony and dental structures to the orthodontist. Irrespective of the cause of a patient's malocclusion, facial balance, healthy function and ideal occlusion are the main objectives of each case. In order to obtain these goals, the clinician must be equipped with as much diagnostic information about the patient as possible. Just as a GPS maps out step by step instructions on how to get from point A to point B, so too the orthodontist must develop a precise road map of how to achieve an ideal result.

One of the unique aspects about orthodontics is that the key to successful treatment is proper diagnosis and treatment planning. Done correctly, depending on the complexity of the case, everything should fall into place over the next eighteen to thirty months. Over the years, clinicians have been able to gather important diagnostic information from two dimensional imaging. However, we live in a three dimension world. Often times, the transverse dimension is evaluated via the presence of posterior crossbites, measuring intermolar and canine width, assessing crown inclination on study models, dark corridors in smile photos and anteroposterior cephalograms. However, on occasion these methods are not enough to detect skeletal and dental discrepancies. Over the past decade, cone beam computed

tomography (CBCT) has been introduced as another diagnostic tool in orthodontics. Three dimensional imaging provides practitioners with a more precise means of analyzing cases. Whether assessing the position of an impacted tooth, root resorption, airway, pre- and post-surgical cases, or alveolar bone width and height, CBCT enables orthodontists to better evaluate how to properly treat their patients.[1,2,3] In addition, it has now opened the door for a more accurate evaluation of the transverse dimension.

In order to maintain the integrity of the profession, the American Board of Orthodontics holds its members to the highest of standards. Obtaining appropriate inclination of posterior teeth is critical in achieving ideal occlusion. The ABO Objective Grading System states that "in order to establish proper occlusion in maximum intercuspation and avoid balancing interferences, there should not be a significant difference between the heights of the buccal and lingual cusps of the maxillary and mandibular molars and premolars."[4] According to Andrews "Six Keys to Normal Occlusion" maxillary posterior teeth should have a negative crown inclination, similarly, mandibular posterior teeth should have a progressively more negative inclination from canine to molar.[5] All in all, tooth angulation

is a critical component of the ideal occlusion and should be assessed in each case.

Few modalities exist for diagnosing maxillary skeletal disharmony with three dimensional imaging. Podessor et al. developed a method of assessing the transverse with CBCT. The study identified seventeen points on slices taken of the maxillary canines and first molars. Ultimately, appropriate measurements of the width of the maxillary base, maxillary alveolar width, inter-molar width (apex), inter-molar width (crown), nasal width, inter-canine width (crown), inter-canine width (apex), right molar angulation, left molar angulation, right canine angulation, and left canine angulation were determined. Although only ten subjects were included in the study, "the system described represents a reasonable method by which the transverse morphology of the maxillary structures can be described."[6]

Case Western Reserve University developed a method of assessing the transverse dimension by measuring buccolingual inclination of molars and canines. In 2008, Dr. Shewinvanakitkul et. al. developed a reliable method of measuring buccolingual inclination of mandibular first molars and canines. By randomly selecting 108 subjects, it was determined that the average mandibular molar angulation is 74.6°

+/- 4.7°, and average mandibular canine angulation is 98.0° +/- 4.1°.[7] In addition, Evangelinakis et. al. evaluated the effects of orthodontic treatment on buccolingual inclination of mandibular molars and canines. Through assessing 70 randomly selected patients, it was determined that mandibular molar angulation increases slightly while canine angulation decreases to a statistically significant degree.[8]

In 2010, Dr. Karamitsuo et al. created a reliable method of quantifying angulation means for maxillary first molars and canines. The study included 97 randomly selected subjects ranging in age from 12 to 15. It was discovered that on average maxillary molar angulations for the right and left were 99.2° +/- 5.3° and 101.7° +/- 5.4°, respectively. Similarly, the average maxillary right canine angulation was 103° +/- 6° and left was 105.9° +/- 6.5°.[9] Similarly, Dr. Miyamoto et. al. assessed the affects of orthodontic treatment on buccolingual inclinations of maxillary first molars and canines. The study consisted of 70 subjects treated with pre-torqued/pre-angulated fixed appliances. The study discovered that maxillary molars tended to increase in inclination posttreatment and maxillary canines decreased. In addition, "the large range of inclinations was clinically significant and suggests that evaluation of the

transverse dimension has the potential to alter treatment decisions."[10]

Ultimately, in 2012, Dr. Streit et. al. conducted a study in which thirty subjects were selected by the orthodontic faculty at CWRU based on which ones were considered to have the ideal transverse dimension. These cases were chosen from pre-existing records and consisted of 15 males and 15 females. The study determined that the "ideal" buccolingual inclination of maxillary molars and canines are 100.1° and 103.9°, respectively. Similarly, mandibular first molars are 76.7°, and canines are 97.3°. With this in mind, differential diagnosis of the transverse dimension can now be reliably assessed with CBCT.[11]

In 2012, Dr. Miner et. al. published a study assessing normative values in the transverse dimension. The sample consisted of 241 subjects of which 33 had bilateral crossibtes, 21 had unilateral crossbites and 187 presented with no crossbites. Although Dr. Miner's study was similar to Dr. streit's, landmarks and orientation method were very different. His study assessed maxillary molar angulation as a line passing through the furcation and central groove and a second line representing the functional occlusal plane. The study found that discrepancies in bilateral crossbites were due to a narrow maxilla and discrepancies with unilateral crossbites were due to

a wider mandible. Similarly, dental compensations exist despite the presence of crossbites in either arch.[12] Ultimately, three dimensional imaging has spurred new and innovative analysis of the transverse dimension.

The aim of this study is to determine if the Case Western Reserve University Transverse Analysis will have an effect on orthodontic treatment planning.

MATERIALS AND METHODS

The Case Western Reserve University Institutional Review Board approved this study. The orthodontic department treats patients ranging from the typical orthodontic case to severe craniofacial anomalies. Of the many different types of cases treated, roughly 60% of patients seen by orthodontic residents are pre-teenagers and teenagers between the ages of 10 and 16 (Core clinic). Each year anywhere from 200 to 300 patients start treatment. In 2010, there were 283 new patients. The sample for this study was drawn from this pool. Each case is treatment planned by an instructor and resident, and eighteen instructors make up the Core clinic. Ultimately, one hundred randomly selected cases made up the group. Each of the 283 subjects received large volume 2mA CBCT scans (CB MercuRay ™, Hitachi Medical Systems America Co. - Twinsburg, OH) during their initial records appointment. In addition, all patients

had completed medical and dental history forms, intra-oral and extra-oral photos, study models and treatments plans. Information included in this study was derived from these materials. Of the subjects included in the study, maxillary and mandibular first molar angulations were recorded by the principal investigator (GC). All together 400 molar angulations were measured. In addition, intra-oral and extra-oral photos, CBCT scans, models, and progress notes were reviewed. This was done to determine (1) if the patient presented with a posterior crossbite, (2)the clinician faced any problems during treatment that may be explained through use of the CWRU's Transverse Analysis, and/or (3) the presence of skeletal asymmetries compensated for dentally. In addition, initial treatment plans were reviewed to see which cases were treatment planned for rapid maxillary expansion, archwire expansion, or no expansion. Means and standard deviations obtain in Dr. Streit's study were used to evaluate molar angulations.

Inclusion criteria consisted of patients presenting for treatment in Core clinic in 2010. Exclusion criteria consisted of patients having not received a CBCT scan or incomplete initial treatment plans. Of the 283 potential subjects, each received CBCT scans and had completed treatment plans. Therefore, a random number generator was used to obtain a sample

of 100. All subjects signed a consent form at the beginning of treatment permitting use of records for research and no patients were contacted for research purposes.

Radiographic data was constructed from CBCT dicom files. Maxillary and mandibular buccolingual molar inclinations were measured using OnDemand3D software. Slice thickness was set at .377mm as a function of the standard voxel size. Measurements were made separately of each molar angulation. To assess reliability, 30 of the 100 subjects were randomly selected and measurements of each molar angulation were repeated three weeks after initial measurement. Patient age, gender, crossbite status and expander status were extrapolated from records.

Method of maxillary molar inclination measurement

Through the work of Karamitsou et al, maxillary molar angulations are measured as a line passing through the root apex and mesiopalatal cusp and a second line tangent to the inferior border of the nasal cavity.

Orientation consisted of (1) in the sagittal view, aligning the line representing the axial view along ANS (See Figure 1), (2) in the axial view, locate ANS with the intersection of the lines representing the coronal view and saggital view (See Figure 2), (3) in the sagittal view, pass the line representing

the axial view through the Atlas (See Figure 3), (4) in the axial view, rotate the line representing the sagittal view about ANS so that it passes through the Odontoid Process (See Figure 4). In addition, molar angulation was established by locating the maxillary molar in the axial view (the point at which the palatal root is the longest in the sagittal view) (See Figure 5), (2) in the sagittal view, align the line representing the coronal view along the mesiopalatal cusp and palatal root apex (See Figure 6), (3) in coronal view, draw the reference line tangent to the inferior border of nasal cavity (See Figure 7), (4) in the coronal view, measure the buccolingual inclination by forming an angle along the inferior border of the nasal cavity and the long axis of the molar (apex of palatal root to mesial palatal cusp tip) (See Figure 8).

Method of mandibular molar inclination measurement

Based on a method derived from the study done by Shewinvanakitkul et. al., mandibular molar angulations were determined to be the angle formed between the long axis of the tooth (line drawn through central groove and middle of root apices) and a line tangent to the mandibular border. The method is as follows: (1) locate the molar in the axial view where the roots are the longest in the sagittal view (See Figure 9), (2) in the sagittal view, align the line representing the coronal

view along the apex of the mesial root and the mesial cusp tip (See Figure 10), (3) draw a reference line tangent to the inferior border of the mandible in the coronal view (See Figure 11), (4) in the coronal view, measure the angle represented by a line along the inferior border of the mandible and the long axis of the molar (See Figure 12).

Cases in which at least one maxillary molar was one standard deviation above the norm or at least one mandibular molar was one standard deviation below the norm qualified as cases that should have been treatment planned for rapid maxillary expansion (RME). Similarly, cases with at least one molar angulation below one standard deviation in the maxillary arch were grouped as cases needing archwire expansion.

Statistical Analysis

Descriptive statistics (means, standard deviations and ranges) were used to assess the data.

RESULTS

During the initial records appointment, the average age of the sample was 13.03. The group was predominately Caucasian (94 of the 100) and made up of 44 males and 56 females. Thirteen cases were treatment planned for rapid maxillary expansion and three for archwire expansion. In addition, eleven cases

presented with a posterior crossbites of which 7 were unilateral, and 4 bilateral (Table 1). The sample consisted of mostly non-extraction cases (94%).

The average maxillary molar angulations were 98.5° +/- 5.8° and 101.7° +/- 6.1° for right and left molars, respectively. Angulations ranged from 87.2° to 114.8° for the upper right first molar and 80.9° to 115.5° for the upper left first molar. The average mandibular molar angulations were 72.8° +/- 5° and 72.0° +/- 4.9° for right and left, respectively. Angulations ranged from 57.°1 to 89.2° for the lower right first molar and 55.1° to 80.9° for the lower left first molar (Table 3). Intraclass correlation coefficient (r^2) for buccolingual inclination was greater than .93 (Table 2).

Of the 100 cases, eighty-three had at least one molar angulation outside of one standard deviation from the norm. Nineteen subjects had one molar angulation outside one standard deviation from the norm, twenty-four had two, twenty-eight presented with three and ten with all four. Two cases were treatment planned for rapid maxillary expansion despite the fact all four molar angulation were within normal limits. All three patients' treatment planned for archwire expansion had at least one molar angulation outside of one standard deviation from the norm. Three cases treated with rapid maxillary expansion had

one molar angulation outside the norm, two cases had two, three cases had three, and three cases had all four molars outside one standard deviation from the norm. Similarly, the cases treatment planned for archwire expansion with one case had one molar angulation outside one standard deviation from the norm, one had two and one had three.

Ultimately, twenty eight cases should have been treated with rapid palatal expansion that were not. Tweny-nine cases should have been treatment planned for archwire expansion that were not, and ten cases presented with a cant in the floor of the nasal cavity making it difficult to gauge true skeletal or dental disharmony.

DISCUSSION

Comprehensive diagnosis and treatment planning is key to successful orthodontic treatment. And, because malocclusion is not a disease, the diagnosis of malocclusion requires the clinician to assess each patient on esthetic and functional criteria. For example, traditional cephalometric analysis helped clinicians identify the spatial position of the maxilla, the maxillary teeth, the mandible and the mandibular teeth. Armed with this knowledge, the clinician is able to make a differential diagnosis of patients with class I, class II, and class III molar relationships. For example, the patient shown in

figure 13 has a class I molar relationship but the cephalometric radiograph shows the skeletal and dental components that combine to produce this class I molar. In this patient, the maxilla is orthognathic, the maxillary dentition is within normal limits, mandible is retrognathic and the mandibular dentition is protrusive. The protrusion of the mandibular teeth compensates for the retrognathic position of the mandible and results in a Angle Class I molar relationship. This type of dental compensation for skeletal discrepancies is common. In fact, dental compensations are the primary reason that 95% of the first molar occlusions in human beings show just 6 millimeters of variation (the difference between a Class III molar and a Class II molar). However, the range of variation in facial morphology is vastly greater than six millimeters. Cephalometrics allowed clinicians to recognize the skeletal and dental compensations present in their patients and to use this information to improve treatment outcomes.

Although two dimensional imaging has been used for many years, the clinician operates in a three dimensional world. All can agree that complete analysis in all three planes improves one's ability to properly assess a case. However, until recently the dental cast was the only three dimensional record used for orthodontic diagnosis and treatment planning. With the

advent of CBCT in 2001, the possibility of using a three dimensional radiographic record for diagnosis in orthodontics became a reality. As was the case with cephalometrics, the first analyses trailed the introduction of the technique by more than a decade. Today, we believe that the Case Western Reserve University Transverse Analysis offers additional and important information not commonly discovered with typical orthodontic imaging modalities. Many different dental and skeletal abnormalities which commonly go undiagnosed are readily detectable with this analysis. With this in mind we performed the CWRU analysis on 100 randomly selected patients in our clinic to determine how often the analysis would help the clinician make a better differential diagnosis of transverse conditions. We used a cut off point of one standard deviation above or below the established norms for maxillary and mandibular molar angulation as well as the presence of a posterior crossbite to identify patients whose treatment plan might be influenced by this 3D information. Using this criteria we found 83 cases where the data suggested a more careful analysis of the transverse dimension. We divided these patients into the following groups based on these criteria: (1) presenting with crossbite - normal angles, (2) presenting with crossbite - abnormal angles, (3) presenting without crossbite - normal angles, (4) presenting without crossbite - abnormal

angles (excess maxillary tip), (5) presenting without crossbite – abnormal angles (excess mandibular tip) (See Figure 14).

(1) Presenting with crossbite – normal angles

Case #87 presented with a unilateral crossbite, moderate upper and mild lower crowding, 20% overbite and 4mm of overjet (See Figure 15). She was treatment planned for upper and lower 7-7 bonding, and cross elastics to address the crossbite (upper left 6 and lower left 6). Due to the fact her upper left first molar angulation was 101.3° at the start of treatment (See Figure 16), it is possible that once the crossbite is corrected the upper left 6 will be well outside one standard deviation from the norm. Miyamoto et al found no statistical difference between the change in buccolingual inclination of maxillary molars and canines in patients treated with RPE pre- and posttreatment. With that in mind, this case would have been better suited for RME.

(2) Presenting with crossbite – abnormal angles

An example of this is case #13. He presented to the clinic at sixteen years of age with a unilateral posterior crossbite, subdivision malocclusion (class I left and class II right), 40% deep bite, 3mm of overjet and mild upper and lower crowding (See Figures 17 and 18). The treatment plan consisted of a Hyrax

expander, bonding upper and lower dentition and class II elastics or Forsus on the right side. Although CWRU Transverse Analysis was not used in 2010, rapid maxillary expansion may not have been indicated. Upon further investigation his maxillary right and left first molar angulations were 89.6° and 94.9°, respectively. The mandibular molar angulations were 89.2° for the right first molar and 78.8° for the left (See Figure 19). Ultimately, the patient had what would be classified as a dental crossbite and not a true transverse skeletal deficiency. Not only was the case misdiagnosed, expanding at too late of an age may have lead to other unnecessary complications. Despite the fact maxillary molars erupt with buccal crown torque and upright with age,[11] this patient represents an extreme and could have benefitted from buccal crown torque of the posterior segment.

3) Presenting without crossbite - normal angles

As doctors that work in bone, we have an obligation to at the very least maintain the periodontal health of the patient. Case #7 presented class I molar and canine right and left, ideal overbite, 5mm overjet, mild upper crowding and moderate lower crowding (See figure 20). Although her molar angulations were within normal limits, the upper right 6 was close to one standard deviation from the norm (104°) (See Figure 21). She was treatment planned for RME, upper and lower bonding with the

possibility of lower interproximal reduction if necessary. Although there are several indications for expansion, a contra indication should be tipping molars outside normal limits. Although conjecture, idealizing buccolingual inclination may increase maximum intercuspation, ultimately leading to more stable long term results.

4) Presenting without crossbite – abnormal angles (excess maxillary tip)

Patients may present with a skeletal transverse deficiency in the absence of a posterior crossbite. Case #24 presented with maxillary molars two standard deviations from the norm (114.8° and 112.3°), and mandibular molars within normal limits (70.7° and 72.9°). The patient began treatment class I molar and canine, 100% deep bite and retroclined upper and lower incisors (Figures 22 and 23). The treatment plan consisted of traditional upper and lower bonding with continuous arch mechanic and elastics for detailing. Ultimately, she was not treatment planned for RME, and this skeletal imbalance went undiagnosed throughout treatment. Just as mandibular retrognathia accompanied by proclined lower incisors are diagnosed and treated in the AP dimension, so too skeletal deficiencies with associated dental compensation should be treated for in the transverse dimension.

The idea of extracting teeth can be a scary concept for the patient and difficult decision for the clinician. In a study performed by Dr. Baumrind, clinicians could not agree on whether or not to extract on 34% of cases.[12] Although the number of extraction cases has decreased over the years, orthodontists are still looking for ways to avoid removing teeth when at all possible. Incisor protrusion is one of the most common reasons for extraction amongst clinicians.[13] Although this study did not assess canine angulations, borderline extraction cases may not require removal of teeth by establishing appropriate buccal inclination of canines and molars in situations where they are upright. Case #75 presented to the clinic class II molar and canine, 7mm of crowding in the upper arch, mild lower crowding and 90% overbite. Upper incisor angulation was within normal limits and the lower incisors were slightly proclined. Assessment of the soft tissue profile revealed an obtuse nasolabial angle, thin upper lip and no buccal corridors upon animation (Figure 24). Despite her soft tissue profile, the patient's treatment plan consisted of upper and lower bonding, Forsus for class II correction and re-evaluation for bicuspid extraction six months into treatment. The transverse analysis revealed maxillary molar angulations of 93.1° and 94° (Figure 25). Ultimately, the case was completed without the need for extractions, however, one must assume that if the CWRU

Transverse Analysis was used, the clinician would have known that bicuspid extractions would not be necessary prior to starting treatment. On occasion, there are situations where clinicians will "re-evaluate for possible extractions" well into treatment (hoping it will not be necessary). This causes unnecessary angst for the patient and extended treatment time.[14] If this analysis offers another means to avoid extractions, then it should be used when treatment planning all patients.

5) Presenting without crossbite – abnormal angles (excess mandibular tip).

Similarly, case #7 presented with lower molar angulations of 57.1° and 55.1° and maxillary molar angulations of 93.9° and 103° (See Figure 26). Initial records revealed class I molar and canine right, class I molar and class II canine left, 50% deep bite and little to no crowding in either arch (See Figure 27). The case was not treatment planned for RME. One would assume it would be best to align teeth along the alveolar process. Without sufficient bone this may not be possible. Idealizing molar angulations along the apical base should be addressed in pre-treatment objectives. Evaluating the transverse prior to initial bonding would have made that possible.

Although most cases fell within the aforementioned categories, there were some cases in which one molar angulation was below

one standard deviation from the norm while the contralateral molar was one standard deviation above. Asymmetries such as this were commonly found in the study and require further explanation:

Mandibular asymmetries in the transverse dimension

Skeletal asymmetries in the transverse dimension may not be visible via soft tissue evaluation. Case #21 is an example of a mandibular asymmetry with dental compensation in the maxillary posterior segment. The patient is class III molar and canine right, class I molar and canine left, 70% overbite, moderate upper and lower crowding, and upper 2's in crossbite (See Figures 28, 29 and 30). She was treatment planned for a bonded expander and asymmetric class III mechanics with elastics. Maxillary molar angulations were 93.7° and 113.2° (right and left). The mandibular right molar was 78.2° and left 72° (Figure 31). Due to the fact she presented with socked in class I occlusion on the left, one objective was to maintain the posterior occlusion on that side. However, the upper left molar is severely proclined (two standard deviations from the norm) and will be maintained upon debond. Although expansion has been proven to be a stable treatment option,[15] symmetric expansion in an asymmetric patient may lead to difficulty in idealizing the occlusion. In cases of subdivision malocclusions, asymmetric

mechanics are used in the anteroposterior dimension. Due to the fact that it has been proven that molar angulations after use of bonded expanders,[16] it is that much more important to note nothing was done to address the upper left posterior segment in the transverse dimension and that the upper right segment may become more retroclined with elastic wear. Is the A-P dimension more important than the transverse? Do we ignore the transverse in the absence of crossbites? All should agree that asymmetries must be diagnosed and treated in all dimensions.

Asymmetries in the nasomaxillary complex

In certain situations molar angulations can be deceiving. Case #20 presented at twelve years of age with a blocked out upper left 5, class II molar, class I canine left, class I molar and canine right, mild upper and lower crowding and no posterior crossbites (Figure 32). Her maxillary right and left molar angulations were 111.4° and 99°, respectively (Figure 33). Lower molar angulations were within normal limits, however, due to a cant in the floor of the nasal cavity the upper right 6 is far greater and upper left 6 is far less than it would have been in its absence. Despite the fact that the patient did not present with a posterior crossbite, she was treatment planned for expansion with a rapid palatal expander. Although expansion may be justified in this case, the patient presented for an

adjustment with a posterior crossbite twenty months into treatment. Identification of the cant in the palate and posterior segment may have prevented this issue. These types of asymmetries are more common than expected, and development of asymmetries in the nasal cavity peaks around the pubertal growth spurt.[17] On the other hand, case #59 presented for treatment with no posterior crossbite, super class I molar, class I canine, upper right 2 in crossbite and mild upper and lower crowding (Figure 34). Through evaluation of his soft tissue, a skeletal asymmetry was undetectable. However, his maxillary right molar angulation was 87.5° and left was 112.4°. Similarly, his mandibular right molar angulation was 76.2° and left 71.5° (Figure 35). Due to dental compensations, the skeletal asymmetry went undiagnosed. Throughout treatment the clinician had difficulty correcting the transverse and settling the occlusion on the left side. Identifying the asymmetry prior to bonding may have enabled the clinician to avoid this issue a year and a half into treatment. Whether the etiology of the asymmetry is skeletal, muscular, dental or functional, diagnosis prior to starting treatment is paramount.[18] Just as a short anterior cranial base may produce figures well outside norms for Steiner's analysis, so too cants in the nasal cavity may do the same. Ultimately, it is critical to not solely rely on molar

angulations but to also assess the nasomaxillary complex as a whole.

Conclusion

The Case Western Reserve Transverse Analysis is a reliable and important component to the diagnosis and treatment planning of orthodontic patients. Appropriate buccolingual inclinations of posterior teeth in the mandibular arch are standard amongst all facial types and growth patterns and differ to a small degree in the maxillary arch.[19,20] All in all, it is a key aspect of the ideal occlusion. Therefore, this method of measuring tooth angulation should be used on every orthodontic patient. However, the use of CBCT in orthodontics is a heavily debated topic. Valid concerns for radiation, efficacy and significance of incidental findings have been raised.[21] In that light, CBCT is not the first image modality that has faced resistance in orthodontics. The practicabillity of the cephalogram was questioned roughly 60 years ago by an incredibly respected orthodontist, Dr. Cecil Steiner.[22,23] To date, the lateral cephalogram is used to assess all orthodontic cases, and the Steiner analysis is a key component to it. Clinicians must ask themselves some important questions: would you attempt to complete a puzzle without all the pieces? Travel to a destination without a complete map? Due to the fact that

orthodontic cases are assessed down to the millimeter, concerns should be raised for the prevalence of variability in the diagnosing and treatment planning of cases.[24] Any diagnostic modality that can bring us closer to a standardized approach to the ideal occlusion should be embraced.

References

1. Halazonetis et. al., From 2-Dimensional Cephalograms to 3-Dimensional Computed Tomography Scans. Am J Orthod Dentofacial Orthop. 2005 May;127(5):627-37.
2. Cevidanes et. al., Three-Dimensional Cone-Beam Computed Tomography for Assessment of Mandibular Changes after Orthognathic Surgery. Am J Orthod Dentofacial Orthop 2007;131:44-50.
3. Haney et. al., Comparative Analysis of Traditional Radiographs and Cone Beam Computed Tomography Volumetric Images in the Diagnosis and Treatment Planning of Maxillary Impacted Canines. AM J Orthod Dentofacial Orthop 2010;137 (5):590-7.
4. American Board of Orthodontics. Objective Grading System for Dental Casts and Panoramic Radiographs. Am J Orthod Dentofacial Orthop 1998; 114:296-309.
5. Andrews LF, The Six Keys to Normal Occlusion. Am J Orthod 1944;30:196-205.
6. Podesser et. al., Quantitation of Transverse Maxillary Dimensions Using Computed Tomography: A Methodological and Reproducibility Study. Eur J Orthod. 2004 Apr;26(2):209-15.
7. Shewinvanakitkul et. al., Using CBCT to Measure Buccolingual Inclination of Mandibular Canines and First Molars. Masters Thesis, Case Western Reserve University, 2008.
8. Evangelinakis et. al., Changes in buccolingual inclination of mandibular canines and first molars after orthodontic treatment using CBCT. Masters thesis, Case Western Reserve University, 2010.
9. Karamitsou et. al., Pretreatment Buccal Inclination of Maxillary First Molars and Canines. Master's Thesis, Case Western Reserve University, 2010.
10. Miyamoto et. al., Changes in Buccolingual Inclination of Maxillary Canines and First Molars after Orthodontic Treatment. Masters thesis, Case Western Reserve University, 2011.
11. Streit et. al., Case Western Reserve Transverse Analysis-The Norms. Masters thesis, Case Western Reserve University, 2012.
10. Miner et. al., Cone-Beam Computed Tomography Transverse Analysis. Part I: Normative Data. Am J Orthod Dentofacial Orthop 2012; 142: 300-307.

11. Marshall et. al., Transverse Molar Movements During Growth. Am J Orthod Dentofacial Orthop 2003; 124:615-24.
12. Baumrind et. al., The Decision to Extract: Part I - Interclinician Agreement. Am J Orthod Dentofacial Orthop 1996; 109:297-309.
13. Baumrind et. al., The Decision to Extract: Part II. Analysis of Clinicians' Stated Reasons for Extraction. Am J Orthod Dentofacial Orthop 1996;109:393-402.
14. Skidmore et. al., Factors Influencing Treatment Time in Orthodontic Patients. Am J Orthod Dentofacial Orthop 2006; 129:230-8.
15. McNamara et. al., Rapid Maxillary Expansion Followed by Fixed Appliances: A Long Term Evaluation of Changes in Arch Dimension. Angle orthod. 2003 Aug;73(4):344-53.
16. Spillane et. al., Maxillary Adaptation to Expansion in the Mixed Dentition. Seminars in orthodontics 1995; Vol. 1, No. 3: 176-187.
17. Kyrkanides et. al., Skeletal Asymmetries of the Nasomaxillary Complex in Noncleft and Postsurgical Unilateral Cleft Lip and Palate Individuals.
18. Bishara et. al., Dental and Facial Asymmetries: A Review. The Angle Orthodontist 1994;64(2):89-98.
19. Janson et. al., Buccolingual inclinations of posterior teeth in subjects with different facial patterns. Am J Orthod Dentofacial Orthop 2004;125:316-22.
20. Ross VA et. al., Influence of vertical growth pattern on faciolingual inclinations and treatment mechanics. Am J Orthod Dentofacial Orthop 1990;98:422-9.
21. Halazonetis et. al., Cone-Beam Computed Tomography is not the Imaging Technique of Choice for Comprehensive Orthodontic Assessment. Am J Orthod Dentofacial Orthop 2012;141:403-09.
22. Larson et. al., Cone-Beam Computed Tomography is the Imaging Technique of Choice for Comprehensive Orthodontic Assessment. Am J Orthod Dentofacial Orthop 2012;141: 402-11.
23. Steiner, Cephalometrics for You and Me. Am J Orthod Dentofacial Orthop 1953;39:729-755.
24. Luke et. al., Consistency of Patient Classification in Orthodontic Diagnosis and Treatment Planning. The Angle Orthodontist 1998; 68:513-20.

TABLE 1. -- Descriptive Summary of Demographics, Expander Status and Crossbite Status (N=100)

Variables	Group	Total
Age	10 to 11	16
	12 to 13	49
	14 to 16	35
Gender	Males	44
	Females	56
Race	Caucasian	94
	Asian	2
	African American	3
	Hispanic	1
Expander Status	Expander	13
	No Expander	84
	Archwire Expansion	3
Crossbite status	No crossbite	89
	Unilateral crossbite	7
	Bilateral crossbite	4

TABLE 2 - Intra-Examiner Reliability of Maxillary and Mandibular Molars

Variables	Intra-class correlation
Maxillary Right First Molar	0.99
Maxillary Left First Molar	0.98
Mandibular Right First Molar	0.96
Mandibular Left First Molar	0.94

TABLE 3. -Descriptive Summary of Maxillary and Mandibular Molar Buccolingual Inclination

Variables (N = 100)	Minimum	Maximum	Copeland Mean+/- SD	Karamistou Mean +/- SD	Shewinvanakitkul Mean +/-SD	Streit Mean +/- SD
Upper right first molar (degrees)	87.2	114.8	98.5 +/- 5.8	99.2+/-5.4		Avg. right and left 100.1 +/- 4.1
Upper Left First Molar (degrees)	80.9	115.5	101.7 +/- 6.1	101.7+/- 5.4		
Lower Right First Molar (degrees)	57.1	89.2	72.8 +/- 5		Avg. right and left 74.6+/-4.7	Avg. right and left 76.7+/-4.6
Lower Left First Molar (degrees)	55.1	80.9	71.9 +/- 4.9			

TABLE 4. - Molar Angulations of each Subject

Case #	UR6	UL6	LR6	LL6
Case 1	100.1	98.8	67.5	71.9
Case 2	97.7	102.4	75.1	71.4
Case 3	91.4	98.8	67.3	70.7
Case 4	89.5	110.8	67.1	70.9
Case 5	91.2	99.7	72.5	70.8
Case 6	92.2	100.2	71.9	73.3
Case 7	93.9	103	57.1	55.1
Case 8	99.9	109.7	74.7	77.3
Case 9	95.6	99.4	74.8	73.8
Case 10	105.9	107	78	78.4
Case 11	93	102.8	68.4	70.4
Case 12	103.3	98.9	78.3	74.2
Case 13	89.7	94.9	89.3	78.7
Case 14	101.6	97.3	76.9	73.1
Case 15	88.9	110.1	67.2	70.5
Case 16	98.3	101.4	68.2	67.9
Case 17	98.7	96.4	75.7	68.7
Case 18	101.2	88.7	79	76
Case 19	100.6	99.1	70.2	67
	111.5	99.4	74.4	72.3

Case 20				
Case 21	93.7	113.2	78.1	72
Case 22	92.1	108.8	68.6	72.3
Case 23	96.1	103.7	69.9	65.1
Case 24	114.7	112.1	70.8	72.9
Case 25	99.1	105.5	68.9	63
Case 26	102.1	104.1	71.1	69
Case 27	103.6	98.3	71	71.8
Case 28	99.3	110	69.2	69
Case 29	106.9	114.4	72.3	71.9
Case 30	101.6	100.9	70.5	70.1
Case 31	89.5	110.1	66.2	68.2
Case 32	100.3	103.5	80.1	74.4
Case 33	96.5	100.8	71.9	70.3
Case 34	96.2	103.5	81.2	71.5
Case 35	103.2	110.7	73.6	67.4
Case 36	104.4	115.5	72.6	64.6
Case 37	104.5	110.5	69.6	71.7
Case 38	97.1	103.2	79.1	72.5
Case 39	98.2	101.8	76.4	78
Case 40	103.5	102.6	82.8	80.5
Case 41	104.6	107.2	67.4	62.2
Case 42	95.6	91.4	68.2	71.6
Case 43	101.1	101.2	74.3	75.2

Case 44	98.7	103	72.1	77.7
Case 45	104.5	107.1	70.8	67.2
Case 46	102.9	100.1	65.1	69.2
Case 47	87.2	98.6	71.1	70.6
Case 48	93.6	95.3	71	63.2
Case 49	92.2	96.7	76.7	73.5
Case 50	97.6	105.5	71.2	74.7
Case 51	95.7	105.5	72.5	66.7
Case 52	95.8	95.4	71.7	73.7
Case 53	104	103.1	75.5	78.8
Case 54	100.7	95	71.6	69.3
Case 55	109	109.5	72.7	66.5
Case 56	101.8	100.9	74.7	80.7
Case 57	97.7	102.6	77.5	72.8
Case 58	90.9	102.1	78.7	78.3
Case 59	87.5	112.8	76.2	71.8
Case 60	99.5	97.6	66.4	80.9
Case 61	94	109.1	62.8	65.6
Case 62	102.3	96	70.4	71.9
Case 63	89.2	102.7	66.2	64.5
Case 64	96.7	94.8	71.8	77.9
Case 65	90.5	100	64	60.9
Case 66	88.2	113.5	73.6	65.9
Case	91.4	95.8	83	72.4

67 Case				
68 Case	99.2	99.9	67.8	68.1
69 Case	95.5	99	82.9	79.3
70 Case	98.1	104.3	70.2	70.9
71 Case	96.7	80.9	73.8	69.3
72 Case	100.4	112.5	80.9	78
73 Case	103.1	101.9	72.2	73.4
74 Case	89.2	97.7	69.7	67.8
75 Case	93.1	94.7	76.8	75.9
76 Case	102.2	96.3	70.1	72.3
77 Case	112.3	94.9	70.6	76.7
78 Case	92.2	93.5	77.1	65.4
79 Case	97.6	90.2	68.7	80.4
80 Case	101.8	100.8	72.7	71
81 Case	104	101.2	77.2	76.8
82 Case	95.6	105	80	77.2
83 Case	103.1	105.3	75.5	76.3
84 Case	98.8	103.5	70.5	72.6
85 Case	100.1	99.8	77	79
86 Case	100.2	101.3	77	73
87 Case	99	101.3	77.2	78.2
88 Case	96.4	96	69.6	71.6
89 Case	101.3	97.2	72.9	70.8
90	103.8	100.5	70.7	76.3

Case 91	110.9	107.1	76.5	78.2
Case 92	98.8	105	68.5	64.7
Case 93	105.7	92.1	69.6	71.6
Case 94	104.3	88.3	71.9	76.4
Case 95	99.3	100.3	71.3	68.2
Case 96	99.1	101	73.4	70
Case 97	91.3	101.8	74.3	71.7
Case 98	101.5	104.4	79.3	79.6
Case 99	102.6	100.6	73	78.6
Case 100	91.1	100.2	64.8	68.4

Figure 1. Orientation: In the sagittal view orient the line which represents the axial view so that it passes through ANS.

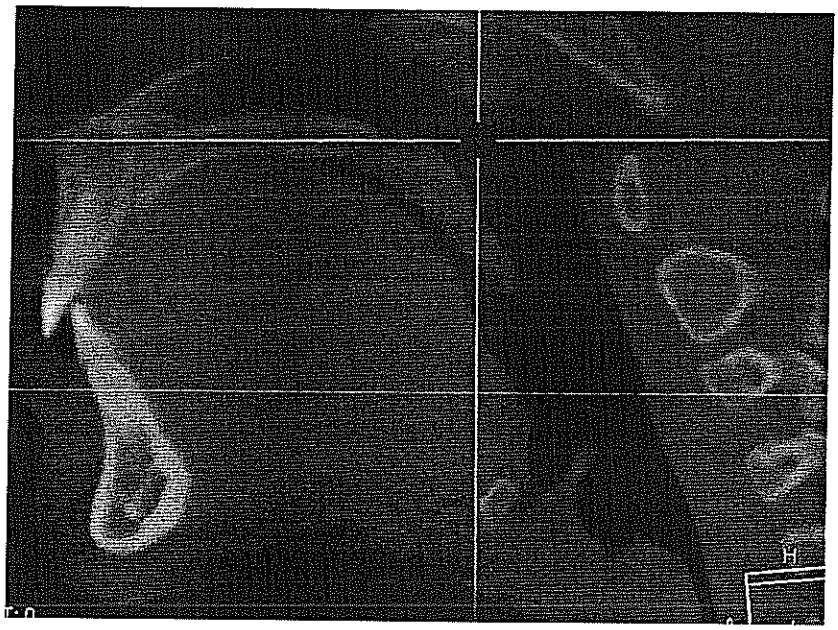


Figure 2. In the axial view locate the ANS (point where coronal and sagittal plane meet).

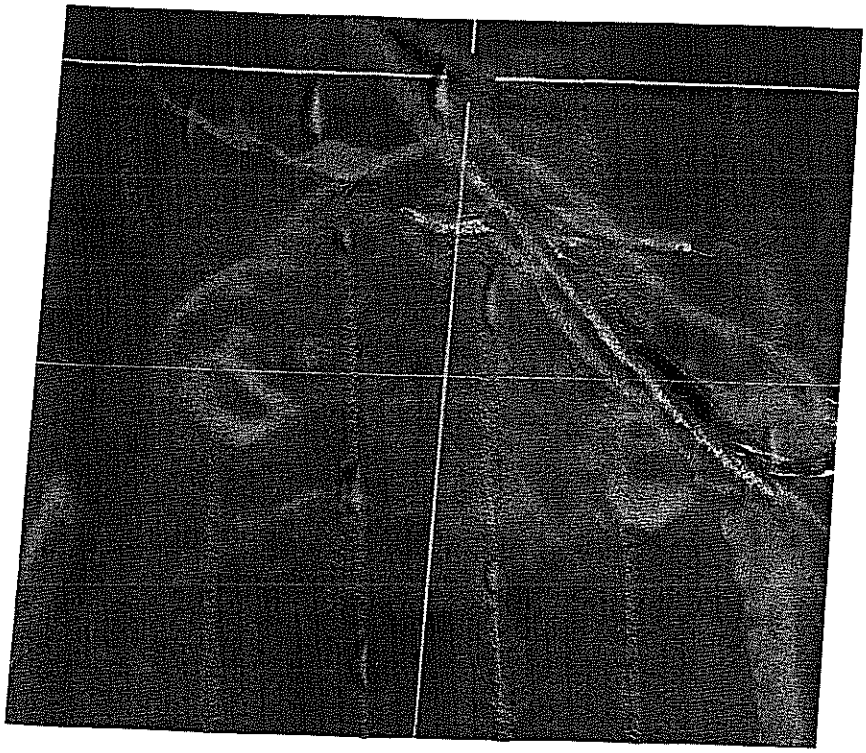


Figure 3. In the sagittal view move the line which represents the axial view downwards so that it passes through the center of the atlas.



Figure 4. Go back to the axial view rotate the line that represents the sagittal plane around the ANS so that it passes through the center of the odontoid process.

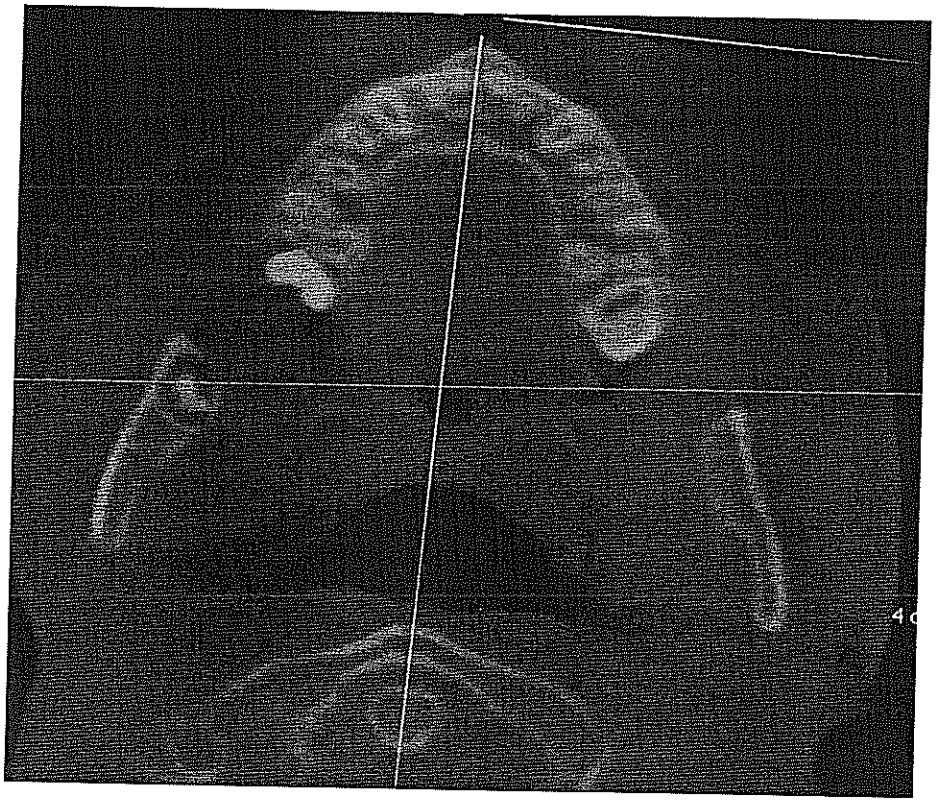


Figure 5. Locate molar in axial view, the point at which the palatal root length is the longest in the sagittal view.

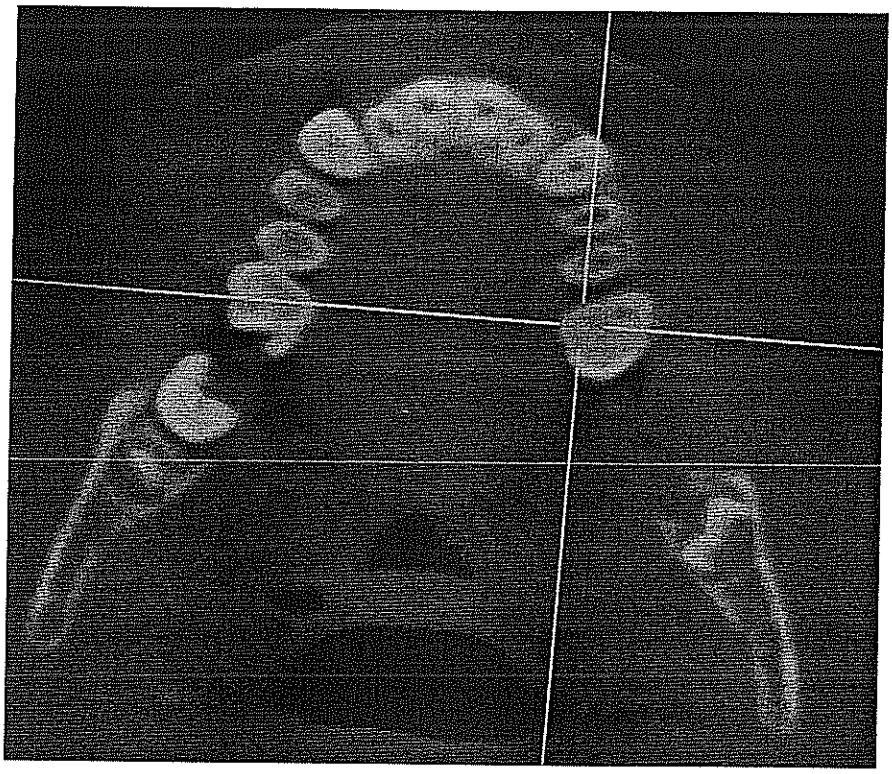


Figure 6. In sagittal view, position the line representing the coronal slice along the mesiopalatal cusp tip and the palatal root apex.

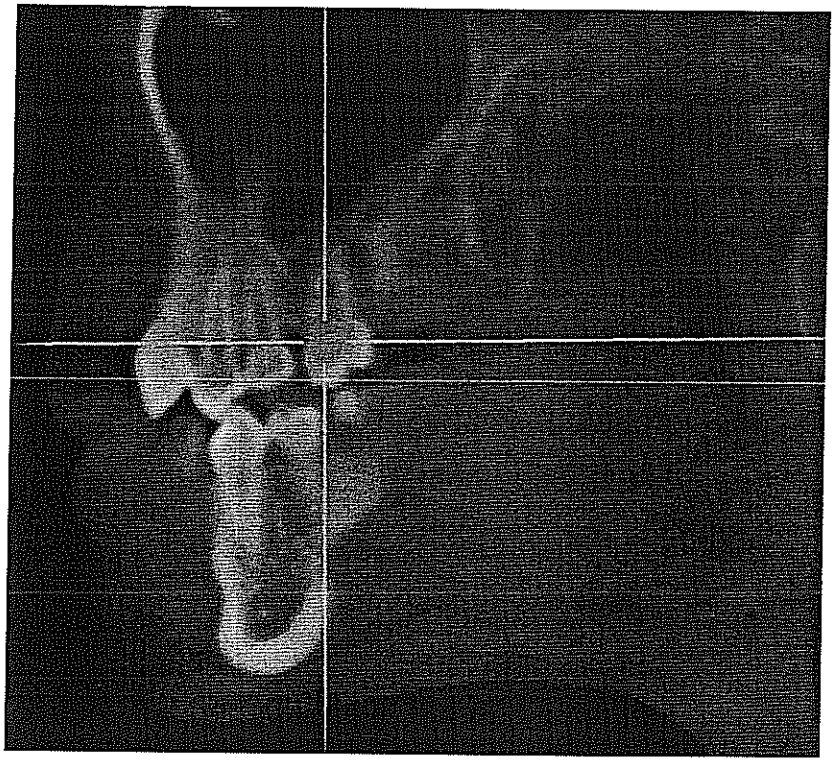


Figure 7. In coronal view, draw the reference line tangent to the inferior border of nasal cavity.

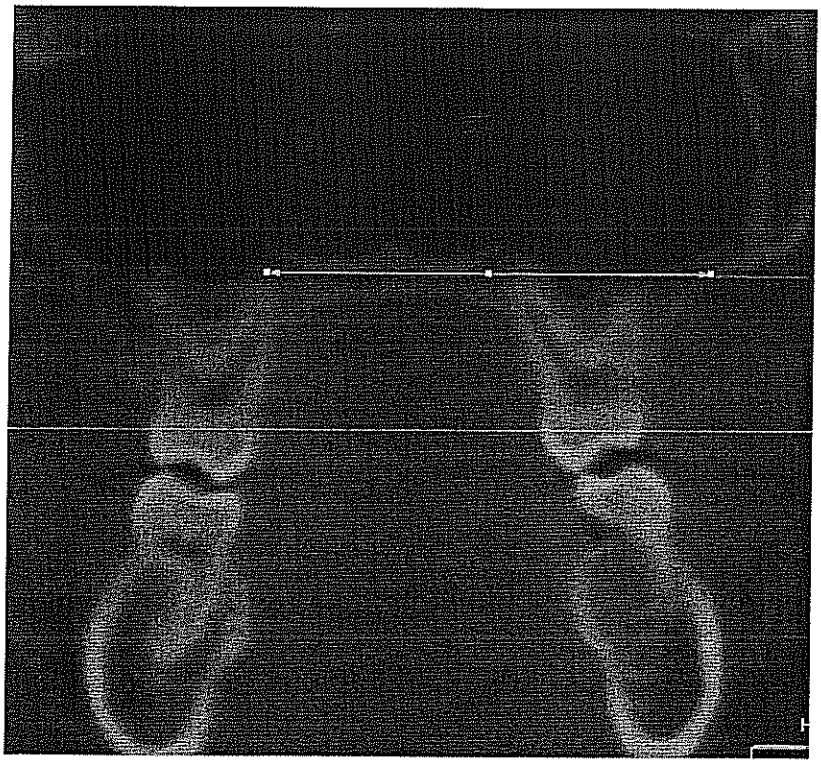


Figure 8. Measure the inclination through the long axis of the molar (represented by a line through the apex of the palatal root and the cusp tip) in the coronal view.

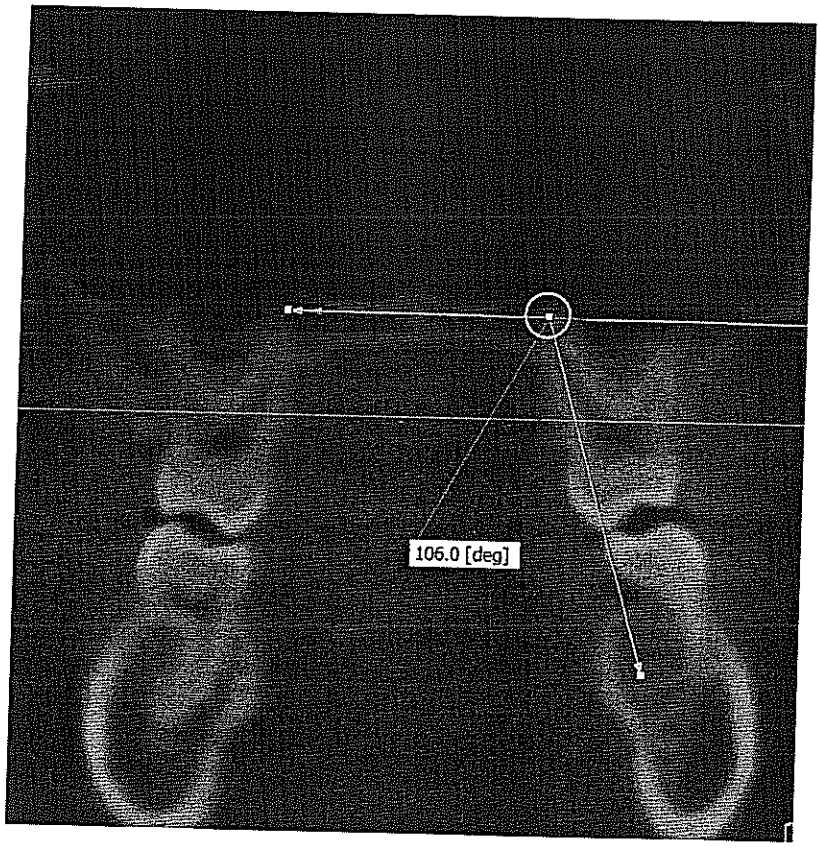


Figure 9. Locate the molar in the axial view, the point at which the roots are longest in the sagittal view.

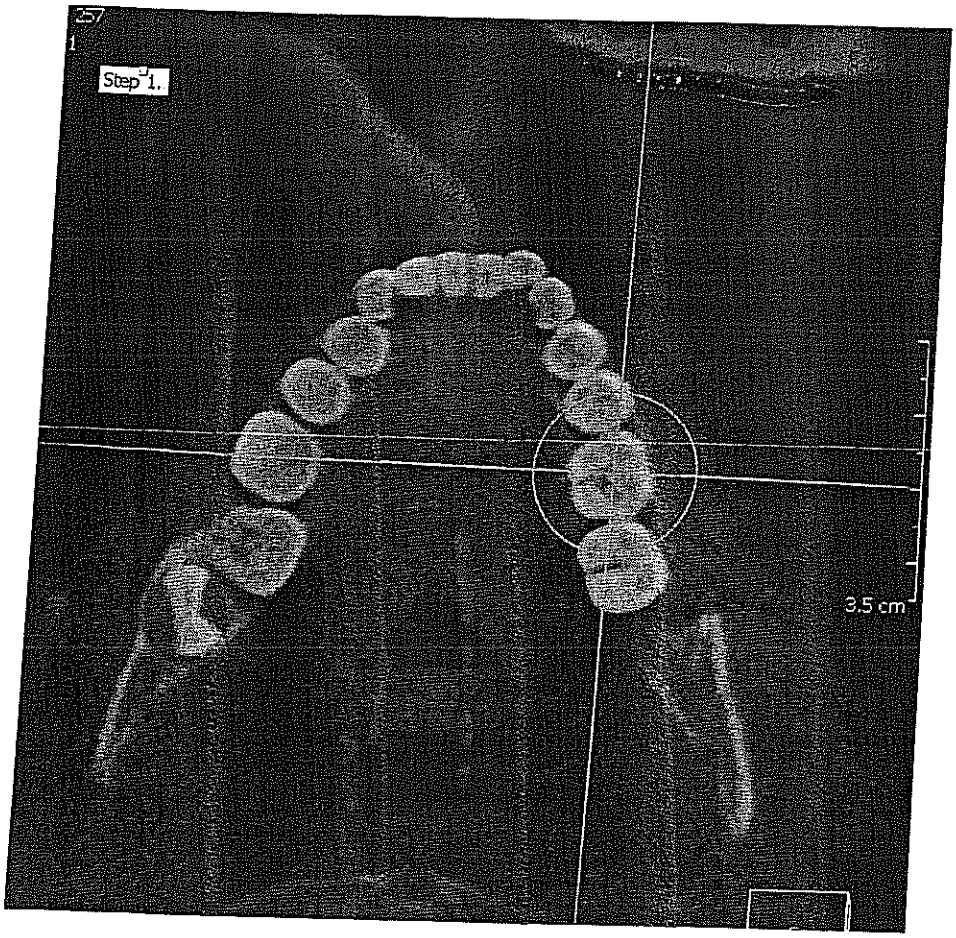


Figure 10. Position the coronal line along the long axis of the tooth (mesial cusp tip to mesial root apex).

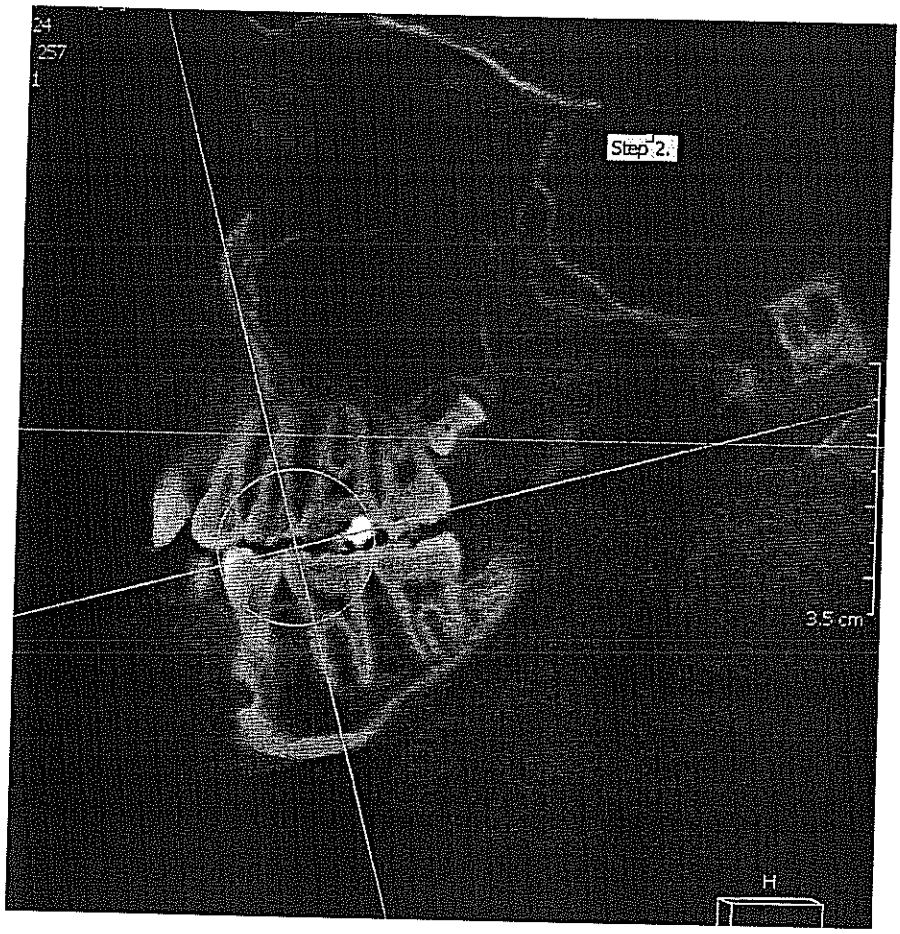


Figure 11. Draw a reference line tangent to the inferior border of the mandible in the coronal view.

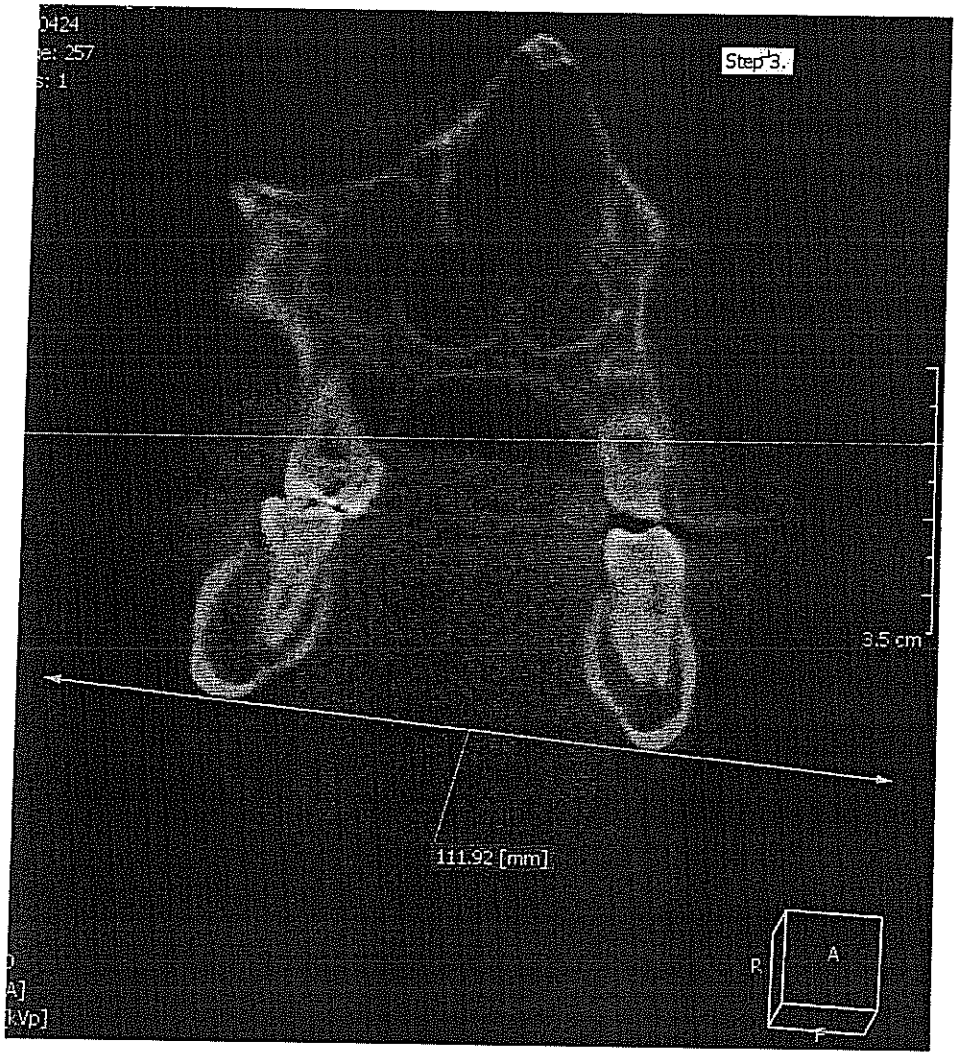


Figure 12. Measure the inclination which is the angle between the line passing the long axis of the molar and the reference line.

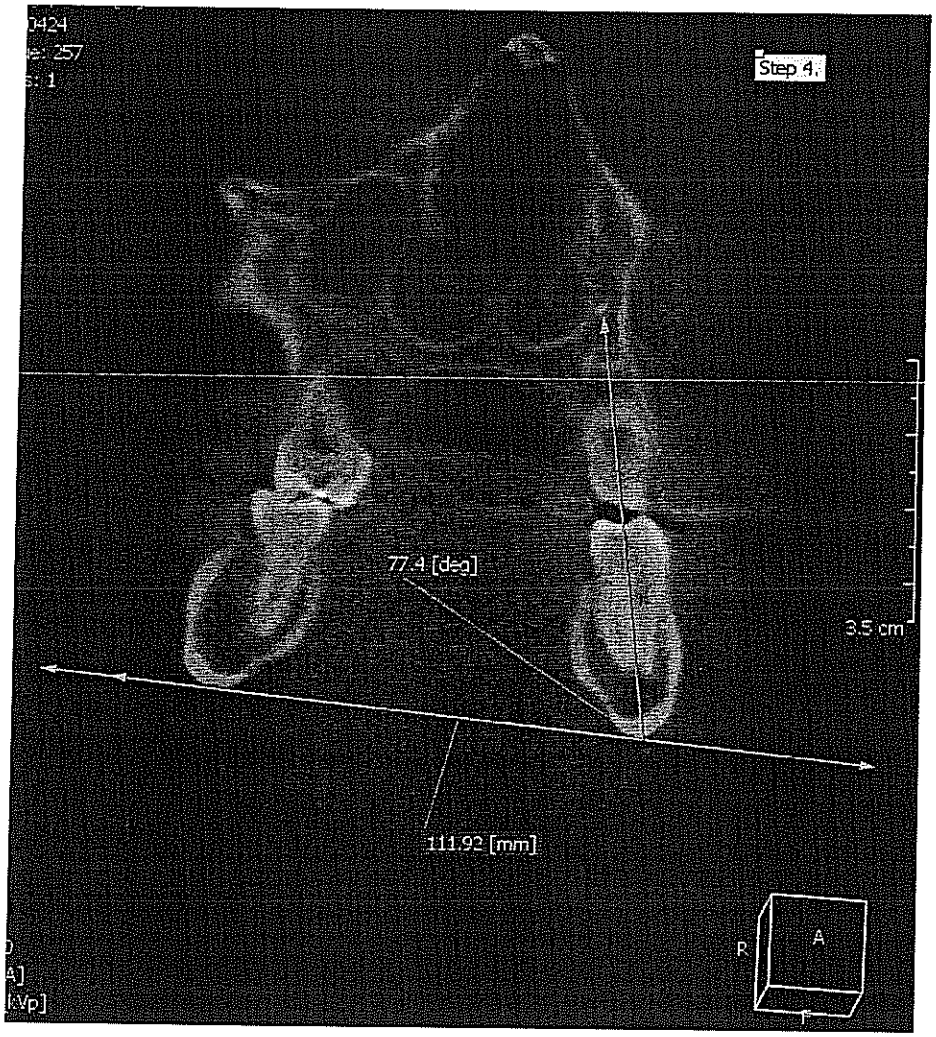


Figure 13. Example of dental compensation for a skeletal discrepancy in the anteroposterior dimension.

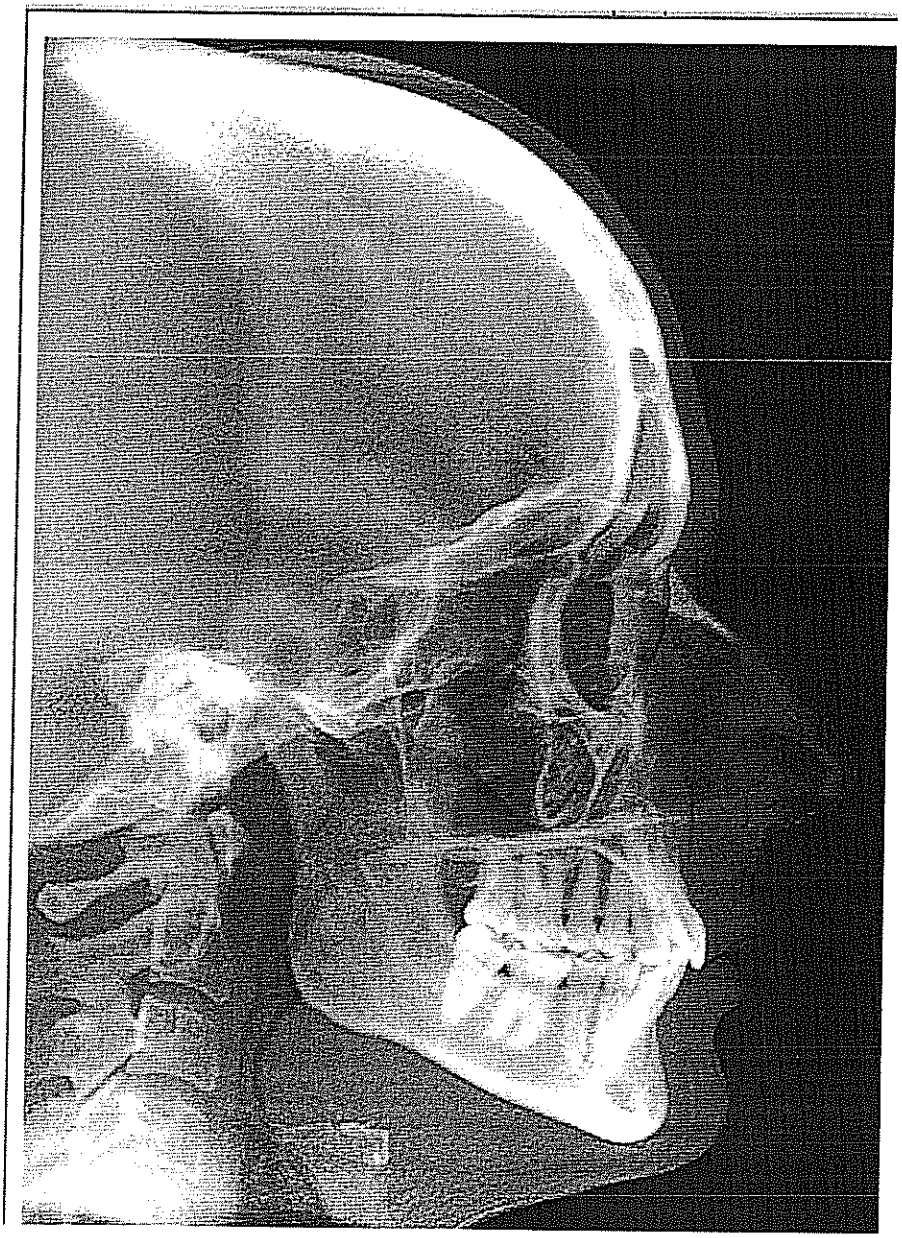


Figure 14. CWRU Transverse Analysis

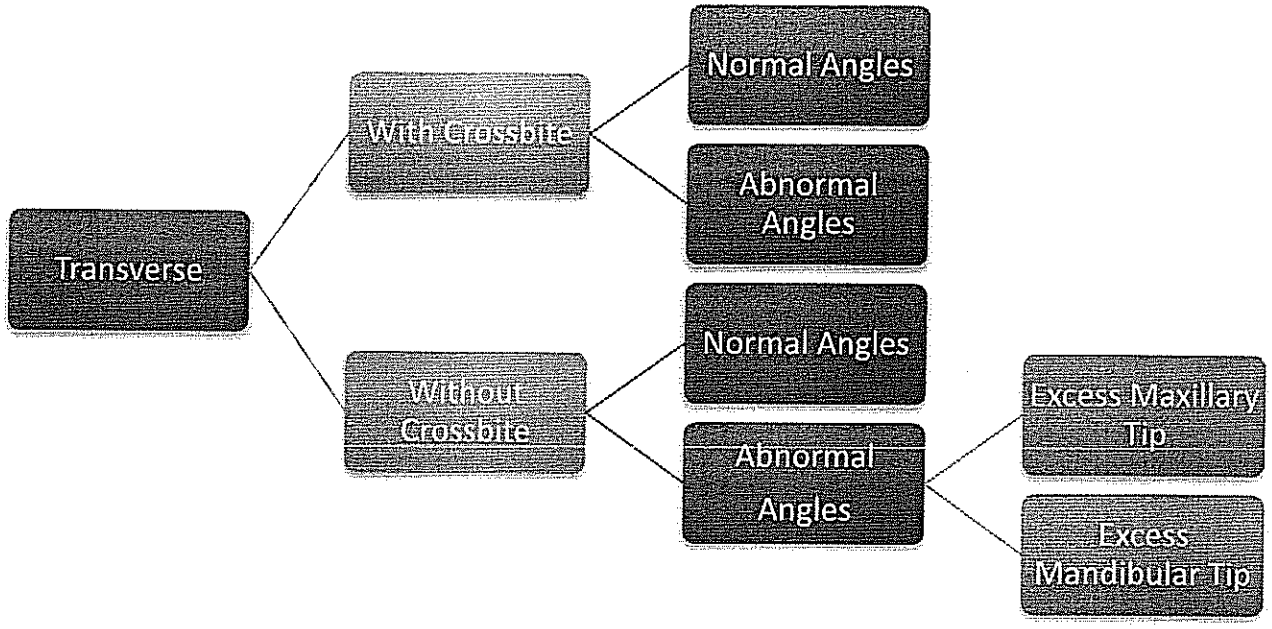


Figure 15. Case #87 composite

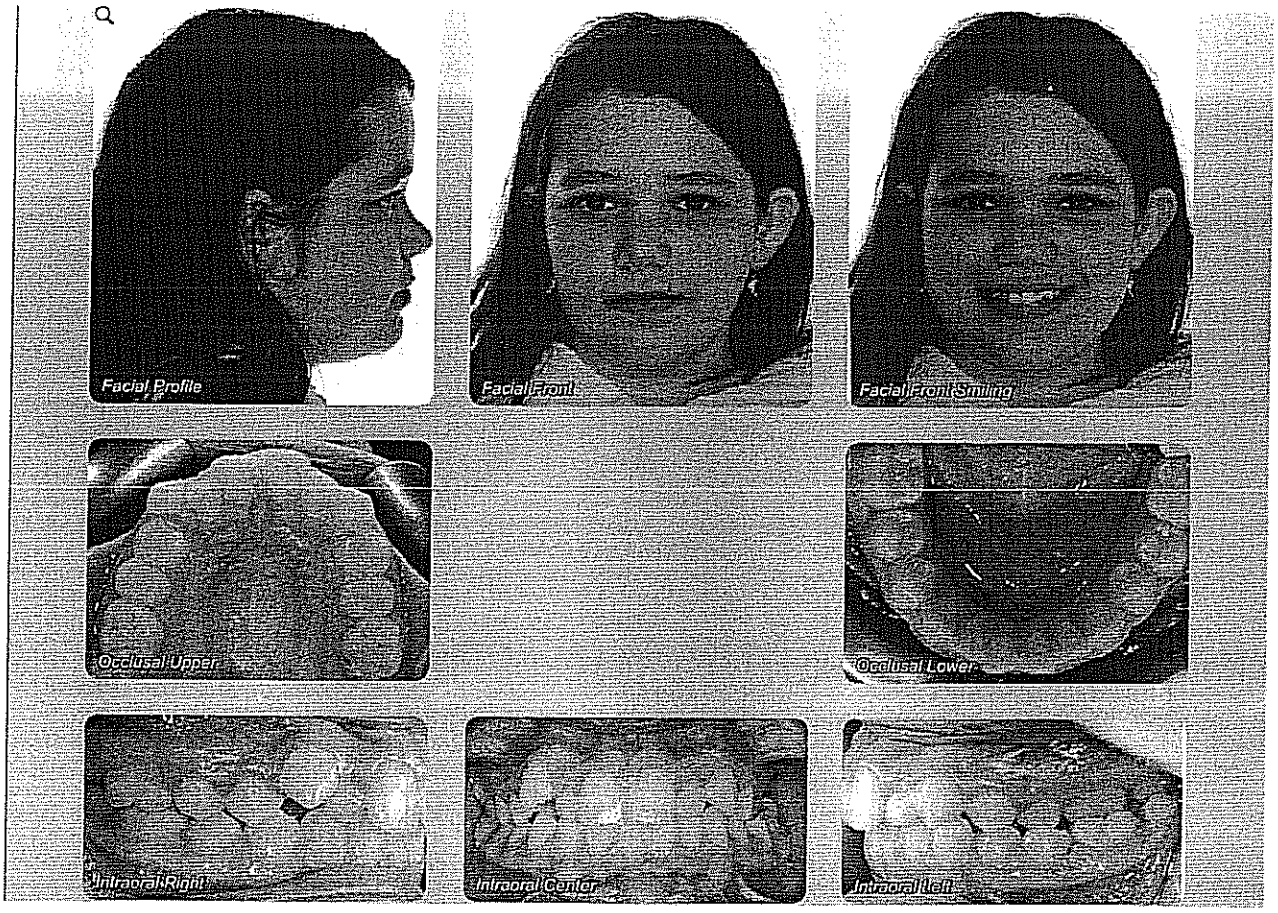
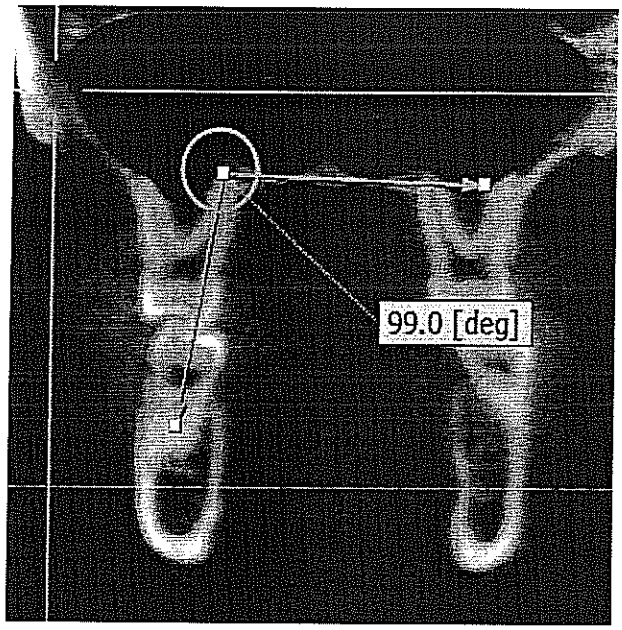
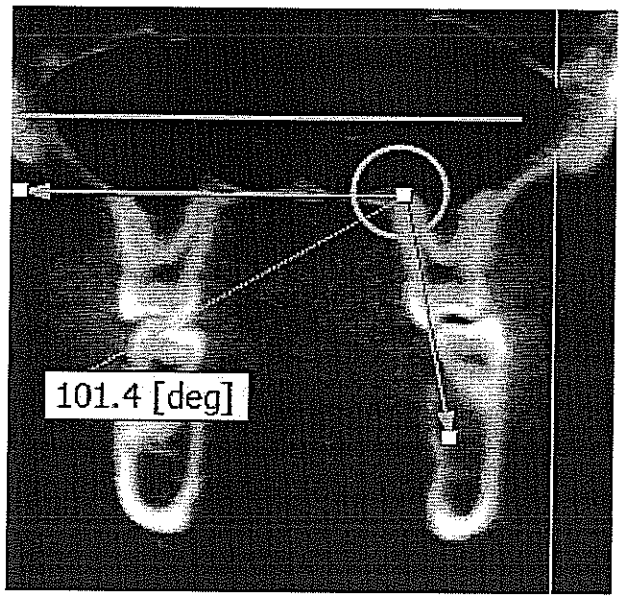
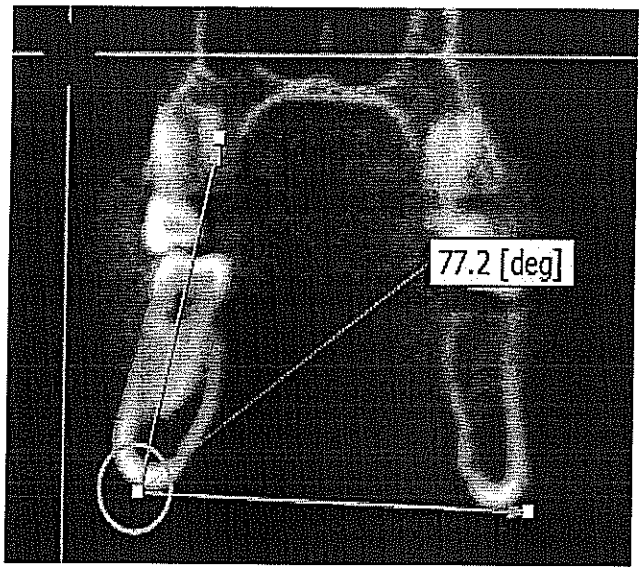


Figure 16. Molar Angulations






77.2 [deg]

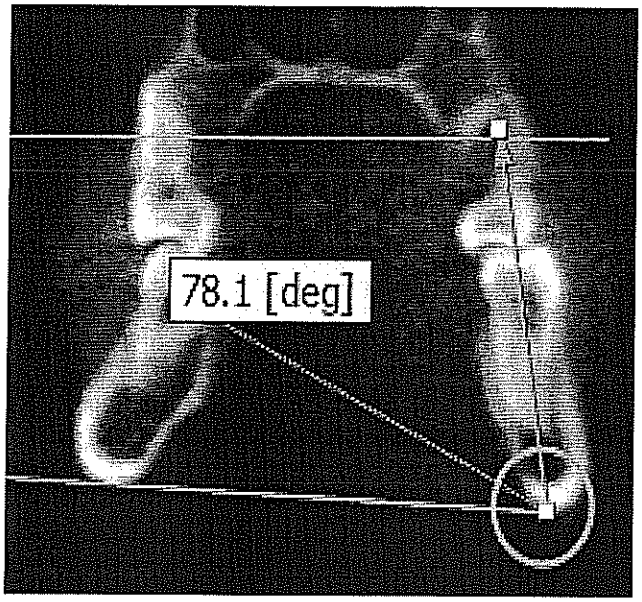

78.1 [deg]

Figure 17. Case #13 composite

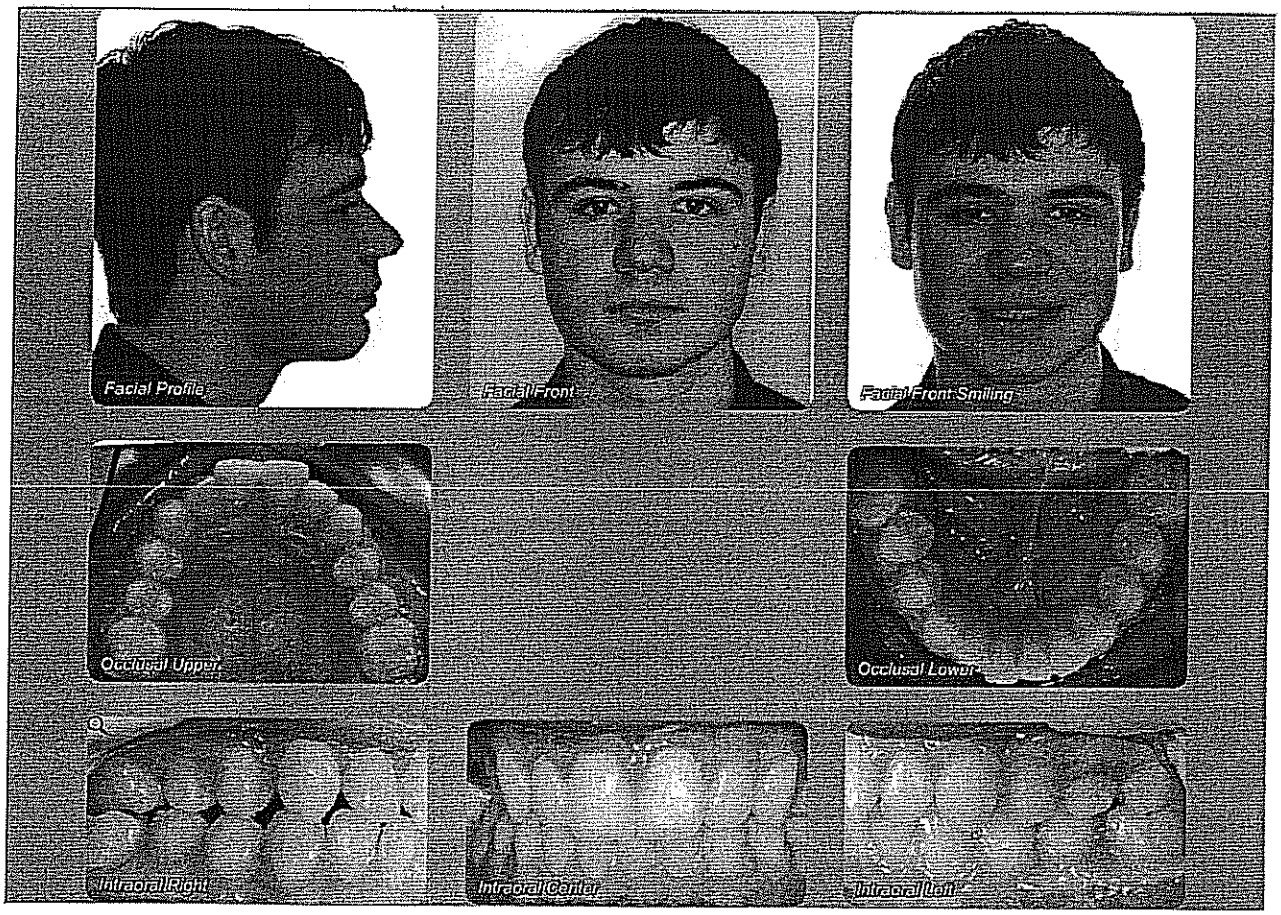
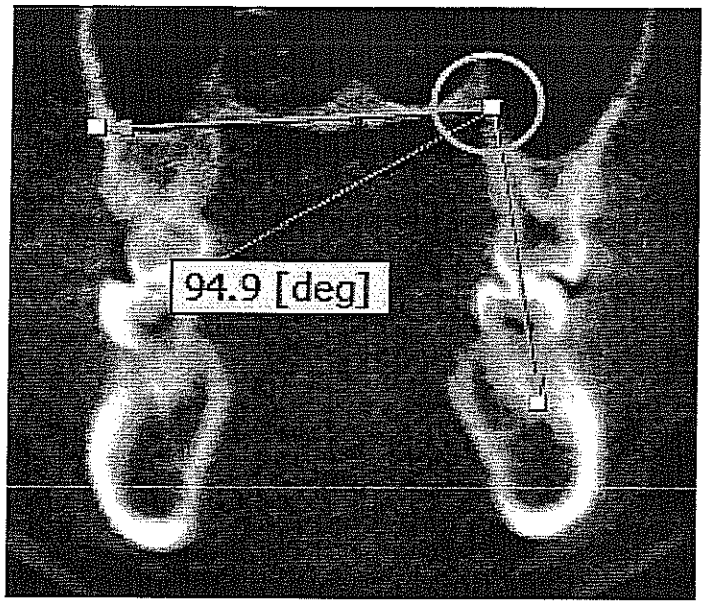
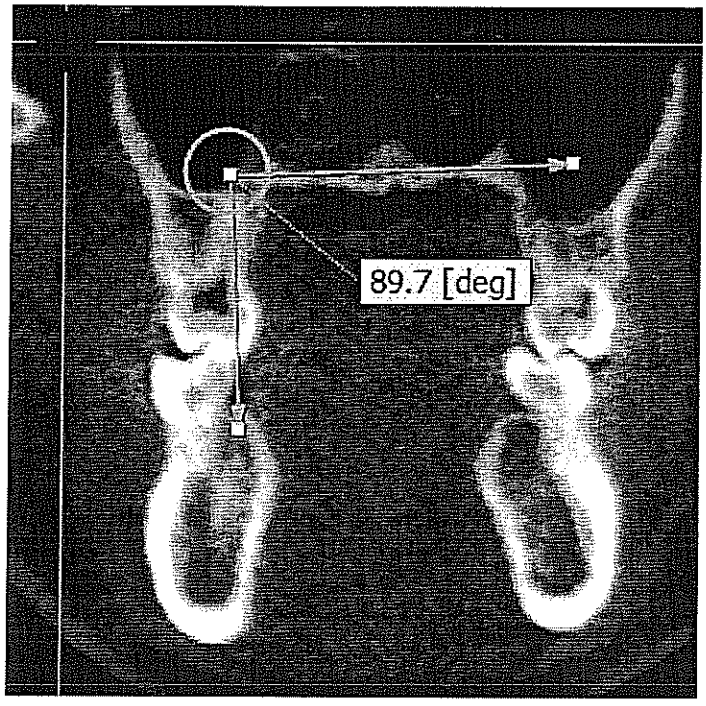


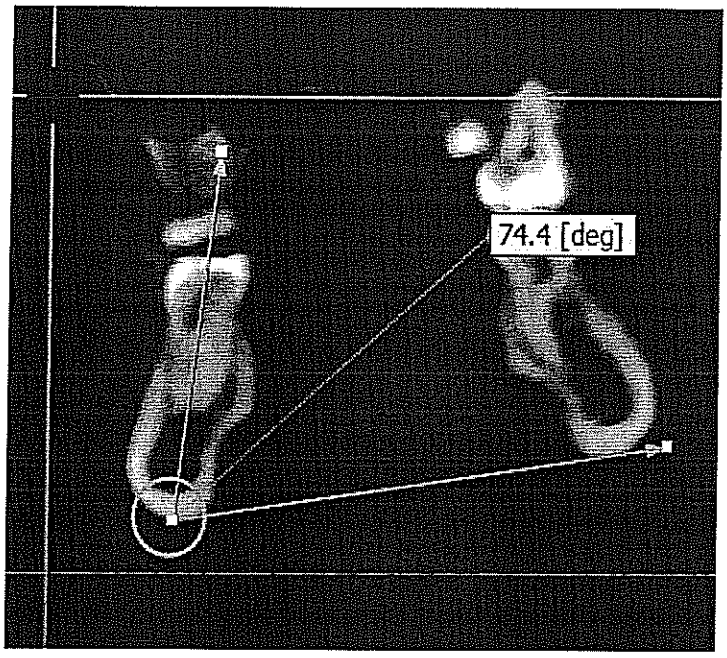
Figure 18. Case #13 CBCT Scan



Figure 19. Case #13 Molar Angulations






74.4 [deg]

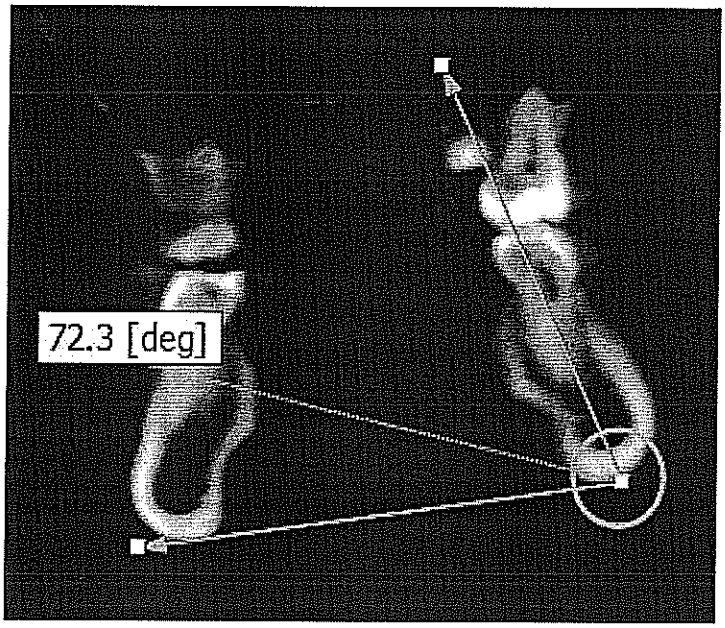

72.3 [deg]

Figure 20. Case #99 composite

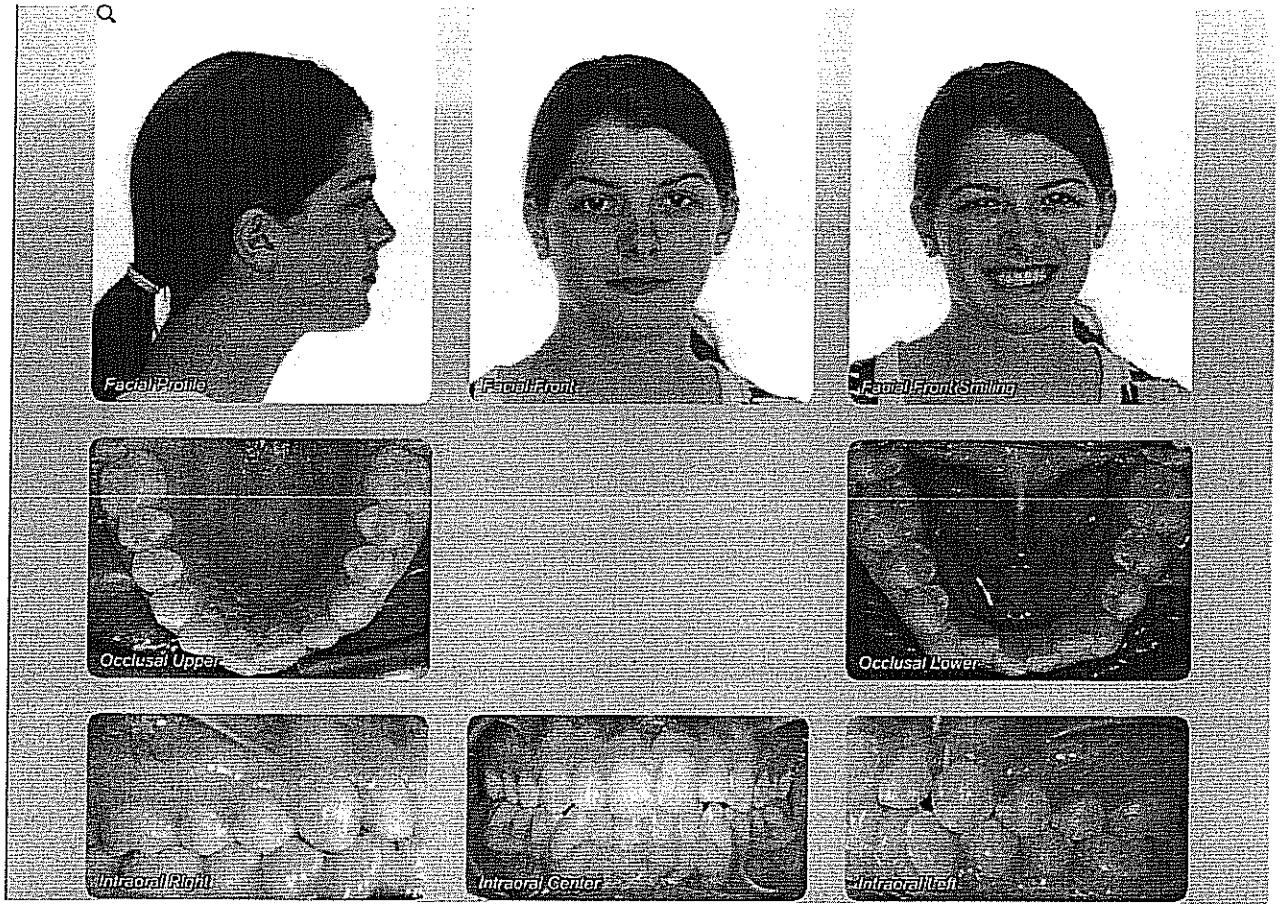
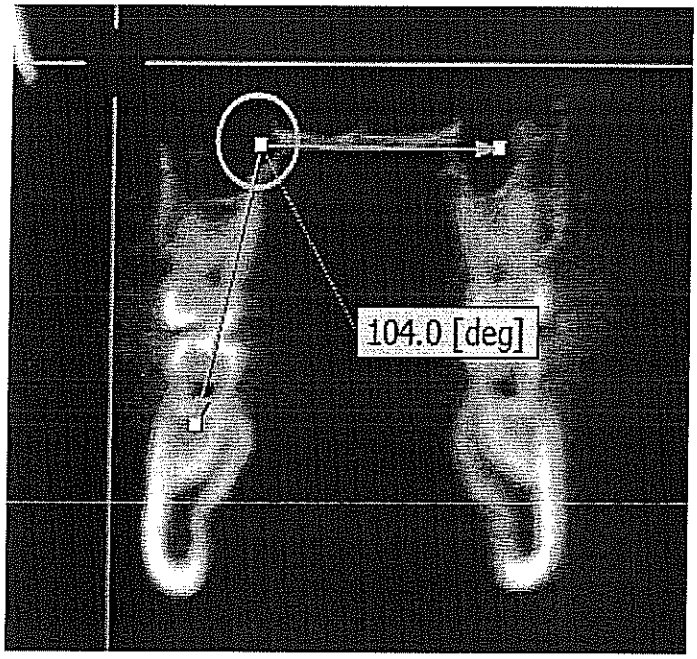
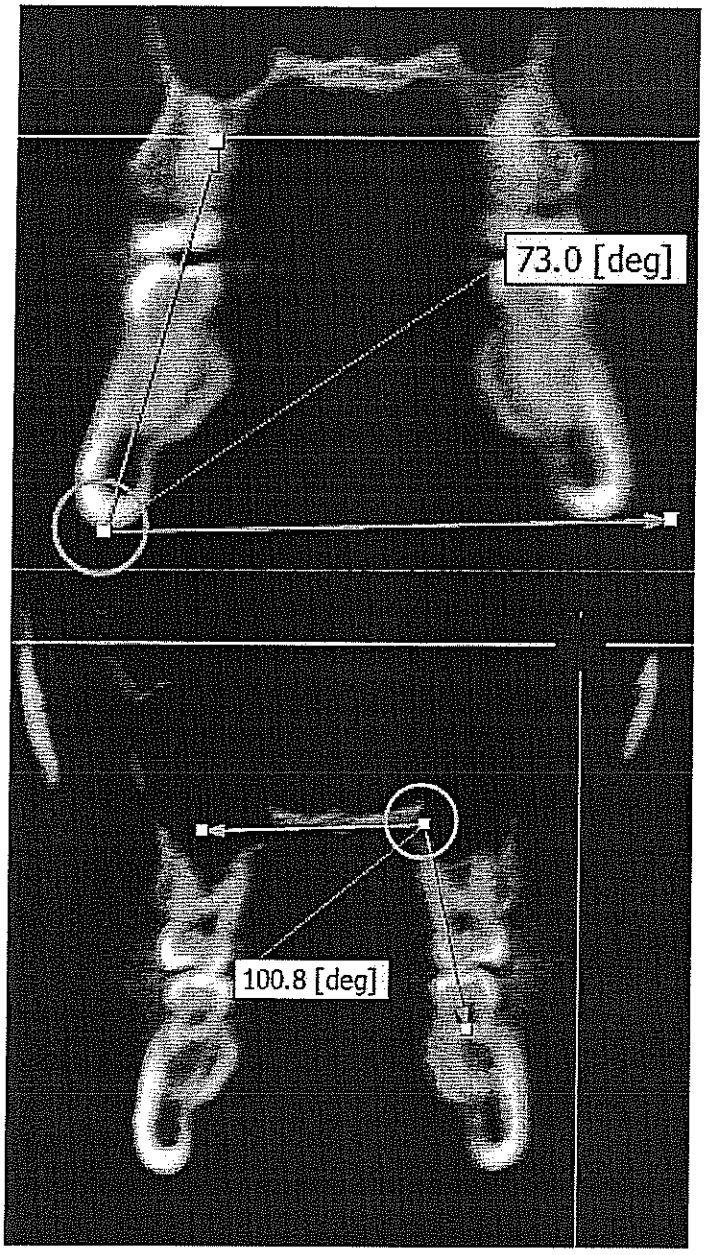


Figure 21. Molar Angulations




73.0 [deg]
100.8 [deg]

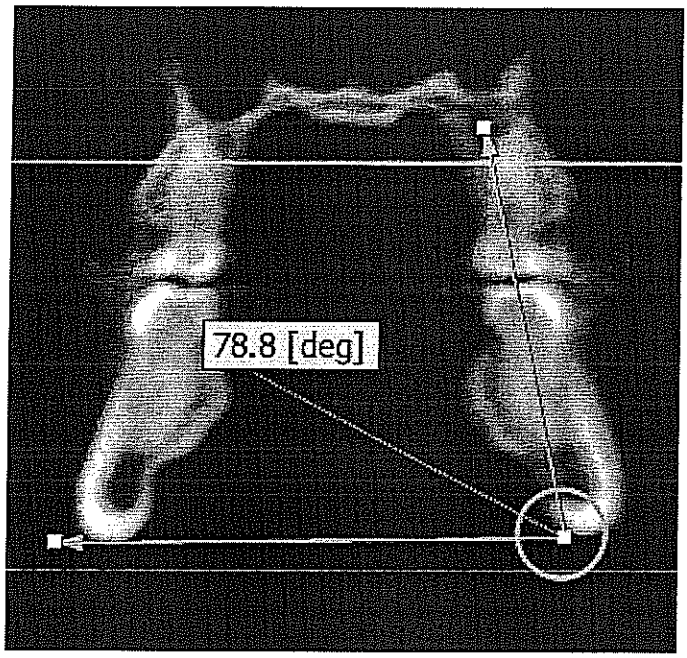

78.8 [deg]

Figure 22. Case#24 Composite

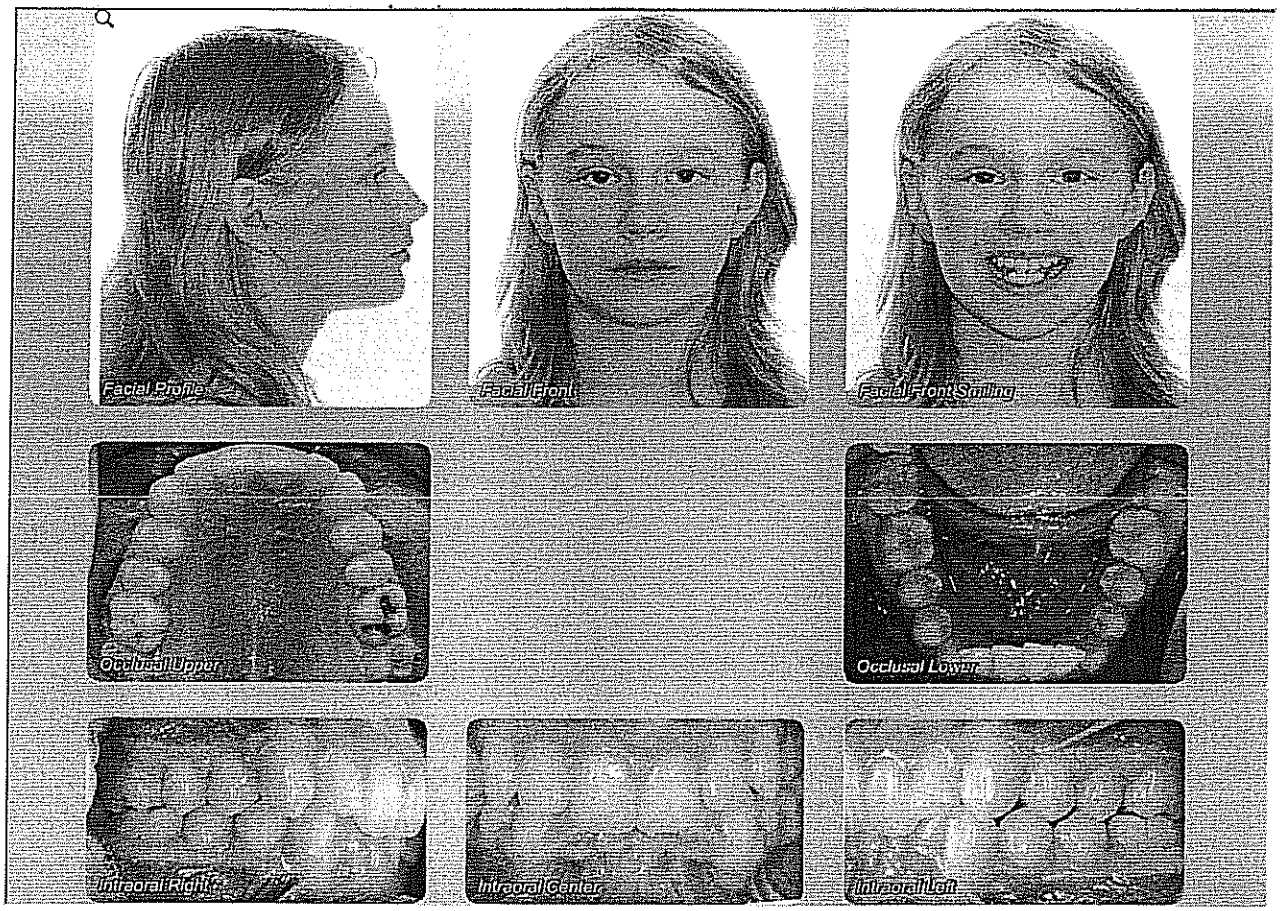
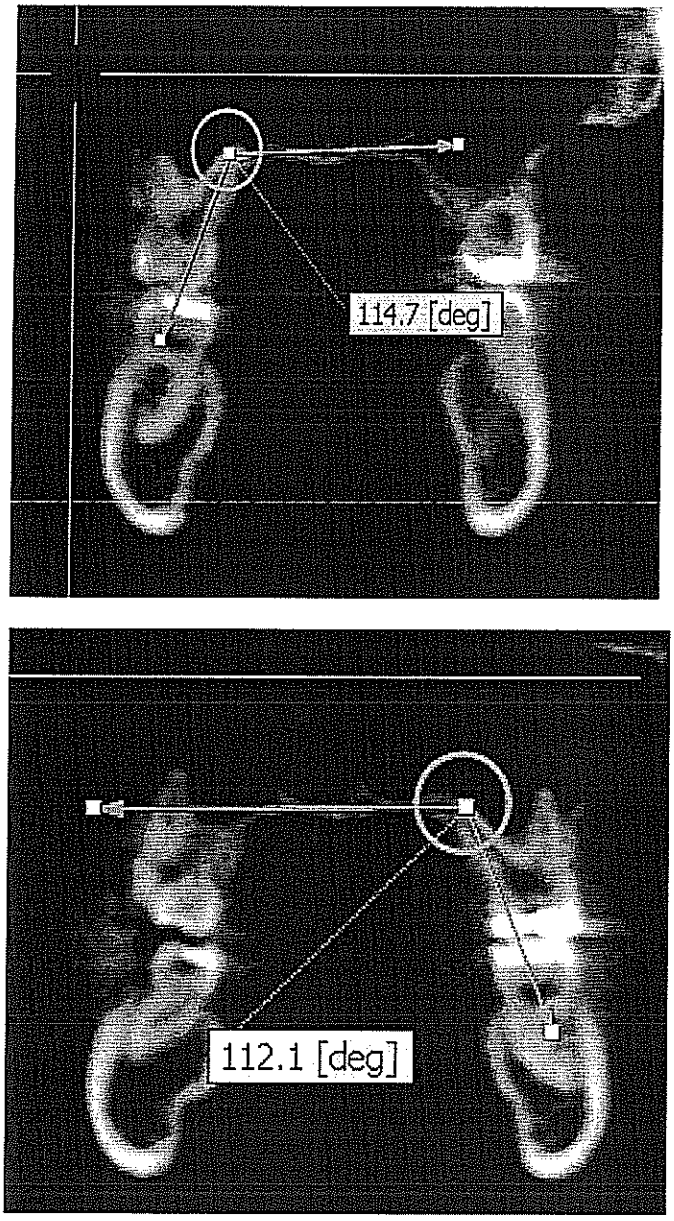
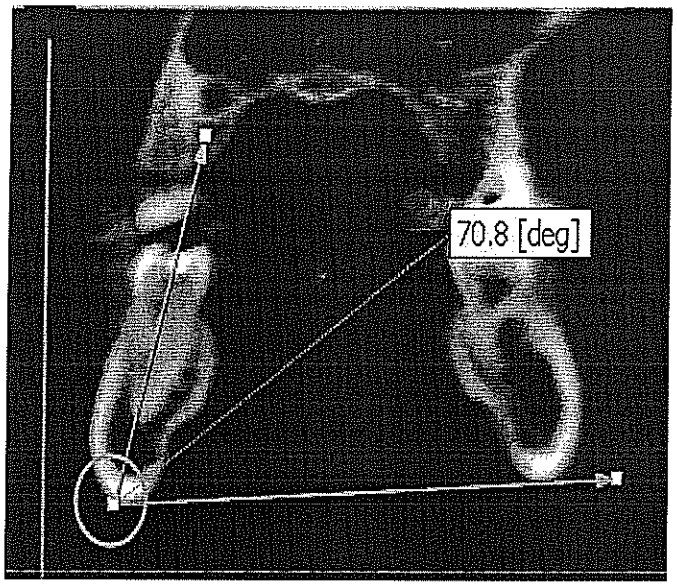


Figure 23. Case#24 Molar Angulations




70.8 [deg]

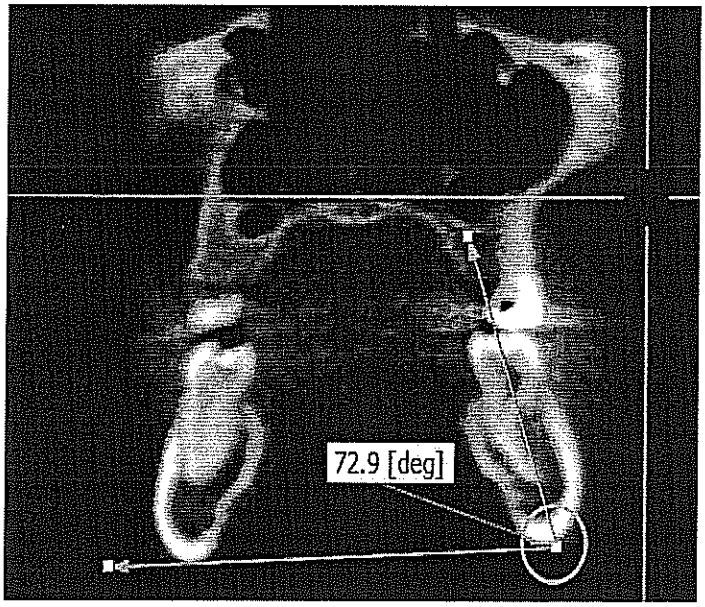

72.9 [deg]

Figure 24. Case #75 composite

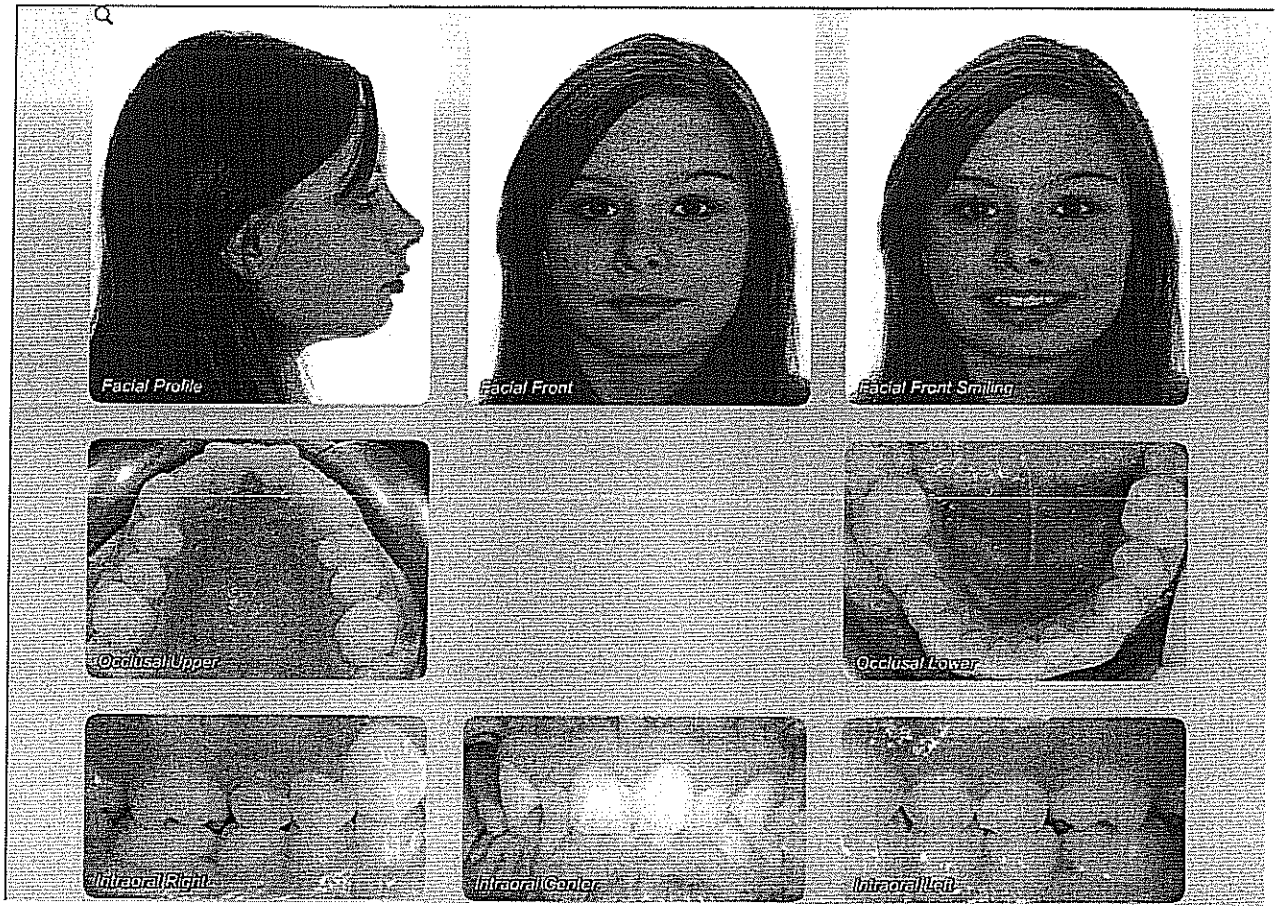
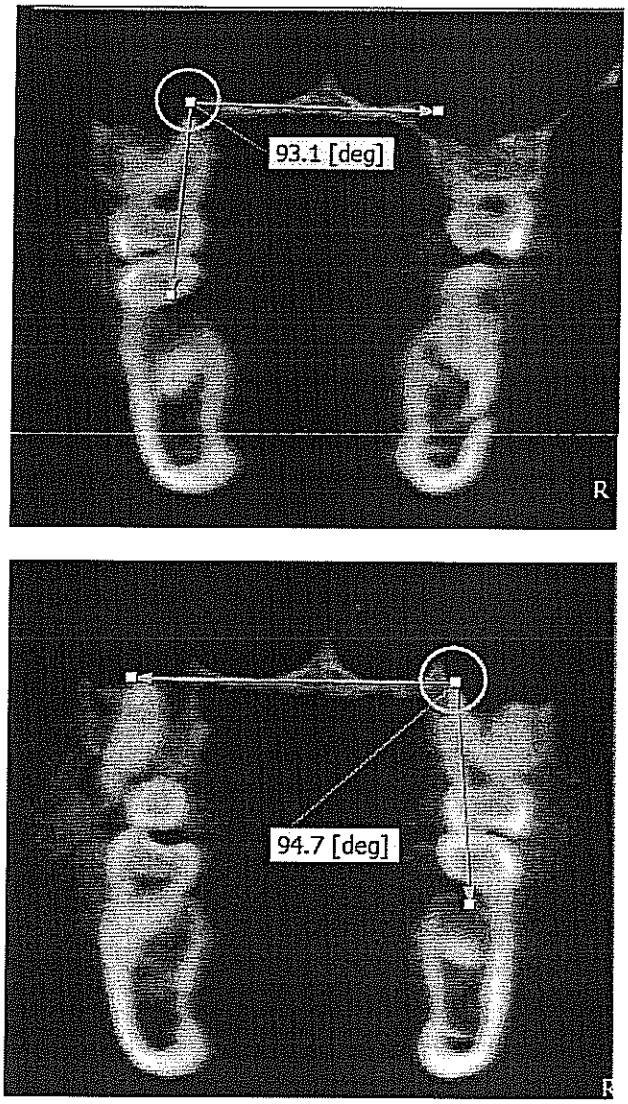


Figure 25. Molar Angulations




76.8 [deg]

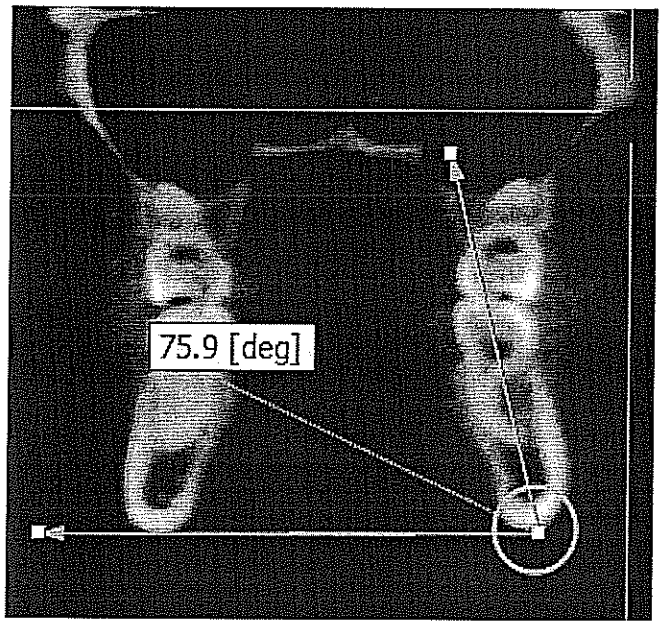
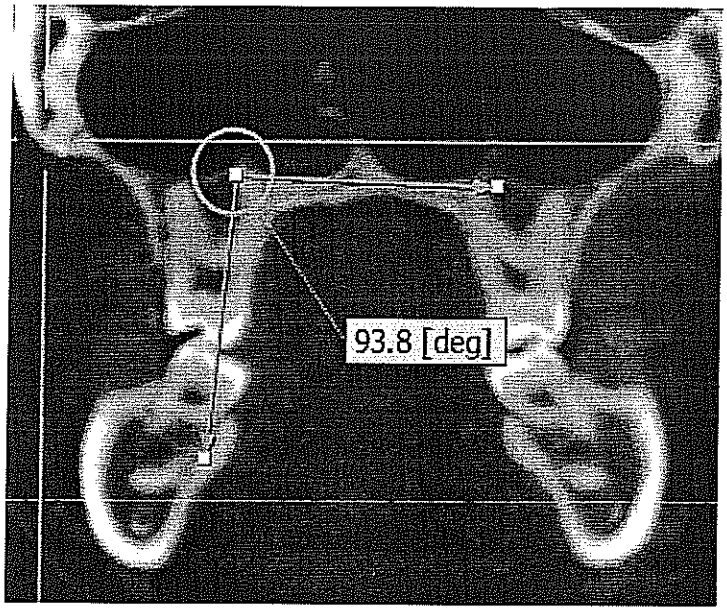
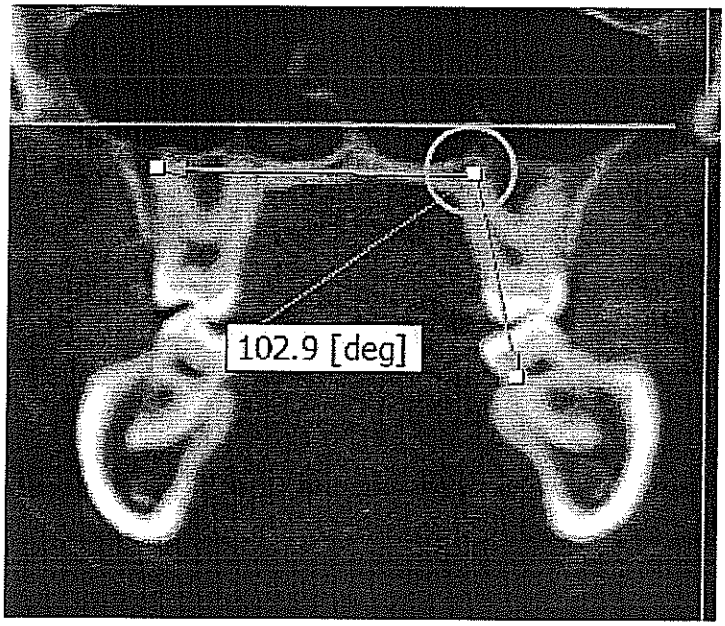
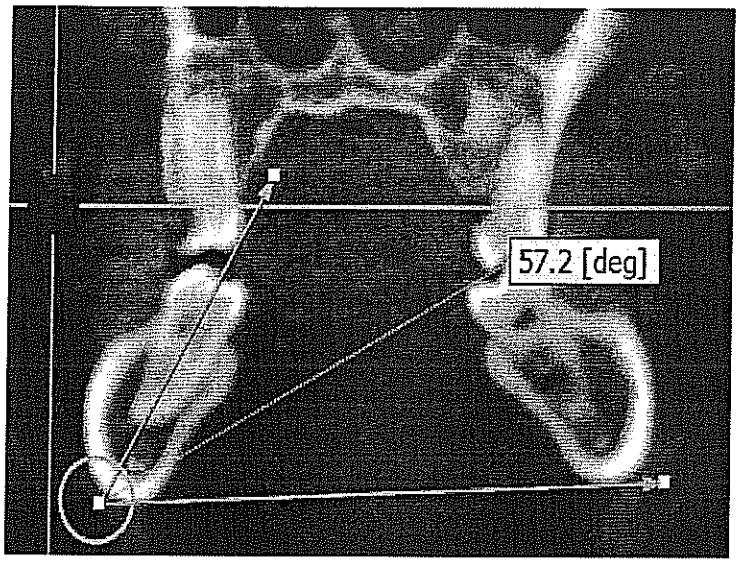

75.9 [deg]

Figure 26. Molar Angulations






57.2 [deg]

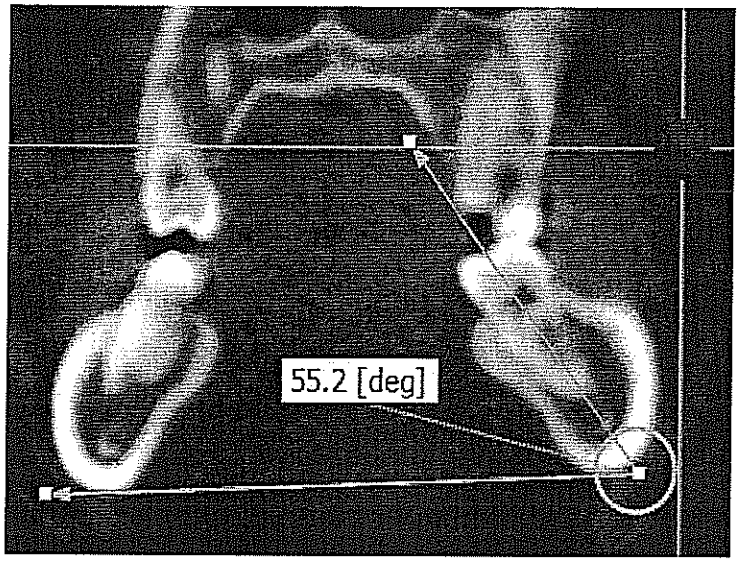

55.2 [deg]

Figure 27. Case # 7 composite

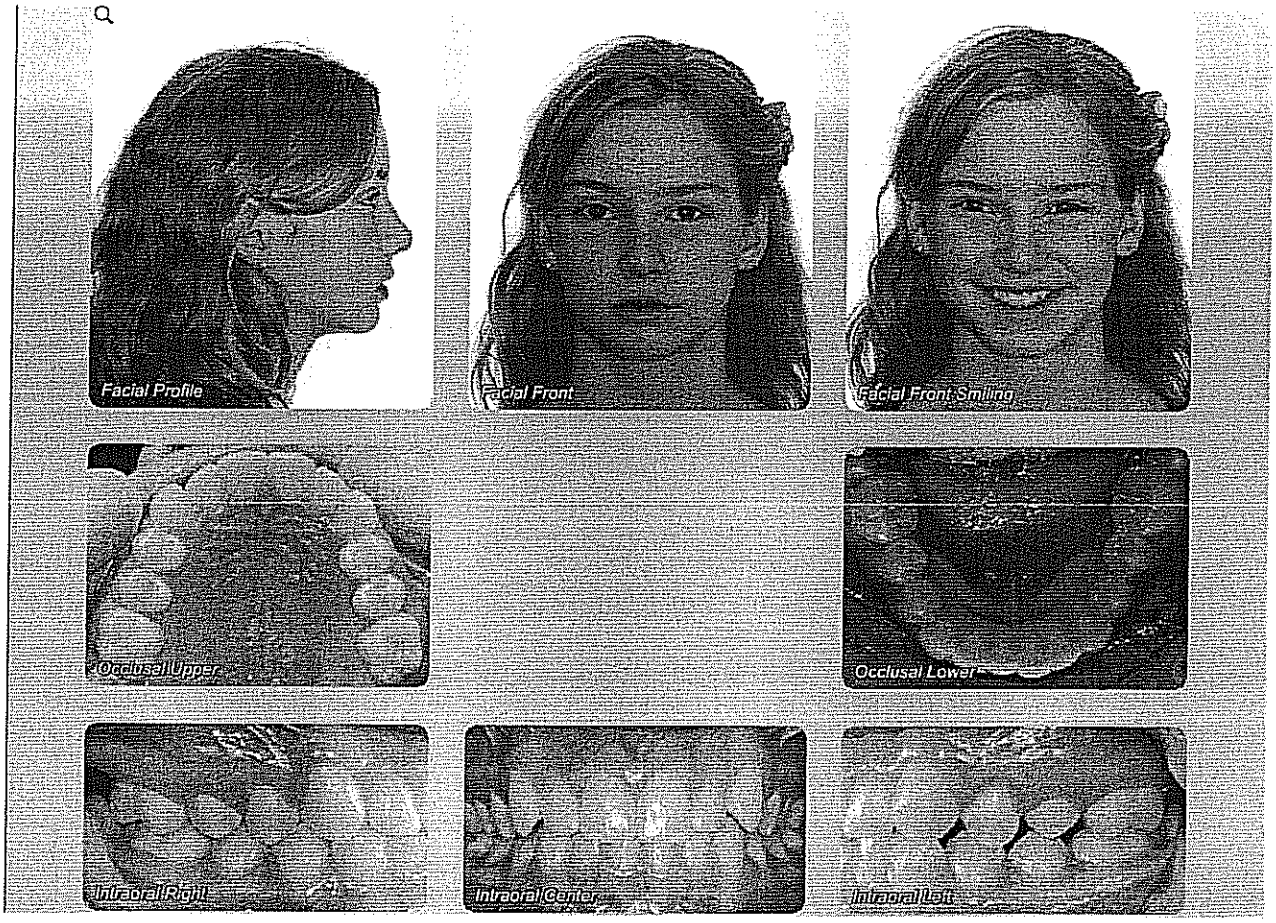


Figure 28. Case #21 Composite

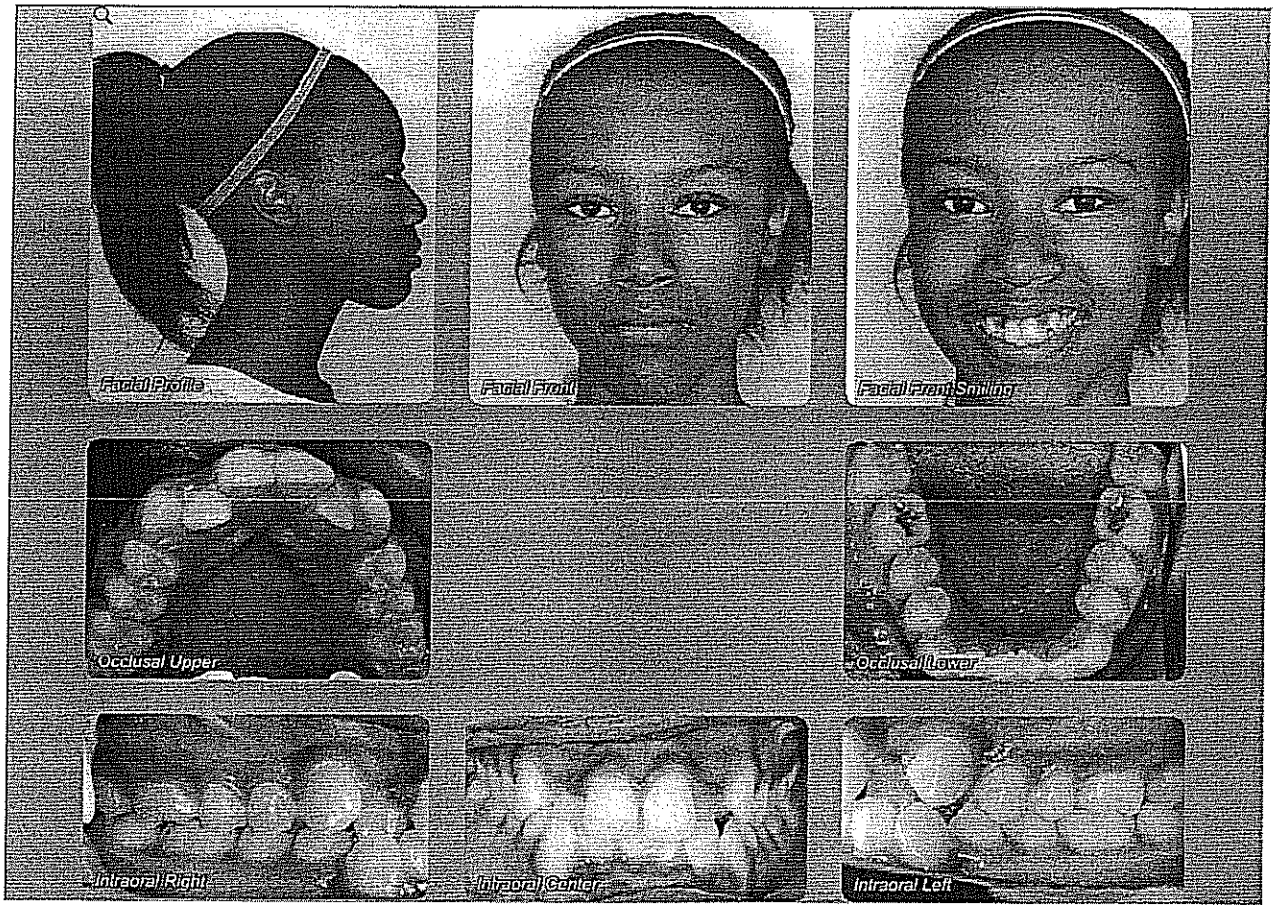


Figure 29. Case #21 Frontal Photo

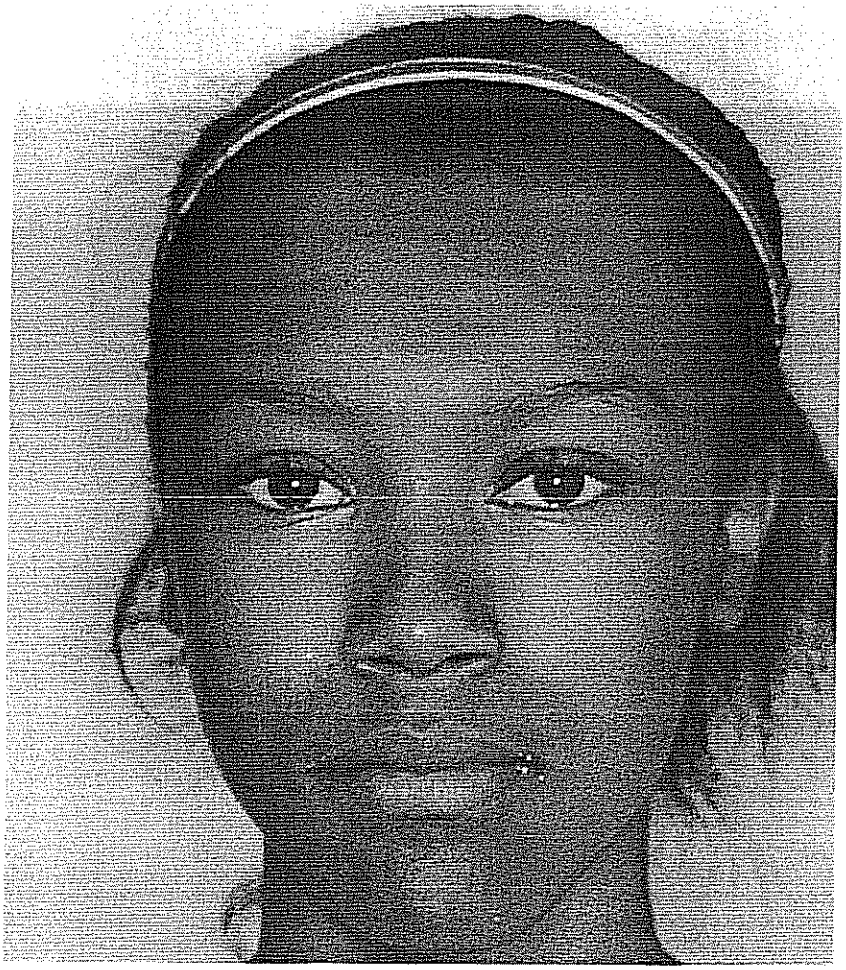


Figure 30. Case #21 CBCT Scan

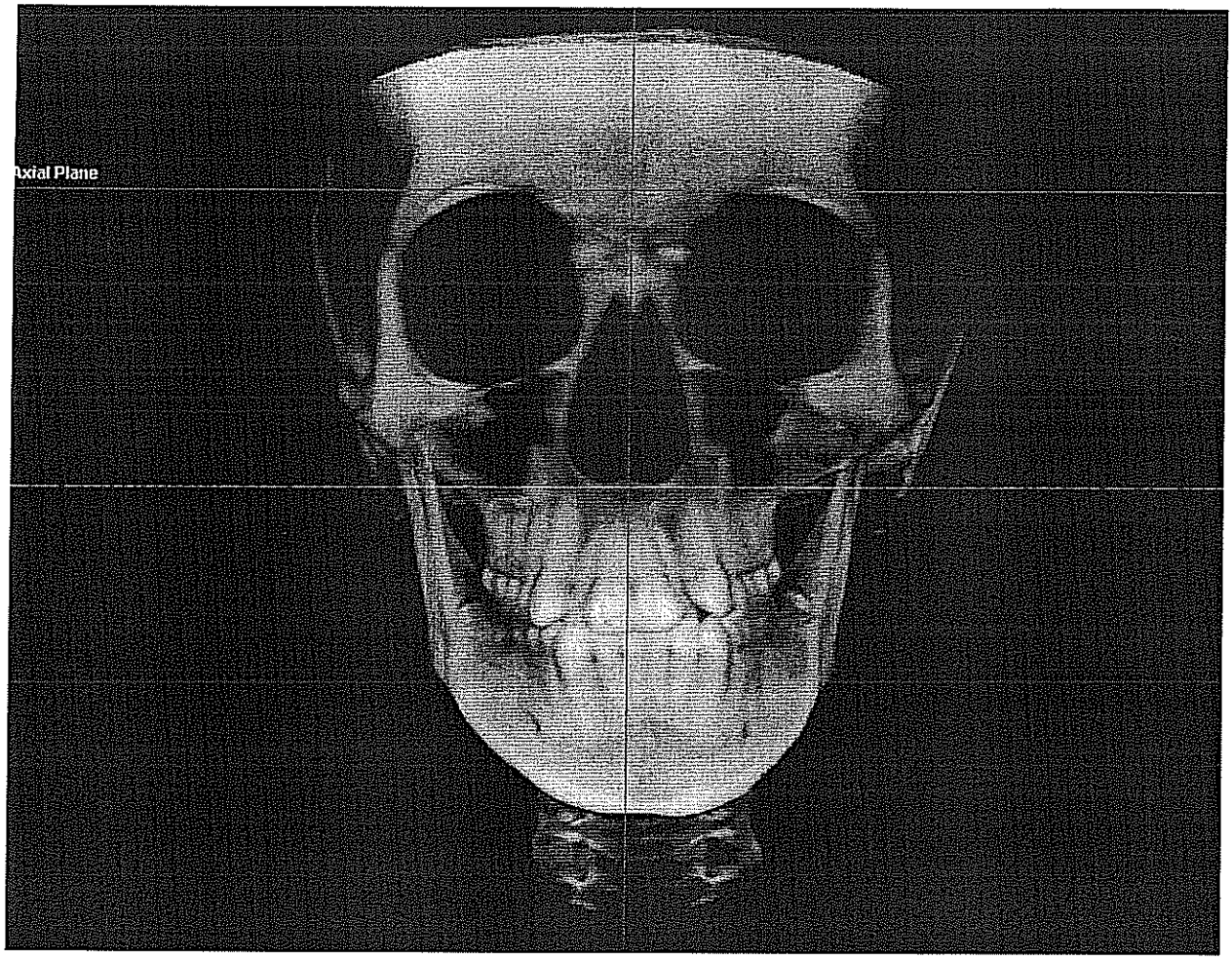
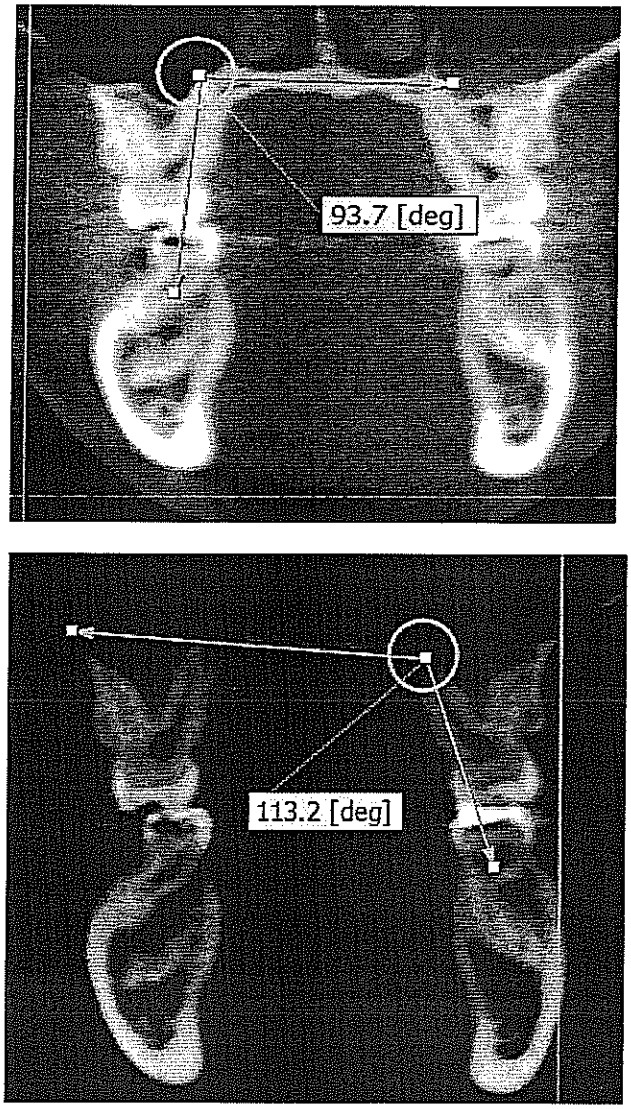
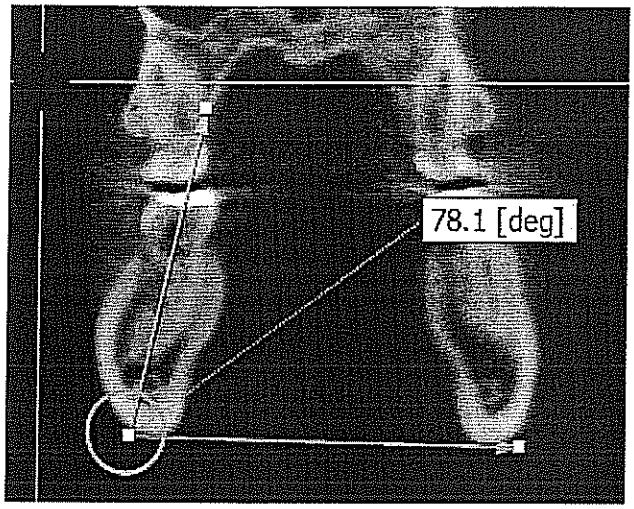


Figure 31. Case #21 Molar Angulations




78.1 [deg]

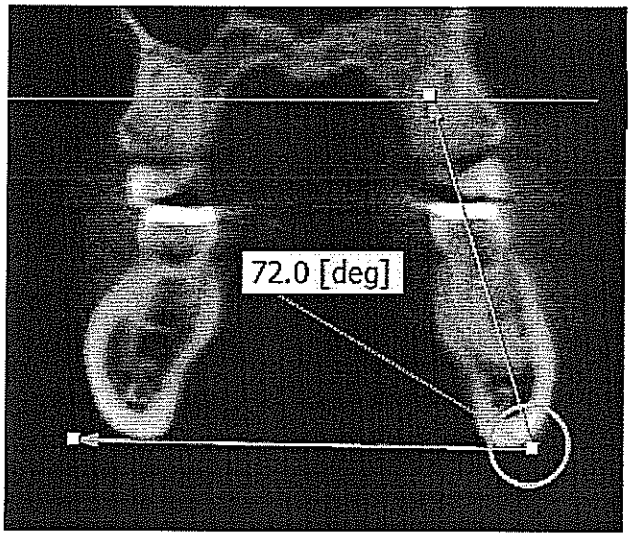

72.0 [deg]

Figure 32. Case #20 Composite

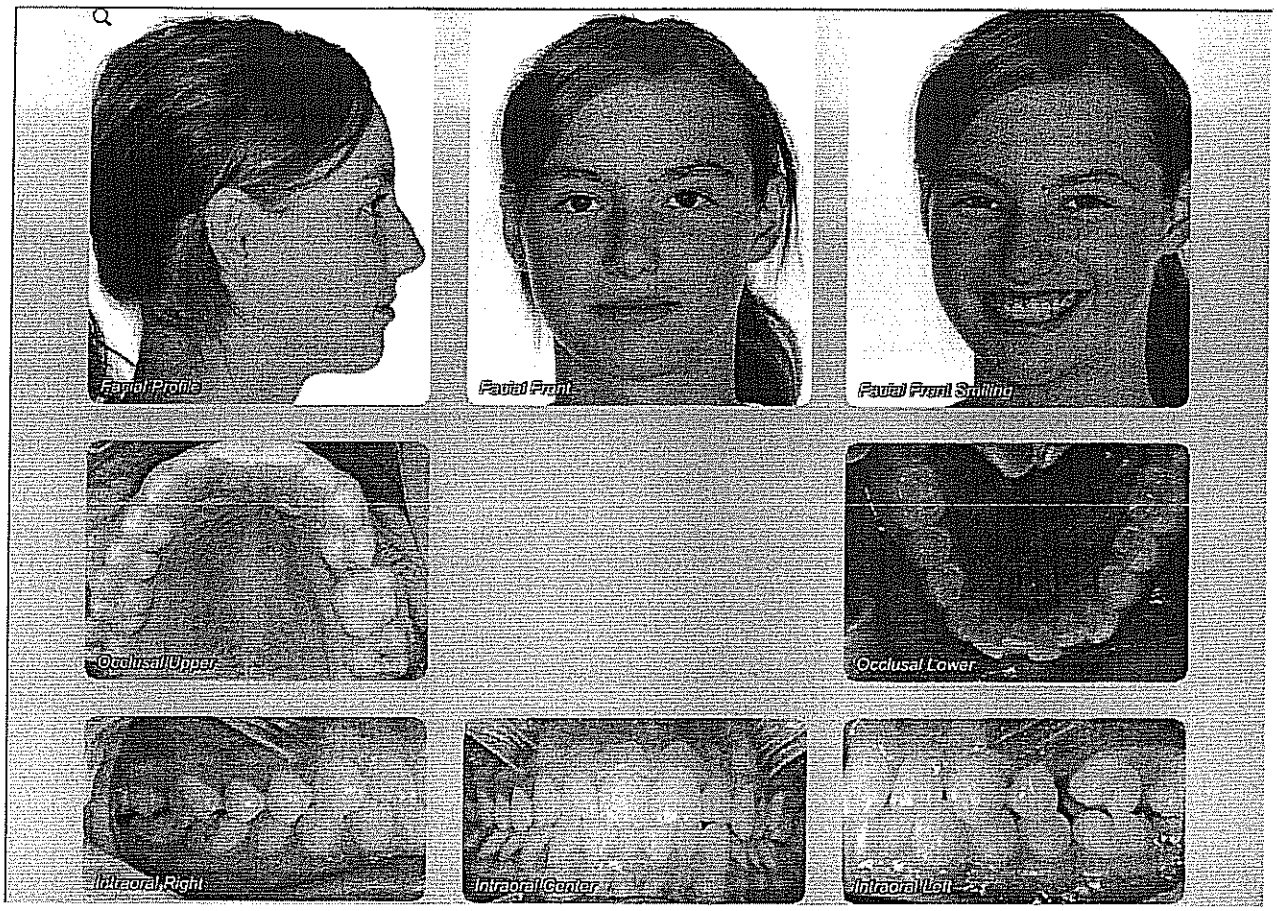
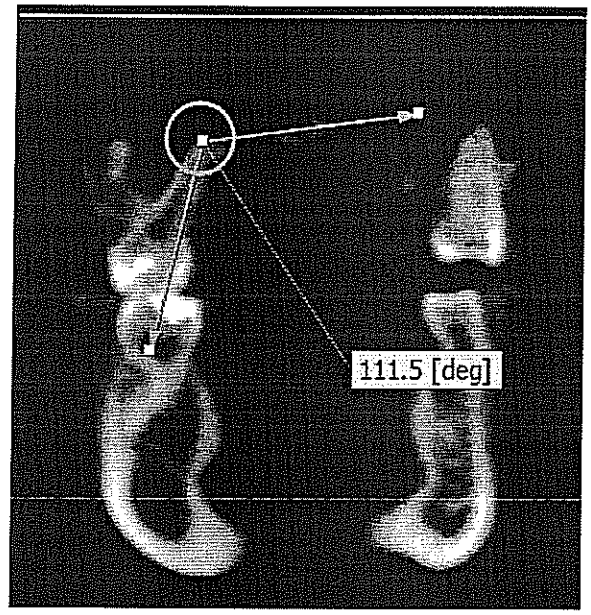
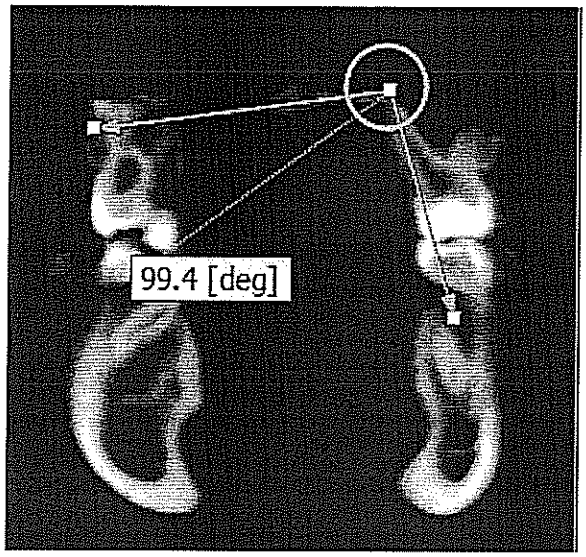
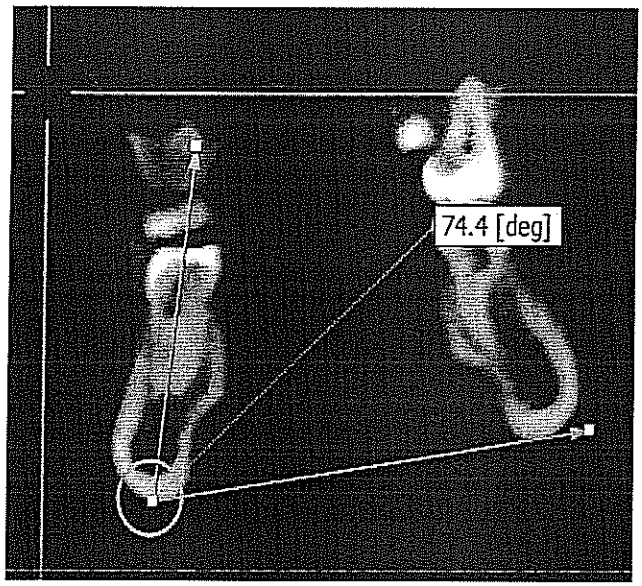


Figure 33. Case #20 Molar Angulations






74.4 [deg]

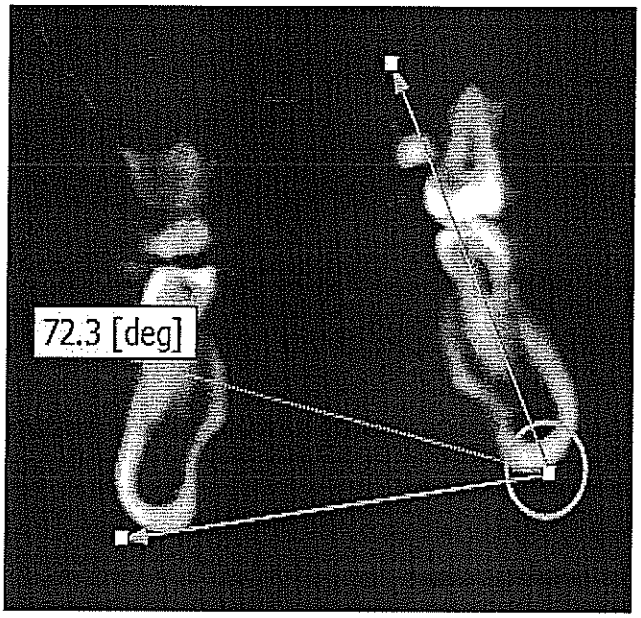

72.3 [deg]

Figure 34. Case #59 Composite

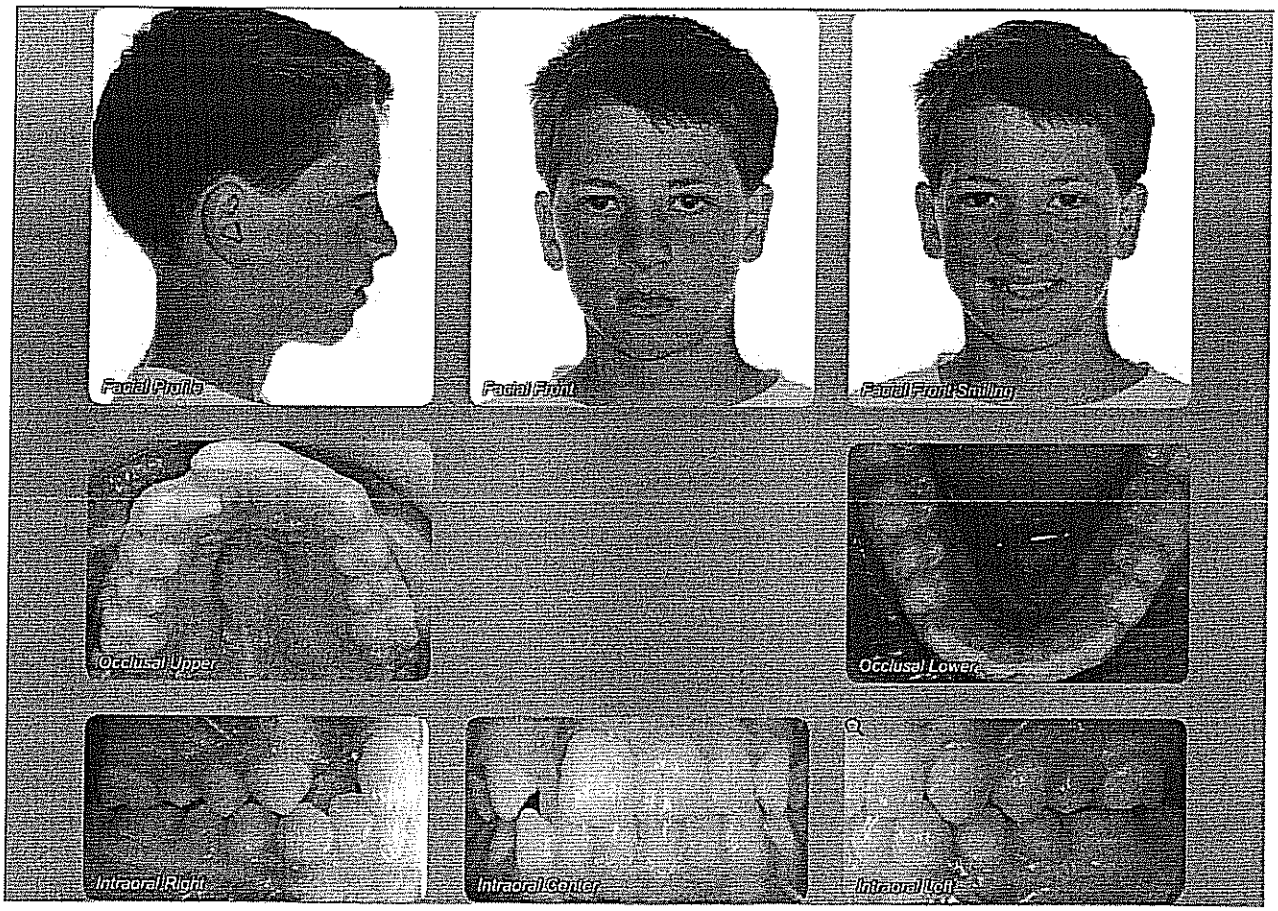
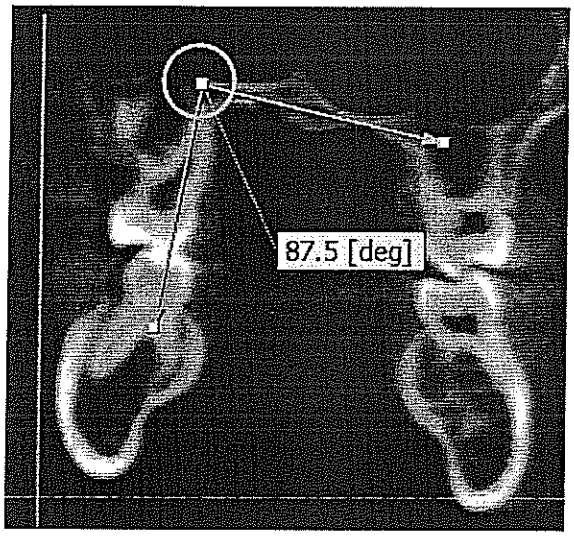
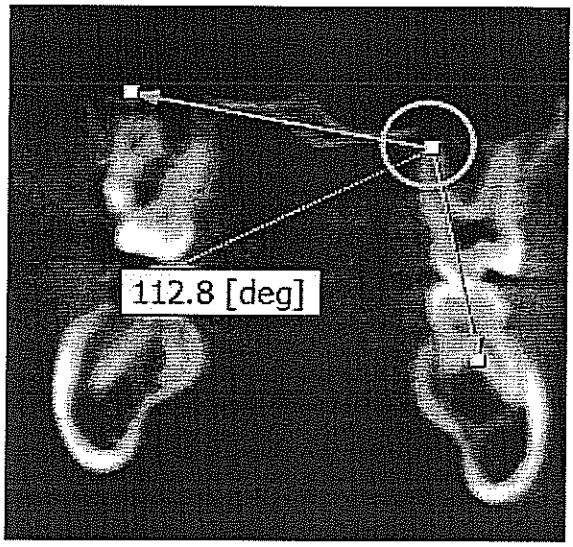
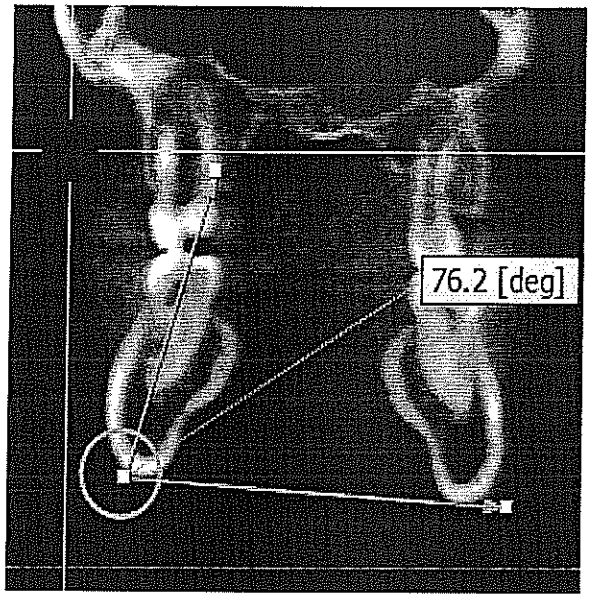
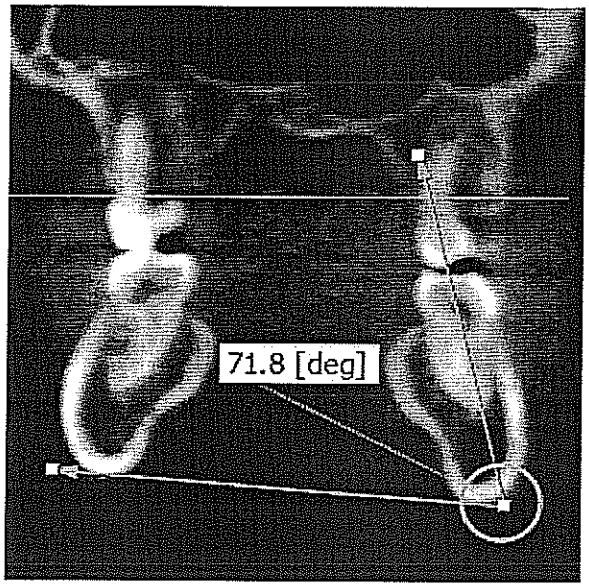


Figure 35. Case #59 Molar Angulations






76.2 [deg]


71.8 [deg]

Appendix

IRB Approval

Case Western Reserve University

Institutional Review Board

NOTICE OF EXEMPTION #1

Investigation conducted in established or commonly accepted educational settings, involving normal educational practices, such as:
(i) research on regular and special education instructional strategies, or
(ii) research on the effectiveness of or the comparison among instructional techniques, curricula, or classroom management methods.

CWRU IRB Protocol Number: **IRB-2012-163**
Protocol Title: ***Case Western Reserve University Transverse Analysis and its Potential Affects on Orthodontic Treatment Planning."***
Responsible Investigator (RI): **Juan Palomo**
Co-Investigator (CI): **Mark Hans**
RI Department: **Orthodontics**
Exemption Date: **06/20/2012**
The Institutional Review Board (IRB) has deemed the above protocol EXEMPT under 45 Code of Federal Regulations (CFR) part 46.101(b)(1). The IRB will not conduct subsequent reviews of this protocol.
IF YOU WISH TO CHANGE THIS EXEMPTED PROTOCOL IN ANY WAY, YOU MUST SUBMIT AN ADDENDUM REQUEST AND WAIT FOR IRB APPROVAL PRIOR TO IMPLEMENTING ANY PROTOCOL CHANGE.
Any changes to the protocol that put it under the purview of the IRB would require a formal application to, and approval of, the IRB prior to implementation of the change.

INFORMED CONSENT

for the Orthodontic Patient

Risks and Limitations of Orthodontic Treatment

Orthodontics and Dentofacial Orthopedics is the dental specialty that includes the diagnosis, prevention, interception and correction of malocclusion, as well as neuromuscular and skeletal abnormalities of the developing or mature orofacial structures.

An orthodontist is a dental specialist who has completed at least two additional years of graduate training in orthodontics at an accredited program after graduation from dental school.

Successful orthodontic treatment is a partnership between the orthodontist and the patient. The doctor and staff are dedicated to achieving the best possible result for each patient. As a general rule, informed and cooperative patients can achieve positiveorthodontic results. While recognizing the benefits of a beautifulhealthy smile, you should also be aware that, as with all healing arts, orthodontic treatment has limitations and potential risks.These are seldom serious enough to indicate that you should not have treatment; however, all patients should seriously consider the option of no orthodontic treatment at all by accepting their present oral condition. Alternatives to orthodontic treatment vary with the individual's specific problem, and prosthetic solutions or limited orthodontic treatment may be considerations. You are encouraged to discuss alternatives with the doctor prior to beginning treatment.

Results of Treatment

Orthodontic treatment usually proceeds as planned, and we intend to do everything possible to achieve the best results for every patient. However, we cannot guarantee that you will be completely satisfied with your results, nor can all complications or consequences be anticipated. The success of treatment depends on your cooperation in keeping appointments, maintaining good oral hygiene, avoiding loose or broken appliances, and following the orthodontist's instructions carefully.

Length of Treatment

The length of treatment depends on a number of issues, including the severity of the problem, the patient's growth and the level of patient cooperation. The actual treatment time is usually close to the estimated treatment time, but treatment may be lengthened if, for example, unanticipated growth occurs, if there are habits affecting the dentofacial structures, if periodontal or other dental problems occur, or if patient cooperation is not adequate. Therefore, changes in the original treatment plan may become necessary. If treatment time is extended beyond the original estimate, additional fees may be assessed.

Discomfort

The mouth is very sensitive so you can expect an adjustment period and some discomfort due to the introduction of orthodontic appliances. Nonprescription pain medication can be used during this adjustment period.

Relapse

Completed orthodontic treatment does not guarantee perfectly straight teeth for the rest of your life. Retainers will be required to keep your teeth in their new positions as a result of your orthodontic treatment. You must wear your retainers as instructed or teeth may shift, in addition to other adverse effects. Regular retainer wear is often necessary for several years following orthodontic treatment. However, changes after that time can occur due to natural causes, including habits such as tongue thrusting, mouth breathing, and growth and maturation that continue throughout life. Later in life, most people will see their teeth shift. Minor irregularities, particularly in the lower front teeth, may have to be accepted.

Some changes may require additional orthodontic treatment or, in some cases, surgery. Some situations may require non-removable retainers or other dental appliances made by your family dentist.

Extractions

Some cases will require the removal of deciduous (baby) teeth or permanent teeth. There are additional risks associated with the removal of teeth which you should discuss with your family dentist or oral surgeon prior to the procedure.

Orthognathic Surgery

Some patients have significant skeletal disharmonies which require orthodontic treatment in conjunction with orthognathic (dentofacial) surgery. There are additional risks associated with this surgery which you should discuss with your oral and/or maxillofacial surgeon prior to beginning orthodontic treatment. Please be aware that orthodontic treatment prior to orthognathic surgery often only aligns the teeth within the individual dental arches. Therefore, patients discontinuing orthodontic treatment without completing the planned surgical procedures may have a malocclusion that is worse than when they began treatment!

Decalcification and Dental Caries

Excellent oral hygiene is essential during orthodontic treatment as are regular visits to your family dentist. Inadequate or improper hygiene could result in cavities, discolored teeth, periodontal disease and/or decalcification. These same problems can occur without orthodontic treatment, but the risk is greater to an individual wearing braces or other appliances.

These problems may be aggravated if the patient has not had the benefit of fluoridated water or its substitute, or if the patient consumes sweetened beverages or foods.

Root Resorption

The roots of some patients' teeth become shorter (resorption) during orthodontic treatment. It is not known exactly what causes root resorption, nor is it possible to predict which patients will experience it. However, many patients have retained teeth throughout life with severely shortened roots. If resorption is detected during orthodontic treatment, your orthodontistmay recommend a pause in treatment or the removal of the appliances prior to the completion of orthodontic treatment.

Nerve Damage

A tooth that has been traumatized by an accident or deep decay may have experienced damage to the nerve of the tooth. Orthodontic tooth movement may, in some cases, aggravate this condition.

In some cases, root canal treatment may be necessary. In severe cases, the tooth or teeth may be lost.

Periodontal Disease

Periodontal (gum and bone) disease can develop or worsen during orthodontic treatment due to many factors, but most often due to the lack of adequate oral hygiene. You must have your general dentist, or if indicated, a periodontist monitor your periodontal health during orthodontic treatment every three to six months. If periodontal problems cannot be controlled, orthodontic treatment may have to be discontinued prior to completion.

Injury From Orthodontic Appliances

Activities or foods which could damage, loosen or dislodge orthodontic appliances need to be avoided. Loosened or damaged orthodontic appliances can be inhaled or swallowed or could cause other damage to the patient. You should inform your orthodontist of any unusual symptoms or of any loose or broken appliances as soon as they are noticed. Damage to the enamel of a tooth or to a restoration (crown, bonding, veneer, etc.) is possible when orthodontic appliances are removed. This problem may be more likely when esthetic (clear or tooth colored) appliances have been selected. If damage to a tooth or restoration occurs, restoration of the involved tooth/teeth by your dentist may be necessary.

Headgears

Orthodontic headgears can cause injury to the patient. Injuries can include damage to the face or eyes. In the event of injury or especially an eye injury, however minor, immediate medical help should be sought. Refrain from wearing headgear in situations where there may be a chance that it could be dislodged or pulled off. Sports activities and games should be avoided when wearing orthodontic headgear.

Temporomandibular (Jaw)

Joint Dysfunction

Problems may occur in the jaw joints, i.e., temporomandibular joints (TMJ), causing pain, headaches or ear problems. Many factors can affect the health of the jaw joints, including past trauma (blows to the head or face), arthritis, hereditary tendency to jaw joint problems, excessive tooth grinding or clenching, poorly balanced bite, and many medical conditions. Jaw joint problems may occur with or without orthodontic treatment. Any jaw joint symptoms, including pain, jaw popping or difficulty opening or closing, should be promptly reported to the orthodontist. Treatment by other medical or dental specialists may be necessary.

Impacted, Ankylosed,

Unerupted Teeth

Teeth may become impacted (trapped below the bone or gums), ankylosed (fused to the bone) or just fail to erupt. Oftentimes, these conditions occur for no apparent reason and generally cannot be anticipated. Treatment of these conditions depends on the particular circumstance and the overall importance of the involved tooth, and may require extraction, surgical exposure, surgical transplantation or prosthetic replacement.

Occlusal Adjustment

You can expect minimal imperfections in the way your teeth meet following the end of treatment. An occlusal equilibration procedure may be necessary, which is a grinding method used to fine-tune the occlusion. It may also be necessary to remove a small amount

of enamel in between the teeth, thereby "flattening" surfaces in order to reduce the possibility of a relapse.

Non-Ideal Results

Due to the wide variation in the size and shape of the teeth, missing teeth, etc., achievement of an ideal result (for example, complete closure of a space) may not be possible. Restorative dental treatment, such as esthetic bonding, crowns or bridges or periodontal therapy, may be indicated. You are encouraged to ask your orthodontist and family dentist about adjunctive care.

Third Molars

As third molars (wisdom teeth) develop, your teeth may change alignment. Your dentist and/or orthodontist should monitor them in order to determine when and if the third molars need to be removed.

Patient or Parent/Guardian Initials _____

Continued on next page

ACKNOWLEDGEMENT

I hereby acknowledge that I have read and fully understand the treatment considerations and risks presented in this form. I also understand that there may be other problems that occur less frequently than those presented, and that actual results may differ from the anticipated results. I also acknowledge that I have discussed this form with the undersigned orthodontist(s) and have been given the opportunity to ask any questions. I have been asked to make a choice about my treatment. I hereby consent to the treatment proposed and authorize the orthodontist(s) indicated below to provide the treatment.

I also authorize the orthodontist(s) to provide my health care information to my other health care providers. I understand that my treatment fee covers only treatment provided by the orthodontist(s), and that treatment provided by other dental or medical professionals is not included in the fee for my orthodontic treatment.

Signature of Patient/Parent/Guardian Date

Signature of Orthodontist/Group Name Date

Witness Date

CONSENT TO UNDERGO

ORTHODONTIC TREATMENT

I hereby consent to the making of diagnostic records, including x-rays, before, during and following orthodontic treatment, and to the above doctor(s) and, where appropriate, staff providing orthodontic treatment prescribed by the above doctor(s) for the above individual.

I fully understand all of the risks associated with the treatment.

AUTHORIZATION FOR RELEASE OF

PATIENT INFORMATION

I hereby authorize the above doctor(s) to provide other health care providers with information regarding the above individual's orthodontic care as deemed appropriate. I understand that once released, the above doctor(s) and staff has(have) no responsibility for any further release by the individual receiving this information.

CONSENT TO USE OF RECORDS

I hereby give my permission for the use of orthodontic records, including photographs, made in the process of examinations, treatment, and retention for purposes of professional consultations, research, education, or publication in professional journals.

Signature Date

Witness Date

I have the legal authority to sign this on behalf of

Name of Patient

Relationship to Patient

Patient or Parent/Guardian Initials _____

Patient _____ Date _____

Allergies

Occasionally, patients can be allergic to some of the component materials of their orthodontic appliances.

This may require a change in treatment plan or discontinuance of treatment prior to completion.

Although very uncommon, medical management of dental material allergies may be necessary.

General Health Problems

General health problems such as bone, blood or endocrine disorders, and many prescription and non-prescription drugs (including bisphosphonates) can affect your orthodontic treatment. It is imperative that you inform your orthodontist of any changes in your general health status.

Use of Tobacco Products

Smoking or chewing tobacco has been shown to increase the risk of gum disease and interferes with healing after oral surgery. Tobacco users are also more prone to oral cancer, gum recession, and delayed tooth movement during orthodontic treatment. If you use tobacco, you must carefully consider the possibility of a compromised orthodontic result.

Temporary Anchorage Devices

Your treatment may include the use of a temporary anchorage device(s) (i.e. metal screw or plate attached to the bone.) There are specific risks associated with them. It is possible that the screw(s) could become loose which would require its/their removal and possibly relocation or replacement with a larger screw. The screw and related material may be accidentally swallowed. If the device cannot be stabilized for an adequate length of time, an alternate treatment plan may

be necessary. It is possible that the tissue around the device could become inflamed or infected, or the soft tissue could grow over the device, which could also require its removal, surgical excision of the tissue and/or the use of antibiotics or antimicrobial rinses.

It is possible that the screws could break (i.e. upon insertion or removal.) If this occurs, the broken piece may be left in your mouth or may be surgically removed. This may require referral to another dental specialist.

When inserting the device(s), it is possible to damage the root of a tooth, a nerve, or to perforate the maxillary sinus. Usually these problems are not significant however, additional dental or medical treatment may be necessary.

Local anesthetic may be used when these devices are inserted or removed, which also has risks. Please advise the doctor placing the device if you have had any difficulties with dental anesthetics in the past.

If any of the complications mentioned above do occur, a referral may be necessary to your family dentist or another dental or medical specialist for further treatment. Fees for these services are not included in the cost for orthodontic treatment.

Notes
401 N. Lindbergh Blvd.
St. Louis, MO, USA 63141-7816
800.424.2841 Toll Free
314.997.6968 outside of the US and Canada
314.993.6992 Fax
orders@aaortho.org
www.AAOmembers.org

© 2005 American Association of Orthodontists

Appendix 2

Raw Data: Right and Left Maxillary and Mandibular Molar Angulations, Age, Race, Gender, Expander Status, and Crossbite Status.

Case #	Code	UR6	UL6	LR6	LL6	Treated w/ expander	Gender	Race	Age	Presented w/ crossbite
Case 1	AB45	100.1	98.8	67.5	71.9	N	F	W	14	N
Case 2	AL124	97.7	102.4	75.1	71.4	N	F	W	13	N
Case 3	BA250	91.4	98.8	67.3	70.7	N	M	W	12	N
Case 4	BO202	89.5	110.8	67.1	70.9	Y	F	A	14	N
Case 5	BO197	91.2	99.7	72.5	70.8	N	F	W	12	N
Case 6	BR232	92.2	100.2	71.9	73.3	N	M	M	15	N
Case 7	BR332	93.9	103	57.1	55.1	N	F	W	13	N
Case 8	BR310	99.9	109.7	74.7	77.3	N	M	W	13	N
Case 9	BR306	95.6	99.4	74.8	73.8	Y	F	W	13	Y bilateral
Case 10	BU142	105.9	107	78	78.4	N	M	W	12	N
Case 11	CA257	93	102.8	68.4	70.4	N	F	W	11	N
Case 12	CA266	103.3	98.9	78.3	74.2	N	M	W	14	N
Case 13	DA193	89.7	94.9	89.3	78.7	Y	M	W	16	Y unilateral
Case 14	EP6	101.6	97.3	76.9	73.1	N	M	W	13	N
Case 15	ES15	88.9	110.1	67.2	70.5	N	M	H?	15	N
Case 16	FE64	98.3	101.4	68.2	67.9	N	F	W	10	N
Case 17	FE62	98.7	96.4	75.7	68.7	N	F	W	15	N
Case 18	FI77	101.2	88.7	79	76	N	M	W	14	N
Case 19	FR118	100.6	99.1	70.2	67	N	M	W	12	N
Case 20	GO143	111.5	99.4	74.4	72.3	Y	F	W	11	N
Case 21	GR224	93.7	113.2	78.1	72	Y	F	B	14	N
Case 22	GR220	92.1	108.8	68.6	72.3	Y	F	W	11	N
Case 23	GR221	96.1	103.7	69.9	65.1	N	F	W	12	N
Case 24	GR223	114.7	112.1	70.8	72.9	N	F	W	12	N
Case 25	HE140	99.1	105.5	68.9	63	N	M	W	13	N
Case 26	HE88	102.1	104.1	71.1	69	N	M	W	14	N
Case 27	HE120	103.6	98.3	71	71.8	N	M	W	13	N
Case 28	FR119	99.3	110	69.2	69	N	M	W	12	N
Case 29	HE114	106.9	114.4	72.3	71.9	N	F	W	13	N
Case 30	HL2	101.6	100.9	70.5	70.1	N	M	A	11	N
Case 31	HO238	89.5	110.1	66.2	68.2	N	F	W	13	N
Case 32	HO245	100.3	103.5	80.1	74.4	N	M	W	13	N
Case 33	KA149	96.5	100.8	71.9	70.3	N	M	W	16	N

Case 34	KE102	96.2	103.5	81.2	71.5	Y	F	W	11	Y unilateral
Case 35	KE105	103.2	110.7	73.6	67.4	N	F	W	12	N
Case 36	KI10B	104.4	115.5	72.6	64.6	N	F	W	10	N
Case 37	KI85	104.5	110.5	69.6	71.7	N	F	W	13	N
Case 38	KL47	97.1	103.2	79.1	72.5	Y	M	W	14	N
Case 39	KN26	98.2	101.8	76.4	78	N	F	W	13	N
Case 40	KN27	103.5	102.6	82.8	80.5	N	F	W	14	N
Case 41	KO124	104.6	107.2	67.4	62.2	Y	F	W	11	N
Case 42	KR63	95.6	91.4	68.2	71.6	N	F	W	15	N
Case 43	MA270	101.1	101.2	74.3	75.2	N	F	B	13	N
Case 44	MA416	98.7	103	72.1	77.7	N	M	W	16	N
Case 45	MA370	104.5	107.1	70.8	67.2	N	F	W	12	N
Case 46	MC196	102.9	100.1	65.1	69.2	N	M	W	16	N
Case 47	MC195	87.2	98.6	71.1	70.6	N	F	W	13	N
Case 48	ME96	93.6	95.3	71	63.2	N	M	W	13	N
Case 49	ME105	92.2	96.7	76.7	73.5	AW	F	W	14	N
Case 50	MI226	97.6	105.5	71.2	74.7	N	M	W	13	N
Case 51	MO229	95.7	105.5	72.5	66.7	N	F	W	14	N
Case 52	MO191	95.8	95.4	71.7	73.7	N	M	W	12	N
Case 53	MU106	104	103.1	75.5	78.8	N	M	W	12	N
Case 54	NA62	100.7	95	71.6	69.3	N	F	W	13	N
Case 55	OG5	109	109.5	72.7	66.5	N	M	W	13	Y bilateral
Case 56	OR26	101.8	100.9	74.7	80.7	N	M	W	15	N
Case 57	PA211	97.7	102.6	77.5	72.8	N	F	W	14	N
Case 58	PA190	90.9	102.1	78.7	78.3	N	M	W	16	N
Case 59	PA208	87.5	112.8	76.2	71.8	N	M	W	13	N
Case 60	PA199	99.5	97.6	66.4	80.9	N	F	W	13	N
Case 61	PE197	94	109.1	62.8	65.6	N	M	W	14	N
Case 62	PO137	102.3	96	70.4	71.9	N	F	W	12	N
Case 63	PO128	89.2	102.7	66.2	64.5	N	M	W	12	N
Case 64	PO135	96.7	94.8	71.8	77.9	N	M	W	11	N
Case 65	PO131	90.5	100	64	60.9	N	F	W	12	N
Case 66	PO132	88.2	113.5	73.6	65.9	AW	M	W	13	Y unilateral
Case 67	RE139	91.4	95.8	83	72.4	Y	M	W	16	Y bilateral
Case 68	RE97	99.2	99.9	67.8	68.1	Y	M	W	13	Y bilateral
Case 69	RI144	95.5	99	82.9	79.3	N	F	W	14	N
Case 70	RI148	98.1	104.3	70.2	70.9	N	F	W	12	N
Case 71	RI130	96.7	80.9	73.8	69.3	N	M	W	14	N
Case 72	RO266	100.4	112.5	80.9	78	N	M	B	12	N
Case 73	RO231	103.1	101.9	72.2	73.4	N	F	W	10	N
Case 74	RO246	89.2	97.7	69.7	67.8	N	F	W	14	N
Case 75	SC189	93.1	94.7	76.8	75.9	N	F	W	13	N

Case 76	SE75	102.2	96.3	70.1	72.3	N	M	W	13	N
Case 77	SE87	112.3	94.9	70.6	76.7	N	M	W	12	N
Case 78	SE93	92.2	93.5	77.1	65.4	N	F	W	10	N
Case 79	SM135	97.6	90.2	68.7	80.4	AW	M	W	15	Y unilateral
Case 80	SO61	101.8	100.8	72.7	71	N	F	W	15	N
Case 81	ST237	104	101.2	77.2	76.8	N	F	W	11	N
Case 82	SU77	95.6	105	80	77.2	N	F	W	13	N
Case 83	SW42	103.1	105.3	75.5	76.3	N	F	W	15	Y unilateral
Case 84	TA135	98.8	103.5	70.5	72.6	N	M	W	12	N
Case 85	TH137	100.1	99.8	77	79	N	F	W	15	N
Case 86	TH95	100.2	101.3	77	73	N	M	W	16	N
Case 87	TO93	99	101.3	77.2	78.2	N	F	W	11	Y unilateral
Case 88	TU78	96.4	96	69.6	71.6	N	F	W	11	Y
Case 89	TE49	101.3	97.2	72.9	70.8	N	F	W	13	N
Case 90	TE51	103.8	100.5	70.7	76.3	N	F	W	10	N
Case 91	WA225	110.9	107.1	76.5	78.2	N	F	W	12	N
Case 92	WA236	98.8	105	68.5	64.7	N	F	W	14	N
Case 93	WE165	105.7	92.1	69.6	71.6	Y	F	W	12	Y unilateral
Case 94	WA237	104.3	88.3	71.9	76.4	N	M	W	14	N
Case 95	WI300	99.3	100.3	71.3	68.2	N	F	W	11	N
Case 96	WI308	99.1	101	73.4	70	N	M	W	13	N
Case 97	WI332	91.3	101.8	74.3	71.7	N	M	W	12	N
Case 98	WI328	101.5	104.4	79.3	79.6	N	F	W	15	N
Case 99	YE12	102.6	100.6	73	78.6	Y	F	W	13	N
Case 100	ZB5	91.1	100.2	64.8	68.4	N	F	W	16	N

Appendix 3

Reliability Raw Data: Maxillary and Mandibular Molar Angulations of Thirty Randomly Selected Patients

UR6	UL6	LR6	LL6	Code
99.9	98	68	71.5	AB45
92.1	99.9	67.4	70.8	BA250
100.4	108.8	75.2	76.8	BR310
105.1	106.4	77.6	78.5	BU142
101.6	97.9	76.2	73.2	EP6
99.1	97.6	76	69.3	FE62
99.9	90.4	79.2	75.1	FI77
100.9	98.9	71.1	66.1	FR118
94	113.7	78.7	71.5	GR224
92.5	110	69.3	72.3	GR220
98.4	103.2	78.8	65	HO245
103.8	114.2	72	64.1	KI108
103.7	109.3	69.7	71.4	KI85
99.3	102.8	73	77.6	MA416
105.1	107.5	71.3	66.8	MA370
94.6	96.3	71.1	64.3	ME96
96.9	105.2	72	75.6	MI226
105	102.8	77.8	78.9	MU106
98.5	103.1	78.2	73.5	PA211
91.8	101.7	79.4	78.9	PA190
88.5	112.2	76.8	72.5	PA208
99.7	98.9	67.4	79.9	PA199
90.2	100.6	64.7	60.6	PO131
103.1	101.1	72.7	73.6	RO231
101.8	100.8	72.1	71.8	SO61
98.9	102.6	69.9	72.6	TA135
99.3	101.3	77.4	78	TO93
104.2	101.3	71.2	76.1	TE51
110.9	107.9	76.4	78.7	WA225
103.6	91.3	71.1	76.4	WA237