Posttreatment Evaluation Through The CWRU's Transverse Analysis And The ABO's Objective Grading System

by

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DEDICATION

This thesis is dedicated to my parents

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POSTTREATMENT EVALUATION THROUGH THE CWRU'S TRANSVERSE ANALYSIS AND THE ABO'S OBJECTIVE GRADING SYSTEM

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ABSTRACT

Introduction: Orthodontic posttreatment evaluation is a challenge for improving not only the orthodontist's self-assessment but also the clinical competency in achieving the orthodontic goals. The purpose of the present study is to evaluate the pretreatment and posttreatment orthodontic records through the Case Western Reserve University's (CWRU's) transverse analysis, to assess the pretreatment records through the American Board of Orthodontics (ABO) discrepancy index (DI), and to appraise the posttreatment study casts through the ABO's objective grading system (OGS). The hypotheses were based on the following three questions: Does the CWRU's transverse analysis improve the orthodontic results? Does the CWRU's transverse analysis minimize the active treatment duration? Does the discrepancy index affect the orthodontic results? **Methods:** A retrospective cohort research study was executed on the basis of an original sample of 100 subjects. The final sample contained 90 subjects for the pretreatment group, and 86 subjects for the posttreatment group. The sample was divided into two groups according to whether or not the subjects were treated according to the CWRU's transverse analysis. The data were statistically analyzed through the t-tests. **Results:** The CWRU's transverse analysis significantly improved the OGS scores. However, it did not significantly affect the active treatment duration. Further, the discrepancy index had significant effects on the OGS scores. **Conclusions:** The CWRU's transverse analysis significantly improves the orthodontic results. However, it does not have significant effects on the active treatment duration. Further, the discrepancy index significantly affects the orthodontic results. **Clinical Implications:** Diagnostic strategies could be applied whereby the treatment plan and mechanotherapy are evidence-based on a clear vision of the desired orthodontic posttreatment outcomes satisfying different physiologic and esthetic requirements for each patient.

Table of Contents

		Page
Title		i
Dedication		ii
Acknowledgements		iii
Abstract		iv
Table of Contents		v
List of Figures		vi
List of Tables		x
Chapter I.	Introduction	1
Chapter II.	Review of the Literature	5
	Review References	31
Chapter III.	Thesis Statement	37
Chapter IV.	Manuscript	39
	Manuscript References	56
	Manuscript Legends	58
Appendix A.	Chapter V. Materials and Methods	70
Appendix B.	Chapter VI. Results	83
Appendix C.	Chapter VII. Discussion	87
Appendix D.	Chapter VIII. Summary and Conclusions	100
Appendix E.	Figures	101
Appendix F.	Tables	140
Appendix G.	IRB Approval	154

LIST OF FIGURES *(48 Figures)*

Figure		Page
1	Outline of the literature's review.	101
2	Methodological topics.	101
3	The ABO's ruler.	102
4	The Hitachi CB MercuRay machine.	103
5	In the sagittal view, orient the line representing the axial view so that it passes through ANS.	104
6	In the axial view, locate the ANS (point where the coronal and sagittal planes meet).	104
7	In the sagittal view, move the line representing the axial view downwards so that it passes through the center of the atlas.	105
8	Go back to the axial view, and rotate the line that represents the sagittal plane around the ANS so that it passes through the center of the odontoid process.	105
9	Locate the molar in the axial view; the point at which the palatal root length is the longest in the sagittal view.	106
10	In the sagittal view, position the line representing the coronal slice along the mesiopalatal cusp tip and the palatal root apex.	106
11	In the coronal view, draw the reference line tangent to the inferior border of the nasal cavity.	107
12	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.	107

Figure		Page
13	Locate the molar in the axial view; the point at which the roots are longest in the sagittal view.	108
14	Position the coronal line along the long axis of the tooth (mesial cusp tip to mesial root apex).	108
15	Draw a reference line tangent to the inferior border of the mandible in the coronal view.	109
16	Measure the inclination which is the angle between the line passing through the long axis of the molar and the reference line.	109
17	Outline of the results chapter.	110
18	Sample power and size estimation.	111
19	Histograms of the ABO's discrepancy index.	112
20	Pie chart of the recoded ABO's discrepancy index.	112
21	Histogram of the ABO's objective grading system.	113
22	Pie chart of the ABO's objective grading system.	113
23	Histograms of the pretreatment buccolingual inclinations of all permanent first molars measured through the CWRU's transverse analysis.	114
24	Histogram of the active treatment duration.	115
25	Histograms of pretreatment and posttreatment age.	116

Figure		Page
26	Histograms, q-plots, and box plots for the dependent variable "Discrepancy Index" with each category of the independent variable CWRU.	117
27	Histograms, q-plots, and box plots for the dependent variable "OGS" with each category of the independent variable CWRU.	118
28	Histograms, q-plots, and box plots for the dependent variable "Active Treatment Duration" with each category of the independent variable CWRU.	119
29	Thesis cycle.	120
30	CWRU’s transverse analysis.	121
31	Case # 9: initial composite.	122
32	Case # 9: CWRU's buccolingual inclinations of the maxillary and mandibular first molars	123
33	Case # 9: final composite.	124
34	Case # 79: initial composite.	125
35	Case # 79: CWRU's buccolingual inclinations of the maxillary and mandibular first molars.	126
36	Case # 79: final composite.	127
37	Case # 44: initial composite.	128
38	Case # 44: CWRU's pretreatment buccolingual inclinations of the maxillary and mandibular first molars.	129
39	Case # 44: CWRU's posttreatment buccolingual inclinations of the maxillary and mandibular first molars.	130

LIST OF FIGURES *(CONTINUED)*

Figure		Page
40	Case # 44: final composite.	131
41	Case # 21: initial composite.	132
42	Case # 21: CWRU's pretreatment buccolingual inclinations of the maxillary and mandibular first molars.	133
43	Case # 21: CWRU's posttreatment buccolingual inclinations of the maxillary and mandibular first molars.	134
44	Case # 21: final composite.	135
45	Case # 7: initial composite.	136
46	Case # 7: CWRU's pretreatment buccolingual inclinations of the maxillary and mandibular first molars.	137
47	Case # 7: CWRU's posttreatment buccolingual inclinations of the maxillary and mandibular first molars.	138
48	Case # 7: final composite.	139

LIST OF TABLES *(20 Tables)*

Table		Page
I	Interrater reliability through the reliability analysis	140
II	Intrarater reliability through the reliability analysis	140
III	Counts and Percentages for ordinal and nominal variables	141
IV	Buccolingual inclinations of permanent first molars through the CWRU's transverse analysis (Mean ± Standard Deviation)	142
V	Descriptive statistics for the pretreatment buccolingual inclinations of permanent first molars through the CWRU's transverse analysis	142
VI	Descriptive statistics for the posttreatment buccolingual inclinations of permanent first molars through the CWRU's transverse analysis	143
VII	Descriptive statistics for the OGS, crossbite status, and maxillary expansion	144
VIII	Descriptive demographic statistics	145
IX	Trichotomization for the pretreatment CWRU's transverse analysis	146
X	Paired samples t-tests for the BL inclinations of the permanent first molars through the CWRU's transverse analysis after splitting	146
XI	Descriptive statistics for the dependent variable “Discrepancy Index” with each category of the independent variable CWRU	147
XII	Kolmogorov-Smirnov and Shapiro-Wilk tests of normality for the dependent variable “Discrepancy Index” with each category of the independent variable CWRU	148

LIST OF TABLES *(Continued)*

Table		Page
XIII	Descriptive statistics for the dependent variable OGS with each category of the independent variable CWRU	149
XIV	Kolmogorov-Smirnov and Shapiro-Wilk tests of normality for the dependent variable OGS with each category of the independent variable CWRU	150
XV	Descriptive statistics for the dependent variable "Duration" with each category of the independent variable CWRU	151
XVI	Kolmogorov-Smirnov and Shapiro-Wilk tests of normality for the dependent variable "Duration" with each category of the independent variable CWRU	152
XVII	Independent-samples t-test between the discrepancy index and the OGS	152
XVIII	Independent-samples t-test between the CWRU's transverse analysis and the discrepancy index	153
XIX	Independent-samples t-test between the CWRU's transverse analysis and the ABO's objective grading system	153
XX	Independent-samples t-test between the CWRU's transverse analysis and the active treatment duration	153

CHAPTER I

INTRODUCTION

The primary goals of orthodontic treatment are to optimize functional protected occlusion, dentofacial esthetics, and long-term stability with the associated improvements in masticatory functions, periodontal status, physical health, and self-esteem. Excellence in treatment finishing is necessary. Further, the posttreatment evaluation of orthodontic records is a challenge for improving not only the orthodontist's self-assessment but also the clinical competency in achieving the above mentioned goals.

The **purpose** of the present research study is tri-partite in nature:

- Evaluate the orthodontic pretreatment and posttreatment records through the Case Western Reserve University's (CWRU's) transverse analysis.
- Assess the pretreatment records through the American Board of Orthodontics' (ABO's) discrepancy index.
- Appraise the posttreatment study casts through the ABO's objective grading system (OGS).

The main research questions are:

- Does the CWRU's transverse analysis improve the orthodontic results?
- Does the CWRU's transverse analysis affect the active treatment duration?
- Does the discrepancy index affect the orthodontic results?

Based on these questions, the following **hypotheses** were formulated:

- *Null Hypothesis (H_0) # 1:*

  The CWRU's transverse analysis does not affect the orthodontic results.

- *Alternate Hypothesis (H_1) # 1:*

  The CWRU's transverse analysis affects the orthodontic results.

- *Null Hypothesis (H_0) # 2:*

  The CWRU's transverse analysis does not affect the active treatment duration.

- *Alternate Hypothesis (H_1) # 2:*

  The CWRU's transverse analysis affects the active treatment duration.

- *Null Hypothesis (H_0) # 3:*

  The discrepancy index does not affect the orthodontic results.

- *Alternate Hypothesis (H_1) # 3:*

  The discrepancy index affects the orthodontic results.

An original **sample** of 100 subjects was studied. However, the final sample sizes were composed of 90 subjects for the pretreatment group, and 86 subjects for the posttreatment group. The sample was divided into two groups according to whether or not the subjects were treated according to the CWRU's transverse analysis.

The following seven independent **variables** were recorded: crossbite status, maxillary expansion, active treatment duration, pretreatment and posttreatment age, gender, and race. Eleven dependent variables were measured: four pretreatment buccolingual inclinations as well as four posttreatment buccolingual inclinations through the CWRU's transverse analysis, one dichotomized CWRU variable (followed or did not follow the CWRU's transverse analysis), the discrepancy index, plus the OGS score.

The results of the transverse analysis were labeled as excellent for those subjects within one standard deviation from the mean, moderate for those subjects within two standard deviations from the mean, and poor for those subjects outside two standard deviations from the mean. To facilitate this labeling process, a trichotomization table for the CWRU's transverse analysis was constructed.

The **study type** was retrospective cohort research investigation. Quality control was achieved through meticulous review of the literature, sound methodology, and powerful statistics.

The **anticipated results** are that the CWRU's transverse analysis not only improves the orthodontic results, but also minimizes the active treatment duration. Further, the discrepancy index affects the orthodontic results. If these anticipated results are achieved, diagnostic strategies could be applied whereby the treatment plan and mechanotherapy are evidence-based on a clear vision of the desired orthodontic posttreatment outcomes satisfying different physiologic and esthetic requisites for each patient.

CHAPTER II

REVIEW OF THE LITERATURE

As shown in Fig 1, the following six topics will be briefly reviewed: CBCT, the transverse analysis of Case Western Reserve University (CWRU's transverse analysis), transverse dimension, buccolingual inclination and Andrews' third key to normal occlusion, the ABO's discrepancy index (DI), and the ABO's objective grading system (OGS).

CBCT

CBCT is an acronym for Cone-Beam Computed Tomography. Kau et al.[28] focused on the cutting edge technology of CBCT; utilizing conventional X-ray expertise and computerized volumetric reconstruction to reproduce a three-dimensional image. The orthodontists are beginning to appreciate the advantages that the third dimension gives to diagnosis, treatment planning, and patient's education.[28] Further, Baumgaertel et al.[4] generated 3-dimensional reconstructions of the dentitions. Dental measurements from CBCT volumes can be used for quantitative analysis.[4]

Mostafa[41] indicated that the introduction of 3-dimensional (3D) imaging is revolutionizing orthodontic diagnostic philosophy. This philosophy emphasizes the

importance of implementing the prospective treatment analysis (PTA) concept and its triad of ERA, SA, and TA (End Result Analysis, Subtraction Analysis, and Treatment Analysis).[41] The questions are whether we have the armamentarium for this triad, and if we are ready for PTA.[41]

El-Zanaty and colleagues[16] found excellent agreement between the measurements with the conventional and the three-dimensional dental measurements (3DD) methods in the 3 planes of space. Thus, 3DD can be an alternative to conventional stone dental casts.[16] Moreover, Othman et al.[48] pointed out that the introduction of 3D volumetric technology and the massive information obtained from it compels the introduction of new methods and new technologies for orthodontic diagnosis and treatment planning. This paves the way for the prospective treatment analysis approach.[48]

El-Beialy and collaborators[15] emphasized that the accuracy and reliability of CBCT measurements are not affected by changing the skull orientations. Therefore, the upper-lip and chin rests should not be considered absolute requirements during CBCT imaging if a stable head position is ensured.[15]

On one hand, Kwong et al.[31] concluded that images taken at lower milliampere settings showed good diagnostic quality. On the other hand, Palomo and colleagues[50] pointed out that a reduction in radiation dose can be achieved by using the lowest exposure settings and narrow collimation.

Al Najjar et al.[2] indicated that CBCT scans with adult settings on both phantom heads resulted in higher radiation doses to the head and neck regions in children compared to adults. This might result in excessive radiation to children scanned with default adult settings.[2] Collimation should be used when possible to reduce the radiation dose to the patients.[2] While CBCT scans offer a valuable tool, use of CBCT scans should be justified on a specific case-by-case basis.[2]

Hodges et al.[23] supported obtaining a pretreatment CBCT scan in cases of unerupted teeth with delayed eruptions or questionable locations, severe root resorptions as diagnosed with periapical or panoramic radiographs, or severe skeletal discrepancies. CBCT scans should be ordered only when there is a clear specific individual clinical justification.[23]

In a point/counterpoint, Larson[34] and Halazonetis[20] discussed cone-beam computed tomography (CBCT). According

to Larson[34], CBCT is the imaging technique of choice for comprehensive orthodontic assessment. Larson[34] indicated that: "Although we still have much to learn about how to best use CBCT imaging to improve the outcomes of orthodontic treatment, we know enough about its application to consider it the imaging of choice for comprehensive orthodontic treatment."

However, according to Halazonetis[20], CBCT is not the imaging technique of choice for comprehensive orthodontic assessment. Halazonetis[20] stated: "Assuming that use for every patient is not advocated, what are the patient selection criteria? The answer should stem from a comprehensive assessment of the benefits and burdens to each patient".

Mostafa et al.[42] revealed that CBCT has become popular, and its many inherent advantages are indisputable. However, CBCT is prescribed cautiously because the radiation dosage is higher than that of conventional radiography.[42] When and to what extent should CBCT be prescribed for orthodontic patients?[42]

To answer the above question, Mostafa et al.[42] presented the following 4 curious cases in which a

considerable discrepancy was found between the conventional panoramic radiograph and the CBCT view:

- In the first case, the conventional panoramic radiograph showed no apparent abnormality.[42] However, the generated panoramic view, of the CBCT scan of the routine orthodontic records, surprisingly showed a radiopaque structure in the nasal region.[42] Initially, it was suspected that it was an artifact.[42] After adjusting the threshold and subtracting the surrounding bone on the 3D surface rendering, the structure maintained its radiopacity and resembled an ectopic tooth crown-like structure.[42] The ear, nose, and throat specialist's differential diagnosis was either a tooth crown, a rhinolith, or a foreign body. Ultimately, it was aspirated and found to be a pencil eraser![42]
- For the second case, the conventional panoramic radiograph showed no obvious explanation for the delayed maxillary left molar's uprighting.[42] However, the panoramic view, generated from CBCT and the 3D volume rendering, showed a well-defined remaining root in the maxillary left second premolar region.[42]
- In the third case, a patient (with a dislodged temporary anchorage device (TAD) in the right maxillary sinus) was

referred for examination.[42] A large discrepancy in the spatial position of the TAD was apparent between the conventional panoramic radiograph and the panoramic-derived view.[42]

- For the fourth case, a patient with a temporomandibular joint disorder (TMD) was treated by her dentist with a temporomandibular joint splint without ameliorations of the symptoms.[42] The panoramic view, generated from the CBCT scan, showed no abnormalities.[42] However, the 3D surface rendering showed a line resembling an unhealed fracture in the symphyseal region extending from the inferior border of the mandible and approaching the alveolar margin.[42]

Thus, the CBCT, with its 3D potential, made possible the diagnosis and spatial identification of structures that were invisible during routine diagnosis with conventional panoramic radiographs.[42] This advantage of CBCT merits further attention.[42] Is it time to spare patients an unnecessary conventional panoramic radiograph and shift to CBCT for all patients?[42]

The Transverse Analysis of Case Western Reserve University (CWRU's Transverse Analysis)

In four consecutive years, the transverse analysis of Case Western Reserve University (CWRU's transverse analysis) was developed by: Shewinvanakitkul[56] (2009), Evangelinakis[17] (2010), Shewinvanakitkul et al.[57] (2011), Karamitsou[27] (2011), Miyamoto[40] (2011), Copeland[11] (2012), and Streit[58] (2012). Shewinvanakitkul[56] (2009) developed a new technique to measure buccolingual inclinations using CBCT.

Shewinvanakitkul et al.[57] (2011) presented a practical and reliable method to measure the buccolingual inclinations of mandibular canines and first molars using CBCT and a commercially available DICOM (Digital Imaging and Communications in Medicine) software. The buccolingual inclinations of mandibular teeth were measured through the angles formed between the long axis of the tooth and a tangent to the inferior border of the mandible.[57]

Evangelinakis[17] (2010) studied the changes in buccolingual inclination of mandibular canines and first molars after orthodontic treatment using CBCT. The author[17] found that the mandibular molar inclinations statistically increased significant amounts posttreatment. Despite

changes in torque, intermolar widths did not significantly change.[17]

Using CBCT, Karamitsou[27] (2011) investigated the pretreatment buccolingual inclinations of the maxillary canines and first molars, and developed a reliable method to measure the maxillary first molar and canine inclinations. The maxillary molar inclinations for the right and left were 99.2° ± 5.3°, and 101.7° ± 5.4° respectively.[27] The range for the maxillary molars was 86.6° to 112.8° for the right side, and 88.5° to 117.5° for the left side.[27]

Miyamoto[40] (2011) assessed the changes in buccolingual inclination of the maxillary canines and first molars after orthodontic treatment using CBCT. The researcher[40] found that the buccolingual inclinations could be measured reliably, and changes in buccolingual inclinations greater than one standard deviation could have clinical significance. There were no statistically significant changes in buccolingual inclinations of canines and first molars after orthodontic therapy.[40]

Copeland[11] (2012) investigated the clinical application of the CWRU transverse analysis. Data were compiled from pretreatment CBCT scans, study casts, intra-oral and extra-

oral photographs, initial treatment plans, and progress notes.[11] Copeland[11] measured the buccolingual inclinations of the maxillary and mandibular first molars through the Karamitsou[27] and the Shewinvanakitkul et al.[57] methods respectively. All cases, presenting with at least one standard deviation from the norm, were appraised to determine if the CWRU transverse analysis would have altered the initial treatment plan.[11] Copeland[11] concluded that the buccolingual inclinations of both maxillary and mandibular molars seemed to play an important role in the diagnosis and treatment planning of orthodontic cases.

Streit[58] (2012) established the buccolingual inclinations of molar and canines that can be reliably used in the differential diagnosis of transverse deficiencies. All the subjects had ideal transverse dimensions.[58] The maxillary canine and molar inclinations were 103.9° and 100.1° respectively.[58] Further, the mandibular canine and molar inclinations were 97.3° and 76.7° respectively.[58]

Transverse Dimension

The following five transverse dimension matters will be concisely reviewed: centers of rotation, asymmetries, craniofacial growth, maxillary expansions, and stability.

Transverse Dimensions & Centers of Rotation

Nägerl et al.[44] (1991) studied the centers of rotation with transverse forces, and found that the occlusoapical position of the center of resistance varied depending upon the transverse direction of loading around the long axis. A transverse force, exerted in a mesiodistal direction at the level of an orthodontic bracket through the long axis, produced different effects from those generated when an identical force was applied in a labiolingual direction.[44]

Transverse Dimensions & Asymmetries

Kusnoto and colleagues[30] investigated the orthodontic correction of transverse arch asymmetries, and noticed that asymmetry, in the transverse dimension, was not corrected. Further, there were no differences between growing and nongrowing individual responses in transverse asymmetry correction.[30]

Transverse Dimension & Craniofacial Growth

Initially, Marshall et al.[35] assessed the transverse molar movements during growth, and concluded that, on the average, the maxillary molars erupt with buccal crown torque and upright with age. Mandibular molars erupt with lingual crown torque and upright with age too.[35] These

molar crown torque changes were accompanied by concurrent increases in maxillary and mandibular intermolar widths.[35]

Later, Hesby and colleagues[21] studied the transverse skeletal and dentoalveolar changes during growth. The researchers[20] noted that there was a pattern of width changes that occurred as a gradient in the vertical dimension in: the maxilla, the maxillary and mandibular alveolar processes, as well as the maxillary and mandibular first molars. However, transverse mandibular basal bone changes, measured as bigonion and biantegonion, did not fit this pattern.[21]

Yavuz et al.[63] investigated the craniofacial longitudinal growth changes in the transverse and vertical dimensions between 10 and 14 years of age. In both sexes, the most pronounced age-related increases occurred in the mandibular width for transverse measurements, and in the total facial height for vertical measurements.[63]

Transverse Dimensions & Maxillary Expansions

McNamara[37] indicated that maxillary transverse deficiency may be indeed one of the most pervasive skeletal problems in the craniofacial region. As part of an initial evaluation of a patient, the distance between the closest points of the upper first molars (i.e., transpalatal

width). Typically, a maxillary arch with a transpalatal width of 36 to 39 mm can accommodate a dentition of average size without crowding or spacing; whereas maxillary arches less than 31 mm in width may be crowded and thus in need of orthopedic or surgically assisted expansion.[37]

The following three maxillary expansion issues will be briefly reviewed: rapid, semirapid, and slow maxillary expansions.

Transverse Dimension & Rapid Maxillary Expansion

In a classic article, Haas[19] indicated that the prime objective of palatal expansion is to coordinate the maxillary and mandibular denture bases. Lagravère et al.[32] studied the meta-analysis of immediate changes with rapid maxillary expansion (RME), and found that the greatest changes resulting from RME were dental and skeletal transverse changes. Few vertical and anteroposterior immediate changes were statistically significant, though they were clinically negligible.[32]

McNamara[38] pointed out that the appliance he uses most effectively to treat young patients is the acrylic splint RME. This appliance produces many treatment effects that are not limited to correcting a crossbite or increasing arch perimeter.[38] Thus, the cornerstone of his early

treatment protocols is RME: a dentofacial orthopedic approach that, when used appropriately, is an efficient and effective option for treating the mixed dentition patient.[38]

In a similar vein, McNamara et al.[39] longitudinally studied the short-term and long-term changes in dental arch dimensions in patients treated with RME followed by fixed edge-wise appliances. The treatment significantly produced favorable short- and long-term changes in almost all the maxillary and mandibular arch measurements.[39] In comparison with controls, a net gain of 6 mm was achieved in the maxillary arch perimeter, whereas a net gain of 4.5 mm was found for the mandibular arch perimeter of treated subjects in the long term.[39] The amount of correction in both maxillary and mandibular intermolar widths equaled two-thirds of the initial discrepancy, whereas treatment eliminated the initial deficiency in both maxillary and mandibular intercanine widths.[39] The amount of correction for the deficiency in maxillary arch perimeter was about 80%, whereas in the mandible a full correction was achieved.[39]

Further, Lagravère and colleagues[33] compared the transverse, vertical, and anteroposterior skeletal and dental changes in adolescents receiving expansion treatment

through bone-anchored maxillary expansion (BAME) versus traditional rapid maxillary expansion (TAME). The researchers[33] concluded that both expanders showed similar results. The greatest changes were seen in the transverse dimension; changes in the vertical and anteroposterior dimensions were negligible.[32,33] Dental expansion was also greater than skeletal expansion.[33]

Furthermore, Weyrich et al.[62] compared a modified RME appliance with other appliances for transverse maxillary expansion. The authors[62] concluded that the modified RME appliance could be used effectively for rapid maxillary expansion in the early mixed dentition. At the end of the retention phase, the overall effect of the modified appliance was similar to that of other expanders.[62]

Transverse Dimension & Semirapid Maxillary Expansion

Işeri et al.[25] explored the long-term transverse effects of semirapid maxillary expansion (SRME) in adults and older adolescents. The hypothesis was that SRME might stimulate the adaptation process in the nasomaxillary complex, and thus would result in relapse minimization.[25] The findings suggested that the dentoskeletal changes after the use of SRME were satisfactorily maintained in the long-term.[25]

Transverse Dimension & Slow Maxillary Expansion

Corbridge and colleagues[12] studied the transverse dentoalveolar changes after slow maxillary expansion, and found that early treatment with the quad-helix appliance was highly effective in increasing intermural, palatal, and alveolar widths. The teeth moved through the alveolus, leading to substantial decreases in buckle bone thickness and increases in lingual bone thickness.[12]

Transverse Dimension & Stability

In a retrospective longitudinal study, Horsley et al.[24] investigated the stability of transverse expansion in the mandibular arch. The researchers[24] found that transverse expansion was more stable in the posterior region of the mandibular dental arch than in the anterior region. Mandibular intercanine width increase could be maintained only by fixed retention.[24]

Vanarsdall[61] emphasized the critical importance of the skeletal differential between the width of the maxilla and the width of the mandible. He stated that: "Undiagnosed transverse discrepancy leads to adverse periodontal response, unstable dental camouflage, and less than optimal dentofacial esthetics".

Buccolingual Inclination, & Andrews' Third Key to Normal Occlusion

Buccolingual Inclination

Masumoto et al.[36] studied the relationships among facial type, buccolingual molar inclination, and cortical bone thickness of the mandible, and found significant complex relationship between structures of the mandibular body and facial types. The morphological features, related to masticatory functions and facial types, were associated with the cortical bone thickness of the mandibular body, and the buccolingual inclination of the first and second molars.[36] Specifically, the teeth of long-faced subjects were more lingually inclined than those of the short-faced subjects.[36] The buccolingual inclinations of the second molars were significantly smaller in the long-faced subjects than in the average- and short-faced subjects.[36] The cortical bone thickness of the first and second molars sections was thicker in the short-faced subjects than in the average- and long-faced subjects.[36]

Janson et al.[26] investigated the buccolingual inclinations of the posterior teeth in subjects with different facial patterns. Buccolingual inclinations of the first molars and second premolars were indirectly

assessed on photocopies of the buccolingual sections of these teeth by measuring their occlusal surfaces (represented by an imaginary line connecting the lingual and buccal cusps).[26] The maxillary posterior teeth of subjects, with a vertical growth pattern, had a significantly greater buccal inclination than those of subjects with a horizontal growth pattern.[26] However, there were no statistically significant differences in the inclinations of the mandibular posterior teeth between these two groups.[26]

Further, Garcia-Figueroa et al.[18] found that the buccolingual orientation changes do not seem to affect the incisor area. The clinical usefulness of panoramic radiography to assess root parallelism should be approached with caution, especially in premolar extraction sites.[18]

Through collaboration with the Dolphin Company, Tong et al.[60] developed the University of Southern California root vector analysis to measure each whole tooth mesiodistal angulation and faciolingual inclination directly from the CBCT volumetric images. The faciolingual inclination was measured in the faciolingual plane, and defined as the angle formed by the projection of the tooth's long axis with the intersection of the mesiodistal

and faciolingual planes.[60] If the root center was lingual to the crown center, the measurement was positive; otherwise, it was negative.[60]

Andrews' Third Key to Normal Occlusion

Andrews[3] studied dental casts of 120 non-orthodontic subjects having normal occlusion, and described the following six dynamically-interrelated characteristics of normal occlusion designed by nature without any orthodontic intervention, and called them "the six keys". These keys are: molar relationship, crown angulation, crown inclination, rotations, tight contacts, and occlusal plane.[3]

Andrews' third key to normal occlusion is the crown inclination; defined as the faciolingual torque of the long axis of the crown (not the long axis of the tooth).[3] It is the angle formed between the facial long axis of the crown (as viewed from a proximal perspective) and a perpendicular line erected from the occlusal plane.[3] It is positive when the gingival portion of the long axis of the crown is lingual to the incisal portion, and vice versa.[3] In normal occlusion, the crown inclination was negative for all the teeth except the maxillary central and lateral incisors.[3]

Further, the lingual crown inclination was similar for the maxillary canines through the maxillary second

premolars, and was slightly more pronounced in the maxillary molars.[3] Furthermore, the lingual crown inclination progressively increased from the mandibular canines through the mandibular second molars.[3]

ABO's Discrepancy Index (DI)

Cangialosi et al.[7] introduced the ABO's discrepancy index (DI) to measure case complexity. The DI measures objectively the following disorders: overjet, overbite, anterior open-bite, lateral open-bite, crowding, buccal posterior crossbite, lingual posterior crossbite, occlusion, ANB angle, IMPA, and SN-GoGn angle.[7] The greater the number of these conditions in a patient, the greater the complexity and the greater the challenge to the orthodontist.[7]

Pulfer et al.[53] indicated that the DI is reliable and relatively stable index for measuring malocclusion complexity. Although the DI is significantly related to outcomes for the most severe malocclusions, it was not a good predictor of outcome for more routine malocclusions.[53]

In a retrospective study of university clinical records, Parrish and colleagues[51] showed that the average increase in treatment duration was about 11 days for each point increase in total DI score. Further, Chaison et al.[8]

illustrated that missing teeth automatically inflate the DI score and improve the OGS score.

ABO's Objective Grading System (OGS)

Traditionally, the evaluation of the orthodontic treatment outcomes has been done through the subjective opinion of experienced orthodontists. In 1998, Casko and colleagues[8] introduced the ABO (American Board of Orthodontics) ruler and the ABO's objective grading system (OGS) for posttreatment dental casts and panoramic radiographs. Actually, the OGS reduces subjectivity when assessing the quality of orthodontic finishing, and helps evaluating cases submitted to the phase II ABO examination for board certification or re-certification.

The eight OGS scoring criteria are: marginal ridges, buccolingual inclinations, interproximal contacts, occlusal contacts, occlusal relationships, overjets, and root angulations.[8] Generally, case reports from which 19 or fewer points are deducted usually "pass", while case reports from which 30 or more points are deducted usually "fail".[8] Self-evaluation helps elevate the quality of orthodontics. According to Hildebrand and colleagues,[22] the OGS is currently the gold standard for evaluating the posttreatment plaster orthodontic casts.

Scott and Freer[55] pointed out that assessment of treatment outcomes has traditionally been accomplished using the subjective opinion of experienced clinicians. However, the occlusal traits defined by the OGS can be accurately assessed by visual inspection.[55]

Murakami et al.[43] suggested that the OGS has great potential to be the "gold standard", and is an ideal scoring index to quantitatively assess orthodontic treatment outcome without specific training for well-trained orthodontists. Among the 8 scoring criteria, the greatest difference in OGS scores was observed in buccolingual inclinations.[43] Thus, extra care might be needed when scoring the buccolingual inclinations.[43]

Pinskaya et al.[52] supplemented the OGS through a Comprehensive Clinical Assessment (CCA) method to evaluate facial form, dental esthetics, vertical dimension, arch form, periodontium preservation, root resorption, and treatment efficiency. The sum of the CCA and the OGS scores was defined as the clinical outcome.[52] Overall, longer active treatment durations resulted in a diminished clinical outcome, primarily due to "patient burn-out."[52] Patients who are progressing well in treatment tend to be finished by the time the current class graduates, and the

problem patients are transferred.[52] Because long treatment durations are associated with diminished clinical outcomes, it is often in the best interest of the uncooperative patients to terminate treatment rather than extend active mechanics in an attempt to achieve better results.[52]

Further, Owens et al.[49] introduced the Case Management Form (CMF) which is the third in a trio of instruments designed to increase the objectivity of the ABO clinical examination. However, the process is by no means complete.[49] The ABO will continue to refine these testing instruments to achieve the most effective examination process.[49] The ABO hopes that participation in the certification process will encourage every orthodontist to achieve his or her highest level of clinical proficiency.[49]

Furthermore, Okunami et al.[46] indicated that the OrthoCAD program (version 2.2) was not adequate for scoring the buccolingual inclination parameter as required by the OGS. Moreover, Hildebrand et al.[22] evaluated a software program for applying the OGS to digital casts. The scores from digital casts exceeded those from plaster casts by an average of 9.0 +/- 5.4 points.[22] This dissimilarity might be due to statistically significant differences in the following 3 OGS components: alignment, occlusal contact,

and overjet.[22] Thus, this software cannot be used as a substitute for manual grading with the ABO ruler.[22]

On one hand, Onyeaso and Begole[47] found that the Index of Complexity, Outcome, and Need (ICON) can replace both the Peer Assessment Rating (PAR) index, and the OGS for assessing treatment outcome, and can also replace the Dental Aesthetic Index (DAI) for assessing treatment need. On the other hand, Campbell and colleagues[6] indicated that the ABO's Discrepancy Index (DI) quantifies the severity of a malocclusion, while the ABO's Objective Grading System (OGS) assesses the quality of orthodontic finishing. Indiana University's Comprehensive Clinical Assessment (CCA) supplements the OGS to provide an instrument to determine clinical outcomes.[6]

Abei et al.[1] found a significantly lower ABO index score for patients treated by orthodontists compared with patients treated by general dentists. Further, Deguchi and colleagues[13] compared orthodontic treatment outcomes between clinics through the peer assessment rating, discrepancy index, objective grading system, and comprehensive clinical assessment. These indexes identified specific problems in treating Asian patients.[13]

Nett and Huang[45] pointed out that the American Board of Orthodontics (ABO) developed the Objective Grading System (OGS) to evaluate cases submitted as a part of the examination for board certification. The authors[45] examined the long-term changes in 6 of the 8 criteria measured by the board, with an emphasis on the relationship between posttreatment results and subsequent improvement or worsening. Well-treated cases tended to deteriorate, and poorly finished cases tended to improve; illustrating a regression to the mean.[45] It was concluded that settling occurs after orthodontic treatment, and that the attainment of perfect occlusal results does not ensure stability.[45]

Struble and Huang[59] specified that Angle Class I malocclusions have some advantage for achieving passing ABO-OGS scores, as does the retrospective selection of cases. Alignment, marginal ridges, and occlusal contacts appear to be where most points are deducted in the evaluation of ABO-OGS scores.[59]

Schabel et al.[54] indicated that neither total scores nor individual components of the ABO Grading system could predict attractive or unattractive smiles; as derived from logistic regression equations. For this reason, the incorporation of additional criteria was suggested for the

overall assessment of orthodontic treatment outcomes, including variables evaluating the smile.[54]

Detterline et al.[14] found statistically, but not clinically, significant differences in treatment durations and in total ABO-OGS scores in favor of 0.018-inch brackets as compared with the 0.022-inch brackets. Further, Chaison et al.[9] demonstrated that well-treated adult cases can pass the ABO clinical examination using the OGS. In addition, they[9] illustrated that missing teeth automatically inflate the Discrepancy Index (DI) score and improve the OGS score.

Cook et al.[10] compared university and private-practice orthodontic treatment outcomes through the OGS. Pretreatment, all subjects had Class II Division 1 malocclusions and ANB angles equal to or greater than 4 degrees.[10] There was no significant difference in the overall score, thus no significant difference in the overall quality of orthodontic treatment outcome between patients treated in university programs and private practices.[10] However, the university group had a significantly larger sample variance for the overall score.[10] There was no significant difference in the duration of the treatment between patients treated in a university setting and in a private practice.[10] In a

similar vein, Brown et al.[5] pointed out that the establishment of an annual objective outcomes assessment benefited patients by improving objective grading system scores and reduced the number of transfers between residents (increased case completion rate); thus reducing faculty time for managing transfer patients.

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CHAPTER III

THESIS STATEMENT

The **purpose** of the present research study is three-dimensional in nature:

- Evaluate the orthodontic pretreatment and posttreatment records through the Case Western Reserve University's (CWRU's) transverse analysis.
- Assess the pretreatment records through the American Board of Orthodontics' (ABO's) discrepancy index.
- Appraise the posttreatment study casts through the ABO's objective grading system (OGS).

The **main research questions** are:

- Does the CWRU's transverse analysis affect the orthodontic results?
- Does the CWRU's transverse analysis affect the active treatment duration?
- Does the discrepancy index affect the orthodontic results?

Based on these research questions, the following **hypotheses** were formulated:

- *Null Hypothesis (H_0) # 1:*

  The CWRU's transverse analysis does not affect the orthodontic results.

- *Alternate Hypothesis (H_1) # 1:*

  The CWRU's transverse analysis affects the orthodontic results.

- *Null Hypothesis (H_0) # 2:*

  The CWRU's transverse analysis does not affect the active treatment duration.

- *Alternate Hypothesis (H_1) # 2:*

  The CWRU's transverse analysis affects the active treatment duration.

- *Null Hypothesis (H_0) # 3:*

  The discrepancy index does not affect the orthodontic results.

- *Alternate Hypothesis (H_1) # 3:*

  The discrepancy index affects the orthodontic results.

Posttreatment Evaluation through the CWRU's Transverse Analysis, and the ABO's Objective Grading System

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ABSTRACT

Introduction: Orthodontic posttreatment evaluation is a challenge for improving not only the orthodontist's self-assessment but also the clinical competency in achieving the orthodontic goals. The purpose of the present study is to evaluate the pretreatment and posttreatment orthodontic records through the Case Western Reserve University's (CWRU's) transverse analysis, to assess the pretreatment records through the American Board of Orthodontics (ABO) discrepancy index (DI), and to appraise the posttreatment study casts through the ABO's objective grading system (OGS). The hypotheses were based on the following three questions: Does the CWRU's transverse analysis improve the orthodontic results? Does the CWRU's transverse analysis minimize the active treatment duration? Does the discrepancy index affect the orthodontic results? **Methods:** A retrospective cohort research study was executed on the basis of a sample of 90 subjects for the pretreatment group, and 86 subjects for the posttreatment group. The sample was divided into two groups according to whether or not the subjects were treated according to the CWRU's transverse analysis. The data were statistically analyzed through the t-tests. **Results:** The CWRU's transverse analysis significantly improved the OGS scores. However, it did not significantly affect the active treatment duration. Further, the discrepancy index had significant effects on the OGS scores. **Conclusions:** The CWRU's transverse analysis significantly improves the orthodontic results. However, it does not have significant effects on the active treatment duration. Further, the discrepancy index significantly affects the orthodontic results. **Clinical Implications:** Diagnostic strategies could be applied whereby the treatment plan and mechanotherapy are evidence-based on a clear vision of the desired orthodontic posttreatment outcomes satisfying different physiologic and esthetic requirements for each patient.

The primary goals of orthodontic treatment are to optimize functional protected occlusion, dentofacial esthetics, and long-term stability with the associated improvements in masticatory functions, periodontal status, physical health, and self-esteem. Excellence in treatment finishing is necessary. Further, the posttreatment evaluation of orthodontic records is a challenge for improving not only the orthodontist's self-assessment but also the clinical competency in achieving the above mentioned goals.

The purpose of the present research study is to: 1. Evaluate the orthodontic pretreatment and posttreatment records through the Case Western Reserve University's (CWRU's) transverse analysis. 2. Assess the pretreatment records through the American Board of Orthodontics' (ABO's) discrepancy index. 3. Appraise the posttreatment study casts through the ABO's objective grading system (OGS).

The sample consisted of 90 subjects for the pretreatment group, and 86 subjects for the posttreatment group. The sample was divided into two groups according to whether or not the subjects were treated according to the CWRU's transverse analysis. The study type was retrospective cohort research investigation (synonym: non-concurrent prospective cohort research study). Quality control was achieved through meticulous review of the literature, sound methodology, and powerful statistics.

The anticipated results are that CWRU's transverse analysis not only improves the orthodontic results, but also minimizes the active treatment duration. Further, the discrepancy index affects the orthodontic results. If these anticipated results are

achieved, diagnostic strategies could be applied whereby the treatment plan and mechanotherapy are evidence-based on a clear vision of the desired orthodontic posttreatment outcomes satisfying different physiologic and esthetic requisites for each patient.

BRIEF REVIEW OF THE LITERATURE

The following five topics will be briefly reviewed: CBCT, the transverse analysis of Case Western Reserve University (CWRU's transverse analysis), transverse dimension, the ABO's discrepancy index (DI), and the ABO's objective grading system (OGS).

CBCT

CBCT is an acronym for Cone-Beam Computed Tomography. Mostafa[1] indicated that the introduction of 3-dimensional CBCT imaging is revolutionizing the orthodontic diagnostic philosophy. Larson[2] indicated that it is the imaging of choice for comprehensive orthodontic treatment.

The CBCT Transverse Analysis of Case Western Reserve University (CWRU's Transverse Analysis)

In four consecutive years, the CBCT transverse analysis of Case Western Reserve University (CWRU's transverse analysis) was developed by: Shewinvanakitkul,[3] Evangelinakis,[4] Shewinvanakitkul et al.,[5] Karamitsou,[6] Miyamoto,[7] Copeland,[8] and Streit.[9] Shewinvanakitkul[3] developed a new technique to measure buccolingual inclinations using CBCT.

Transverse Dimension

The following five transverse dimension matters will be concisely reviewed: centers of rotation, asymmetries, craniofacial growth, maxillary expansions, and stability.

Transverse Dimensions & Asymmetries

Kusnoto and colleagues[10] investigated the orthodontic correction of transverse arch asymmetries, and noticed that asymmetry, in the transverse dimension, was not corrected. Further, there were no differences between growing and nongrowing individual responses in transverse asymmetry correction.[10]

Transverse Dimension & Craniofacial Growth

Initially, Marshall et al.[11] assessed the transverse molar movements during growth, and concluded that, on the average, the maxillary molars erupt with buccal crown torque and upright with age. Mandibular molars erupt with lingual crown torque and upright with age too.[11] These molar crown torque changes were accompanied by concurrent increases in maxillary and mandibular intermolar widths.[11] Later, Hesby and colleagues[12] studied the transverse skeletal and dentoalveolar changes during growth.

Transverse Dimensions & Maxillary Expansions

McNamara[13] indicated that maxillary transverse deficiency may be indeed one of the most pervasive skeletal problems in the craniofacial region. The following three maxillary expansion issues will be briefly reviewed: rapid, semirapid, and slow maxillary expansions.

Transverse Dimension & Rapid Maxillary Expansion

In a classic article, Haas[14] indicated that the prime objective of palatal expansion is to coordinate the maxillary and mandibular denture bases. Lagravère et al.[15] studied the meta-analysis of immediate changes with rapid maxillary expansion (RME), and found that the greatest changes resulting from RME were dental and skeletal transverse changes. Few vertical and anteroposterior immediate changes were statistically significant, though they were clinically negligible.[15]

Further, Lagravère and colleagues[16] compared the transverse, vertical, and anteroposterior skeletal and dental changes in adolescents receiving expansion treatment through bone-anchored maxillary expansion (BAME) versus traditional rapid maxillary expansion (TAME). The researchers[16] concluded that both expanders showed similar results. The greatest changes were seen in the transverse dimension; changes in the vertical and anteroposterior dimensions were negligible.[15,16] Dental expansion was also greater than skeletal expansion.[16]

Transverse Dimension & Stability

In a retrospective longitudinal study, Housley et al.[17] investigated the stability of transverse expansion in the mandibular arch. The researchers[23] found that transverse expansion was more stable in the posterior region of the mandibular dental arch than in the anterior region. Mandibular intercanine width increase could be maintained only by fixed retention.[17]

ABO's Discrepancy Index (DI)

Cangialosi et al.[18] introduced the ABO's discrepancy index (DI) to measure case complexity. The DI measures objectively the following disorders: overjet, overbite, anterior open-bite, lateral open-bite, crowding, buccal posterior crossbite, lingual posterior crossbite, occlusion, ANB angle, IMPA, and SN-GoGn angle.[18] The greater the number of these conditions in a patient, the greater the complexity and the greater the challenge to the orthodontist.[18]

ABO's Objective Grading System (OGS)

Traditionally, the evaluation of the orthodontic treatment outcomes has been done through the subjective opinion of experienced orthodontists. In 1998, Casko and colleagues[19] introduced the ABO (American Board of Orthodontics) ruler and the ABO's objective grading system (OGS) for posttreatment dental casts and panoramic radiographs. Actually, the OGS reduces subjectivity when assessing the quality of orthodontic finishing, and helps evaluating cases submitted to the phase II ABO examination for board certification or re-certification.

MATERIALS AND METHODS

The following four major topics will be discussed: sample, materials, methods, and statistics.

Sample

The selection criteria and the sample size will be identified.

Selection Criteria

1. Inclusion Criteria:

Subjects who started orthodontic treatment in the core clinic at CWRU in 2010 and who completed active treatment.

2. Exclusion Criteria: a. Incomplete pretreatment records (i.e.; pretreatment CBCT scans, study casts, intra-oral and extra-oral photographs, and initial treatment plans). b. Incomplete posttreatment records (i.e.; study casts, intra-oral and extra-oral photographs, and progress notes).

Sample Size

The sample was composed of 90 subjects for the pretreatment group, and 86 subjects for the posttreatment group.

Materials

- Pretreatment records (i.e.; pretreatment CBCT scans, study casts, intra-oral and extra-oral photographs, and initial treatment plans).
- Posttreatment records (i.e.; study casts, intra-oral and extra-oral photographs, and progress notes).
- The Hitachi CB MercuRay machine.
- The ABO (American Board of Orthodontists) measuring gauge.

Methods

The IRB (Institutional Review Board) approved the experimental protocol. The sample was divided into two groups on the basis of whether or not the subjects were treated according to the CWRU's CBCT transverse analysis. These two groups are: 1. Followed the CWRU's transverse analysis. 2. Did not follow the CWRU's transverse analysis.

In the "Followed" group, the treatment plan included rapid maxillary expansion (RME) for those subjects who had at least either one maxillary molar having abnormal buccolingual inclinations (more than one standard deviation above the mean), or one mandibular molar having abnormal buccolingual inclinations (more than one standard deviation below the mean). Further, in the "Followed" group, the treatment plan included archwire expansion for those subjects who had at least one maxillary molar having abnormal buccolingual inclinations (more than one standard deviation below the mean).

The following seven independent variables were recorded: crossbite status, maxillary expansion, active treatment duration, pretreatment and posttreatment age, gender, and race. Eleven dependent variables were measured: four pretreatment buccolingual inclinations as well as four posttreatment buccolingual inclinations through the CWRU's transverse analysis, one dichotomized CWRU variable (followed or did not follow the CWRU's transverse analysis), the discrepancy index, plus the OGS score.

The CBCT scans were taken through the "Hitachi CB MercuRay". Customization to CWRU were as follows: 2 mA, 120 kVp, 12 inch field of view, 512 slices, 0.377 mm slice thickness, resolution of 1024x1024 pixels, 12 bits per pixel, and 4096 gray scale.[20,21] For the CWRU's transverse analysis, the pretreatment buccolingual inclinations of the maxillary and mandibular permanent first molars were determined for each quadrant (as described by Karamitsou[6] and Shewinvanakitkul et al.[5]) through the Dolphin 3D volumetric images.

The buccolingual inclination of each maxillary first molar was measured through the angle outlined between the palatal long axis of the tooth (the line joining the mesiopalatal cusp tip with the palatal root apex) and a tangent to the inferior border of the nasal cavity.[6] The buccolingual inclination of each mandibular first molar was measured through the angle formed between the long axis of the tooth (the line connecting the central groove with the middle of root apices) and a tangent to the inferior border of the mandible.[5]

The results of the transverse analysis, were labeled as excellent for those subjects within one standard deviation from the mean, moderate for those subjects within two standard deviations from the mean, and poor for those subjects outside two standard deviations from the mean.

For the discrepancy index (DI), the pretreatment records were evaluated to objectively measure the following disorders: overjet, overbite, anterior open-bite, lateral open-bite, crowding, buccal posterior crossbite, lingual posterior crossbite, occlusion, ANB angle, IMPA, SN-GoGn angle, and other complexities. However, for the objective grading system (OGS), the posttreatment dental casts were scored, through the following seven criteria: marginal ridges, buccolingual inclinations, interproximal contacts, occlusal contacts, occlusal relationships, and overjets.

Statistics

The following four statistical matters will be clarified: intrarater reliability, normal distribution, significance level, and statistical tests.

Intrarater Reliability

Through the CWRU's transverse analysis, the primary author measured the posttreatment buccolingual inclinations of the maxillary and mandibular permanent first molars on 30 subjects. Further, this author estimated the ABO's discrepancy index through the pretreatment records of 30 subjects. Furthermore, the same author gauged the OGS measurements through the posttreatment orthodontic casts of 30 subjects. After an interval of 4 weeks, all of the above measurements were repeated by the same author. The reliability analyses were utilized to evaluate the intrarater reliability.

Normal Distribution

In order to satisfy the major assumptions of parametric statistical testing, normality of the data distribution were evaluated. To assess normal distribution, the following numerical and visual outputs were investigated:

- *The Shapiro-Wilk,[22] and the Kolmogorov-Smirnov Tests:*

  The significance level ought to be a non-significant p-value of 5% or more.

- *Skewness[23] and Kurtosis:*

  Their z-values must be in the range of -1.96 to +1.96. Further, they should visually indicate that the data are approximately normally distributed.

Significance Level: The p-value was predefined as less than 5%.

Statistical Tests: The data were analyzed through the independent-samples t-tests.

RESULTS

The summary of the results are presented in Tables I - VI and Figs 1 – 5.

DISCUSSION

The following ten topics will be briefly discussed: research questions, data collection, methodological aspects, limitation of the study, descriptive statistics, inferential statistics, statistical conclusions, research conclusions, clinical implications, and case presentation.

Research Questions

Does the CWRU's transverse analysis improve the orthodontic results? Does the CWRU's transverse analysis affect the active treatment duration? Does the discrepancy index affect the orthodontic results?

Data Collection

The data were collected. A retrospective cohort research study was executed on the basis of a sample of 90 subjects for the pretreatment group, and 86 subjects for the posttreatment group. The sample was divided into two groups according to whether or not the subjects were treated according to the CWRU's transverse analysis.

Methodological Aspects

Two methodological aspects will be discussed. The reason for the discrepancy between the pretreatment and posttreatment sample sizes is that 4 subjects, who completed active treatment, did not have posttreatment CBCT scans.

The intrarater reliabilities (Table I) were computed. Cronbach's alpha was used because it is a strong model of internal consistency based on the mean (absolute value) inter-item correlation for all possible variable pairs. Reliability is the extent to which an experiment, test, or measuring device yields the same results on repeated trials.

However, validity is the conformity to accepted biological principles. Thus, reliability is a necessary condition for validity.[24]

Limitations of the Study

Two limitations. The measurements were prone to systematic errors because a single researcher measured all the data. Further, the ABO ruler showed a limitation in the measurement of the BL inclinations whenever a molar was severely proclined buccally.

Descriptive Statistics

The descriptive statistics are presented in Figs 1 -5 as well as Table II.

Inferential Statistics

The discrepancy index significantly affects the OGS scores (Table III). Further, there was no significant difference between the mean discrepancy index of those who followed the CWRU's transverse analysis and the mean of those who did not follow the CWRU's transverse analysis (Table IV). In other words, the CWRU did not significantly affect the discrepancy index.

As evident from Table V, the mean OGS scores of those who followed the CWRU's transverse analysis was significantly lower than the mean OGS scores of those who did not follow the CWRU's transverse analysis. Thus, the CWRU's transverse analysis significantly improved the OGS scores.

However, there was no significant difference between the mean active treatment duration of those who followed the CWRU's transverse analysis and the mean of those who did not follow the CWRU's transverse analysis (Table VI). In other words, the CWRU's transverse analysis did not significantly affect the active treatment duration.

Statistical Conclusions

- The CWRU's transverse analysis significantly improved the OGS scores (Table V).
- Further, the discrepancy index significantly affected the OGS scores (Table III).
- However, the CWRU's transverse analysis did not have significant effects on the discrepancy index (Table IV).
- Further, the CWRU's transverse analysis did not significantly affect the active treatment duration (Table VI).

Research Conclusions

- The CWRU's transverse analysis significantly improves the orthodontic results (Table V).
- Further, the discrepancy index has significant effects on the orthodontic results (Table III).
- However, the CWRU's transverse analysis does not significantly affect the discrepancy index (Table IV).
- Further, the CWRU's transverse analysis does not have significant effects on the active treatment duration (Table VI).

Clinical Implications

Clinical implications will be presented. The CBCT CWRU's transverse analysis could identify abnormalities in buccolingual inclinations (Fig 6) leading to either excess or deficient torque in the maxilla and/or the mandible. In the same vein, Vanarsdall[25] emphasized the critical importance of the skeletal differential between the width of the maxilla and the width of the mandible. He stated that: Undiagnosed transverse

discrepancy leads to adverse periodontal response, unstable dental camouflage, and less than optimal dentofacial esthetics.

Further, diagnostic tactics could be applied whereby the treatment plans and biomechanics are evidence-based on a clear mental picture of the desired orthodontic posttreatment outcomes satisfying diverse physiologic and esthetic requisites for each patient.

Case Presentation

The pretreatment records revealed Class I molar and canine on the right side, Class I molar and Class II canine on the left side, without crowding in either arch (Fig 7). By looking at Fig 8, one can notice that the pretreatment buccolingual inclinations were as follows: 103.2° (maxillary right first molar), 104.5° (maxillary left first molar), 57.1° (mandibular right first molar), and 57.3° (mandibular left first molar). These measurements indicate normal maxillary buccolingual inclinations accompanied with abnormal deficient mandibular inclinations.

The treatment plan did not include expansion. If the CWRU's transverse analysis was used, the biomechanics would have included rapid palatal expansion (RPE) with mandibular archwire expansion.

During treatment, the case had mandibular archwire expansion for a couple of appointments. By looking at Fig 9, one can see that the posttreatment buccolingual inclinations were as follows: 105.7° (maxillary right first molar), 109° (maxillary left first molar), 68.3° (mandibular right first molar), and 71.1° (mandibular left first molar).

The OGS score was 17 indicating good posttreatment results. Looking closely on the section, the OGS molar inclination of the maxillary left first molar and the mandibular right first molar actually scored 1 (Fig 10).

CONCLUSIONS

On the basis of the results obtained from the present research study, the following conclusions were drawn:

- The CWRU's transverse analysis significantly improves the orthodontic results (Table V).
- However, it does not have significant effects on the active treatment duration (Table VI).
- Further, the discrepancy index has significant effects on the orthodontic results (Table III).

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Legends of Figures & Tables

According to the Order of Appearance in the Manuscript

Page 59. **Table I.** Intrarater reliability through the reliability analysis

Page 60. **Fig 1.** Histograms of the ABO's discrepancy index.

Page 60. **Fig 2.** Pie chart of the recoded ABO's discrepancy index.

Page 61. **Fig 3.** Histogram of the ABO's objective grading system.

Page 61. **Fig 4.** Pie chart of the ABO's objective grading system.

Page 62. **Fig 5.** Histograms of the pretreatment buccolingual inclinations of all permanent first molars measured through the CWRU's transverse analysis.

Page 63. **Table II.** Buccolingual inclinations of permanent first molars through the CWRU's transverse analysis (Mean ± Standard Deviation)

Page 63. **Table III.** Independent-samples t-test between the discrepancy index and the OGS

Page 64. **Table IV.** Independent-samples t-test between the CWRU's transverse analysis and the discrepancy index

Page 64. **Table V.** Independent-samples t-test between the CWRU's transverse analysis and the ABO's objective grading system

Page 64. **Table VI.** Independent-samples t-test between the CWRU's transverse analysis and the active treatment duration

Page 65. **Fig 6.** CWRU's transverse analysis.

Page 66. **Fig 7.** Initial composite

Page 67. **Fig 8.** CWRU's pretreatment buccolingual inclinations of the maxillary and mandibular first molars.

Page 68. **Fig 9.** CWRU's posttreatment buccolingual inclinations of the maxillary and mandibular first molars.

Page 69. **Fig 10.** Final composite.

Table I. Intrarater reliability[a] through the reliability analysis

Variables		Cronbach's Alpha
Discrepancy Index		98.7%****
OGS		98.9%****
Posttreatment Buccolingual Inclinations	# 3: Permanent Maxillary Right First Molars	99.8%****
	# 14: Permanent Maxillary Left First Molars	99.9%****
	# 30: Permanent Mandibular Right First Molars	99.8%****
	# 19: Permanent Mandibular Left First Molars	99.7%****

n = 30

[a] The measurements were repeated after an interval of 4 weeks

**** Significant at a p-value (probability value) of less than 0.0001, (2-tailed)

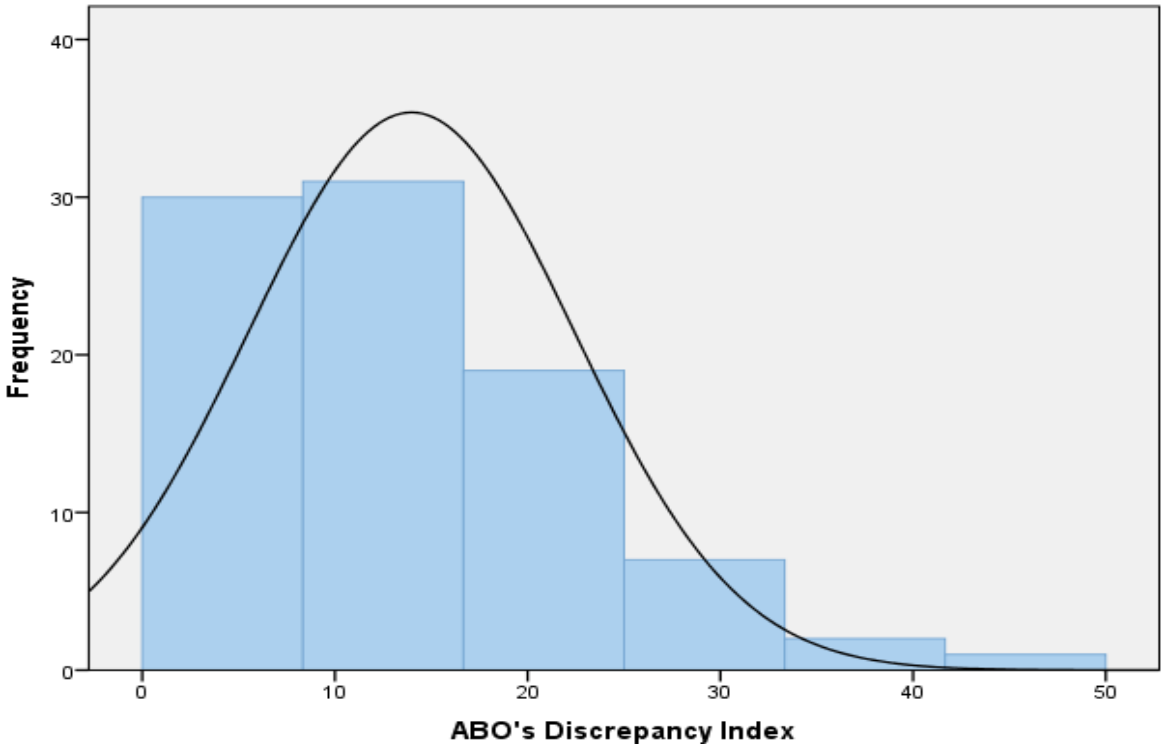


Fig 1. Histogram of the ABO's discrepancy index.

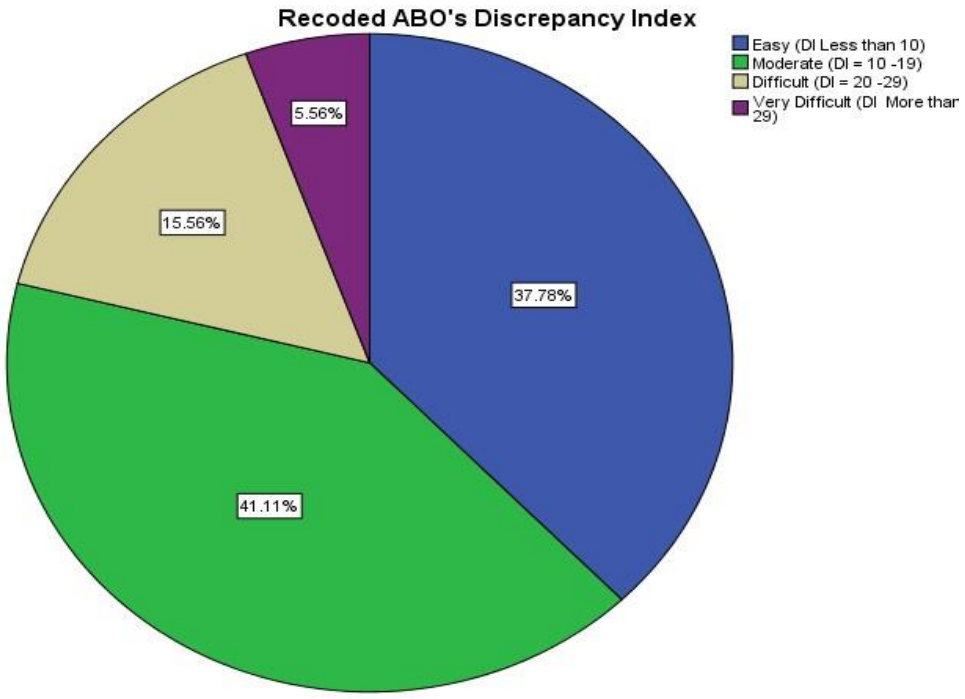


Fig 2. Pie chart of the recoded ABO's discrepancy index.

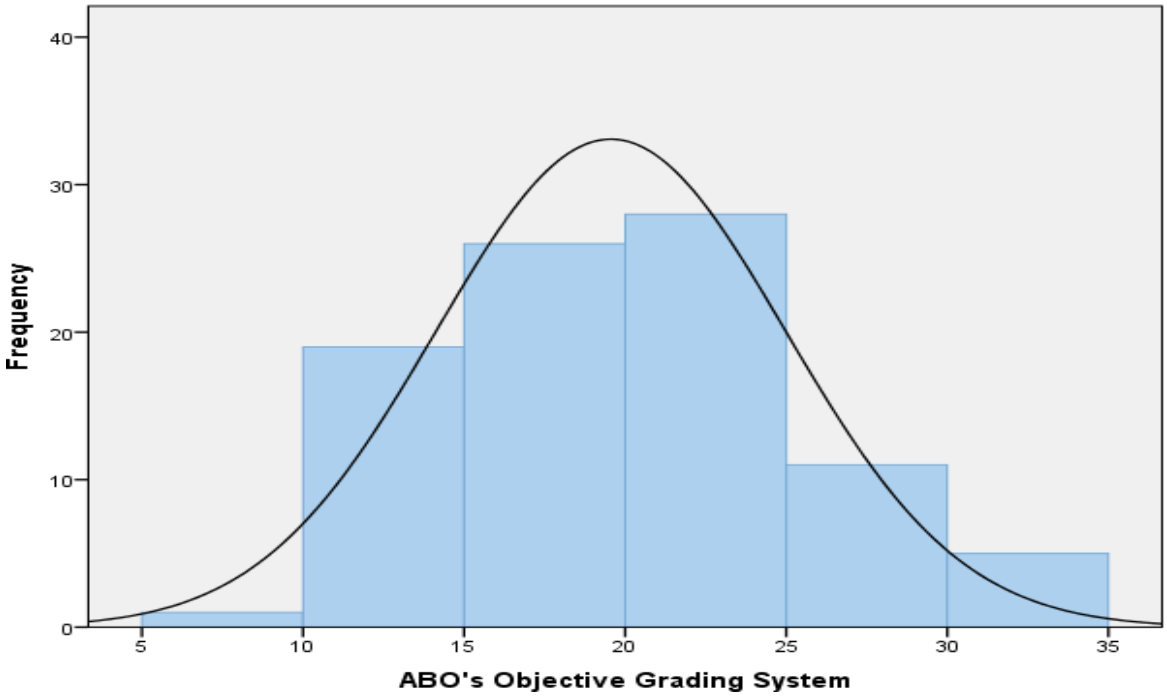


Fig 3. Histogram of the ABO's objective grading system.

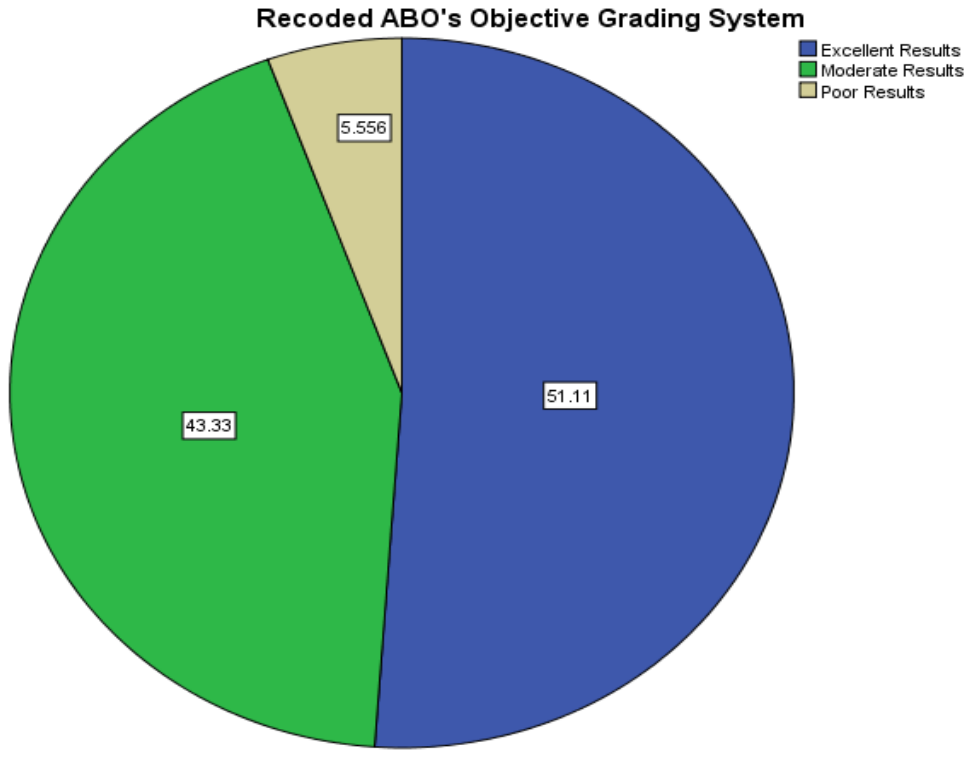


Fig 4. Pie chart of the recoded ABO's objective grading system.

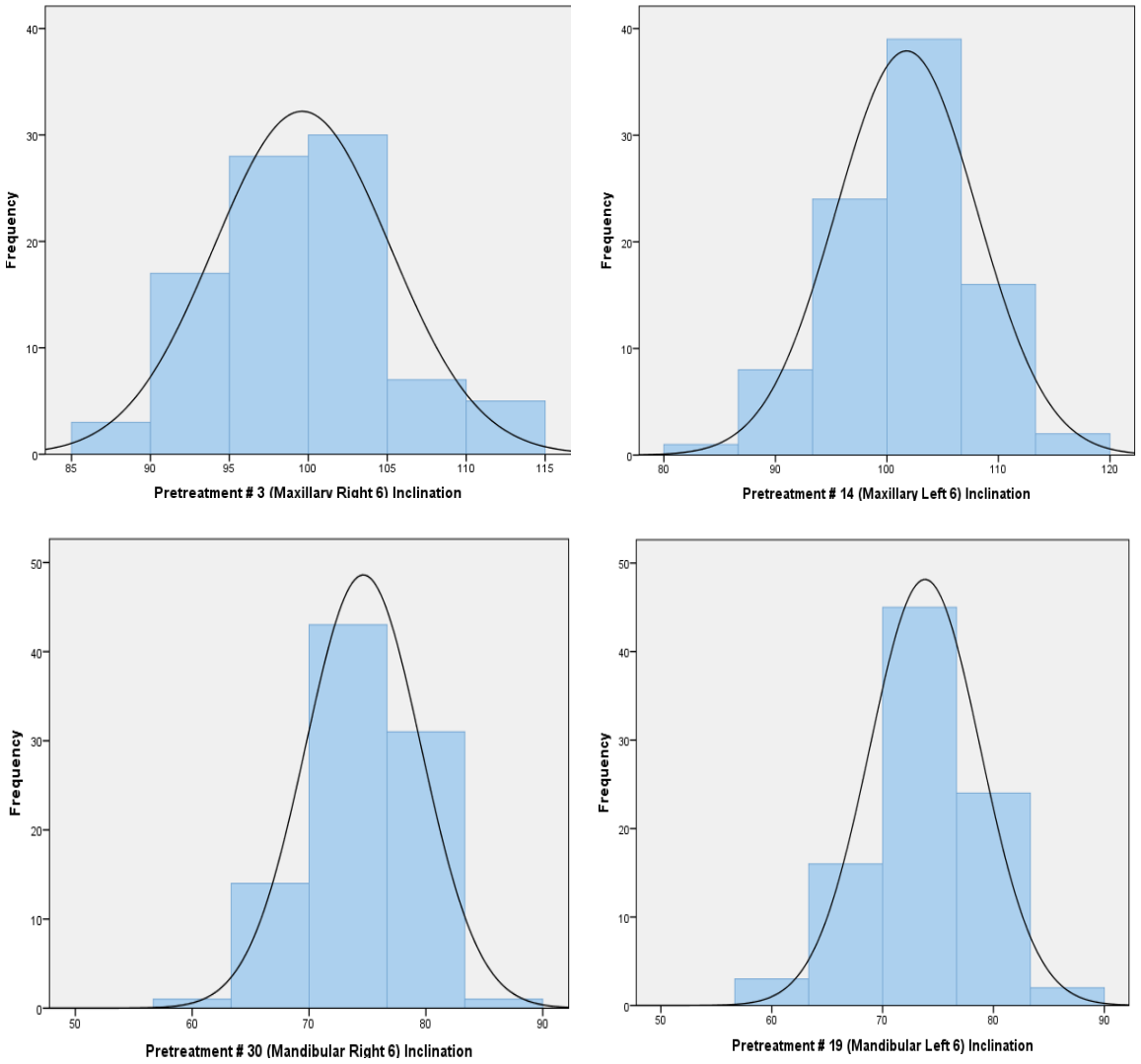


Fig 5. Histograms of the pretreatment buccolingual inclinations of all permanent first molars measured through the CWRU's transverse analysis.

Table II. Buccolingual inclinations of permanent first molars through the CWRU's transverse analysis (Mean ± Standard Deviation)

Transverse Analysis	Buccolingual Inclinations of Permanent First Molars			
	Permanent Maxillary First Molars		Permanent Mandibular First Molars	
	# 3 (UR6)	#14 (UL6)	#30 (LR6)	#19 (LL6)
Pretreatment	99.61 ± 5.57[a]	101.76 ± 6.31	74.64 ± 4.92	73.82 ± 4.97
Posttreatment	101.77 ± 4.89	102.38 ± 5.94	77.50 ± 4.97	76.57 ± 5.10

n = 90 (Pretreatment), & 86 (Posttreatment)
[a] Mean ± Standard Deviation

Table III. Independent-samples t-test between the discrepancy index and the OGS

Discrepancy Index		Mean	Standard Deviation	Significance
OGS	**DI >= 21**	23.13	5.61	***
	DI < 21	18.78	5.10	

******* Significant at a p-value of less than 0.005, (2-tailed)
n = 90 (Total), 16 (Moderate), 74 (Difficult)

Table IV. Independent-samples t-test between the CWRU's transverse analysis and the discrepancy index

CWRU Transverse Analysis		Mean	Standard Deviation	Significance
Discrepancy Index	Followed CWRU	14.00	7.18	NS
	Did Not Follow CWRU	13.93	9.92	

NS = Not Significant
n = 90 (Total), 50 (Followed), 40 (Did not follow)

Table V. Independent-samples t-test between the CWRU's transverse analysis and the ABO's objective grading system

CWRU Transverse Analysis		Mean	Standard Deviation	Significance
ABO's Objective Grading System (OGS)	Followed CWRU	17.64	5.42	****
	Did Not Follow CWRU	21.95	4.44	

******** Significant at a p-value of less than 0.0001, (2-tailed)
n = 90 (Total), 50 (Followed), 40 (Did not follow)

Table VI. Independent-samples t-test between the CWRU's transverse analysis and the active treatment duration

CWRU Transverse Analysis		Mean	Standard Deviation	Significance
Active Treatment Duration	Followed CWRU	24.30	4.87	NS
	Did Not Follow CWRU	25.83	4.63	

NS = Not Significant
n = 90 (Total), 50 (Followed), 40 (Did not follow)

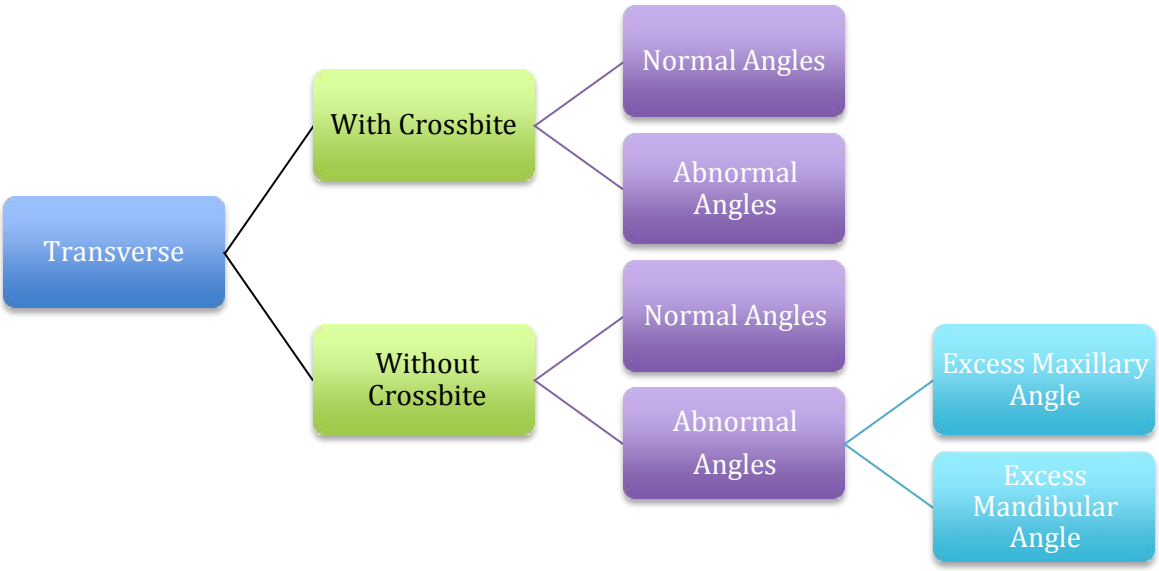


Fig 6. CWRU's transverse analysis.

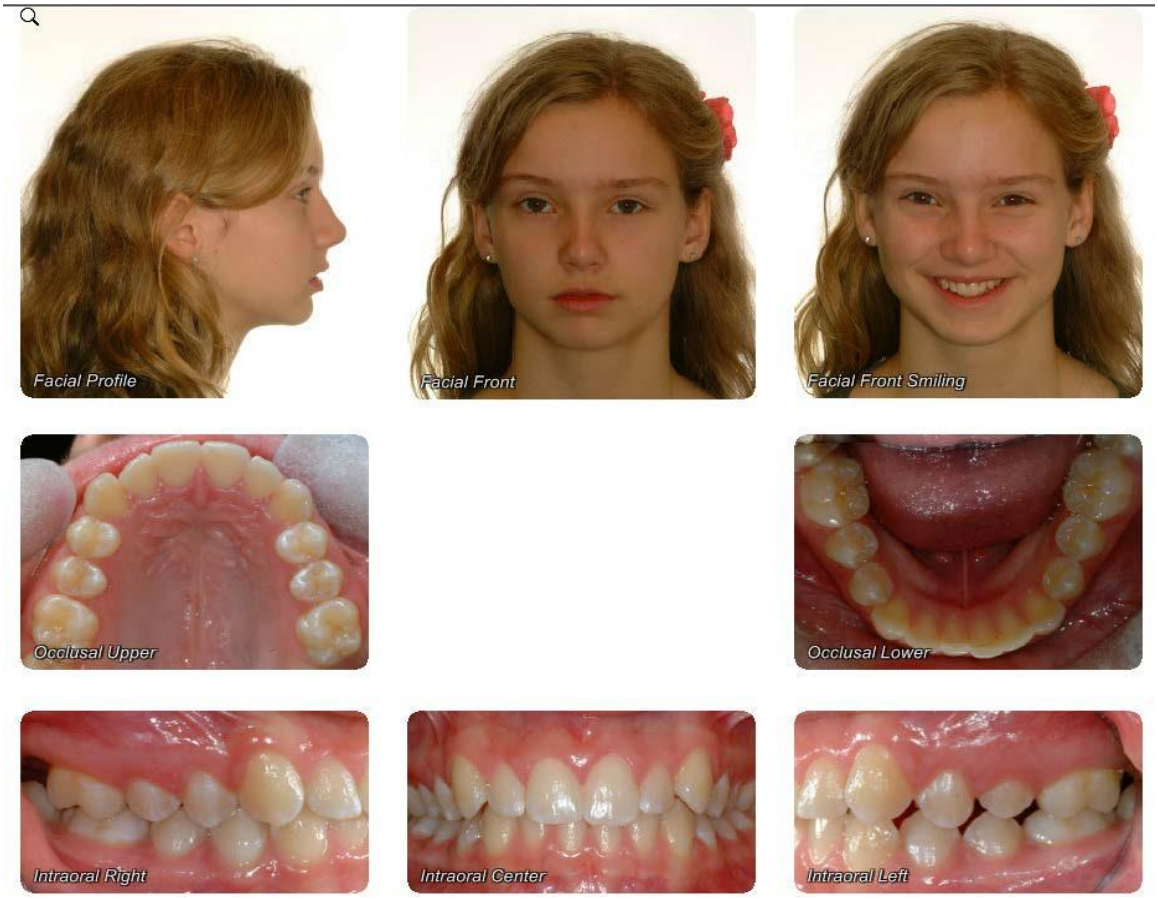


Fig 7. Initial composite.

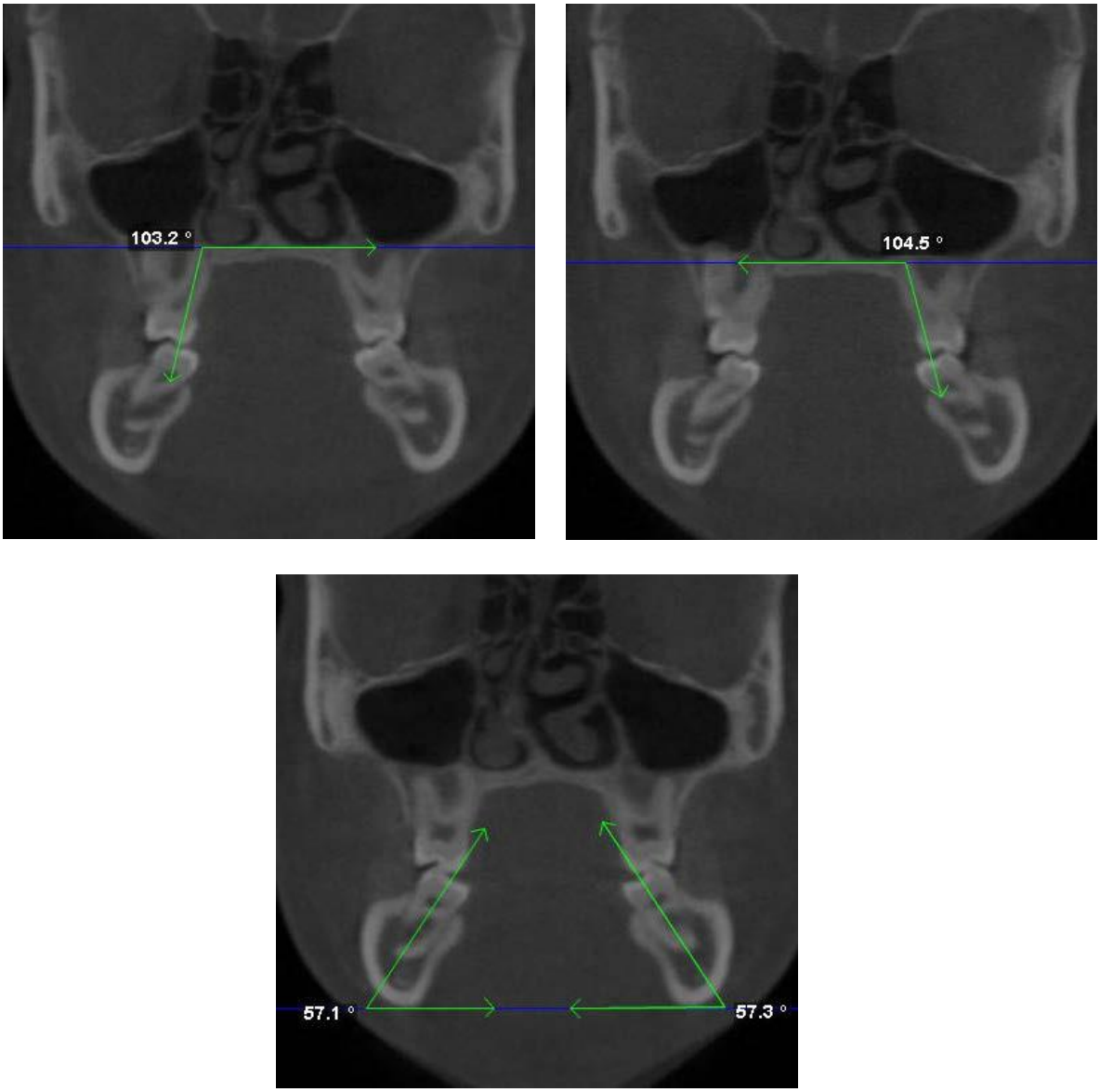


Fig 8. CWRU's pretreatment buccolingual inclinations of the maxillary and mandibular first molars.

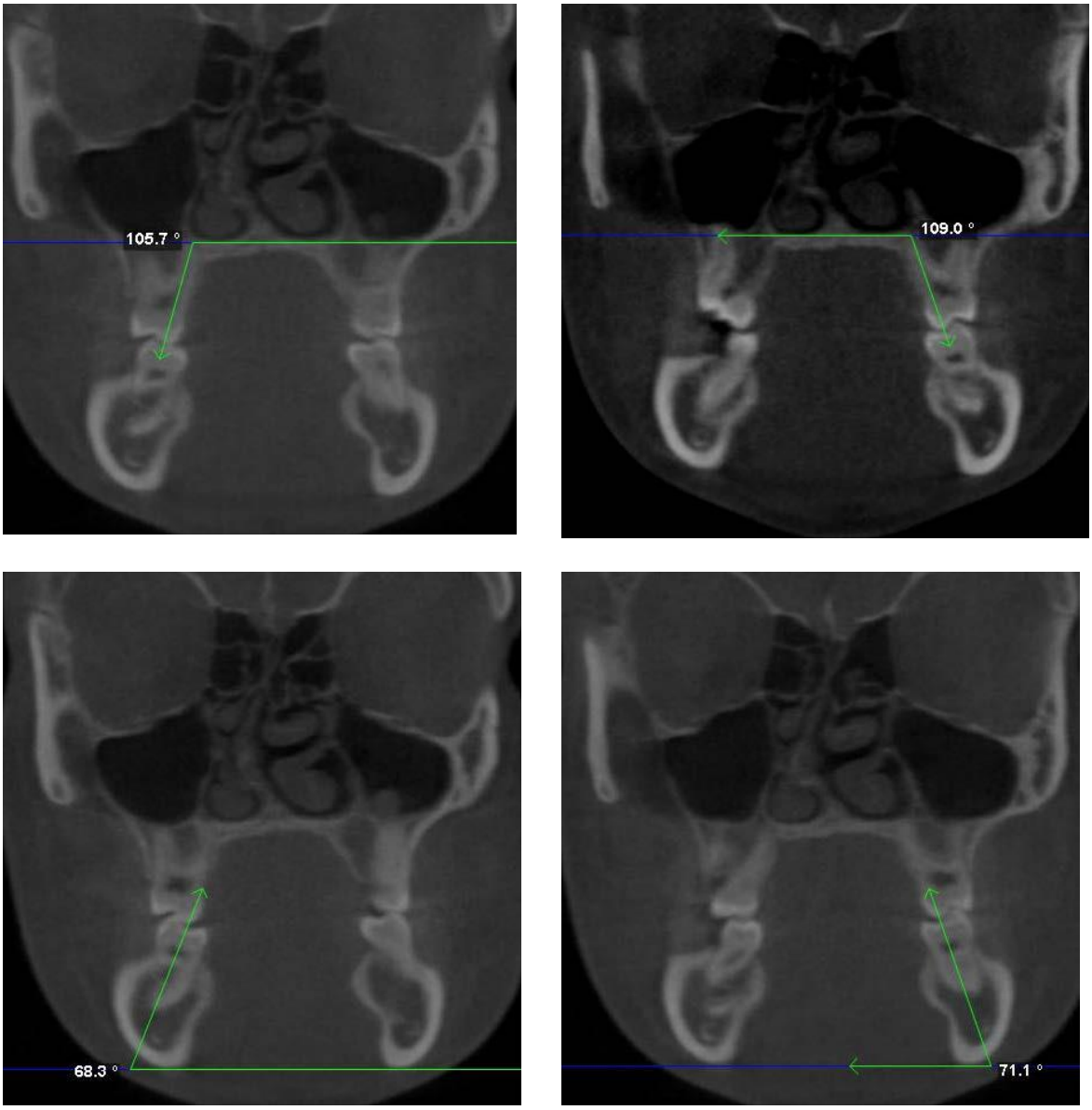


Fig 9. CWRU's posttreatment buccolingual inclinations of the maxillary and mandibular first molars.

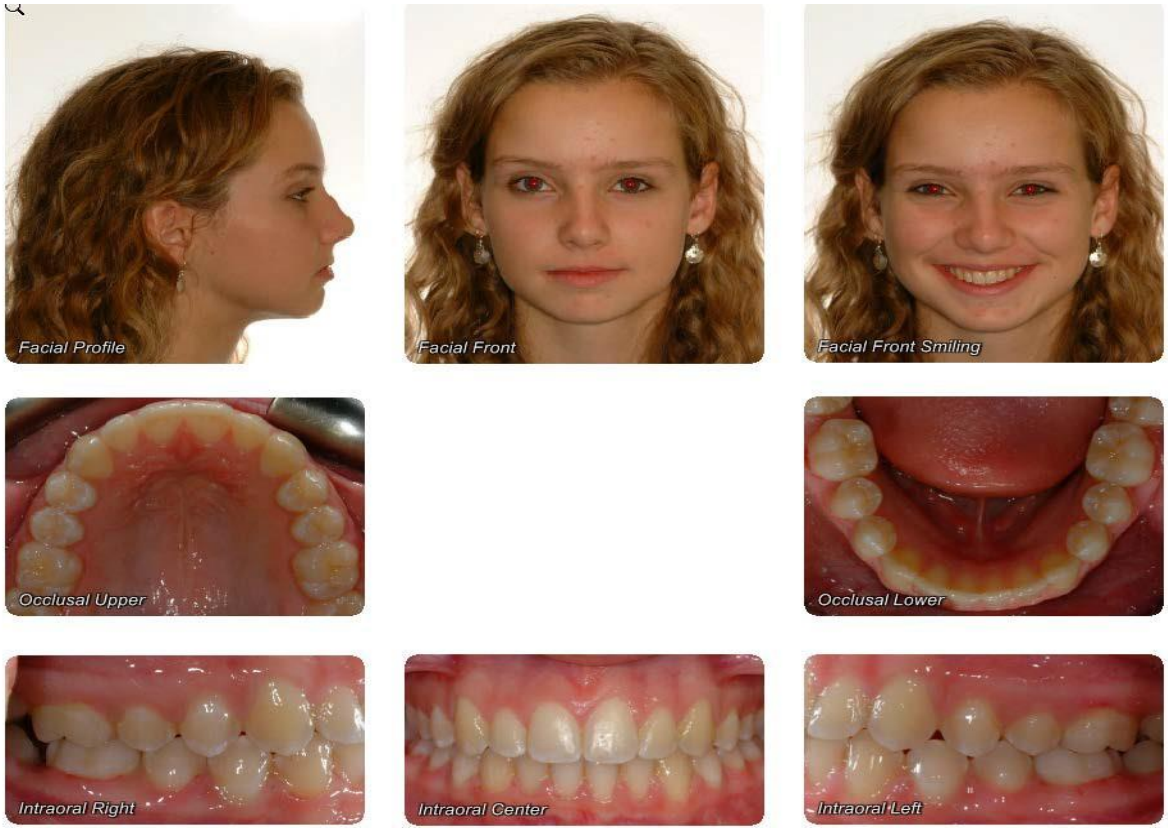


Fig 10. Final composite.

Appendix A. **CHAPTER V**

MATERIALS AND METHODS

The following four major topics will be discussed: sample, materials, methods, and statistics (Fig 2).

Sample

The selection criteria and the sample size will be identified.

Selection Criteria

1. Inclusion Criteria:

   Subjects who started orthodontic treatment in the core clinic at CWRU in 2010,[11] and who completed active treatment.

2. Exclusion Criteria:

   - Incomplete pretreatment records (i.e.; pretreatment CBCT scans, study casts, intra-oral and extra-oral photographs, and initial treatment plans).
   - Incomplete posttreatment records (i.e.; study casts, intra-oral and extra-oral photographs, and progress notes).

Sample Size

The original sample contained 100 subjects,[11] randomly selected from 283 cases, who started orthodontic treatment

in the core CWRU clinic in 2010. However, the final samples were composed of 90 subjects for the pretreatment group, and 86 subjects for the posttreatment group.

Materials

- Pretreatment records (i.e.; pretreatment CBCT scans, study casts, intra-oral and extra-oral photographs, and initial treatment plans).[11]
- Posttreatment records (i.e.; study casts, intra-oral and extra-oral photographs, and progress notes).
- The Hitachi CB MercuRay machine.
- The ABO (American Board of Orthodontists) measuring gauge (Fig 3).

Methods

The following four methodological issues will be explained: methodological description, study type, quality control, and anticipated results.

Methodological Description

The CWRU's IRB (Institutional Review Board) approved the experimental protocol; as evidenced from Appendix A. The present research study is based on a continuation of Copeland[11] research investigation. The original sample size was composed of 100 subjects,[11] randomly selected from 283 cases, who began orthodontic treatment in the core CWRU

clinic in 2010. The final sample sizes comprised 90 subjects for the pretreatment group, and 86 subjects for the posttreatment group.

The sample was divided into two groups on the basis of whether or not the subjects were treated according to the CWRU's transverse analysis. These two groups are:

- Followed the CWRU's transverse analysis.
- Did not follow the CWRU's transverse analysis.

In the "Followed" group, the treatment plan included rapid maxillary expansion (RME) for those subjects who had at least either one maxillary molar having abnormal buccolingual inclinations (more than one standard deviation above the mean), or one mandibular molar having abnormal buccolingual inclinations (more than one standard deviation below the mean). Further, in the "Followed" group, the treatment plan included archwire expansion for those subjects who had at least one maxillary molar having abnormal buccolingual inclinations (more than one standard deviation below the mean).

The following seven independent variables were recorded: crossbite status, maxillary expansion, active treatment duration, pretreatment and posttreatment age, gender, and race. Eleven dependent variables were

measured: four pretreatment buccolingual inclinations as well as four posttreatment buccolingual inclinations through the CWRU's transverse analysis, one dichotomized CWRU variable (followed or did not follow the CWRU's transverse analysis), the discrepancy index, plus the OGS score.

The CBCT scans were taken through the "Hitachi CB MercuRay" (Fig 4). Customization to CWRU were as follows: 2 mA, 120 kVp, 12 inch field of view, 512 slices, 0.377 mm slice thickness, resolution of 1024x1024 pixels, 12 bits per pixel, and 4096 gray scale.[31,50] For the CWRU's transverse analysis, the buccolingual inclinations of the maxillary and mandibular permanent first molars were determined for each quadrant (as described by Karamitsou[27] and Shewinvanakitkul et al.[57]) through the Dolphin 3D volumetric images.

Specifically, the Karamitsou[27] method for measuring the maxillary molar inclinations is as follows. First, in the sagittal view, align the line representing the axial view along the ANS (Fig 5). In the axial view, locate the ANS with the intersection of the lines representing the coronal and saggital views (Fig 6). In the sagittal view, pass the line representing the axial view through the Atlas (Fig 7).

In the axial view, rotate the line representing the sagittal view about ANS so that it passes through the odontoid process (Fig 8). The maxillary molar inclination (Fig 9) 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). In the sagittal view, align the line representing the coronal view along the mesiopalatal cusp and palatal root apex (Fig 10). In the coronal view, draw the reference line tangent to the inferior border of the nasal cavity (Fig 11). In the coronal view (Fig 12), measure the buccolingual inclination through the angle formed between the inferior border of the nasal cavity and the long axis of the molar (apex of palatal root to mesial palatal cusp tip).

Further, the Shewinvanakitkul et al.[57] method of measuring mandibular molar inclinations is as follows. First, locate the molar in the axial view where the roots are the longest in the sagittal view (Fig 13). In the sagittal view, align the line representing the coronal view along the apex of the mesial root and the mesial cusp tip (Fig 14). Then, draw a reference line tangent to the inferior border of the mandible in the coronal view (Fig 15). In the coronal view, measure the angle formed by a

line along the inferior border of the mandible and the long axis of the molar (Fig 16).

The results of the transverse analysis, were labeled as excellent for those subjects within one standard deviation from the mean, moderate for those subjects within two standard deviations from the mean, and poor for those subjects outside two standard deviations from the mean. To facilitate this labeling process, a trichotomization table for the CWRU's transverse analysis (Table IX) was built by including the means plus and minus one standard deviation, as well as the means plus and minus two standard deviations.

For the discrepancy index (DI), the pretreatment records were evaluated to objectively measure the following disorders: overjet, overbite, anterior open-bite, lateral open-bite, crowding, buccal posterior crossbite, lingual posterior crossbite, occlusion, ANB angle, IMPA, SN-GoGn angle, and other complexities. However, for the objective grading system (OGS), the posttreatment dental casts were scored, through the following seven criteria: marginal ridges, buccolingual inclinations, interproximal contacts, occlusal contacts, occlusal relationships, and overjets.

Study Type

Retrospective cohort research study.

Quality Control

Quality control was achieved through meticulous review of the literature, sound methodology, and powerful statistics.

Anticipated Results

The CWRU's transverse analysis not only improves the orthodontic results, but also minimizes the active treatment duration. Further, the discrepancy index affects the orthodontic results.

Statistics

The following eleven statistical matters will be clarified:

- Variables.
- Measurement scales.
- Dummy tables.
- Sample power and size estimation.
- Reliability.
- Counts and percentages.
- Descriptive statistics.
- Trichotomization,
- Normal distribution.
- Inferential statistics.
- Statistical conclusions.

Variables

1. Seven Independent Variables (IV, Exposures, Predictors, or Inputs):
   - Crossbite status, maxillary expansion, active treatment duration, pretreatment and posttreatment age, gender, and race.
2. Eleven Dependent Variables (DV, Outcomes, Predicted variables, or Targets):
   - Nine CWRU's transverse analysis variables:
     - Four CWRU's transverse analysis pretreatment measurements: the buccolingual inclinations of the maxillary and mandibular permanent first molars for each quadrant.
     - Four CWRU's transverse analysis posttreatment measurements: the buccolingual inclinations of the maxillary and mandibular permanent first molars for each quadrant.
     - One dichotomized CWRU variable (followed or did not follow the CWRU's transverse analysis).
   - The ABO's discrepancy index.
   - The ABO's OGS score for the posttreatment dental casts, calculated from the following seven variables: alignments, marginal ridges, buccolingual

inclinations, interproximal contacts, occlusal contacts, occlusal relationships, and overjets.

Measurement Scales

1. Continuous Ratio Scale:
   - Pretreatment and posttreatment buccolingual inclinations of the maxillary and mandibular permanent first molars; measured through the CWRU's transverse analysis.
   - Active treatment duration.
   - Age: pretreatment and posttreatment.
2. Continuous Ordinal Scale or Categorical Ordinal Scale
   - The ABO's discrepancy index.
   - The ABO's OGS score of the posttreatment dental casts.
   - The recoded pretreatment and posttreatment buccolingual inclinations of the maxillary and mandibular permanent first molars; measured through the CWRU's transverse analysis. The recoded inclinations were labeled as excellent inclinations (for those subjects within one standard deviation from the mean), moderate inclinations (for those subjects within two standard deviations from the mean), or poor inclinations (for those subjects outside two standard deviations from the mean).

- Recoded Pretreatment Age: younger (range 10 to 13 years), or older (range 14 to 16 years).
- Recoded Posttreatment Age: younger (range 12 to 15 years), or older (range 16 to 19 years).

3. Categorical Nominal Scale:
   - Crossbite Status: no crossbite, unilateral crossbite, or bilateral crossbite.
   - Maxillary Expansion: no expansion, RME (rapid maxillary expansion), or maxillary archwire expansion.
   - Gender: female or male.
   - Race: Caucasian or non-caucasian.

Dummy Tables

Dummy tables were designed and constructed prior to the statistical analyses to facilitate the data tabulation in the Results Chapter.

Sample Power and Size Estimation

They were calculated through the "SPSS SamplePower".

Reliability

- Interrater Reliability

  Through the CWRU's transverse analysis, Copeland[11] measured the pretreatment buccolingual inclinations of the maxillary and mandibular permanent first molars on 100 subjects. The same measurements were repeated by

the present researcher. The reliability analyses were used to assess the interrater reliability.

- Intrarater Reliability
  - Through the CWRU's transverse analysis, the present researcher measured the posttreatment buccolingual inclinations of the maxillary and mandibular permanent first molars on 30 subjects.
  - Further, the present researcher estimated the ABO's discrepancy index through the pretreatment records of 30 subjects.
  - Furthermore, the present researcher gauged the OGS measurements through the posttreatment orthodontic casts of 30 subjects.
  - After an interval of 4 weeks, all of the above measurements were repeated by the same researcher.
  - The reliability analyses were utilized to evaluate the intrarater reliability.

Counts & Percentages

The counts and percentages of the ordinal and nominal variables were reported through the SPSS Codebook.

Descriptive Statistics

Descriptive statistics were computed, and data graphics were done.

Trichotomization

To support the labeling process of the buccolingual inclinations variables of the CWRU's transverse analysis, a trichotomization table was constructed by including the means plus and minus one standard deviation, as well as the means plus and minus two standard deviations.

Normal Distribution

In order to satisfy the major assumptions of parametric statistical testing, normality of the data distribution was evaluated. To assess normal distribution, the following numerical and visual outputs were investigated:

- The Shapiro-Wilk, and the Kolmogorov-Smirnov Tests:

  The significance level ought to be a non-significant p-value of 5% or more.

- Skewness and Kurtosis:

  Their z-values must be in the range of -1.96 to +1.96.

- Histograms, Q-Plots, and Box Plots:

  They should visually indicate that the data are approximately normally distributed.

Inferential Statistics

- Significance Level:

  The p-value was predefined as less than 5%.

- Statistical Tests:

The data were analyzed through the independent-samples t-tests as well as the paired t-tests.

Statistical Conclusions: listed at the end of the Results chapter.

Appendix B. **CHAPTER VI**

RESULTS

The following seven topics (Fig 17) will be presented: sample power and size estimation, reliability, counts and percentages, descriptive statistics, trichotomization, normal distribution, and inferential statistics. The summary of the results are presented in Tables I through XX and Figs 18 through 28. This chapter will end with the statistical conclusions.

Sample Power & Size Estimation

Through a sample power analysis (Fig 18), the sample size estimation was 26 per group.

Reliability

In the present research, all the interrater and intrarater reliabilities (Tables I & II) showed significant strong positive correlations through the Cronbach's alpha, at a probability of less than 0.0001.

Counts & Percentages

For ordinal and nominal variables, the counts and percentages are presented in Table III.

Descriptive Statistics

The descriptive statistics are presented in Tables IV-VIII and Tables XI, XIII, and XV, as well as Figs 19 through 25.

Trichotomization

A trichotomization table (Table IX) was constructed for the CWRU's transverse analysis to facilitate labeling of the results of the buccolingual inclinations.

Normal Distribution

Through numerical and visual outputs (Tables XI and XII, as well as Fig 26), the data was found to be approximately normally distributed for the dependent variable "Discrepancy Index" with each category of the independent variable CWRU. Specifically:

- All the z-values of skewness and kurtosis were within the range of -1.96 to + 1.96 (Table XI).
- There were no significant differences through the Shapiro-Wilk and the Kolmogorov-Smirnov tests (Table XII).
- The histograms, q-plots, and box plots showed visually that the data are approximately normally distributed (Fig 26).

Further, through numerical and visual outputs (Tables XIII and XIV, as well as Fig 27), the data was

approximately normally distributed for the dependent variable "OGS" with each category of the independent variable CWRU. Precisely:

- All the z-values of skewness and kurtosis were within the range of -1.96 to + 1.96 (Table XIII).
- There were no significant differences through the Shapiro-Wilk and the Kolmogorov-Smirnov tests (Table XIV).
- The histograms, q-plots, and box plots visually confirmed that the data are approximately normally distributed (Fig 27).

Furthermore, through numerical and visual outputs (Tables XV and XVI, as well as Fig 28), the data was found to be approximately normally distributed for the dependent variable "Active Treatment duration" with each category of the independent variable CWRU. Particularly:

- All the z-values of skewness and kurtosis were within the range of -1.96 to + 1.96 (Table XV).
- There were no significant differences through the Shapiro-Wilk and the Kolmogorov-Smirnov tests (Table XVI).

- The histograms, q-plots, and box plots showed visually that the data are approximately normally distributed (Fig 28).

Statistical Conclusions

- The CWRU's transverse analysis significantly improved the OGS scores (Table XIX).
- Further, the discrepancy index significantly affected the OGS scores (Table XVII).
- However, the CWRU's transverse analysis did not have significant effects on the discrepancy index (Table XVIII).
- Further, the CWRU's transverse analysis did not significantly affect the active treatment duration (Table XX).

Appendix C. **CHAPTER VII**

DISCUSSION

Posttreatment evaluation of orthodontic results is a challenge for developing not only the orthodontist's self-appraisal but also the clinical proficiency in attaining the pretreatment objectives. The aim of the present investigation is to assess the orthodontic pretreatment and posttreatment records through the Case Western Reserve University's (CWRU's) transverse analysis, appraise the pretreatment records through the ABO's discrepancy index, and score the posttreatment study casts through the ABO's objective grading system (OGS). In this Chapter, the thesis cycle (Fig 29) will be discussed.

Research Question

The main research questions are: Does the CWRU's transverse analysis improve the orthodontic results? Does the CWRU's transverse analysis affect the active treatment duration? Does the discrepancy index affect the orthodontic results?

Data Collection

The data were collected. A retrospective cohort research study was executed on the basis of an original sample of

100 subjects. However, the final sample sizes were composed of 90 subjects for the pretreatment group, and 86 subjects for the posttreatment group. The sample was divided into two groups according to whether or not the subjects were treated according to the CWRU's transverse analysis.

Methodological Aspects

Few methodological aspects will be discussed. The reasons for these discrepancies between the sample sizes are that 5 subjects were still in active treatment, 5 subjects had no posttreatment study casts, and 4 subjects had no posttreatment CBCT scans.

The interrater and intrarater reliabilities (Tables I & II) were computed. Cronbach's alpha was used because it is a strong model of internal consistency based on the mean (absolute value) inter-item correlation for all possible variable pairs. Reliability is the extent to which an experiment, test, or measuring device yields the same results on repeated trials. However, validity is the conformity to accepted biological principles. Thus, reliability is a necessary condition for validity.

The data were analyzed through the paired samples t-tests and the independent-samples t-tests. The paired

samples t-tests (Table X) were done to compare the pretreatment with the posttreatment buccolingual inclinations of the permanent first molars for those who followed the CWRU's transverse analysis (n=48), as well as for those who did not follow the CWRU's transverse analysis (n=38).

Further, four independent-samples t-tests (Tables XVII – XX) were executed. The first independent-samples t-test (Table XVII) was done to compare the means of OGS (a normally distributed continuous ordinal dependent variable) for two independent discrepancy groups (Difficult discrepancy versus moderate discrepancy).

The second through the fourth independent-samples t-test (Tables XVIII - XX) were executed to compare the means of three different dependent variables for two independent CWRU groups (Followed or did not follow the CWRU's transverse analysis). The means of the discrepancy index (a normally distributed continuous ordinal dependent variable) were compared in Table XVIII, while the OGS means were compared in Table XIX. The fourth of these t-tests (Table XX) was carried out to compare the means of the active treatment duration (a normally distributed interval dependent variable).

Limitations of the Study

Two limitations. The measurements were prone to systematic errors because a single researcher measured all the data. Further, the ABO ruler showed a limitation in the measurement of the BL inclinations whenever a molar was severely proclined buccally.

Inferential Statistics

- As obvious from Table X, when following the CWRU's transverse analysis, the paired pretreatment and posttreatment buccolingual inclinations of most first molars (i.e.; # 3 [UR6], # 30 [LR6] and # 19 [LL6]) were significantly different at a probability of less than 0.0001. However, when not following the CWRU's transverse analysis, only the paired pretreatment and posttreatment buccolingual inclinations of the mandibular molars were significantly different (Table X).
- The discrepancy index significantly affects the OGS scores (Table XVII).
- There was no significant difference between the mean discrepancy index of those who followed the CWRU's transverse analysis and the mean of those who did not follow the CWRU's transverse analysis (Table XVIII). In

other words, the CWRU does not significantly affect the discrepancy index.

- As evident from Table XIX, the mean OGS scores of those who followed the CWRU's transverse analysis was significantly lower than the mean OGS scores of those who did not follow the CWRU's transverse analysis. Thus, the CWRU's transverse analysis significantly improves the OGS scores.
- However, there was no significant difference between the mean active treatment duration of those who followed the CWRU's transverse analysis and the mean of those who did not follow the CWRU's transverse analysis (Table XX). In other words, the CWRU's transverse analysis did not significantly affect the active treatment duration.

Statistical Conclusions

- The CWRU's transverse analysis significantly improved the OGS scores (Table XIX).
- Further, the discrepancy index significantly affected the OGS scores (Table XVII).
- However, the CWRU's transverse analysis did not have significant effects on the discrepancy index (Table XVIII).

- Further, the CWRU's transverse analysis did not significantly affect the active treatment duration (Table XX).

Research Conclusions

- The CWRU's transverse analysis significantly improves the orthodontic results (Table XIX).
- Further, the discrepancy index has significant effects on the orthodontic results (Table XVII).
- However, the CWRU's transverse analysis does not significantly affect the discrepancy index (Table XVIII).
- Further, the CWRU's transverse analysis does not have significant effects on the active treatment duration (Table XX).

Clinical Implications

Clinical implications will be presented. The CWRU's transverse analysis could identify abnormalities in buccolingual inclinations (Fig 30) leading to either excess or deficient torque in the maxilla and/or the mandible.

In the same vein, Vanarsdall[61] emphasizes the critical importance of the skeletal differential between the width of the maxilla and the width of the mandible. He stated that: "Undiagnosed transverse discrepancy leads to adverse

periodontal response, unstable dental camouflage, and less than optimal dentofacial esthetics".

Further, diagnostic tactics could be applied whereby the treatment plans and biomechanics are evidence-based on a clear mental picture of the desired orthodontic posttreatment outcomes satisfying diverse physiologic and esthetic requisites for each patient.

Presentation of Cases

1. Crossbite and normal inclinations

Case # 9 is an example. She had a bilateral crossbite (Fig 31). To address the crossbite, her treatment plan was maxillary and mandibular 7-7 bonding, and a hyrax expander. Treating this case with the hyrax expander is the classic approach in treating a bilateral crossbite because symmetric expansion can be achieved. It should be noted that Miyamoto[7] found no statistical significant differences between the changes in buccolingual inclinations of maxillary molars and canines in subjects treated with rapid palatal expansion (RPE) pretreatment as well as posttreatment. Taking this into consideration, this case would have been better suited for rapid maxillary expansion (RME).

By looking at Fig 32, one can see that the buccolingual inclinations were as follows: 98.8° (maxillary right first molar), 98.5° (maxillary left first molar), 72.2° (mandibular right first molar), and 74.4° (mandibular left first molar). This indicates that the buccolingual inclinations of the all permanent first molars are within normal range which suggests using an expander. The reason is that if the biomechanics were addressed with crossbite elastics or archwire expansion, we would observe maxillary molar inclinations ending up outside the normal range at the end of treatment. The OGS score was 15 indicating good posttreatment results (Fig 33).

2. Crossbite and abnormal inclinations

Case # 79 is an example. The patient had a unilateral posterior crossbite (Fig 34). The treatment plan consisted of archwire expansion, bonding the maxillary and mandibular dentitions, and class II elastics to address the class II malocclusion. Because of the presence of a unilateral crossbite, archwire expansion is a good choice because unilateral expansion could be reached.

Upon further investigations (Fig 35), the maxillary right and left first molar inclinations were 98.8° and 91.6° respectively. The mandibular molar inclinations were

69.7° for the right first molar and 81.1° for the left first molar. The OGS score was 17 designating good posttreatment results (Fig 36).

3. Normal inclinations without crossbite

Case # 44 is an example (Fig 37). By looking at Fig 38, one can see that the buccolingual inclinations were as follows: 98.2° (maxillary right first molar), 102° (maxillary left first molar), 82.6° (mandibular right first molar), and 80.1° (mandibular left first molar). This indicates that all four molar inclinations are within the normal range.

The treatment plan did not include any kind of expansions because of the absence of a transverse deficiency. Notice that the mandibular right first permanent molar was 82.6°. If the molar inclinations were measured prior to treatment, it would have been helpful to put into consideration not to torque the mandibular right first molar buccally.

By looking at Fig 39, one can notice that the posttreatment buccolingual inclinations were as follows: 103.5° (maxillary right first molar), 103.2° (maxillary left first molar), 89.6° (mandibular right first molar), and 78.1° (mandibular left first molar). This indicates

that all four molar inclinations are within the normal range with the exception of the mandibular right first molar which ended up being torqued buccally.

The OGS score was 23 designating moderate posttreatment results (Fig 40). Other categories in the OGS may lead to that score. However, looking closely on the section of the molar inclinations of the OGS, the mandibular right first molar actually scored 1.

4. Abnormal inclinations without posterior crossbite (excess maxillary torque)

Case # 21 is an example (Fig 41). The patient has anterior crossbite on the maxillary lateral incisors without posterior crossbite. By looking at Fig 42, one can note that the buccolingual inclinations were as follows: 95.8° (maxillary right first molar), 113.1° (maxillary left first molar), 79.8° (mandibular right first molar), and 71.5° (mandibular left first molar).

The treatment plan included expansion. If the patient did not have an anterior crossbite, treating with expansion without measuring the BL inclinations was not going to be the common theme. The maxillary molar inclinations were 102.7° and 99.8°, and the mandibular molar inclinations were 82.4° and 73.2° (Fig 43). Thus, the transverse

analysis revealed that the posttreatment inclinations of the maxillary molars were within the normal range.

However, the OGS score was 33 indicating poor results. The case was finished with Class II canines and first premolars on the left side with rotations of the mandibular anterior teeth. The maxillary and mandibular second molars were not aligned properly; where they were scored for the uneven marginal ridges (Fig 44). Looking through the progress chart, there were several appointments where the maxillary and mandibular second molar brackets were debonded. This makes it harder for the orthodontist to properly finish the case and may prolong the active treatment duration.

5. Abnormal inclinations without crossbite (excess mandibular torque)

Case # 7 is an example. The pretreatment records revealed Class I molar and canine on the right side, Class I molar and Class II canine on the left side, without crowding in either arch (Fig 45). By looking at Fig 46, one can notice that the pretreatment buccolingual inclinations were as follows: 103.2° (maxillary right first molar), 104.5° (maxillary left first molar), 57.1° (mandibular right first molar), and 57.3° (mandibular left first molar).

The treatment plan did not include expansion. If the CWRU's transverse analysis was used, the biomechanics would have included rapid palatal expansion (RPE).

During treatment, the case had mandibular archwire expansion for a couple of appointments. By looking at Fig 47, one can see that the posttreatment buccolingual inclinations were as follows: 105.7° (maxillary right first molar), 109° (maxillary left first molar), 68.3° (mandibular right first molar), and 71.1° (mandibular left first molar).

The OGS score was 17 indicating good posttreatment results. Looking closely on the section, the OGS molar inclination of the maxillary left first molar and the mandibular right first molar actually scored 1 (Fig 48).

6. Other cases

In addition to the degree of case difficulty as measured through the discrepancy index, missed appointments and broken appliances tend to prolong the active treatment duration. Ten cases did not complete active treatment yet. If the CWRU's transverse analysis was followed, three out of the ten cases would have been treatment planed differently with the resultant decrease in the active treatment duration.

One case should have a treatment plan for extraction mechanotherapy due to severe crowding and ectopically erupting canines. However, it was not. In the progress notes, the patient started to develop an open-bite during treatment.

Appendix D. **CHAPTER VIII**

SUMMARY AND CONCLUSIONS

The purpose of the present research study was to evaluate the orthodontic pretreatment and posttreatment records through the Case Western Reserve University's (CWRU's) transverse analysis, assess the pretreatment records through the ABO's discrepancy index, and appraise the posttreatment study casts through the ABO's objective grading system (OGS). The main research questions were as follows: 1. Does the CWRU's transverse analysis improve the orthodontic results? 2. Does the CWRU's transverse analysis affect the active treatment duration? 3. Does the discrepancy index affect the orthodontic results?

An original sample of 100 subjects was studied. The final sample sizes were composed of 90 subjects for the pretreatment group, and 86 subjects for the posttreatment group.

On the basis of the results obtained from the present research study, the following conclusions were drawn:

The CWRU's transverse analysis significantly improves the orthodontic results. However, it does not have significant effects on the active treatment duration. Further, the discrepancy index significantly affects the orthodontic results.

Appendix E. **Figures**

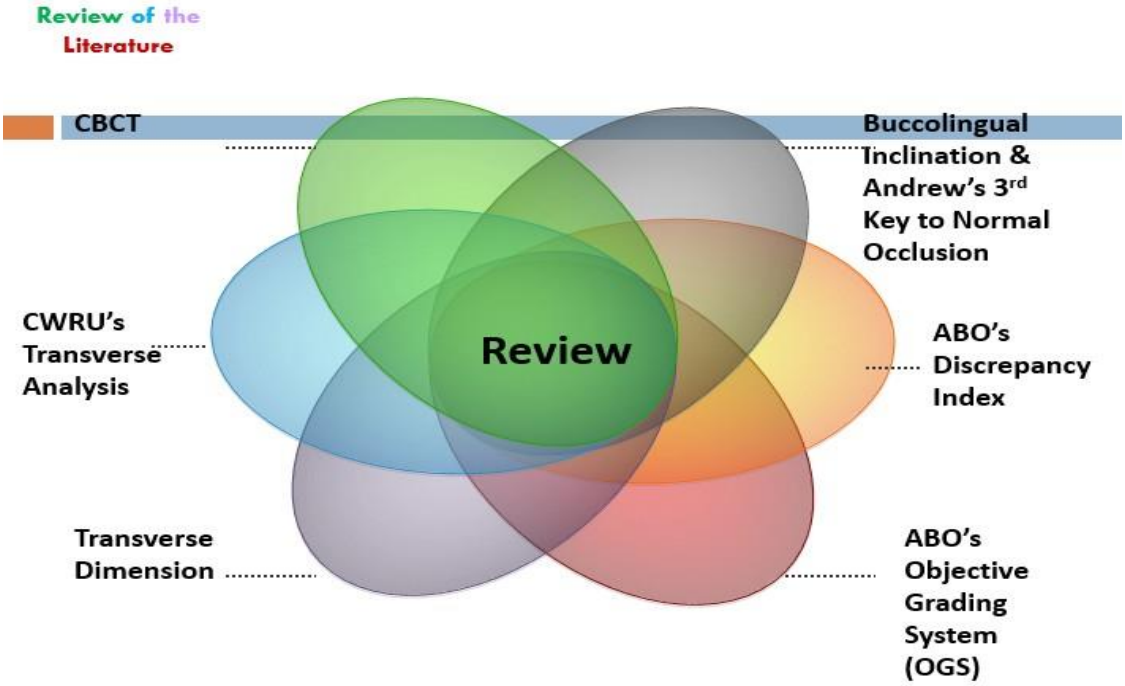


Fig 1. Outline of the literature's review.

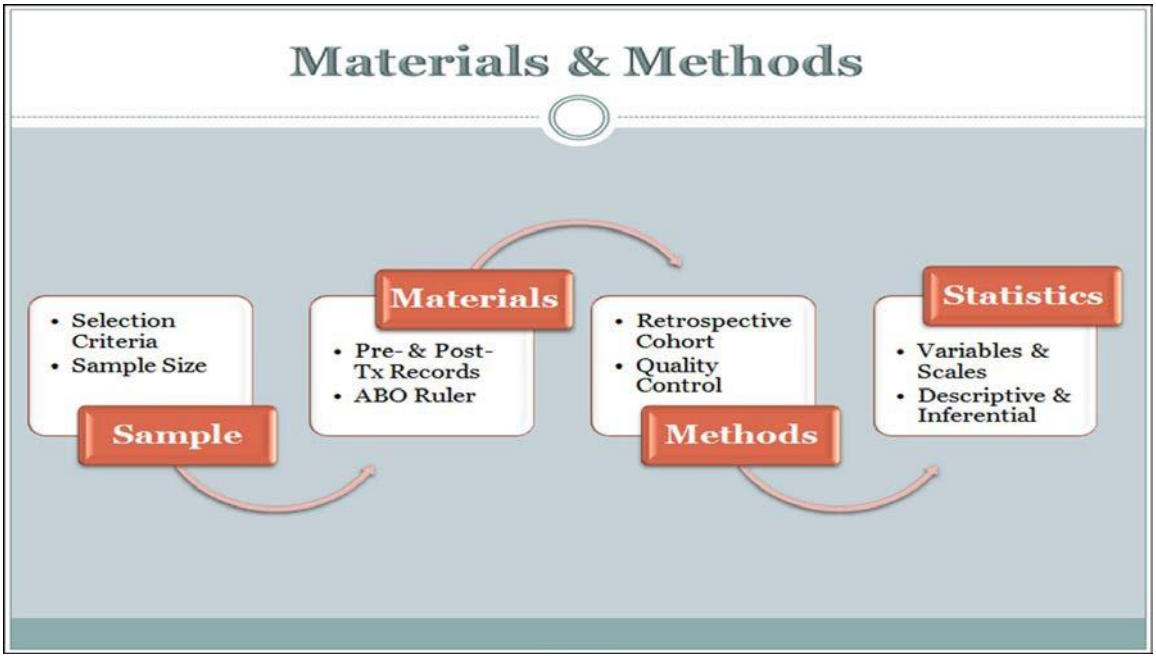


Fig 2. Methodological topics.

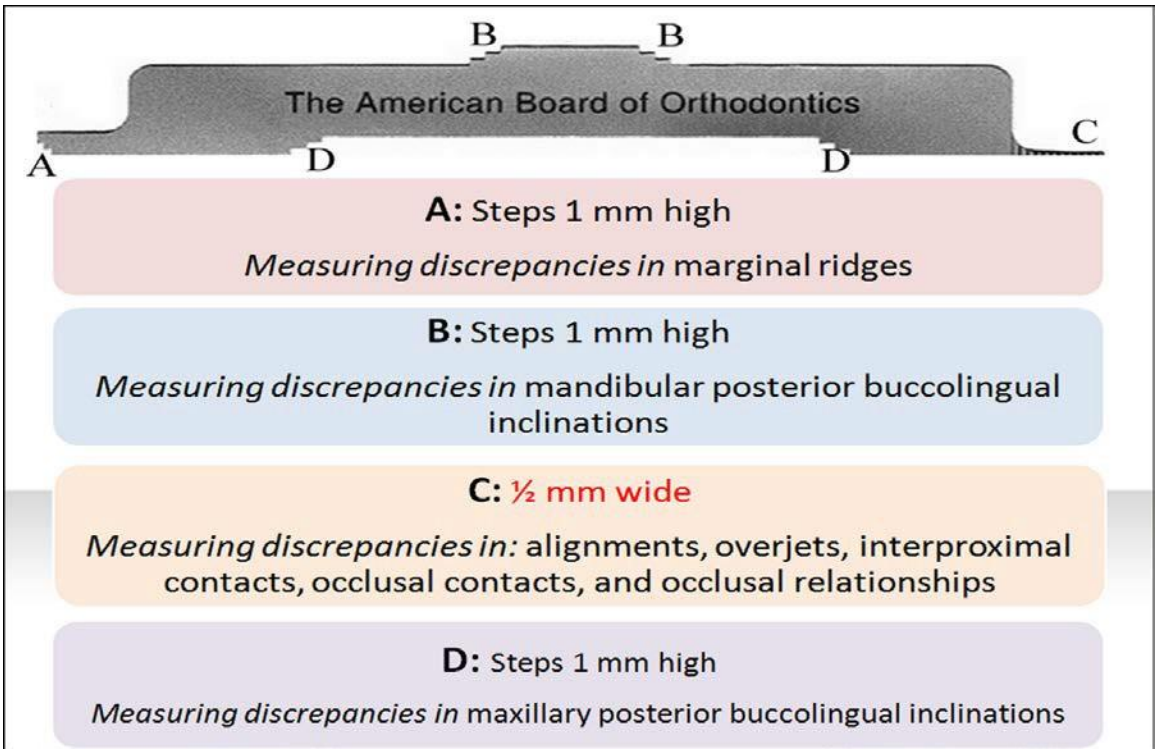


Fig 3. The ABO's ruler.

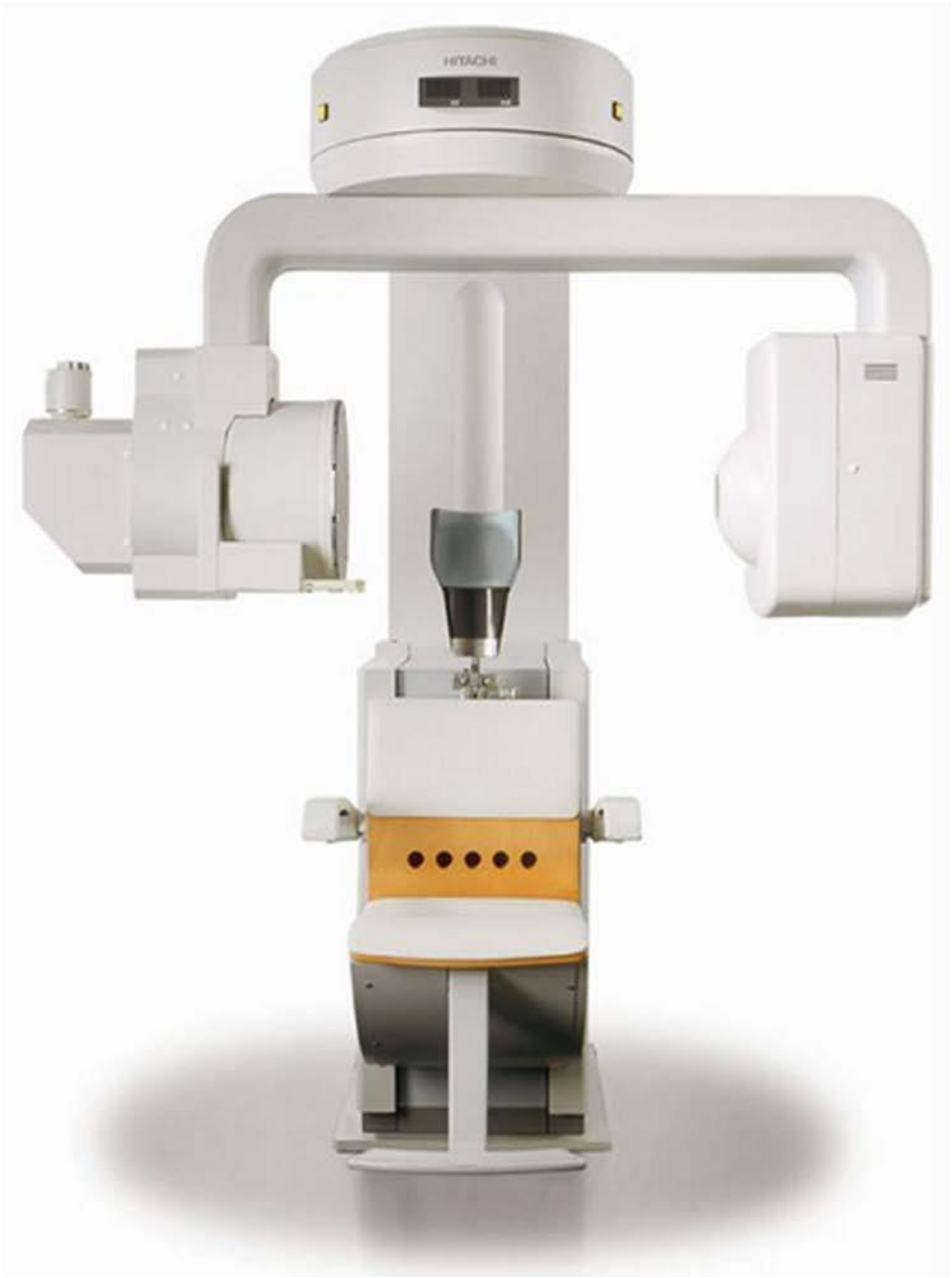


Fig 4. The Hitachi CB MercuRay machine.

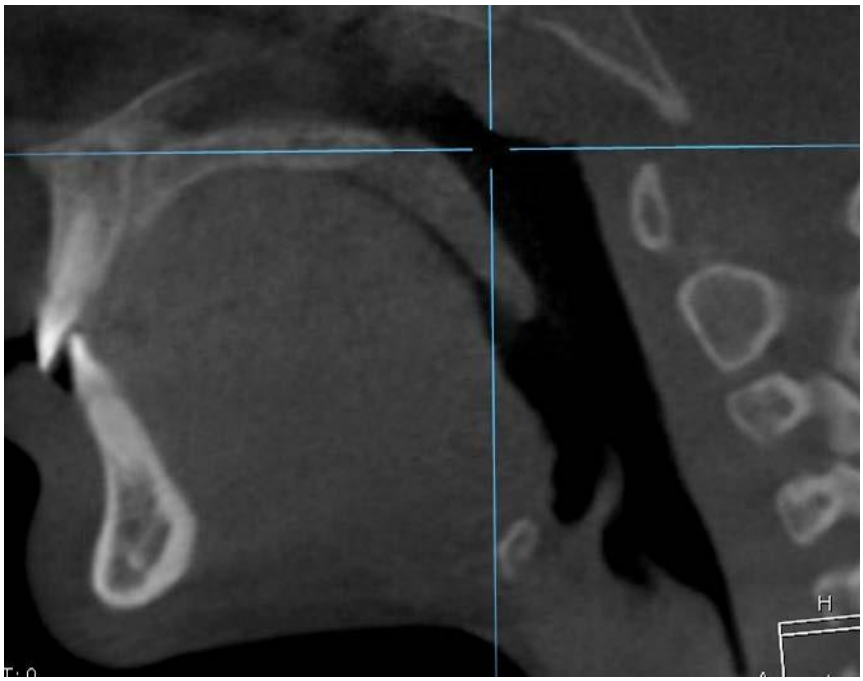


Fig 5. In the sagittal view, orient the line representing the axial view so that it passes through ANS.

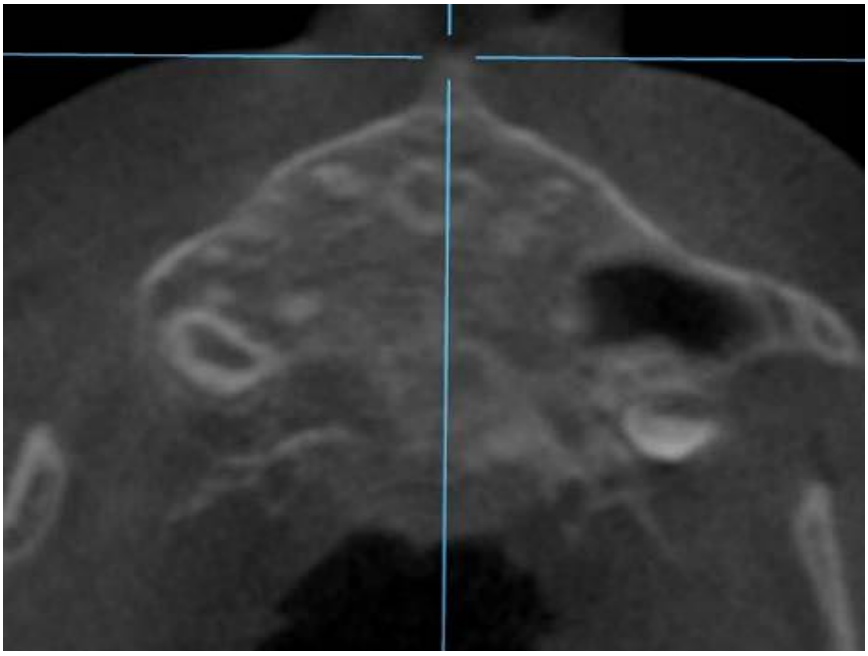


Fig 6. In the axial view, locate the ANS (point where the coronal and sagittal planes meet).

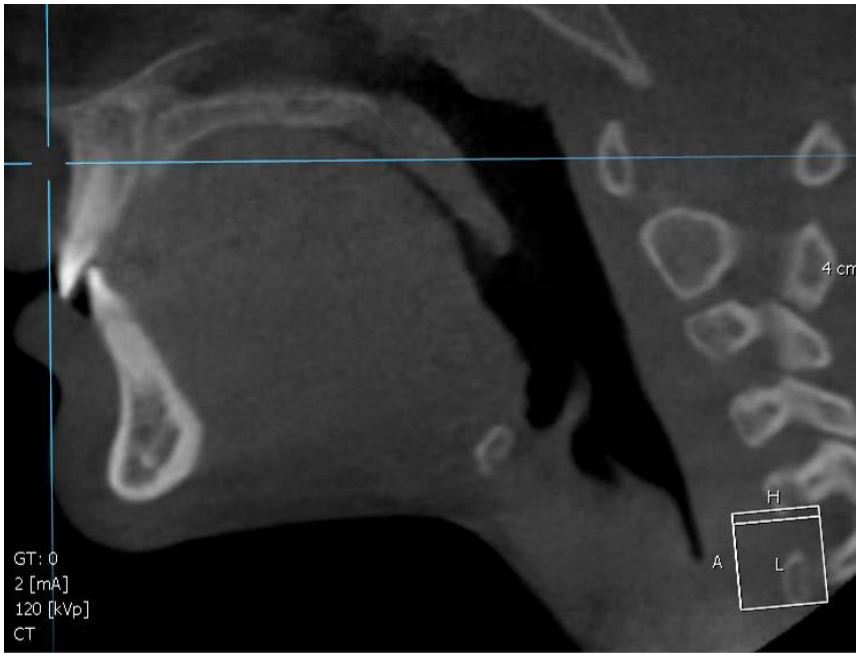


Fig 7. In the sagittal view, move the line representing the axial view downwards so that it passes through the center of the atlas.



Fig 8. Go back to the axial view, and rotate the line that represents the sagittal plane around the ANS so that it passes through the center of the odontoid process.

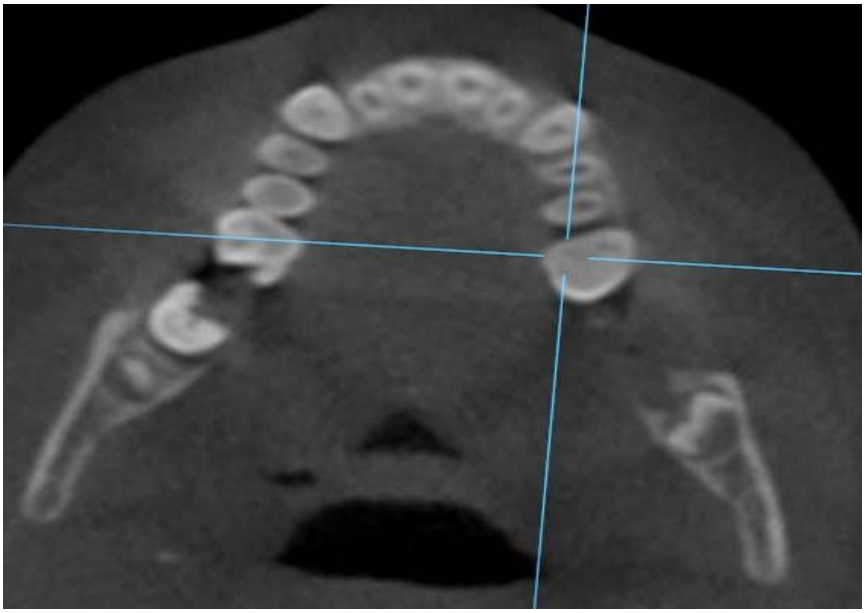


Fig 9. Locate the molar in the axial view; the point at which the palatal root length is the longest in the sagittal view.

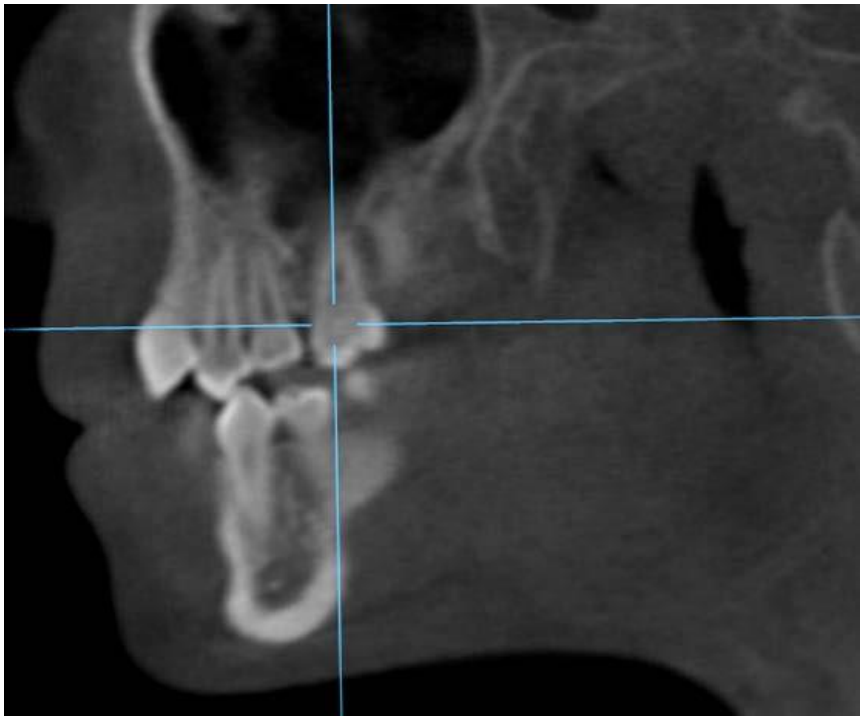


Fig 10. In the sagittal view, position the line representing the coronal slice along the mesiopalatal cusp tip and the palatal root apex.

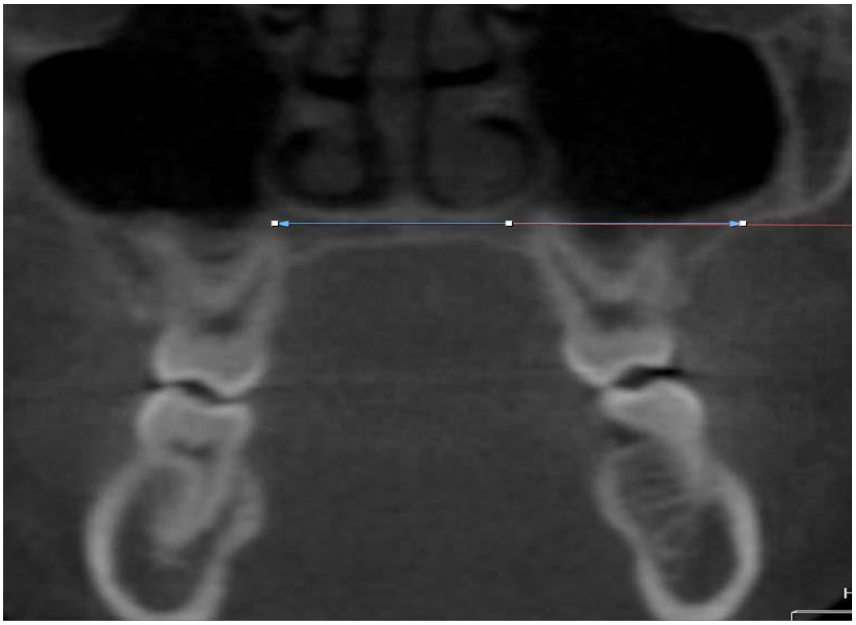


Fig 11. In the coronal view, draw the reference line tangent to the inferior border of the nasal cavity.

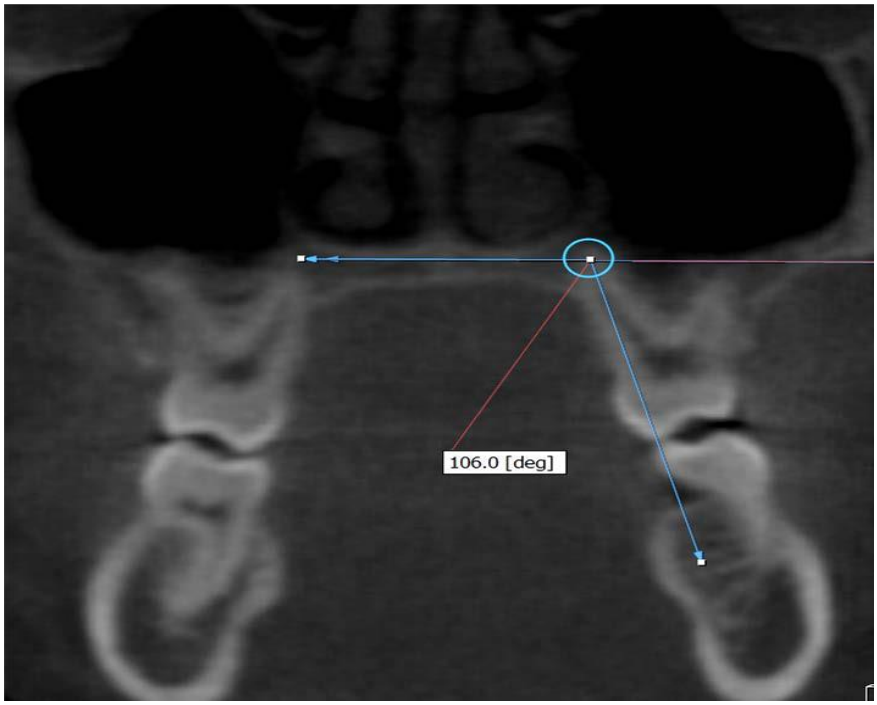


Fig 12. Measure the inclination through the long axis of the molar (represented by a line through the apex of the palatal root and the cusp tip) in the coronal view.

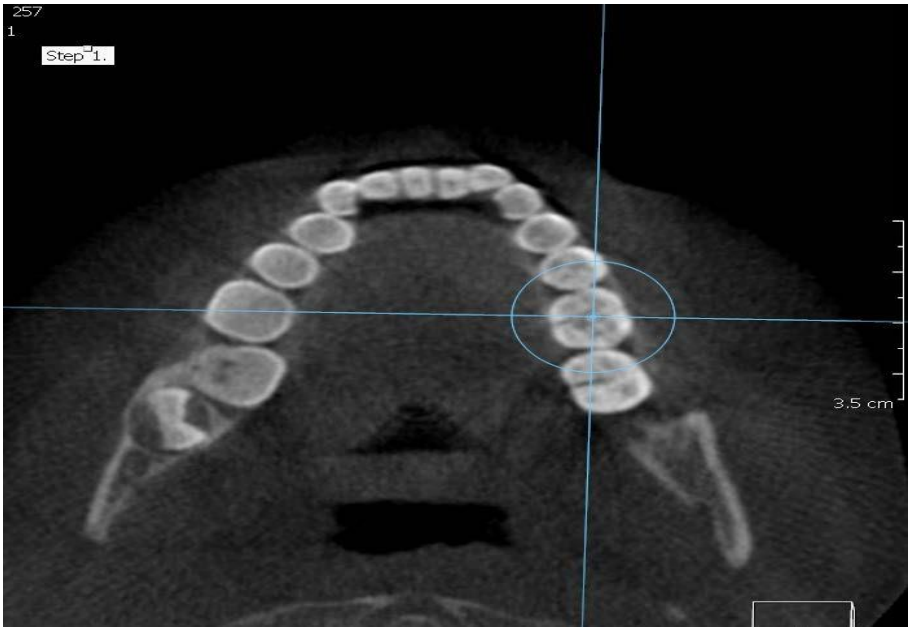


Fig 13. Locate the molar in the axial view; the point at which the roots are longest in the sagittal view.

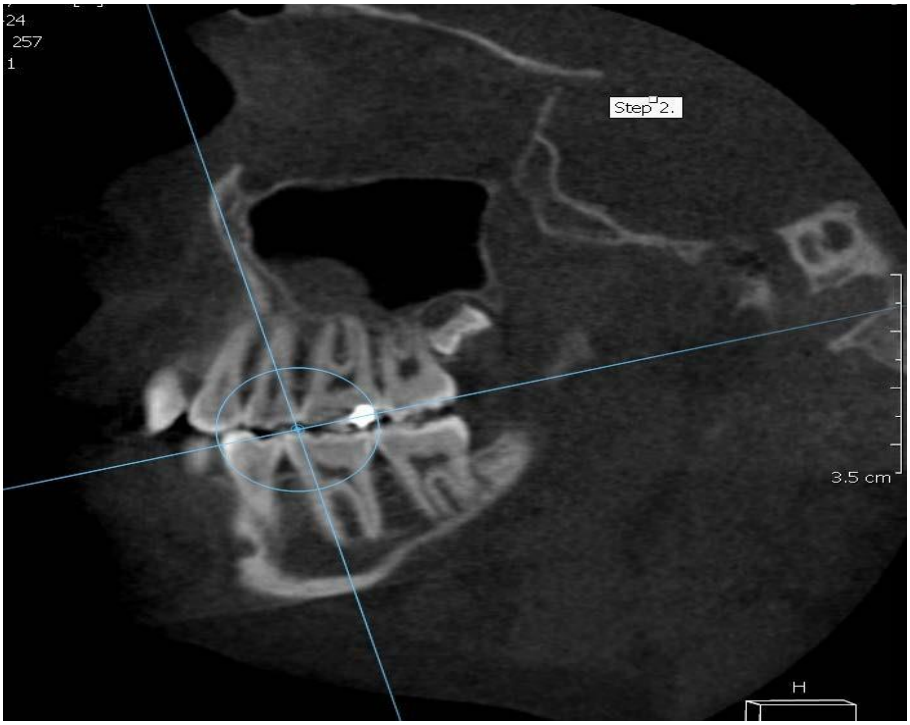


Fig 14. Position the coronal line along the long axis of the tooth (mesial cusp tip to mesial root apex).

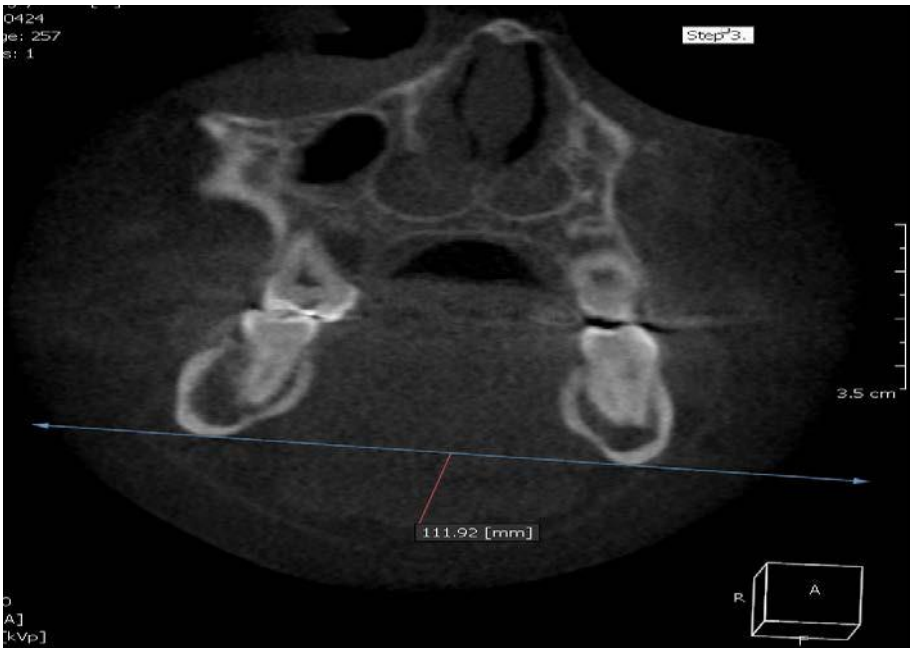


Fig 15. Draw a reference line tangent to the inferior border of the mandible in the coronal view.

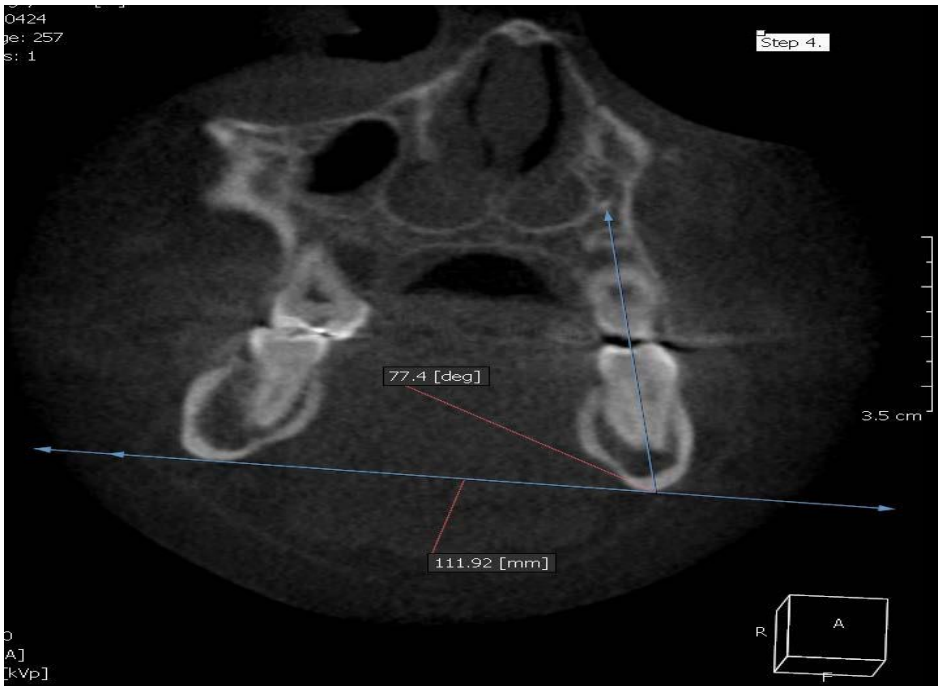


Fig 16. Measure the inclination which is the angle between the line passing through the long axis of the molar and the reference line.

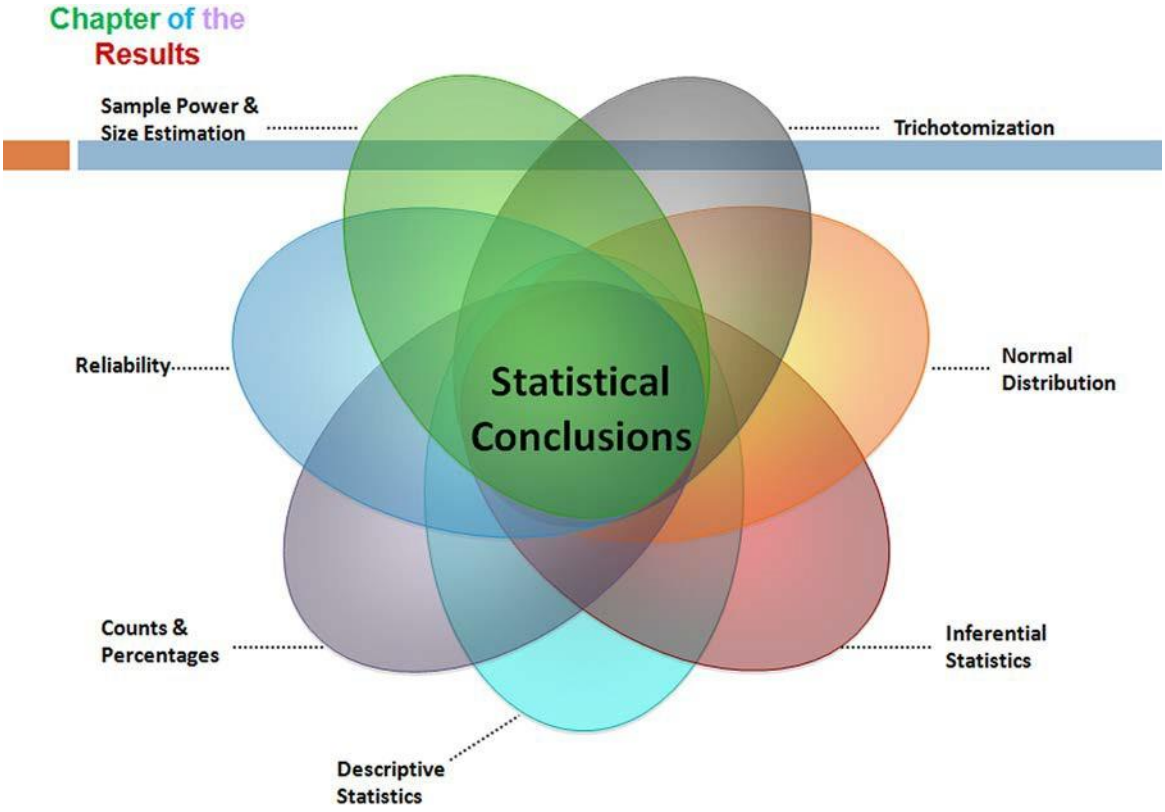


Fig 17. Outline of the results chapter.

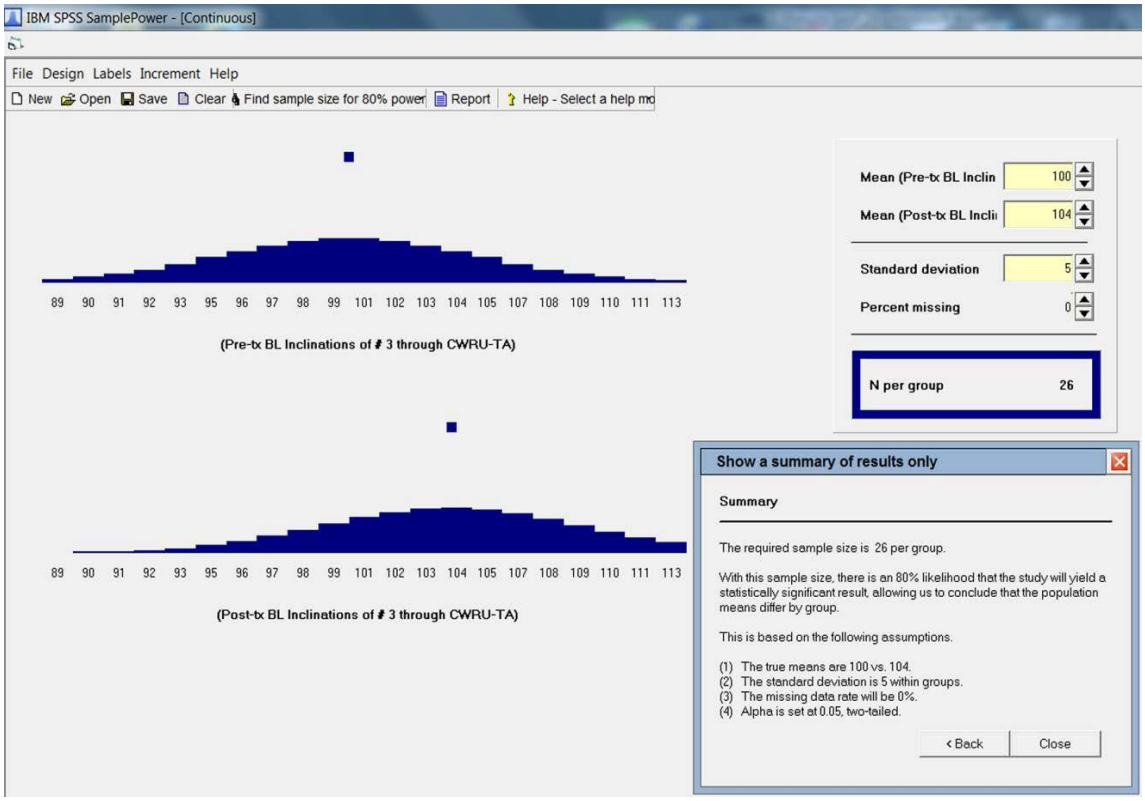


Fig 18. Sample power and size estimation.

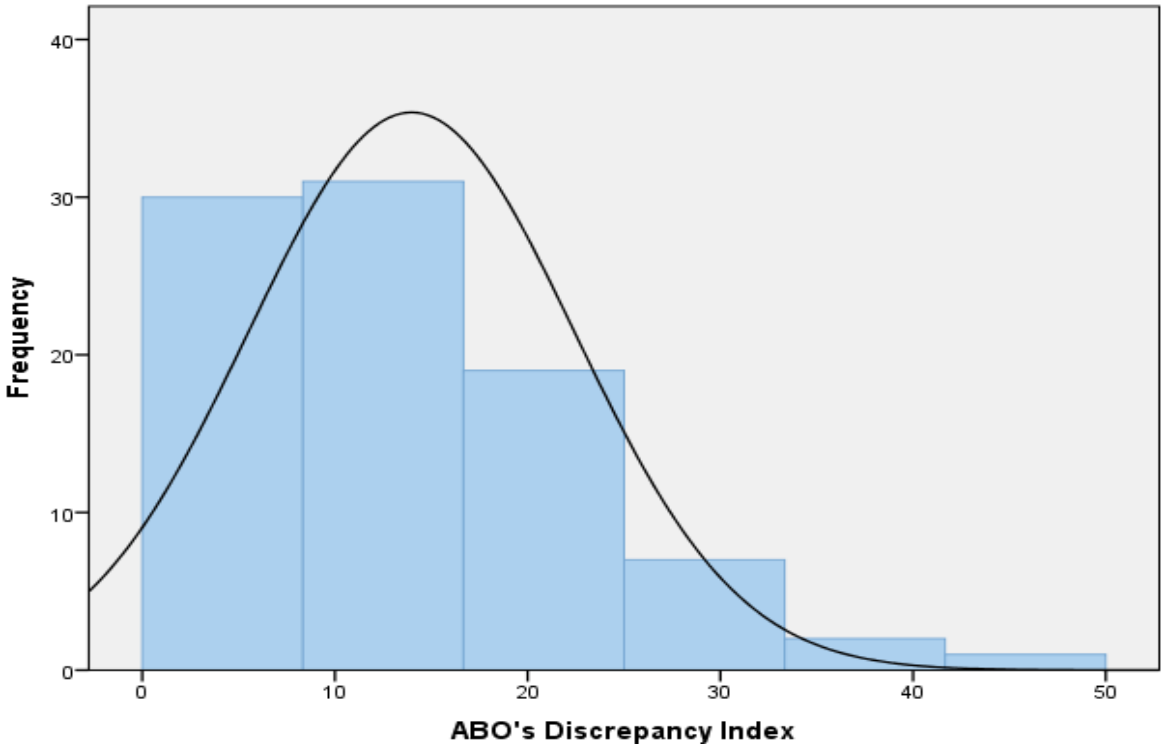


Fig 19. Histogram of the ABO's discrepancy index.

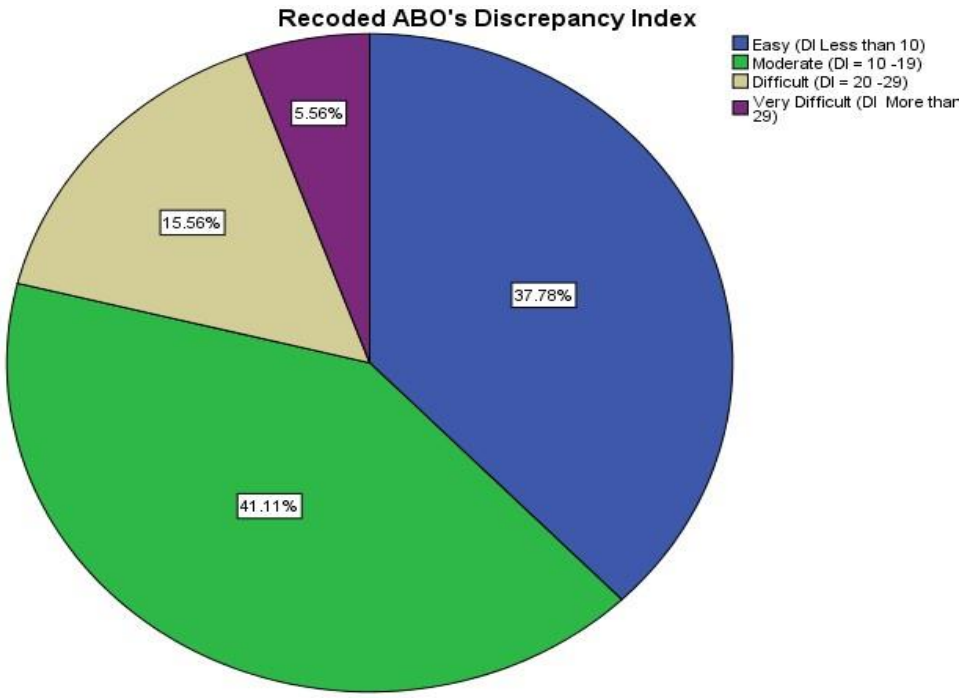


Fig 20. Pie chart of the recoded ABO's discrepancy index.

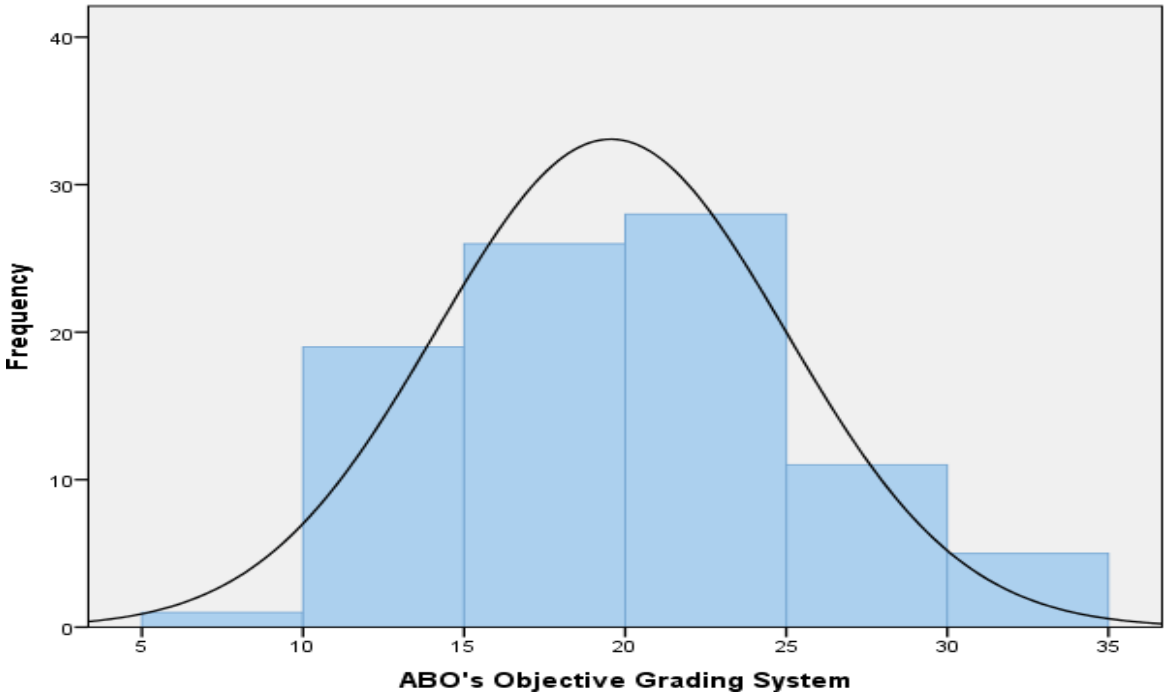


Fig 21. Histogram of the ABO's objective grading system.

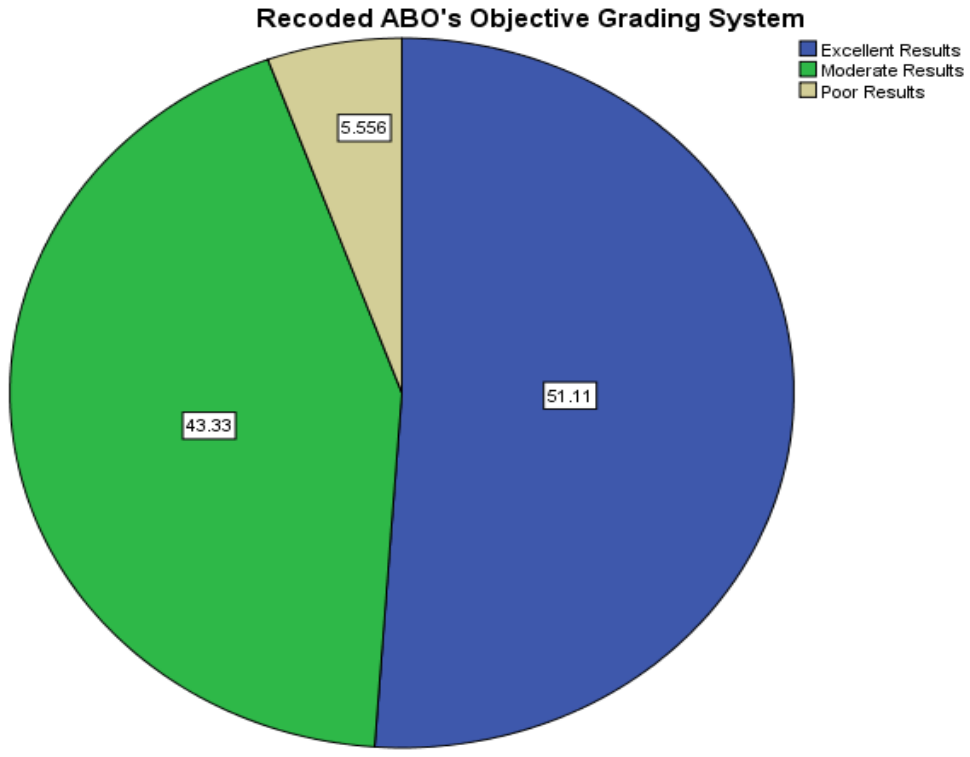


Fig 22. Pie chart of the recoded ABO's objective grading system.

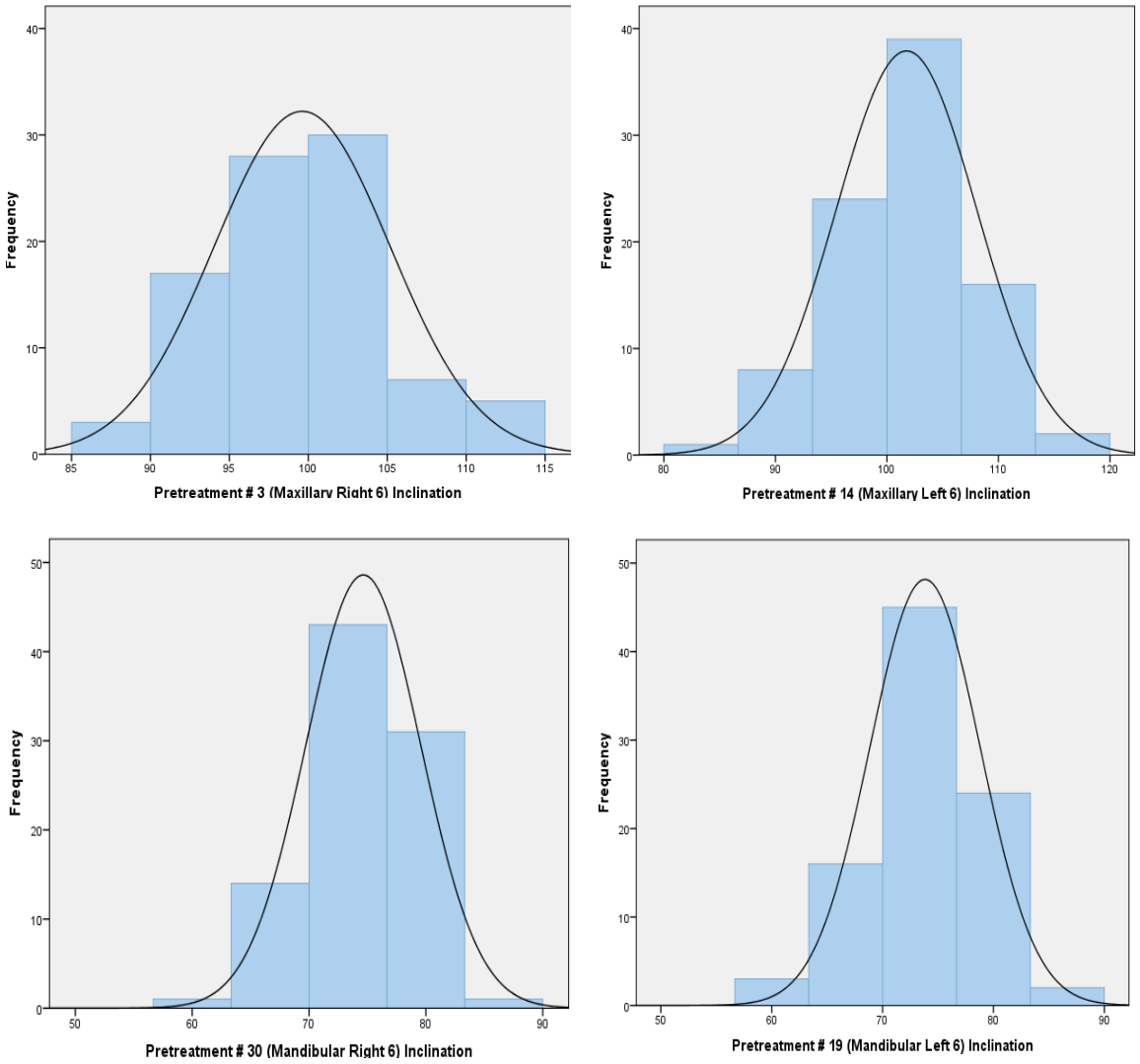


Fig 23. Histograms of the pretreatment buccolingual inclinations of all permanent first molars measured through the CWRU's transverse analysis.

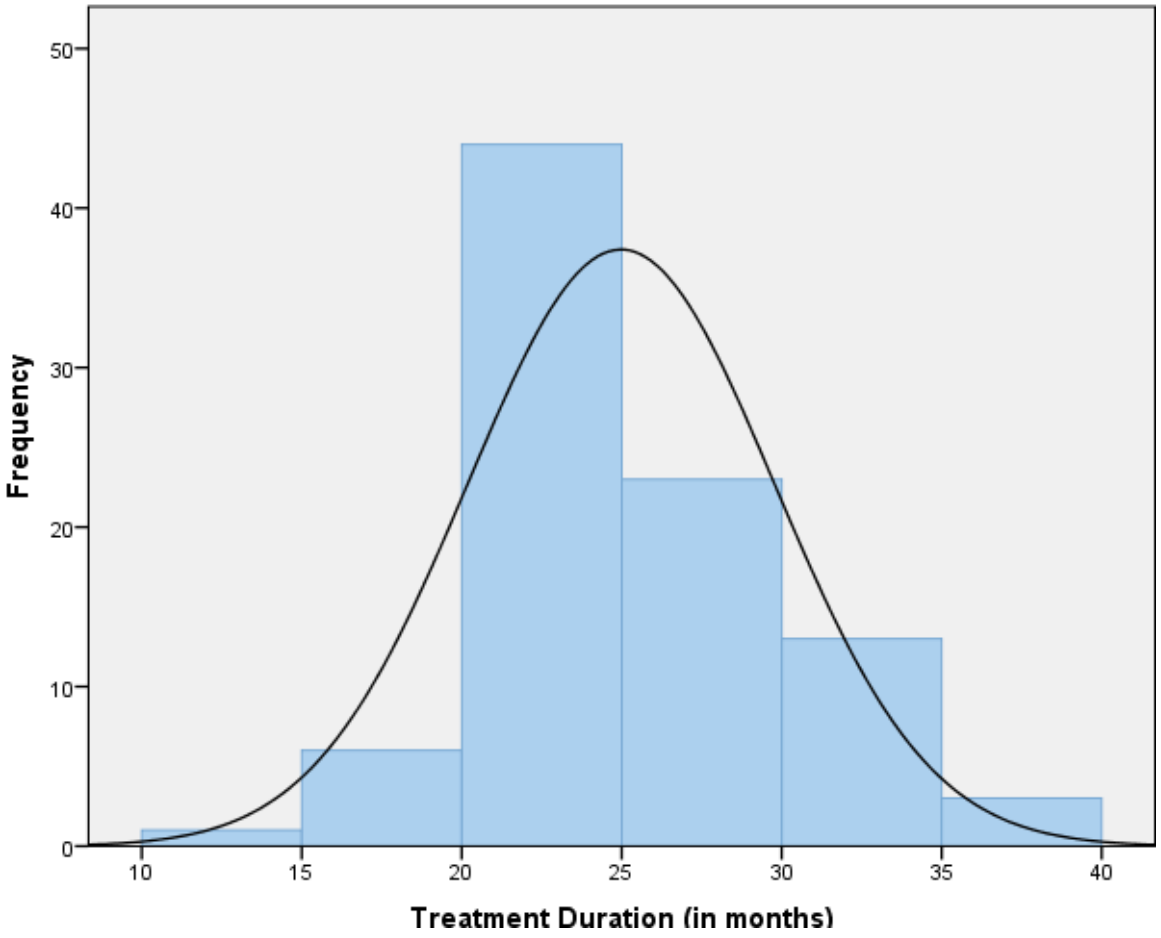
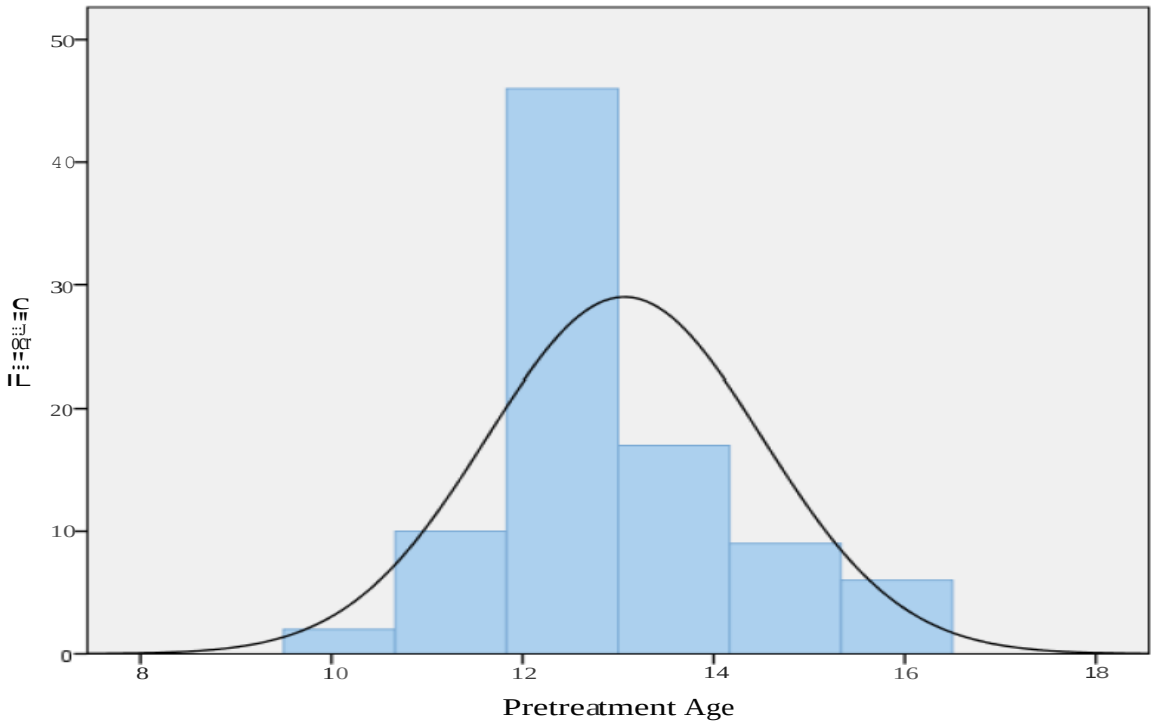


Fig 24. Histogram of the active treatment duration.



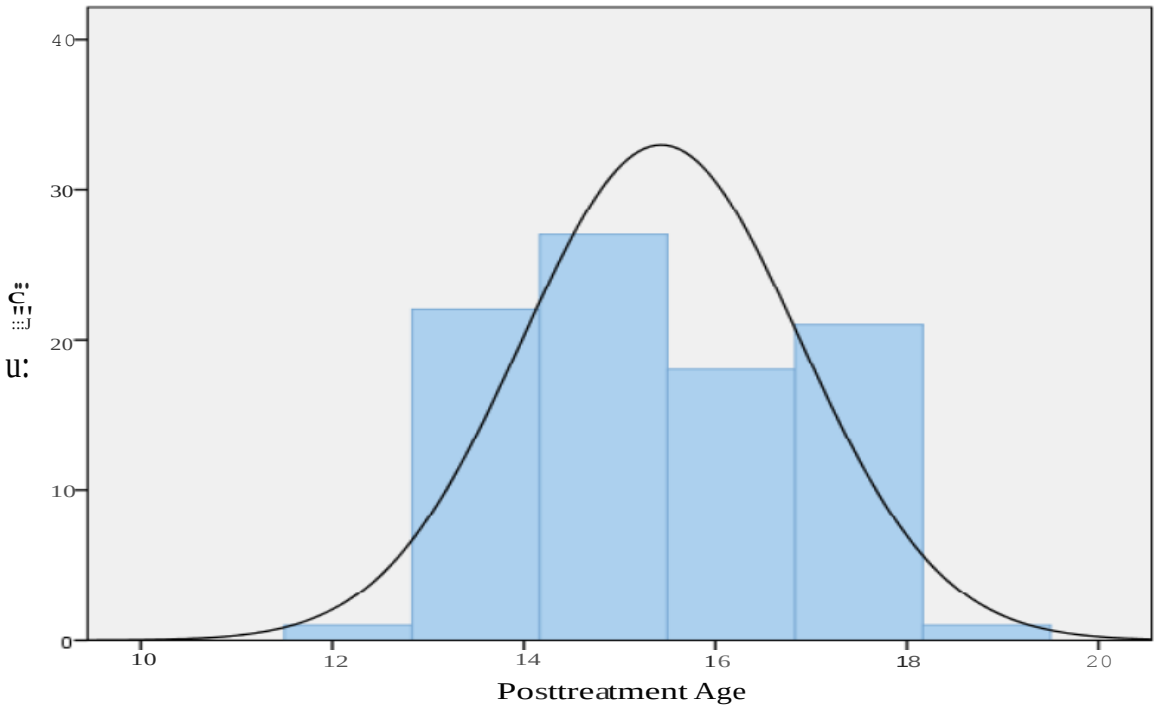


Fig 25. Histograms of the pretreatment and posttreatment age.

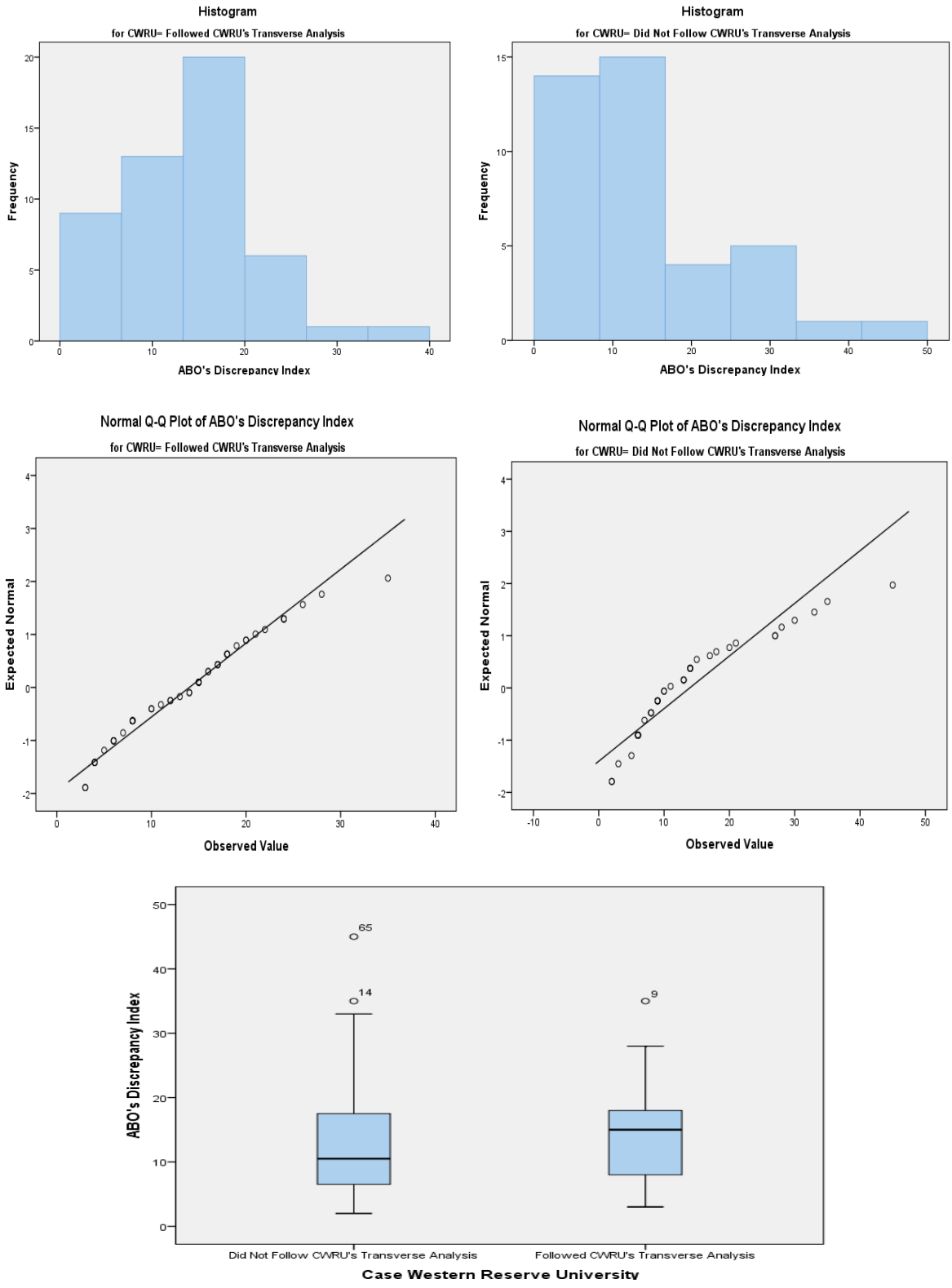


Fig 26. Histograms, q-plots, and box plots for the dependent variable "Discrepancy Index" with each category of the independent variable CWRU.

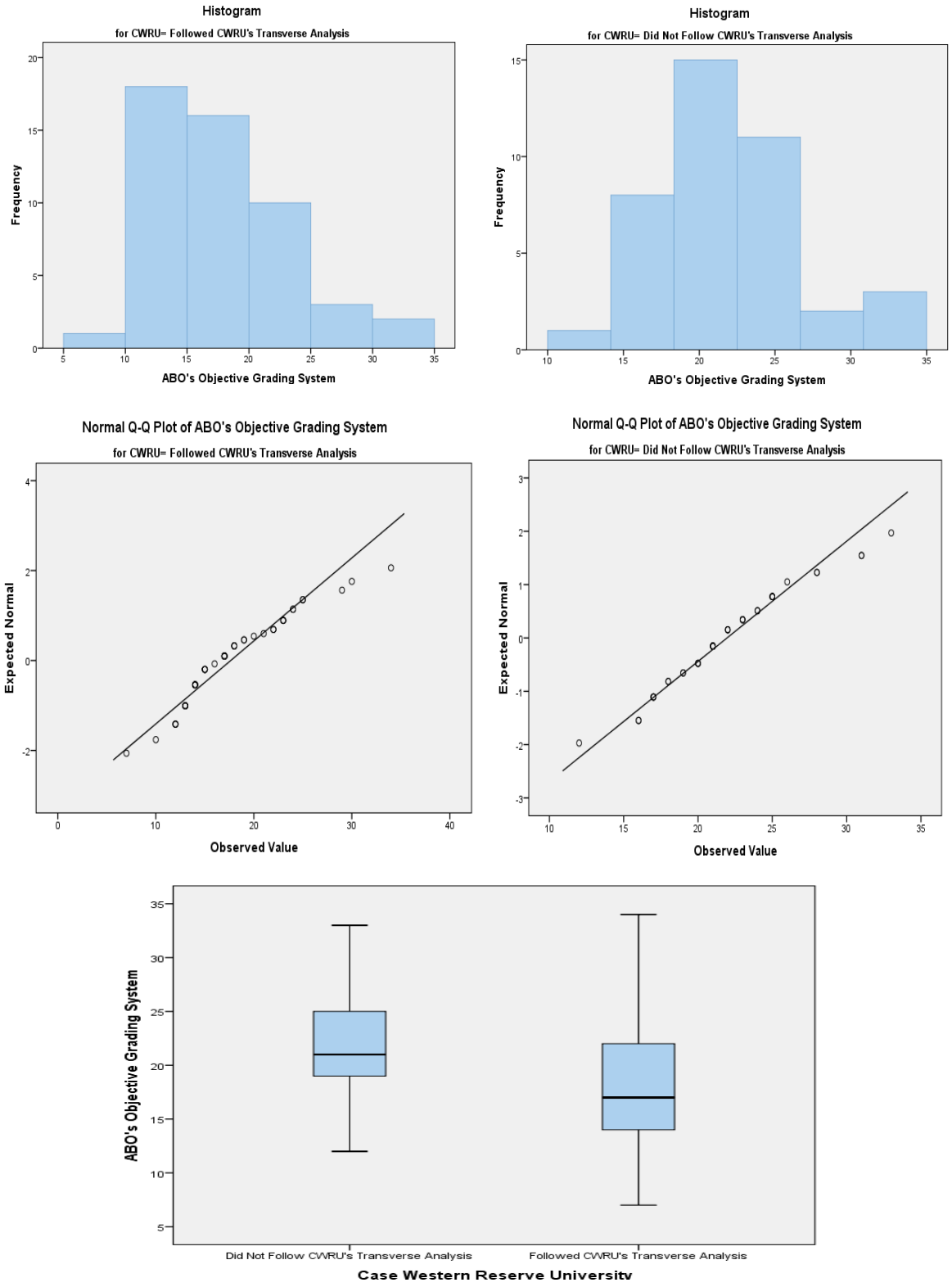


Fig 27. Histograms, q-plots, and box plots for the dependent variable "OGS" with each category of the independent variable CWRU.

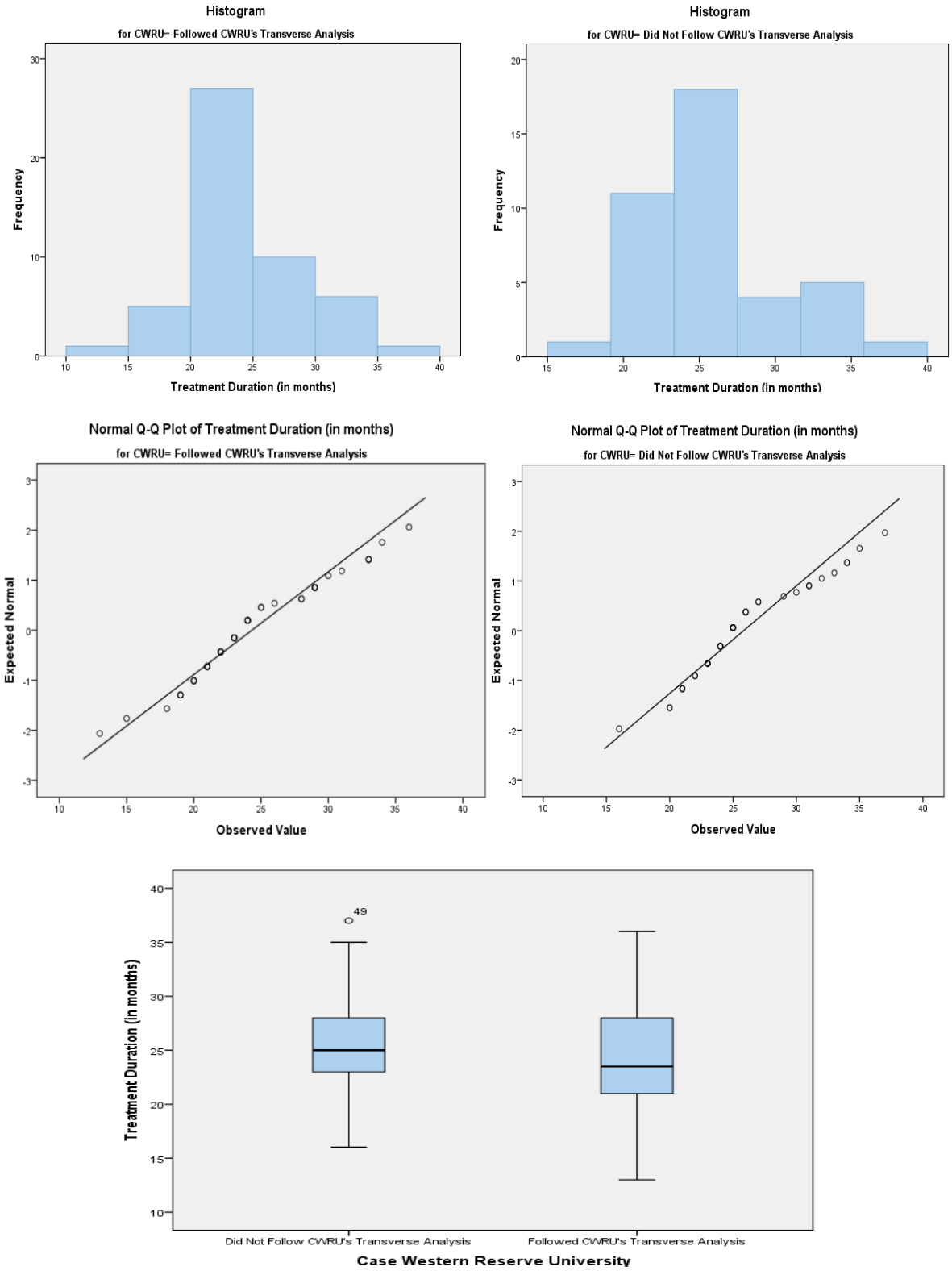


Fig 28. Histograms, q-plots, and box plots for the dependent variable "Active Treatment Duration" with each category of the independent variable CWRU.



Fig 29. Thesis cycle.

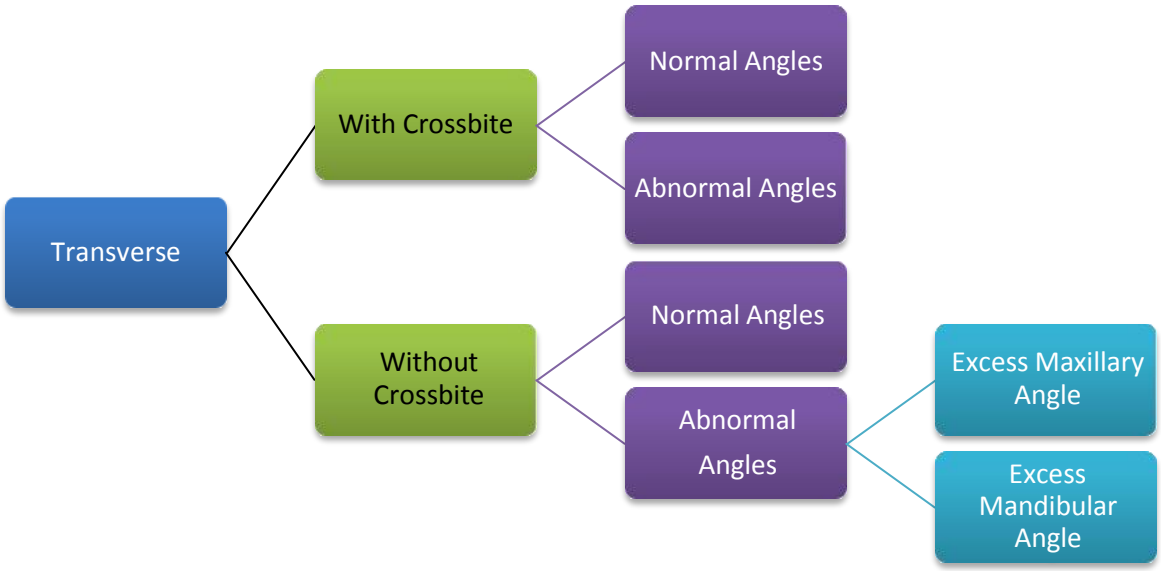


Fig 30. CWRU's transverse analysis.



Fig 31. Case # 9: initial composite.

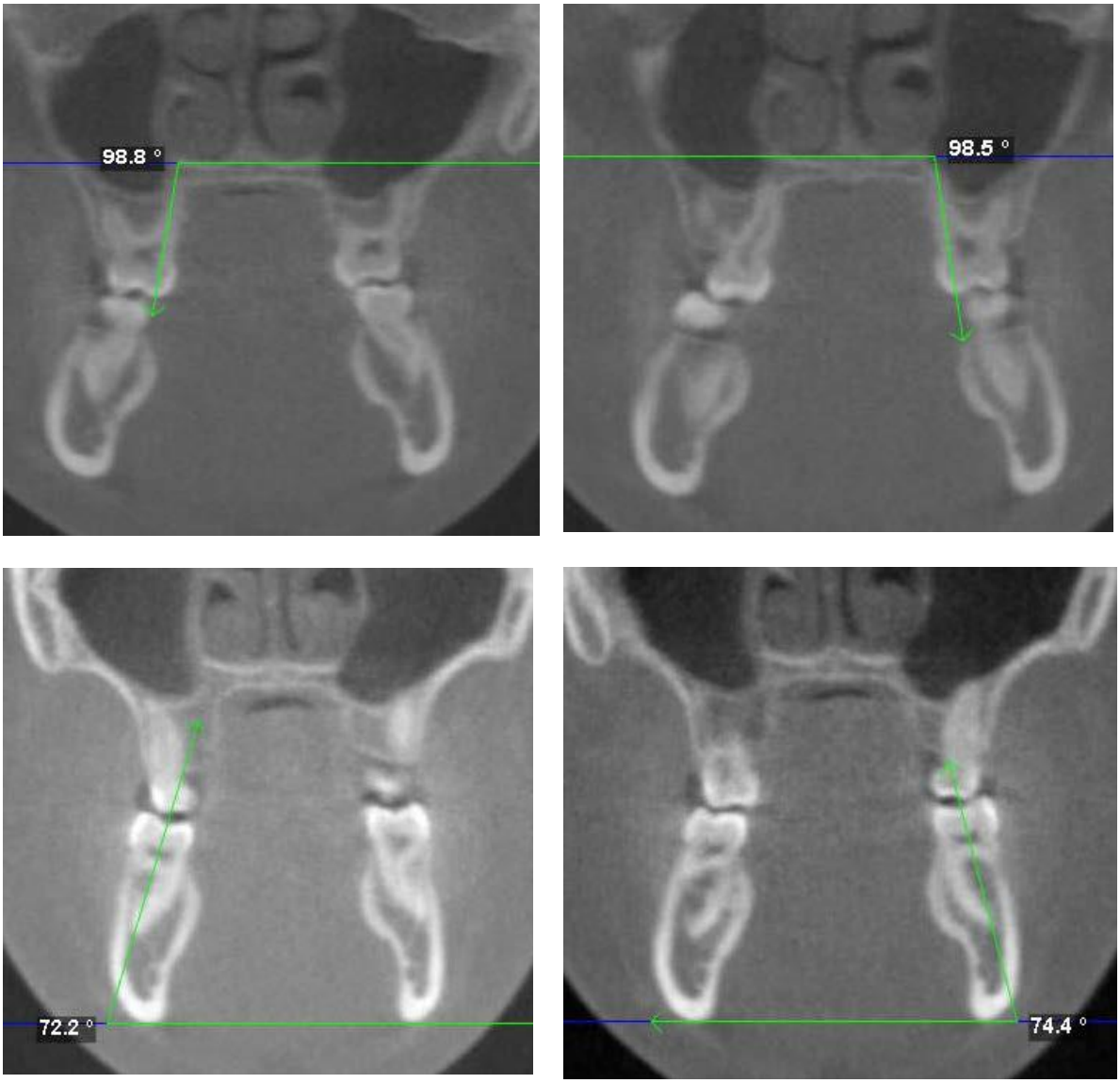


Fig 32. Case # 9: CWRU's buccolingual inclinations of the maxillary and mandibular first molars.



Fig 33. Case # 9: final composite.



Fig 34. Case # 79: initial composite.

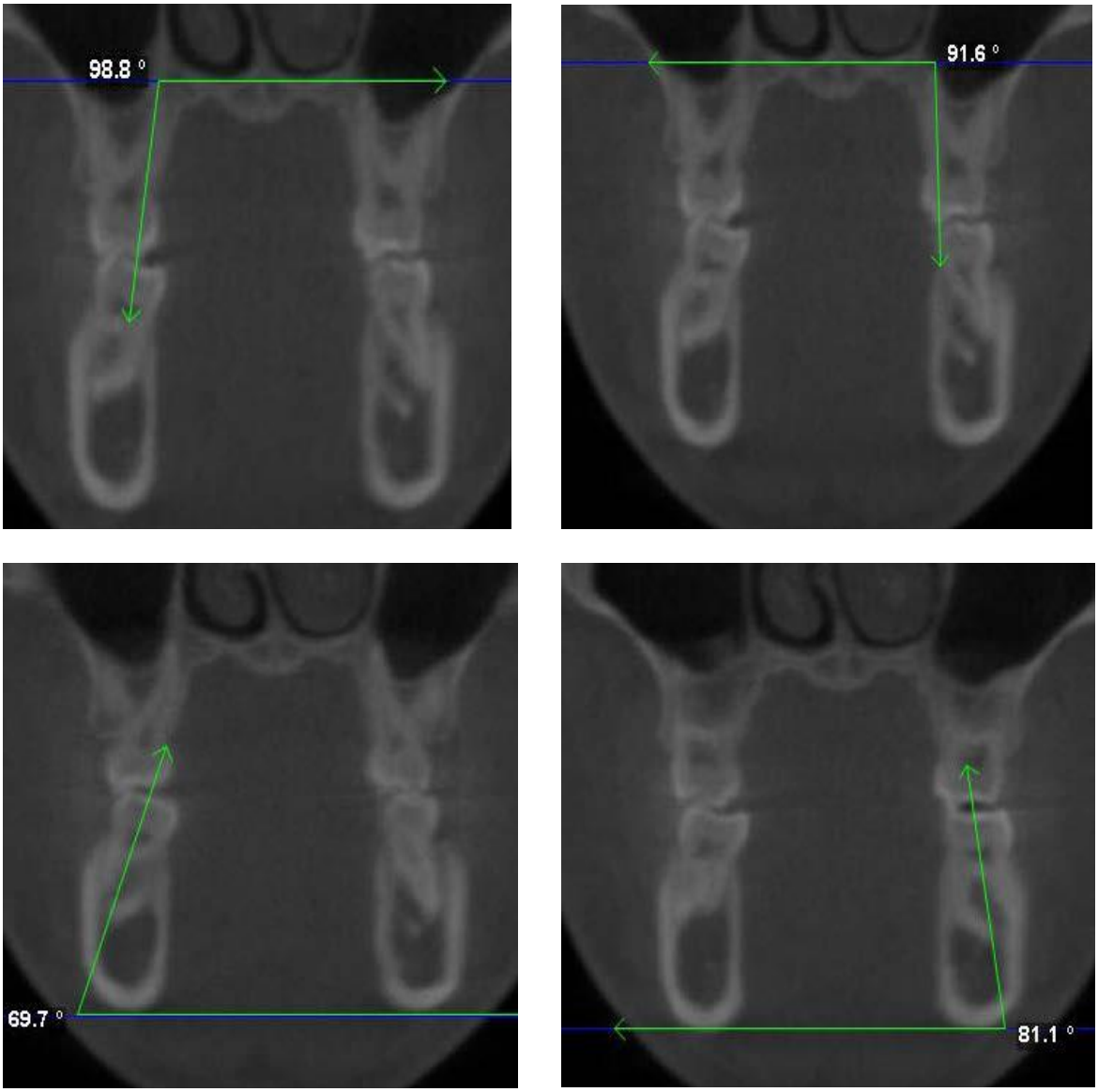


Fig 35. Case # 79: CWRU's buccolingual inclinations of the maxillary and mandibular first molars.

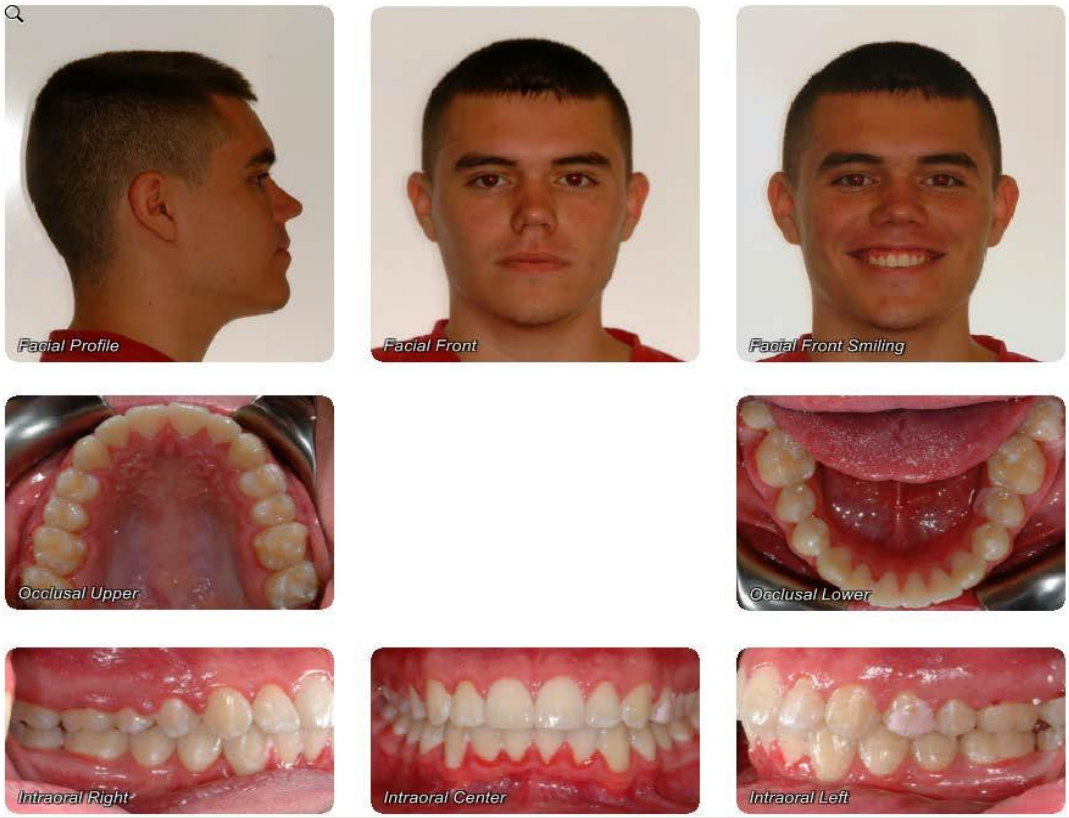


Fig 36. Case # 79: final composite.

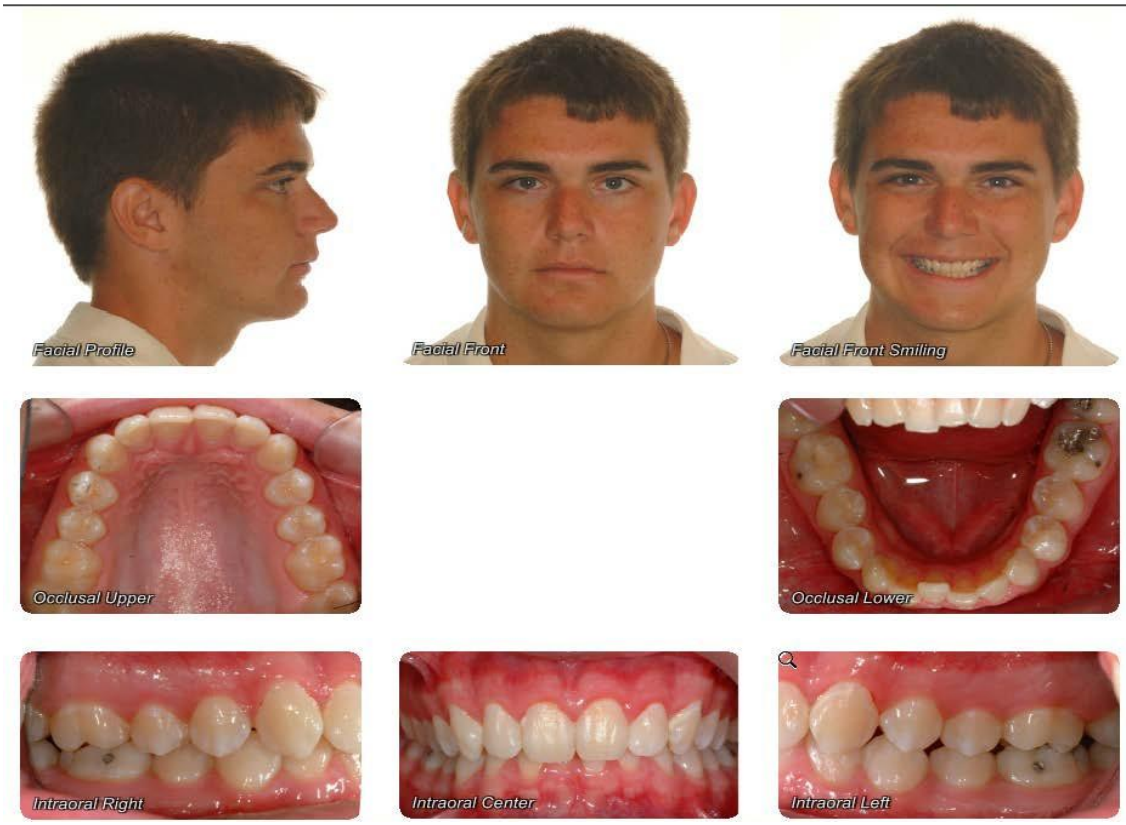


Fig 37. Case # 44: initial composite.

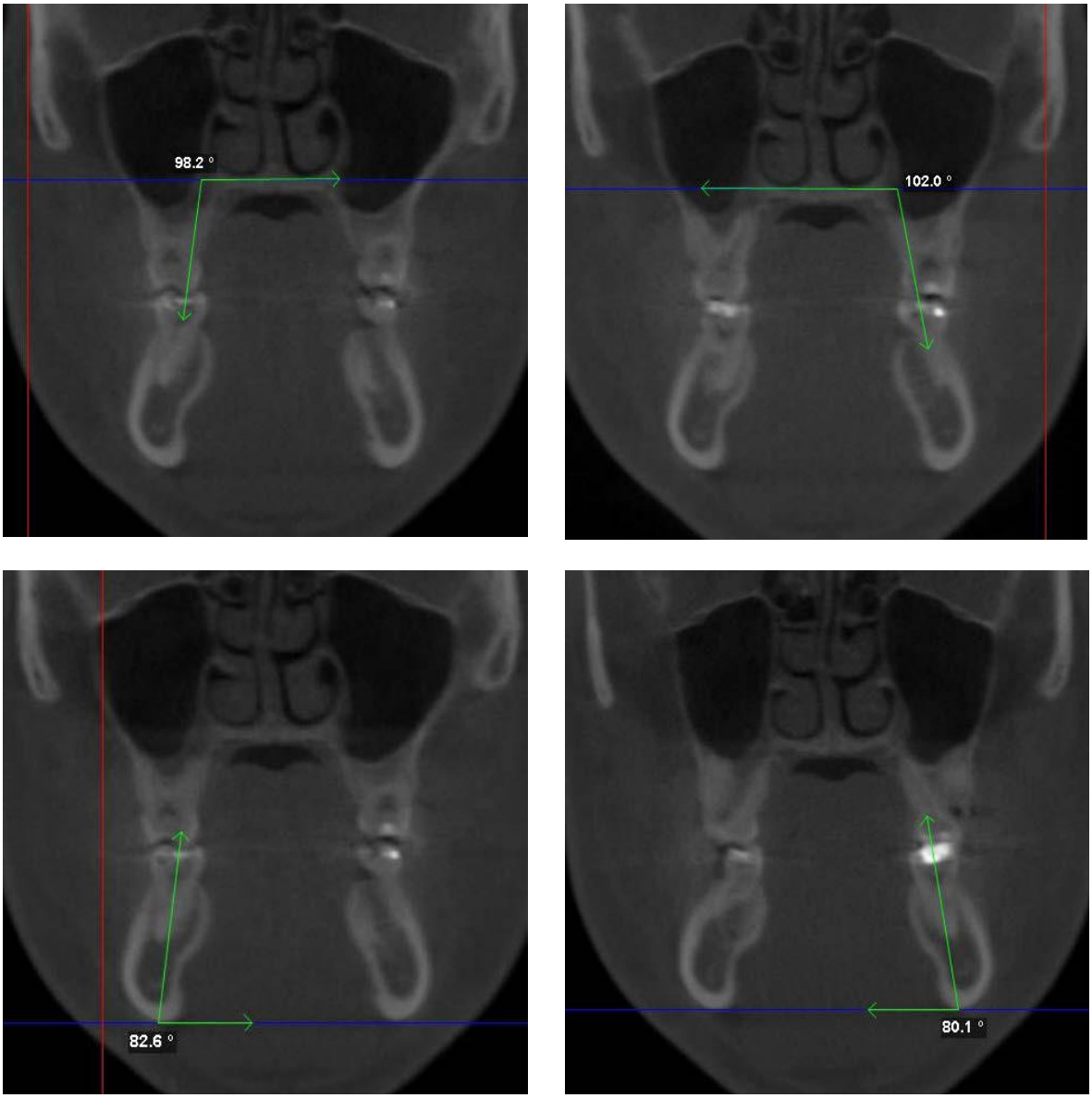


Fig 38. Case # 44: CWRU's pretreatment buccolingual inclinations of the maxillary and mandibular first molars.

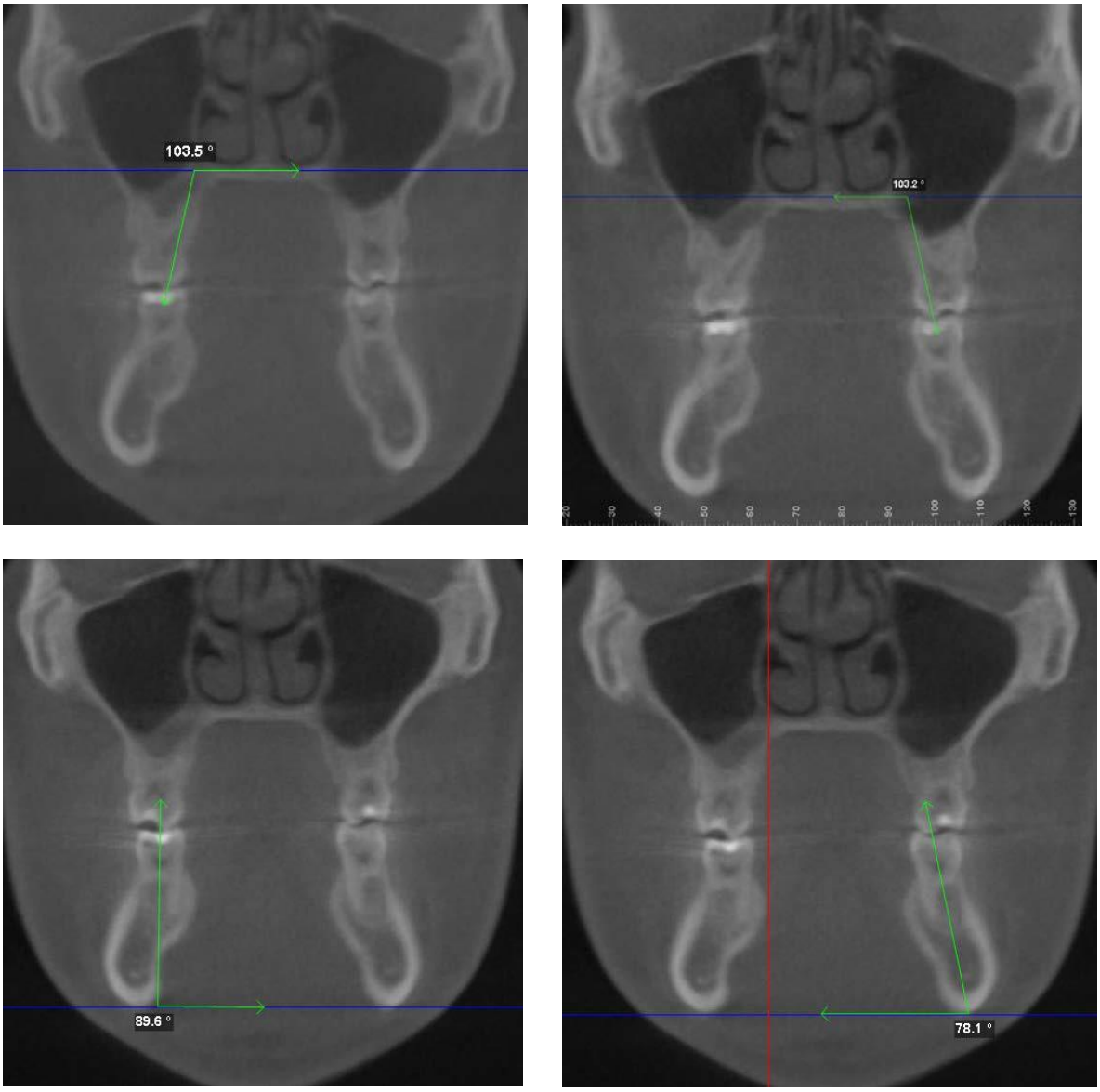


Fig 39. Case # 44: CWRU's posttreatment buccolingual inclinations of the maxillary and mandibular first molars.

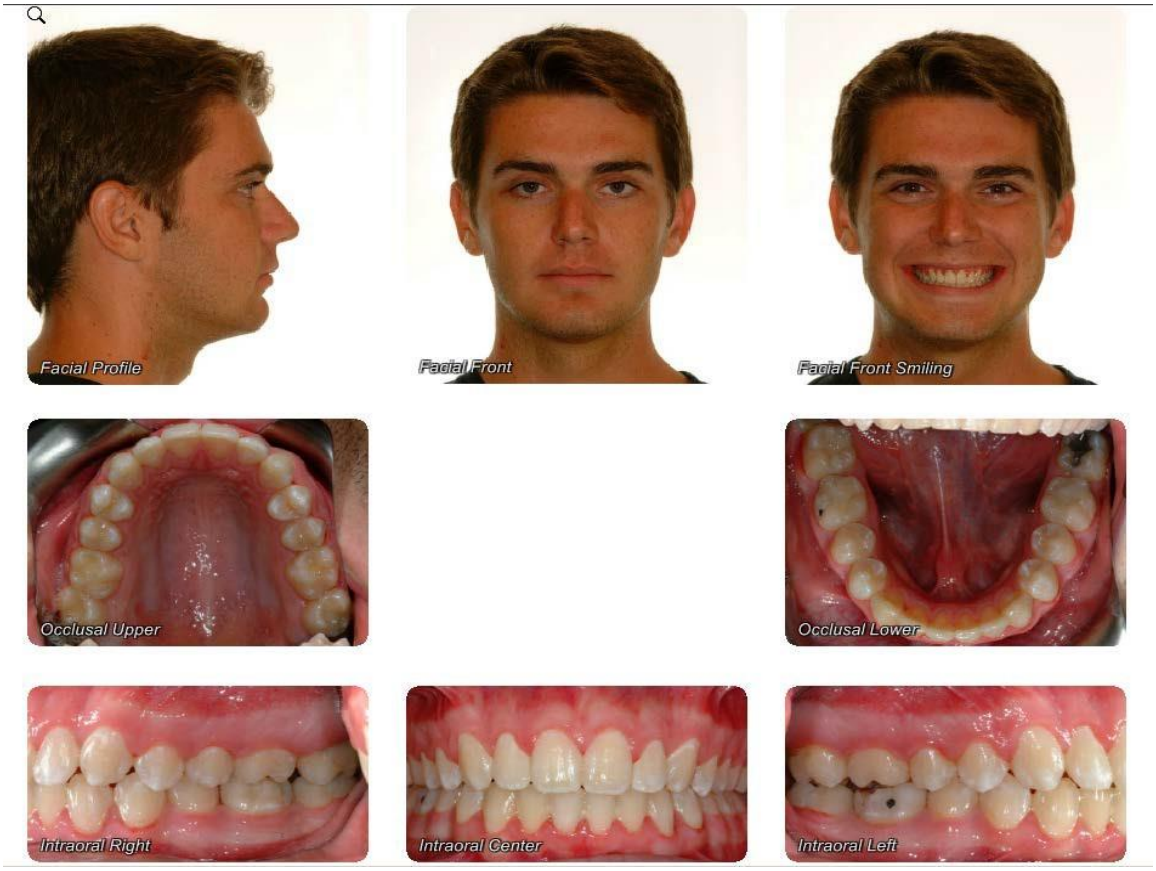


Fig 40. Case # 44: final composite.



Fig 41. Case # 21: initial composite.

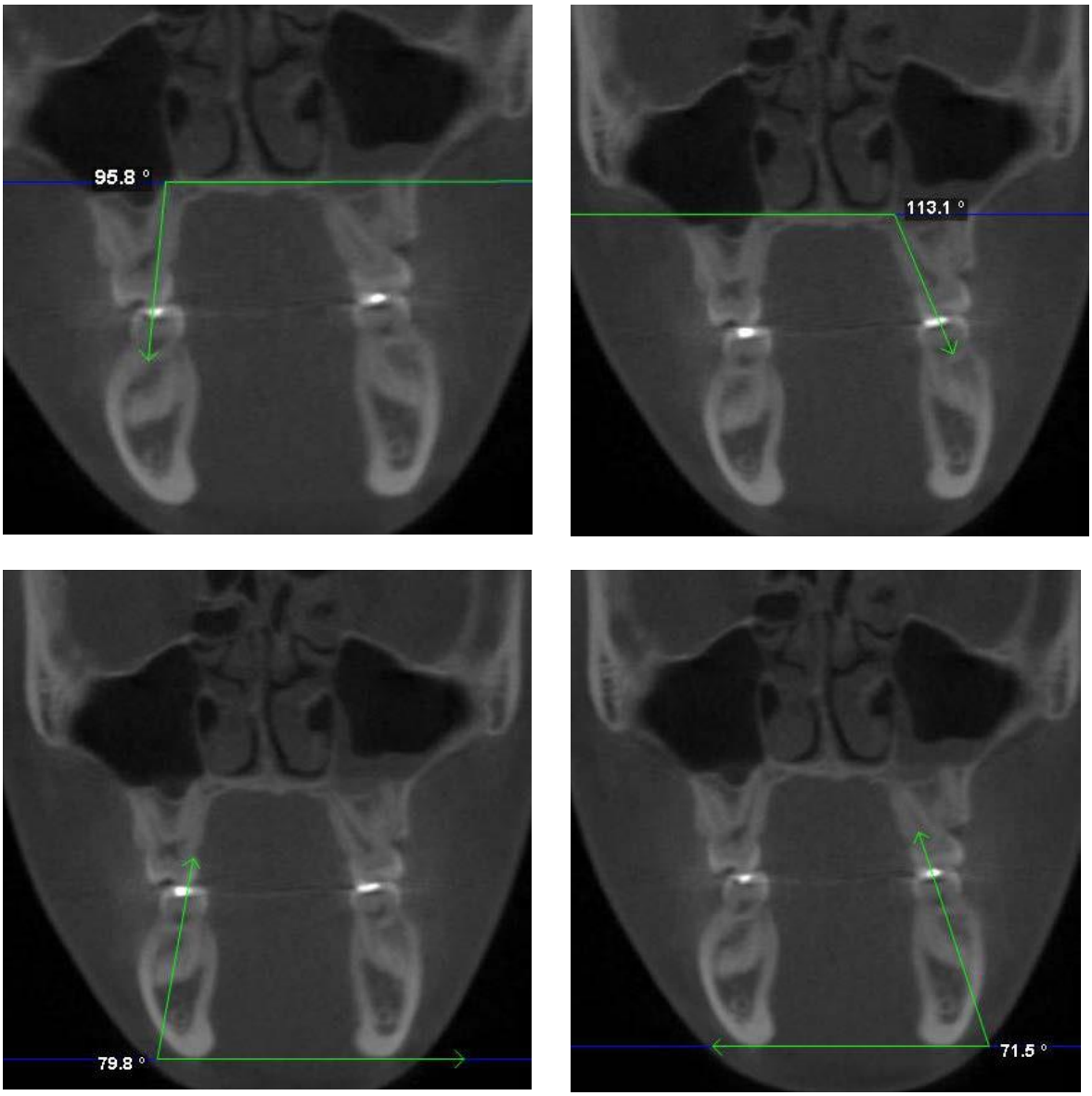


Fig 42. Case # 21: CWRU's pretreatment buccolingual inclinations of the maxillary and mandibular first molars.

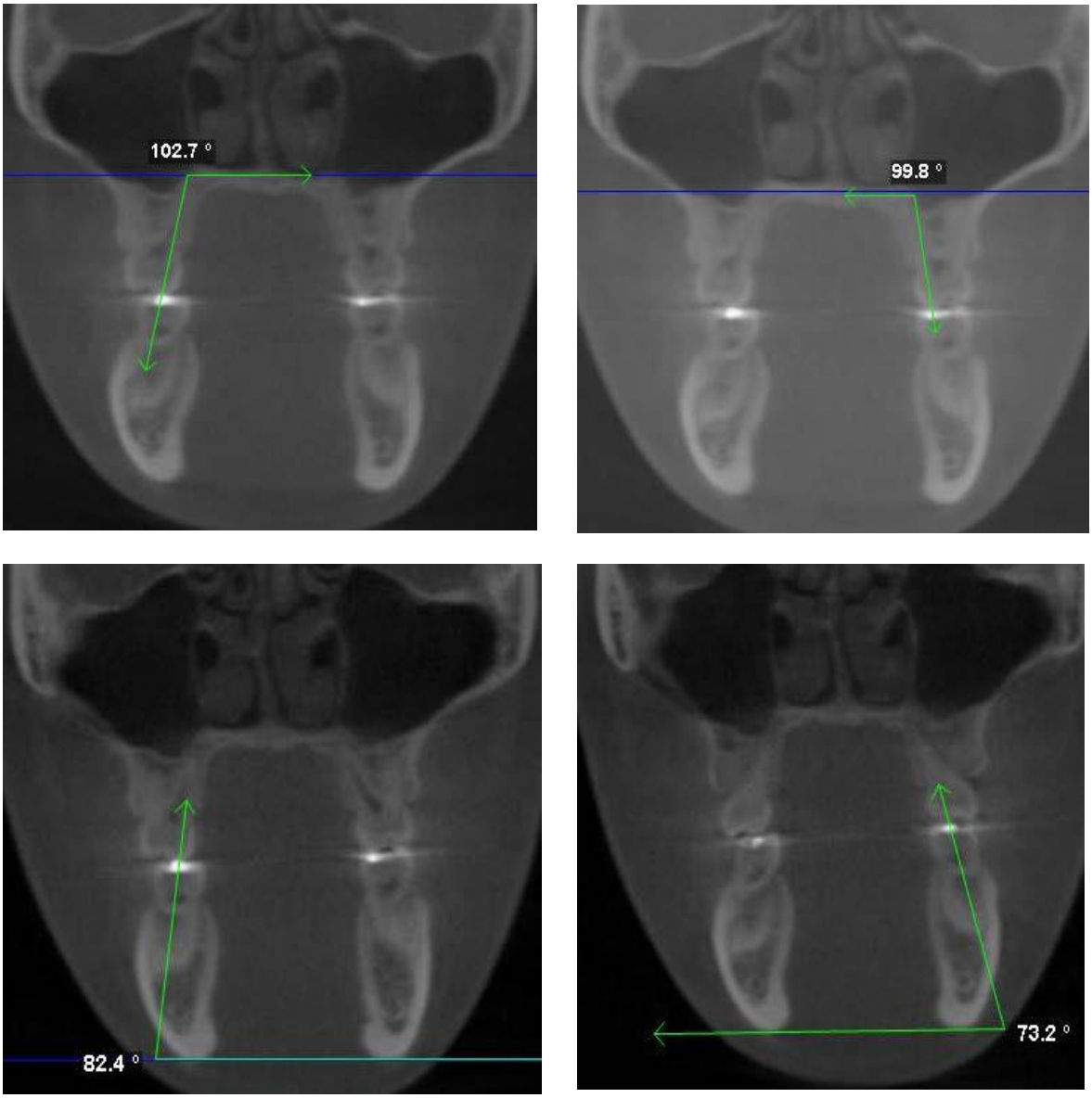


Fig 43. Case # 21: CWRU's posttreatment buccolingual inclinations of the maxillary and mandibular first molars.

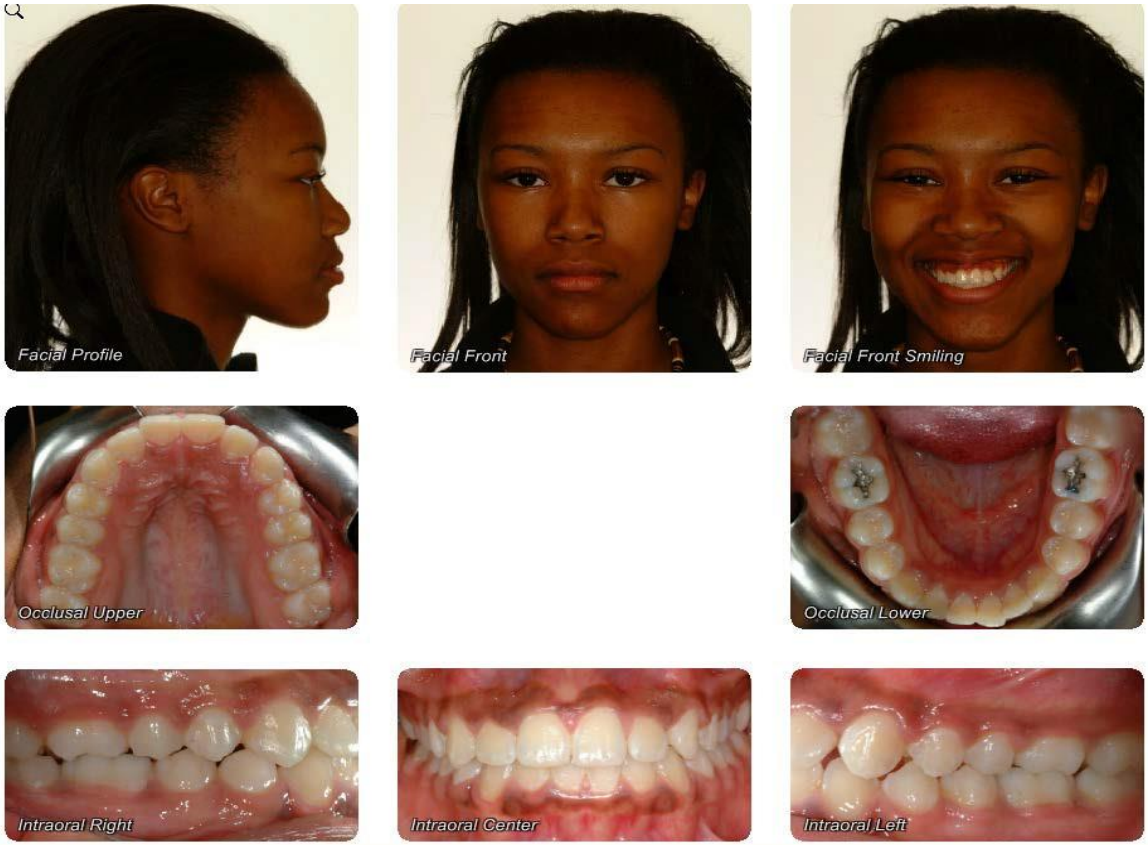


Fig 44. Case # 21: final composite.



Fig 45. Case # 7: initial composite.

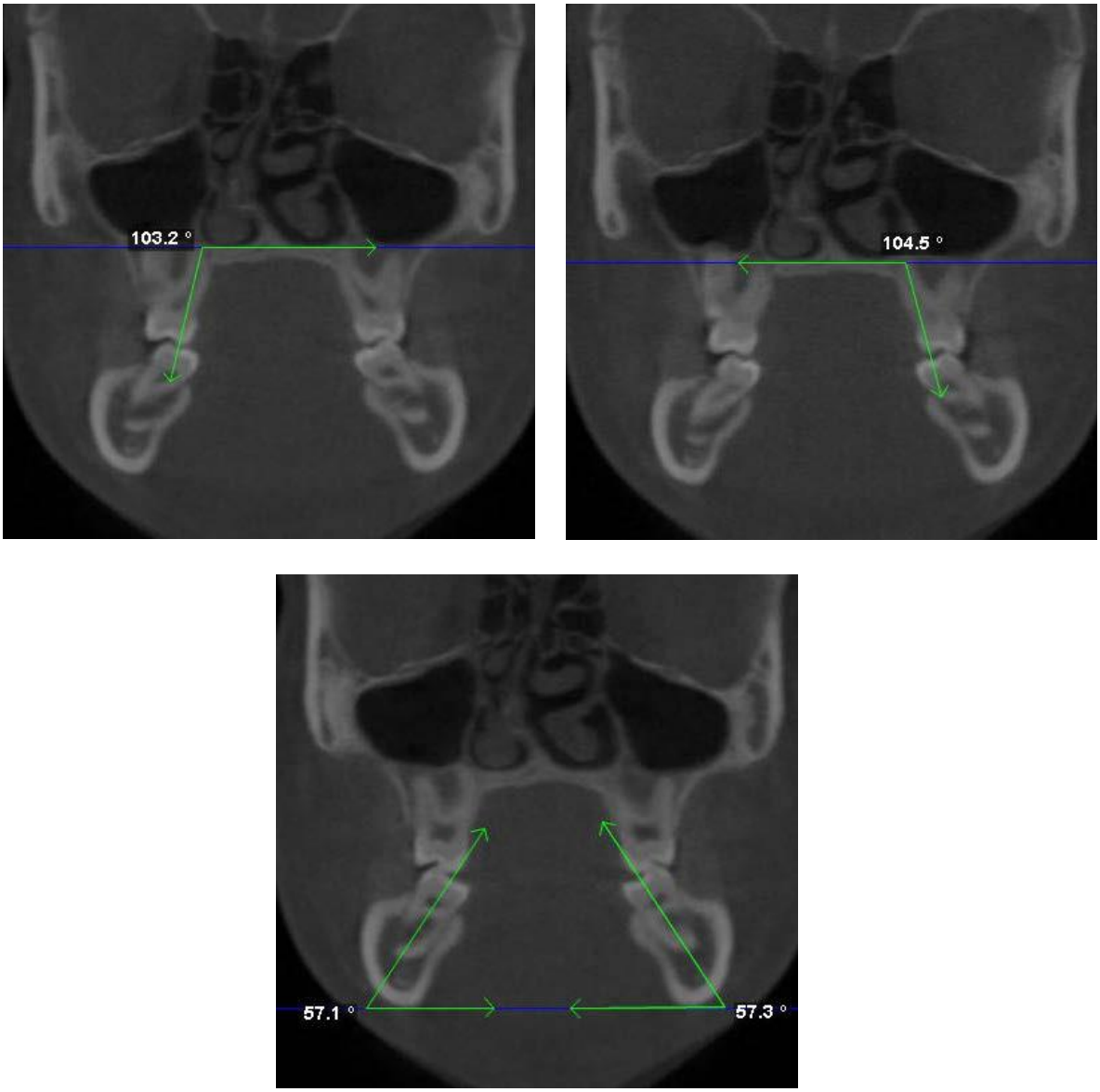


Fig 46. Case # 7: CWRU's pretreatment buccolingual inclinations of the maxillary and mandibular first molars.

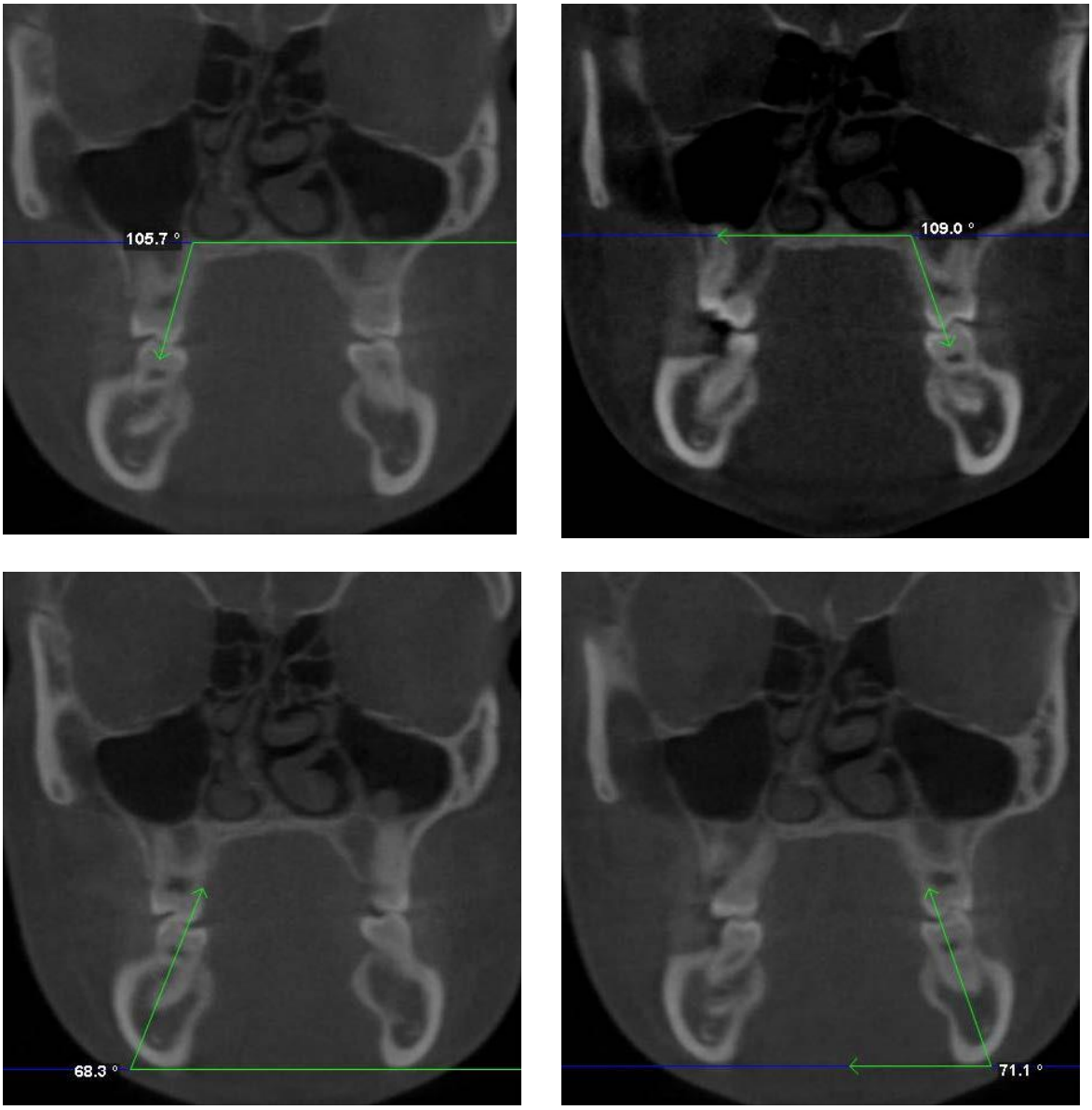


Fig 47. Case # 7: CWRU's posttreatment buccolingual inclinations of the maxillary and mandibular first molars.

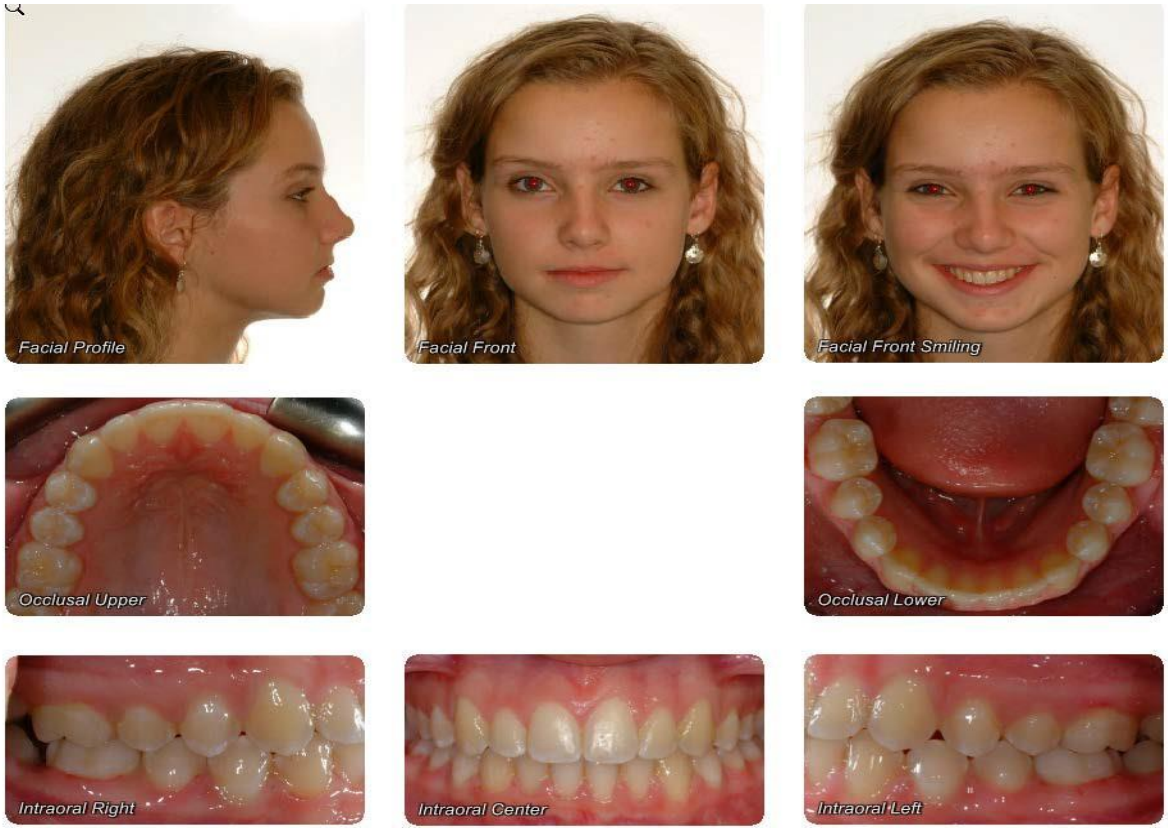


Fig 48. Case # 7: final composite.

Table I. Interrater reliability through the reliability analysis

Pretreatment Buccolingual Inclinations	Cronbach's Alpha
# 3: Permanent Maxillary Right First Molars	90.4%****
# 14: Permanent Maxillary Left First Molars	89.6%****
# 30: Permanent Mandibular Right First Molars	81.7%****
# 19: Permanent Mandibular Left First Molars	89.1%****

n = 100

**** Significant at a p-value (probability value) of less than 0.0001, (2-tailed)

Table II. Intrarater reliability[a] through the reliability analysis

Variables		Cronbach's Alpha
Discrepancy Index		98.7%****
OGS		98.9%****
Posttreatment Buccolingual Inclinations	# 3: Permanent Maxillary Right First Molars	99.8%****
	# 14: Permanent Maxillary Left First Molars	99.9%****
	# 30: Permanent Mandibular Right First Molars	99.8%****
	# 19: Permanent Mandibular Left First Molars	99.7%****

n = 30

[a] The measurements were repeated after an interval of 4 weeks

**** Significant at a p-value (probability value) of less than 0.0001, (2-tailed)

Table III. Counts and Percentages for ordinal and nominal variables

Variables	Counts	Percentages
Recoded DI	Easy: 34 Moderate: 37 Difficult: 14 Very Difficult: 5	Easy: 37.8 % Moderate: 41.1% Difficult: 15.5% Very Difficult: 5.6%
Recoded OGS	Excellent Results: 46 Moderate Results: 39 Poor Results: 5	Excellent Results: 51.1% Moderate Results: 43.3% Poor Results: 5.6%
CWRU	Followed: 40 Did not follow: 50	Followed: 44.4% Did not follow: 55.6%
Recoded Pretreatment BL Inclinations # 3 (UR6)	Excellent Inclinations: 63 Moderate Inclinations: 27	Excellent Inclinations: 70% Moderate Inclinations: 30%
Recoded Pretreatment BL Inclinations # 14 (UL6)	Excellent Inclinations: 62 Moderate Inclinations: 28	Excellent Inclinations: 68.9% Moderate Inclinations: 31.1%
Recoded Pretreatment BL Inclinations # 30 (LR6)	Excellent Inclinations: 68 Moderate Inclinations: 22	Excellent Inclinations: 75.6% Moderate Inclinations: 24.4%
Recoded Pretreatment BL Inclination # 19 (LL6)	Excellent Inclinations: 61 Moderate Inclinations: 29	Excellent Inclinations: 67.8% Moderate Inclinations: 32.2%
Crossbite Status	No Crossbite: 81 Crossbite: 9	No Crossbite: 90.0% Crossbite: 10%
Maxillary Expansion	No Expansion: 79 Expansion: 11	No Expansion: 87.8% Expansion: 12.2%
Recoded Pretreatment Age	Younger (10-13): 58 Older (14-16): 32	Younger (10-13): 64.4% Older (14-16): 35.6%
Recoded Posttreatment Age	Younger (12-15): 50 Older (16-19): 40	Younger (12-15): 55.6% Older (16-19): 44.4%
Gender	Females: 53 Males: 37	Females: 58.9% Males: 41.1%
Race	Caucasians: 86 Non-caucasians: 4	Caucasians: 95.6% Non-caucasians: 4.4%

n = 90

Table IV. Buccolingual inclinations of permanent first molars through the CWRU's transverse analysis (Mean ± Standard Deviation)

Transverse Analysis	Buccolingual Inclinations of Permanent First Molars			
	Permanent Maxillary First Molars		Permanent Mandibular First Molars	
	# 3 (UR6)	#14 (UL6)	#30 (LR6)	#19 (LL6)
Pretreatment	99.61 ± 5.57[a]	101.76 ± 6.31	74.64 ± 4.92	73.82 ± 4.97
Posttreatment	101.77 ± 4.89	102.38 ± 5.94	77.50 ± 4.97	76.57 ± 5.10

n = 90 (Pretreatment), & 86 (Posttreatment)
[a] Mean ± Standard Deviation

Table V. Descriptive statistics for the pretreatment BL inclinations of permanent first molars through the CWRU's transverse analysis

Variables	Central Tendency Measures	Dispersion Measures	
Pretreatment BL Inclinations # 3 (UR6)	Mean: 99.61 Median: 99.70 Mode: 99.5	SD[a]: 5.57	
		Min[b]: 89	Max[c]: 113
		Range: 24	25 %ile[d]: 96.4
		50 %ile[e]: 99.7	75 %ile[f]: 103.3
Pretreatment BL Inclinations # 14 (UL6)	Mean: 101.76 Median: 101.85 Mode: 102.7	SD: 6.31	
		Min: 82	Max: 115
		Range: 33	25 %ile: 98.1
		50 %ile: 101.8	75 %ile: 105.3
Pretreatment BL Inclinations # 30 (LR6)	Mean: 74.64 Median: 74.90 Mode: 72.2	SD: 4.92	
		Min: 57	Max: 88
		Range: 31	25 %ile: 71.3
		50 %ile: 74.9	75 %ile: 78.5
Pretreatment BL Inclinations # 19 (LL6)	Mean: 73.82 Median: 73.80 Mode: 71.8	SD: 4.97	
		Min: 57	Max: 87
		Range: 30	25 %ile: 70.9
		50 %ile: 73.8	75 %ile: 77.1

[a]**SD:** Standard Deviation [b]**Min**: Minimum [c]**Max**: Maximum
[d]**25 %ile**: 25 percentile [e]**50 %ile**: 50 percentile [f]**75 %ile**: 75 percentile
n = 90

Table VI. Descriptive statistics for the posttreatment BL inclinations of permanent first molars through the CWRU's transverse analysis

Variables	Central Tendency Measures	Dispersion Measures	
Posttreatment BL Inclinations # 3 (UR6)	Mean: 101.77 Median: 102.20 Mode: 101.2	SD[a]: 4.89	
		Min[b]: 83	Max[c]: 112
		Range: 29	25 %ile[d]: 99.4
		50 %ile[e]: 102.2	75 %ile[f]: 105.2
Posttreatment BL Inclinations # 14 (UL6)	Mean: 102.38 Median: 102.15 Mode: 100.1	SD: 5.94	
		Min: 85	Max: 118
		Range: 33	25 %ile: 98.7
		50 %ile: 102.2	75 %ile: 106.2
Posttreatment BL Inclinations # 30 (LR6)	Mean: 77.50 Median: 77.25 Mode: 79.2	SD: 4.97	
		Min: 64	Max: 90
		Range: 26	25 %ile: 74.7
		50 %ile: 77.2	75 %ile: 80.7
Posttreatment BL Inclinations # 19 (LL6)	Mean: 76.57 Median: 77.00 Mode: 76.1	SD: 5.10	
		Min: 62	Max: 86
		Range: 24	25 %ile: 73.6
		50 %ile: 77.0	75 %ile: 80.2

[a]**SD:** Standard Deviation [b]**Min**: Minimum [c]**Max**: Maximum
[d]**25 %ile**: 25 percentile [e]**50 %ile**: 50 percentile [f]**75 %ile**: 75 percentile
n = 86

Table VII. Descriptive statistics for the OGS, crossbite status, and maxillary expansion

Variables	Central Tendency Measures	Dispersion Measures	
Discrepancy Index	Mean: 13.97 Median: 13 Mode: 6	SD[a]: 8.46	
		Min[b]: 2	Max[b]: 45
		Range: 43	25 %ile[e]: 8
		50 %ile[e]: 13	75 %ile[e]: 18
Recoded Discrepancy Index	Median: Moderate Mode: Moderate	25%ile: Easy 50%ile: Moderate 75%ile: Moderate	
OGS	Mean: 19.56 Median: 19 Mode: 17	SD: 5.42	
		Min[b]: 7	Max[b]: 34
		Range: 27	25 %ile[e]: 15
		50 %ile[e]: 19	75 %ile[e]: 23
Recoded OGS	Median: Excellent Results Mode: Excellent Results	25%ile: Excellent Results 50%ile: Excellent Results 75%ile: Moderate Results	
CWRU	Median: Followed Mode: Followed	25%ile: Did Not Follow 50%ile: Followed 75%ile: Followed	
Crossbite Status	Mode: No Crossbite	25%ile: No Crossbite 50%ile: No Crossbite 75%ile: No Crossbite	
Maxillary Expansion	Mode: No Expansion	25%ile: No Expansion 50%ile: No Expansion 75%ile: No Expansion	

[a]**SD**: Standard Deviation [b]**Min**: Minimum [c]**Max**: Maximum
[d]**25 %ile**: 25 percentile [e]**50 %ile**: 50 percentile [f]**75 %ile**: 75 percentile
n = 90

Table VIII. Descriptive demographic statistics

Variables	Measurement Scales	Central Tendency Measures	Dispersion Measures
Active Treatment Duration	Continuous Ratio Scale	Mean: 24.98 Median: 24 Mode: 24	SD[a]: 4.80 Min[b]: 13 Max[c]: 37 Range: 24 25 Percentile: 22 50 Percentile: 24 75 Percentile: 28
Pretreatment Age	Continuous Ratio Scale	Mean: 13.07 Median: 13 Mode: 13	SD: 1.44 Min: 10 Max: 16 Range: 6 25 Percentile: 12 50 Percentile: 13 75 Percentile: 14
Posttreatment Age	Continuous Ratio Scale	Mean: 15.43 Median: 15 Mode: 15	SD: 1.45 Min: 12 Max: 19 Range: 7 25 Percentile: 14 50 Percentile: 15 75 Percentile: 16
Recoded Pretreatment Age	Categorical Ordinal Scale	Median: 10-13 Mode: 10-13	25 Percentile: 10-13 50 Percentile: 10-13 75 Percentile: 14-16
Recoded Posttreatment Age	Categorical Ordinal Scale	Median: 12-15 Mode: 12-15	25 Percentile: 12-15 50 Percentile: 12-15 75 Percentile: 16-19
Gender	Categorical Nominal Scale	Mode: Females	25 Percentile: Males 50 Percentile: Females 75 Percentile: Females
Race	Categorical Nominal Scale	Mode: Caucasians	25 Percentile: Caucasians 50 Percentile: Caucasians 75 Percentile: Caucasians

[a]**SD**: Standard Deviation [b]**Min**: Minimum [c]**Max**: Maximum
n = 90

Table IX. Trichotomization for the pretreatment CWRU's transverse analysis

Variables	$\bar{x}$ ± 1 SD	$\bar{x}$ ± 2 SD
Pretreatment Maxillary Right 6 BL Inclinations	94.04 – 105.18	88.46 – 110.75
Pretreatment Maxillary Left 6 BL Inclinations	95.44 – 108.07	89.13 – 114.39
Pretreatment Mandibular Right 6 BL Inclinations	69.72 – 79.57	64.79– 84.49
Pretreatment Mandibular Left 6 BL Inclinations	68.85 – 78.79	63.88 – 83.76

n = 90
$\bar{x}$ = Mean
SD = Standard Deviation

Table X. Paired samples t-tests for the BL inclinations of the permanent first molars through the CWRU's transverse analysis after splitting

CWRU Transverse Analysis	BL Inclinations	Pretreatment	Posttreatment	Significance
Followed CWRU n = 48	# 3 (UR6)	98.98[a]	101.93	****[b]
	# 14 (UL6)	101.35	101.72	NS
	# 30 (LR6)	76.02	78.21	****
	# 19 (LL6)	74.52	77.81	****
Did Not Follow CWRU n = 38	# 3 (UR6)	100.38	101.57	NS
	# 14 (UL6)	102.32	103.20	NS
	# 30 (LR6)	72.76	75.82	****
	#19 (LL6)	72.97	75.02	*

[a]Mean
**** Significance at a p-value (probability value) of less than 0.0001, (2 tailed)
* Significance at a p-value (probability value) of less than 0.05, (2 tailed)
n = 86

Table XI. Descriptive statistics for the dependent variable "Discrepancy Index" with each category of the independent variable CWRU

Discrepancy Index	CWRU	Descriptive Statistics	
Followed CWRU's Transverse Analysis		**Mean**	14.00
		Standard Error	1.02
		Median	15
		Standard Deviation	7.18
		Minimum	3
		Maximum	35
		Range	32
		Skewness	0.50
		Standard Error	0.34
		Z-value	1.49
		Kurtosis	0.14
		Standard Error	0.66
		Z-value	0.21
Did Not Follow CWRU's Transverse Analysis		**Mean**	13.93
		Standard Error	1.57
		Median	10.5
		Standard Deviation	9.92
		Minimum	2
		Maximum	45
		Range	43
		Skewness	1.34
		Standard Error	0.37
		Z-value	3.58
		Kurtosis	1.46
		Standard Error	0.73
		Z-value	1.99

n = 90 (Total), 50 (Followed), 40 (Did not follow)

Table XII. Kolmogorov-Smirnov and Shapiro-Wilk tests of normality for the dependent variable "Discrepancy Index" with each category of the independent variable CWRU

Discrepancy Index	CWRU	Kolmogorov-Smirnov	Shapiro-Wilk
Followed CWRU's Transverse Analysis (n = 50)		Not Significant	Not Significant
Did Not Follow CWRU's Transverse Analysis (n = 40)		Significant P < 0.001	Significant P < 0.001

n = 90

Table XIII. Descriptive statistics for the dependent variable OGS with each category of the independent variable CWRU

OGS	CWRU	Descriptive Statistics	
Followed CWRU's Transverse Analysis		**Mean**	17.64
		Standard Error	0.77
		Median	17
		Standard Deviation	5.42
		Minimum	7
		Maximum	34
		Range	27
		Skewness	0.89
		Standard Error	0.34
		Z-value	2.64
		Kurtosis	0.77
		Standard Error	0.66
		Z-value	1.16
Did Not Follow CWRU's Transverse Analysis		**Mean**	21.95
		Standard Error	0.70
		Median	21
		Standard Deviation	4.44
		Minimum	12
		Maximum	33
		Range	21
		Skewness	0.44
		Standard Error	0.37
		Z-value	1.16
		Kurtosis	0.39
		Standard Error	0.53
		Z-value	0.73

n = 90 (Total), 50 (Followed), 40 (Did not follow)

Table XIV. Kolmogorov-Smirnov and Shapiro-Wilk tests of normality for the dependent variable OGS with each category of the independent variable CWRU

OGS	CWRU	Kolmogorov-Smirnov	Shapiro-Wilk
Followed CWRU's Transverse Analysis (n = 50)		Significant P < 0.01	Significant P < 0.01
Did Not Follow CWRU's Transverse Analysis (n = 40)		Not Significant	Not Significant

n = 90

Table XV. Descriptive statistics for the dependent variable "Duration" with each category of the independent variable CWRU

Active Treatment Duration	CWRU	Descriptive Statistics	
Followed CWRU's Transverse Analysis		**Mean**	24.30
		Standard Error	0.69
		Median	23.5
		Standard Deviation	4.87
		Minimum	13
		Maximum	36
		Range	23
		Skewness	0.40
		Standard Error	0.34
		Z-value	1.18
		Kurtosis	0.09
		Standard Error	0.66
		Z-value	0.14
Did Not Follow CWRU's Transverse Analysis		**Mean**	25.83
		Standard Error	0.73
		Median	25
		Standard Deviation	4.63
		Minimum	16
		Maximum	37
		Range	21
		Skewness	0.63
		Standard Error	0.37
		Z-value	1.69
		Kurtosis	0.11
		Standard Error	0.73
		Z-value	0.15

n = 90 (Total), 50 (Followed), 40 (Did not follow)

Table XVI. Kolmogorov-Smirnov and Shapiro-Wilk tests of normality for the dependent variable "Duration" with each category of the independent variable CWRU

Active Treatment Duration	CWRU	Kolmogorov-Smirnov	Shapiro-Wilk
Followed CWRU's Transverse Analysis (n = 50)		Significant P < 0.001	Not Significant
Did Not Follow CWRU's Transverse Analysis (n = 40)		Significant P < 0.01	Not Significant

n = 90

Table XVII. Independent-samples t-test between the discrepancy index and the OGS

Discrepancy Index		Mean	Standard Deviation	Significance
OGS	**Difficult Discrepancy DI >= 21 n = 74**	23.13	5.61	***
	Moderate Discrepancy DI < 21 n = 16	18.78	5.10	

*** Significant at a p-value of less than 0.005, (2-tailed)
n = 90 (Total), 74 (Difficult), 16 (Moderate)

Table XVIII. Independent-samples t-test between the CWRU's transverse analysis and the discrepancy index

CWRU Transverse Analysis		Mean	Standard Deviation	Significance
Discrepancy Index	Followed CWRU	14.00	7.18	NS
	Did Not Follow CWRU	13.93	9.92	

NS = Not Significant
n = 90 (Total), 50 (Followed), 40 (Did not follow)

Table XIX. Independent-samples t-test between the CWRU's transverse analysis and the ABO's objective grading system

CWRU Transverse Analysis		Mean	Standard Deviation	Significance
ABO's Objective Grading System (OGS)	Followed CWRU	17.64	5.42	****
	Did Not Follow CWRU	21.95	4.44	

******** Significant at a p-value of less than 0.0001, (2-tailed)
n = 90 (Total), 50 (Followed), 40 (Did not follow)

Table XX. Independent-samples t-test between the CWRU's transverse analysis and the active treatment duration

CWRU Transverse Analysis		Mean	Standard Deviation	Significance
Active Treatment Duration	Followed CWRU	24.30	4.87	NS
	Did Not Follow CWRU	25.83	4.63	

NS = Not Significant
n = 90 (Total), 50 (Followed), 40 (Did not follow)

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CVlR.U IRB Protocol:--lumber. IRB-1011-3 9

Protocol Title: *Post-"tatmtnt t>aluation through tht CWRU's "ann·trs.r analysis antltht ABO's objutit-e grading s,-sttm.*

o tble InYngator (RI): Ju:n P: lomo

Co-Investigator (CI): **Raweya Mostafa**

RI Department: Orthodontics

Type ofRe\1ew: Expedited

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The CWR.U ltitutional R.e\1ew Bo;ud (IR.B) I= appro\·ed the abo\'e new protocol tbrothe EXPEDITED rt\1ew proce

When conductmr; Human Subjecb" Re;uch. your respo ibilirieinclude the follo\\-i.og;

1. 1. Report all adnr..e e\·enb and Wlanhctpaied problem:; m\'ohi.or; human ▮=> jecb to the IR.B Office, located m the Office of ;ucb Ad.txu.nrnration (ORA), withm three (3) b mdayof your knowledge of the occurrence.

2. 2. ProYide the IRB n-ith a complete Continuing Re\-iew follll (a\·.ulable in our electromc applicationyem at bttp: lbenrb-app.ra;e.edu. or from the ORA) by the connnuing rt\iew deadhne noted abon. and when theudyito be terminated..

3. 3. Submit all propo:ed c eto the protocol to the IR.B and wait for IR.B appronl before unplementing any protocol change or modification.

4. 4. Keep all rese;uch data and original coru.ent documents in your psion for at lust three (3) yafter the study ts tellllinated..

5. 5. otethat completely de-tdenrified data can be kept and u:ed for fe;uch indefinitely. The IR.B LS primarily concerned abouttdentifier..ltdentifiable data. If you \\'ant to terminate your study, identifier..fidentifiable data mtube destroyed. This mcludpaper or electronic master lim. contact lLSts.codes/codebooks, ▮ i p ts containmg tdentifiers and \ideo and audio recording

6. 6. lhpphcable, pluse u::e the mo:a current IR3-appro\·ed co ent fo Feel free to use copteofthee follll;long athey aJe tdenttcal to what waonp.nally IR.B appro\'ed. If you WISh to ch.tnr;e the forms or any other pan of thrudy. you mtubmtt an addendum requtprotocol mod.t.ficanon wuh rt\1copy(:)of the rtle\·ant document() and wau for IR.B app1oval before a mod!ficanon can be I.Dlplemented.

7. 7. *Discontinue afl K"0rlr pertaining to this protocol i(a continuing re.--ieM• appro•e1* is *JI;OT {ineli;.Jtl bt• the expiration dqtc aowl* eberc No further work on this protocolallowable unttl the proper continuing rmew materials or required redbm appro\'ed by the IR.B.

a. a. Ptea note that, if the connnuing review materilh or reqw.red rensiom ;ue not recei,ed by the expiration date. the R.I and this study would be automatically placed on Admini!.lrltive Hold for 30 days. !hi$ means that the RI loses their IR.B prh-ilege-:. and rese;uch from this study must cease.

b. b. If after 30 days, the C IR.Bill dnot have the protocol for procsing, thlS protocol n1ll be admi.rtr:lti\-eh tellllinated and vouT IRB pri\1leges \\-ill be revoked for all vour protocoh.

Thank you for your attention to thh matter. P!ue contact the IR.B office at 216-368-6993 if we can be of further aL.Stance.