Mandibular Growth Changes in Class II Subjects Treated with Palatal Expansion:
A Retrospective Study

BY

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THESIS

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TO

TABLE OF CONTENTS

TABLE OF CONTENTS (continued)

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

IRB	Institutional Review Board

SUMMARY

Dentofacial orthopedics is a fundamental part of orthodontics. Throughout the literature, different orthopedic approaches have been utilized in order to correct skeletal discrepancies along with dental problems. Orthopedic intervention in growing individuals can dramatically change the skeletal growth trend in a favorable magnitude and direction facilitating the correction of the malocclusion. Transverse palatal expansion is one of the most commonly prescribed treatment modalities in the early mixed dentition. Not only does it increase arch width and correct posterior crossbite, but also it increases arch length which may help prevent the need for extractions later on.

The effect of palatal expansion on the transverse dimension has been repeatedly mentioned in the literature, especially with regard to treatment of posterior crossbites. However, the effect of palatal expansion and bite opening on the antero-posterior position of the mandible was not clearly established. This study investigated the potential effect of palatal expansion and bite opening on mandibular growth. It included two groups with a class II skeletal pattern, mandibular retrusion and average direction of skeletal vertical growth. The studied sample consisted of subjects treated with the Quad-Helix expander and utility arches but without the use of class II mechanics, while the control sample included an untreated group with similar skeletal features. Lateral cephalometric radiographs were used to evaluate and measure skeletal changes between both groups within a specific observation period. The results demonstrated that the skeletal antero-posterior relationship showed a favorable improvement in both groups within the observation period.

In its attempt to correct class II malocclusion, the treatment protocol in the treated group managed to maintain vertical control, reduce overjet and overbite, but no significant differences on the total mandibular growth changes between both groups during the observation period were detected. In conclusion, the null hypothesis was not rejected and the investigated treatment protocol did not affect mandibular growth when compared to the untreated group.

1. INTRODUCTION

1.1 **Background**

Class II malocclusion has been traditionally treated after proper diagnosis of the sagittal discrepancies and vertical problems. Skeletal treatment objectives are to either restrict the maxilla from its typical downward and forward growth direction and allow~~ing~~ the mandible grow to its full potential or to posture the mandible forward by using a functional appliance, whereas the vertical problem is primarily addressed by controlling and preventing clockwise rotation of the mandible.

The transverse characteristics of class II malocclusion have been thoroughly investigated throughout the literature. Since class II malocclusion is almost always accompanied with transverse deficiency (Tollaro et al., 1996), maxillary expansion is recommended during early mixed dentition to resolve the transverse problems.

Spontaneous sagittal correction in class II malocclusion has been reported after rapid palatal expansion of the maxilla. McNamara (2005) explains this phenomenon further in several articles, suggesting that by over-expanding the maxilla, the occlusion disrupts, therefore the patient becomes more comfortable posturing forward eliminating the tendency toward a buccal crossbite and improving the overall sagittal occlusal relationship. This forward posture and subsequent mandibular growth will make the initial postural change permanent.

The utility arch, first presented by Ricketts (1979), is recommended for the resolution of different orthodontic problems, but is primarily used to level Curve of Spee and to reduce the overbite by incisor intrusion. The biomechanical effects (Davidovitch et al., 1995) of the utility arch include intrusion and flaring of incisors and possible molar extrusion. In order to reduce the amount of molar extrusion, Ricketts et al. (1979) introduced the cortical bone anchorage, in which buccal root torque is applied to mandibular first molars causing the roots to be trapped beneath the external oblique ridge of the external alveolar plate of bone in the mandible. Several studies have been done on the effect of the utility arch on lower molars, and they all found that there was no significant extrusion of lower molars after using utility arch with cortical anchorage (Ulger et al., 2001; Cook et al., 1994).

Since maxillary transverse deficiency and constriction in class II division 1 cases may act as an obstacle to the natural forward growth of the mandible, it would also seem logical that the vertical element defined by the vertical relationship between the upper and lower incisors might play a similar role. Some clinicians believe that along with maxillary expansion, reducing the overbite without affecting the vertical dimension of the mandibular relationship to the cranial base may help in freeing the mandible and enhance its growth potential.

In order to improve mandibular position in relation to the dentofacial complex, a treatment modality is used which combines slow maxillary expansion as well as intrusion of upper and lower incisors with utility arches to treat patients with Class II skeletal and dental pattern during the early mixed dentition age.

1.2 Objectives

To evaluate mandibular growth changes and position relative to the maxilla and cranial base in subjects treated with maxillary skeletal and dental transverse expansion and incisor intrusion, and compare them to an untreated control group.

1.3 Null Hypothesis

Null Hypothesis: there is no difference in mandibular growth as assessed by position and total length in Class II subjects treated with palatal expansion and utility arches, compared with an untreated group of similar skeletal pattern.

1. REVIEW OF LITERATURE

2.1 Epidemiology

Approximately one third of the American population has a Class II malocclusion. The skeletal growth pattern of individuals with a Class II division 1 malocclusion, from deciduous dentition through the permanent dentition has not been evaluated extensively. According to the literature, mandibular retrusion seems to be a major characteristic (60%) of Class II malocclusion in the mixed dentition, with a smaller total mandibular length and smaller gonial angle compared to class I samples (Baccetti et al., 1997). Forty percent of the Class II malocclusion present with neutral vertical dimension, 17.5% present with increased mandibular plane angle while only 10% showed decrease in anterior lower facial height. Concerning the maxillary sagittal position, there has been controversy as to whether it is positioned in a more forward, neutral, or backward position. The majority of cases turned out to have neutral maxillary position and only 10-15% showed maxillary protrusion (McNamara, 2009).

Throughout various longitudinal studies that evaluated the relationship of Class II skeletal pattern to Class II malocclusion, there has been controversy as to whether the skeletal pattern would be expressed through the dentition or the skeletal pattern develops as secondary adaptation. Several cephalometric studies were done on children between three to seven years old, to investigate the relationship of their skeletal pattern and their malocclusion. Varrela (1998), found in his sample that the skeletal Class II traits (short mandibular corpus, large but constant gonial angle, normal ramus length, retruded dentoalveolar complex , normal skeletal position and chin which becomes more retruded after 5 years of age), developed later than the occlusal characteristics. Also, a study done by Moyers and Wainright (1977) found that the distal step in the deciduous dentition likely reflects any underlying skeletal imbalance resulting in a Class II malocclusion.

2.2 Class II Malocclusion:

Occlusal traits of Class II malocclusion are manifested early in the dentition. The presence of distal step relationship of second deciduous molars, distal canine relationship large overjet and large overbite indicates the characteristics of Class II deciduous dentition. All the observations done on occlusal changes from deciduous dentition throughout the permanent dentition confirm that the Class II relationship will never "self-correct" in a growing patient, any favorable change toward Class I occlusion is dependent on a number of dental and facial skeletal changes where genetic and environmental factors interaction achieve, a normal occlusion. (Bishara et al., 1988)

2.3 Maxillary Expansion in Class II

Considering maxillary skeletal and dental transverse expansion as an essential step of the orthodontic treatment in Class II malocclusion was and is still controversial. Some clinicians believe that palatal expansion facilitates Class II molar correction by widening the maxillary dental base and unlocking the occlusion allowing the mandible to grow forward, which in turn, allows the mandibular growth to be fully expressed. Others, however, think it is not appropriate to treat Class II patients with rapid palatal expanders unless a bilateral or unilateral posterior crossbite is present (Gianelly, 2003).

Interestingly, Tollaro et al. (1996) found that even with the absence of posterior crossbite, the normal buccolingual relationship of the posterior dentition usually has a 3-5 mm transverse discrepancy between maxilla and mandible. McNamara (2002) and Baccetti et al. (1997) also came to the same conclusion; the Class II pattern was always associated with maxillary constriction, even in the absence of a posterior crossbite.

2.4 Rapid versus Slow Expansion

Maxillary expansion in growing children can be done by two different mechanisms; Rapid Palatal Expansion (RPE) either with a Haas expander or Hyrax expander; or Slow Maxillary Expansion (SME), in which Quad-Helix expander is most commonly used. Deciding which protocol to use depends on the practitioner's experience, the patient's age, and certain features of malocclusion (Lagravère et al., 2005).

Chaconas and Caputa (1982) reported that the effects produced by a Quad-Helix appliance are dependent on the patient's age. When midfacial sutures are patent, as seen in children seven to nine years old, activation of the quad-helix appliance meets with little resistance, meaning that more skeletal expansion can be obtained than for older patients. Proffit (2007) states that the overall results of rapid vs. slow expansion are similar but the slow expansion requires a longer time (2-3 months longer) and results in a more physiologic response.

2.4 Class II Treatment Options

Class II skeletal and dental disharmony can be approached through proper diagnosis and treatment planning. Growth plays a central role in improving skeletal pattern through modifying the growth direction.

Headgear therapy has been found to be the most efficient means of obtaining growth modification in Class II malocclusion; it restricts the forward and downward growth of the maxilla, and allows the mandible to grow to its full potential. On the other hand, there have been many controversies on the effect of functional appliances on growth.

Functional appliances, such as Bionator, Herbst, and Twin-Block, are thought to modify growth and improve the anteroposterior relationship by posturing the mandible forward and stimulating the growth at the condylar cartilage. Some studies report an increase in the overall mandibular length, but others believe that most of the correction is due to dentoalveolar changes with a small amount of skeletal change. The effect of the functional appliance on the maxilla has also been debated. Many studies showed an inhibitory effect on maxillary forward growth, while, other studies could not find any effect. A recent systematic review (Marsico et al., 2011) looked at the short term effect of functional appliances on the mandibular growth and reported a statistically significant increase in mandibular length that unlikely was to be clinically significant.

Whether the actual effect is to grow the mandible beyond its genetic potential or accelerate the mandibular growth is also an important concept to consider when talking about functional appliances. In his study of long term dentofacial adaptations in patients treated with the Herbst appliance, Pancherz (1997) found that there was less increase in mandibular length in treated subjects when compared with the untreated subjects 7.5 years post-treatment, but there was an increase in mandibular height and decrease in gonial angle in the Class II treated group. He interpreted this as indicating bone apposition at the posterior part of the lower corpus border in the Herbst subjects and bone resorption in the control subjects and less sagittal condylar growth in the Herbst group than in the control group. Hence, accelerating growth may be the direct effect of Herbst appliance.

2.6 Spontaneous Class II Correction

Based on the belief that Class II stays Class II and does not self correct (Bishara et al., 1988), You et al (2001) were interested in looking at the movements of the dentoalveolar complex during maxillary and mandibular forward growth in non-treated subjects with bilateral full step Class II molar relationship and compared these changes with subjects with optimal facial and dental development. Both groups were evaluated at two different time points, one before the growth spurt and the other beyond the growth spurt. They found a strong linear correlation between forward growth of the mandible and maxillary dentition forward movement and mandibular dentition backward movement. This was referred to as the “adaptation phenomenon”. With his final results, it was concluded that the effect of forward growth of the mandible relative to maxilla, which could potentially bring the lower dentition forward, vanished into adaptation movements of the dentoalveolar complex.

This type of adaptation phenomenon could be due to the intercuspation of the upper and lower dentition. This study suggests that a class II malocclusion does not self-correct and that disarticulating the occlusion to minimize the effects of the adaptive changes of the dentoalveolar complex should greatly facilitate treating Class II malocclusions in growing patients.

Since Class II malocclusion is almost always accompanied with a transverse deficiency and the midpalatal suture is more amenable to orthopedic expansion during the juvenile age period, as shown in a histological study of sutural morphology and skeletal maturation of rapid maxillary expansion (Meslen, 1972), maxillary expansion is recommended during early mixed dentition to resolve this transverse skeletal deficiency. McNamara (2002) found a spontaneous sagittal correction occurring in Class II patients with end- to- end molar relationship and moderate skeletal discrepancy due to slight mandibular retrusion. He explains the phenomenon further in several articles;” by over-expanding the maxilla, occlusion disrupts and the patient becomes more comfortable to posture forward eliminating the tendency toward a buccal crossbite and improving the overall sagittal occlusal relationship. This forward and subsequent mandibular growth will make the initial postural change permanent.” He also stated that this correction usually occurs during the first 6 to 12 months of the post-RME period. If further Class II correction is needed, it could be addressed during growth spurt.

In a later study, McNamara (2006) looked at whether maxillary expansion causes spontaneous Class II correction and found that, in the untreated Class II tendency group, the molar relationship of 48% of the subjects remained unchanged, 41% improved, and 11% worsened; in the treated Class II tendency group, 35% remained unchanged, 63% improved, and 2% became worse. In his paper, he proposed the use of RME in cases where “maxillary deficiency syndrome” is noticed; this “syndrome” is typically characterized clinically by an orthognathic facial profile, mild to moderate mandibular retrognathism, and maxillary constriction.

The effect of rapid maxillary expansion on the sagittal and vertical component in different types of malocclusion was also studied by Farronato et al. (2011). The sample included growing patients with maxillary hypoplasia and bilateral crossbite. In Class II sample, there was a significant increase in SNB angle and decrease in ANB angle while the anterior facial height and mandibular plane angle remained unchanged.

Volk et al. (2010) evaluated the effect of rapid maxillary expansion on Class II molar relationships and mandibular skeletal position using articulator-mounted pre- and post-treatment dental casts. Thirteen subjects with a Class II malocclusion treated with palatal expanders were evaluated. Models were mounted in centric occlusion and maximum intercuspation before and after treatment in order to evaluate mandibular forward posture. Although 7 patients out of 13 showed an improvement in molar relationship, there was no statistical difference before and after maxillary expansion. In addition, the condylar position indicator showed no significant difference in molar relationship between centric occlusion and maximum intercuspation. Therefore, the chance of anterior functional shift of the mandible was eliminated.

Lima Filho et al., (2003) described the treatment of a seven year-old female with a Class II Div I subdivision right, and unilateral crossbite with mandibular asymmetry and functional shift. ANB angle was 4 degrees in the presence of a high mandibular plane angle and retrusive mandible and maxilla. The patient underwent phase I treatment using a Haas expander, which was stabilized for three months post-expansion and retained using a bite plate. After one year of treatment the transverse dimensions were properly corrected, and the mandible was carried forward to its normal position resulting in spontaneous correction of the Class II malocclusion.

According to Haas (2000), "all Class II Div 2 patients, and most Class II Division I patients, are in functional mandibular retrusions, where the Class II div 2 is due to the lingual inclinations of the upper central incisors and the Class II div 1 is because of the maxillary constricted base, particularly from canine to canine. The freed mandible can move forward to assist in the correction of the Class II." The Class II molar relationship correction was about one half of a premolar width. Haas' explanation for this favorable correction is modifying muscle pull direction and maximizing growth of the oro-facial musculature giving a favorable effect on jaw growth, tooth alignment, and dento-labial esthetics.

Others explain that the spontaneous correction of Class II molar relationship, in Class II div 2 individuals, is due to freeing the mandible from its distal position to the centric relation where the condyles are also trapped in a more distal position. Once the occlusion is disrupted by converting the malocclusion into Class II div 1, the mandible will be spontaneously corrected.

A study by Engel et al. (1980) determined that there is more than the normal amount of mandibular growth following correction of deep overbite and unfavorable incisor inclination of the Class II division 2 malocclusion.

The results indicated an increase in corpus length to cranial base ratio, and also an increase in condylar length change to cranial base ratio relative to a normal case. The study also indicated that the interincisal angle and overbite is good predictor of mandibular growth. Additionally, it was found that when the interincisal angle exceeds 145 degrees, there is a high probability of excessive mandibular growth.

2. MATERIALS AND METHODS

3.1 Study Design

A retrospective study design was implemented to evaluate the direct treatment effects of maxillary palatal expansion and intrusion of incisors on the improvement of Class II skeletal pattern and mandibular growth changes. Mandibular growth changes in treated subjects with Class II skeletal pattern due to mandibular retrusion were evaluated in relation to the cranial base and maxillary basal bone. A growing untreated control group was used to compare the results.

3.2 Data Collection

A sample of 54 Class II untreated subjects' lateral cephalometric radiographs was obtained from multiple growth studies (Matthew, Michigan, Denver, Oregon, Forsyth and Burlington growth studies) found in the Craniofacial Growth Legacy Collection of the American Association of Orthodontists Foundation. All radiographs were sent to the primary investigator as encoded high resolution JPEG files.

The Mathews Implant Growth Study collection includes longitudinal cephalometric record sets of 1000 images of lateral and posterior-anterior cephalograms which were taken annually. Interestingly, this sample includes subjects with Bjork - type implants. This collection is considered the largest collection of subjects with Class II malocclusion.

The Michigan Growth Study is comprised of annual records taken on students enrolled in the University School, a laboratory school housed in the School of Education on the Ann Arbor campus. Data collection began in 1935, at which time medical, dental, psychological, and anthropologic data were gathered. The taking of cephalograms began in 1953 and continued routinely until about 1970, when the University School closed and data collection was discontinued. Several recall studies have been conducted since that time, most recently in 2007. This collection includes useful sample size of subjects with Class II malocclusion and increased lower anterior facial height, with only very few individuals presenting with a Class III malocclusion.

The Forsyth growth study includes a twin sample, and is considered ~~as~~ the largest prospective growth sample collected on twins and their families. The subjects are primarily of Northern European origin and some have received orthodontic treatment.

The Oregon growth study includes mixed longitudinal records of an untreated Caucasian individual, and it includes photographs, study casts and lateral cephalometric radiographs (closed and wide-open).

The Burlington Growth Centre at the University of Toronto was initiated by Dr. Robert Moyers in 1952 when Burlington was a town with a population of 9,000 situated approximately 30 miles from Toronto in the province that at that time comprised 30% of the national population. The predominant racial group was Caucasian and mostly Anglo- Saxon.

The lateral cephalometric radiographs of the treated sample were obtained and collected by the orthodontist's office staff. Each radiograph was de-identified, replaced by a number and scanned using Adobe Photoshop 7.0 (San Jose, CA, USA). Thirty seven digitally scanned radiographs were given to the primary investigator with the requested demographic data (gender, age, and race) and history of orthodontic treatment information. The removal of identification for the records per Health Insurance Portability and Accountability Act ensured that the patient could not be identified by the principal investigator.

The untreated control and treated groups were selected from the first and second samples respectively, according to the following criteria:

1. Growing individuals with an age range of 8-14 years old.
2. Patients with Class II skeletal pattern determined by ANB angle greater than 4.5 degrees (Walker and Kawalski, 1971).
3. Patients with mandibular retrusion determined by facial angle less than 85.4 degrees (Jacobson, 1995).
4. Patients with normal total facial height determined by total facial angle (Ricketts et al., 1979).
5. Subjects in the treated group who underwent palatal expansion with a Quad-Helix appliance with upper and lower utility arches as an initial orthodontic treatment protocol. Individuals treated with Class II elastics were excluded.
6. No orthodontic treatment was performed on the untreated control group.

Using Dolphin Digital Imaging software version 11.5 (Chatsworth, CA, USA), all pre-treatment radiographs of both samples were traced and analyzed. Twenty out of 37 subjects of the treated group and 18 of 54 subjects of the untreated group satisfied the inclusion criteria and were included in this study.

Final observation (T2) radiographs were taken 1-3 years after the initial observation.

3.3 Cephalometric Analysis

Angular and linear cephalometric measurements were used to evaluate skeletal and dental changes during the observation period.

Since the control group consisted of different growth studies, calibration was performed to correct any magnification errors produced from using different X-ray machines. Fiduciary points and a ruler were used for calibration.

The following landmarks, linear planes and angular measurements were used in cephalometric analysis.

3.3.1 Landmarks

The following landmarks were used in Figure 1

- Articulare (Ar): a constructed point represents the intersection of the image of the posterior border of the mandibular ramus with the base of the occipital bone.
- Anterior Nasal Spine (ANS): the anterior tip of the sharp bony process of the maxilla at the lower margin of the anterior nasal opening.(Jacobson)
- Basion (Ba): the most anterior inferior point on the border of foramen magnum in the mid-sagittal plane.
- DC point: the point in the center of the condyle neck along the Ba-N plane (Jacobson, 1995).
- Nasion (N): the frontonasal suture at its most superior point on the curve at the bridge of the nose at the mid-sagittal plane.
- Gonion (Go): the most posterior inferior point at the angle of the mandible.

- Gnathion (Gn): the most anterior inferior point on the lateral image of the chin, it is approximately midway between Pogonion and Menton on the contour of the chin at the midsagittal plane.
- Menton (Me): the lowest point on the symphyseal outline of the chin.
- Orbitale (Or) the lowest point of the inferior orbital margin.
- Porion (P): the point on the upper margin of the external acoustic meatus.
- Pterygoid (Pt): the intersection of the inferior border of foramen rotundum with the posterior wall of pterygo-maxillary fossa, being the most superior posterior point of the pterygo-maxillary fissure. It is used to find a central coordinate reference (cc) on the basion-nasion plane.
- Pogonion (Pog): the most anteriorpoint on the contour of the chin, in the midsagittal plane, located by drawing a perpendicular to mandibular plane, tangent to the chin at the midsagittal plane.
- R1: deepest point on the anterior border of the ramus, located halfway between the superior and the inferior curves.
- R2: located on the posterior border of the ramus, opposite to R1.
- R3: Deepest point of the sigmoid notch, halfway between the anterior and posterior curves.
- R4: Opposite to R3 on the inferior border of the mandible.
- Sella Turcica (S): Geometric center of the pituitary fossa located by visual inspection.
- Supragonion (Pm): Protuberance menti or supragonion point selected at the anterior border of the symphysis between B point and Pog where the curve changes from convex to concave.
- Subspinale (A): the deepest midline point on the premaxilla in the midsagittal plane between ANS and Prosthion. It is usually found 2 mm anterior to the apices of the

maxillary central incisor roots. It is usually used for anteroposterior measurements and can be influenced somewhat with by the position of the roots of the maxillary incisor teeth

- Submentale (B): the most posterior point in the concavity between ID and Pogonion in the mid-sagittal plane, usually found near the apical third of the roots of the mandibular incisors.
- Xi point: the geographic center of ramus, selected by geometric bisecting of the height and width of the ramus (center of R1, R2, R3, and R4), Xi point is located in the center of the triangle at the intersection of the diagonal.

3.3.2 Planes:

- Anterior cranial base (S-N).
- Ba-N: basicranial axis anterior and middle cranial planes some contend that it represents cranial base more accurately then SN or Bolton Plane.
- Condylar axis (Xi –DC): Line drawn down long axis of the condyle head by inspection. Usually it intersects lower border of the mandible (Jacobson, 1995).
- Corpus axis (Xi- Pm): a plane extends from Xi point to Pm; used to describe mandibular morphology and as a plane of reference to evaluate dentition changes (Jacobson, 1995).
- Denture plane(A-Pog)
- Facial axis (PtV-Gn): A plane connecting PT with cephalometric Gnathion. It forms almost exactly the central axis of the face.
- Frankfort Horizontal Plane (Or-Po): an anthropological horizontal plane described on dry skull as passing through the lowest point in the floor of the left orbit and the highest point on the margins of the external auditory meati. It represents the true horizontal line when head is in upright position.
- Lower facial plane (N-B).

- Mandibular Plane (Me-Go): Plane
- Occlusal Plane (OP): a plane drawn through the cusps of the molars and bisecting the incisors overbite anteriorly (Jacobson, 1995).
- Pterygoid Vertical (PtV): line passing through Pt and perpendicular to FH.
- Total Facial plane (N-Pog).
- Upper facial plane (N-A).

3.3.3 Cephalometric measurements:

Skeletal measurements

Cranial Base

- SN-FH: measures the relative position of the Sella in relation to N-Point, this angular measurement affects SNB and SNA readings.

Antero-posterior

- SNA: measures the anteroposterior position of maxillary base in relation to the cranial base. It determines the degree of protrusion or retrusion of the maxilla relative to cranial base.
    - Clinical Norms according to Steiner (1959):
        - SNA= 82 degrees
- SNB: ~~it~~ measures the anteroposterior position of mandibular base in relation to the cranial base.
    - Clinical Norms according to Steiner (1959):
        - SNB= 80 degrees.
- ANB: measures the anteroposterior discrepancy between maxillary and mandibular base.
    - Clinical norms according to Steiner (1959):
        - ANB= 2 degrees

    - Clinical Norms according to Walker (1971):
        - ANB = 4.5 degrees
- Facial Angle (FA): according to Down's analysis, it indicates Facial depth, and ~~it~~ assesses the anteroposterior chin position in relation to Frankfort-Horizontal plane. It is the inferior posterior angle formed by the intersection of FH and FP.
    - Clinical norms according to Ricketts (Jacobson, 1995):
        - N-Pog/FH = 85.4 $\pm$ 3.7 degrees
- Facial convexity (NPog-NA) measures the extent of protrusion or retrusion of the lower jaw and the relationship of the jaws to each other; also locates the maxillary basal arch at its anterior limit relative to the total facial profile. This angle is read positive if the line Pog-A point is located anterior to N-A line.
    - Clinical norms according to Down's analysis (Jacobson, 1995):
        - NA- NPog-= 8.5-10 degrees.

<u>Vertical measurements</u>

- Facial Axis Angle (FAx): describes the facial height, it is the inferior angle formed by the intersection of the Facial Axis and Ba-N plane, used as an indicator for direction of facial development.
    - Clinical norms according to Ricketts (1975):
        - PtV-Pog/ Ba-N = 90 $\pm$ 3 degrees; smaller value indicates vertical facial growth while bigger values indicate a horizontal growth pattern.
- Frankfort- Mandibular plane Angle (FMA): The anterior angle formed by the intersection of mandibular and the Frankfort Horizontal Plane.
    - Clinical Norms according to Down's Analysis (Jacobson, 1995):
        - FMA= 21.9 $\pm$ 3.2
- SN-MP: The inferior angle formed by anterior cranial base S-N and mandibular plane.

- Clinical norms in Caucasians according to Steiner (1959):
    - Sn-MP= 32 degrees
- SN-OP: the ingle formed between anterior cranial base and occlusal plane.
    - Clinical norms according to Steiner's analysis (Jacobson, 1995):
        - SN-OP= 14 degrees.
- FMA, SN-MP and OP-SN measure the hypodivergency or hyperdivergency of the facial planes
- Anterior Lower facial height (LFH): (Xi-ANS-Pm): indicates the denture height, It is the angle formed by the intersection of corpus axis and Xi-ANS plane.
    - Clinical norms according to Ricketts Analysis:
        - LFH= 46± 3degrees.
- Mandibular arc (MA): indicates mandibular form, the angle formed between Corpus axis (Xi-Pm) and condylar axis (DC-Xi.
    - Clinical norms According to Rickett's Analysis:
        - Mandibular arc= 26 degrees± 4.5.

Dental measurements

- U6-PtV: the distance between Pterygoid vertical to the distal surface of maxillary first molar. It evaluates whether the malocclusion is due to maxillary molar position or mandibular molar position.
    - According to Ricketts (Jacobson, 1995):
        - U6-PtV= the age of the patient + 3 mm.
- Overjet: measured from the lingual surface of the most protrusive maxillary incisor to the labial surface of the lower incisor at the incisal third.
- Overbite: measured from the incisor edge of the maxillary central incisor to the incisal edge of the mandibular central incisor.

- L1 to APog (mm): defines the protrusion of lower arch in relation to the denture plane and is used to measure the position of lower incisor;
    - Clinical norms, according to McNamara (Jacobson, 1995):
        - U1-APog= 1-3 mm

- L1-APog inclination: the angle between the long axis of the lower incisor and A-Po plane.
    - Clinical norms according to Ricketts (1960):
        - L1-APog= 0.5 degress $\pm$ 2.7
- L1/NB inclination: the axial inclination of the long axis of lower incisors in relation to N-B line.
    - According to Steiner the inclination of lower incisor:
        - L1/NB= 25 degrees.
- L1 to NB: measures the forward or the backward position of the lower incisor in relation to N-B plane.
    - According to Steiner:
        - L1 to NB= 4 mm ahead of this plane.
- U1/NA inclination: indicates the axial inclination of the long axis of the most anteriorly positioned central incisor to the N-A plane.
    - According to Steiner (1959):
        - U1/NA= 22 degrees.
- U1 to NA (mm): measures the forward or backward position of the incisor teeth to the NA line.
    - According to Steiner:
        - U1-NA= 4 mm ahead of the N-A line.

- U1 to APog (mm): measures the forward or backward position of the upper incisor to the APog plane.
    - Clinical norms accordning to Ricketts (1960)
        - U1-APog = 5.7 mm, $\pm$ 3 mm
- Interincisal Angle (U1/L1): established by passing a line through the incisal edges and the apices of the roots of the maxillary and mandibular central incisors.
    - Clinical norms according to Down's Analysis, (Jacobson, 1995):
        - U1/L1= 130-150 degrees.

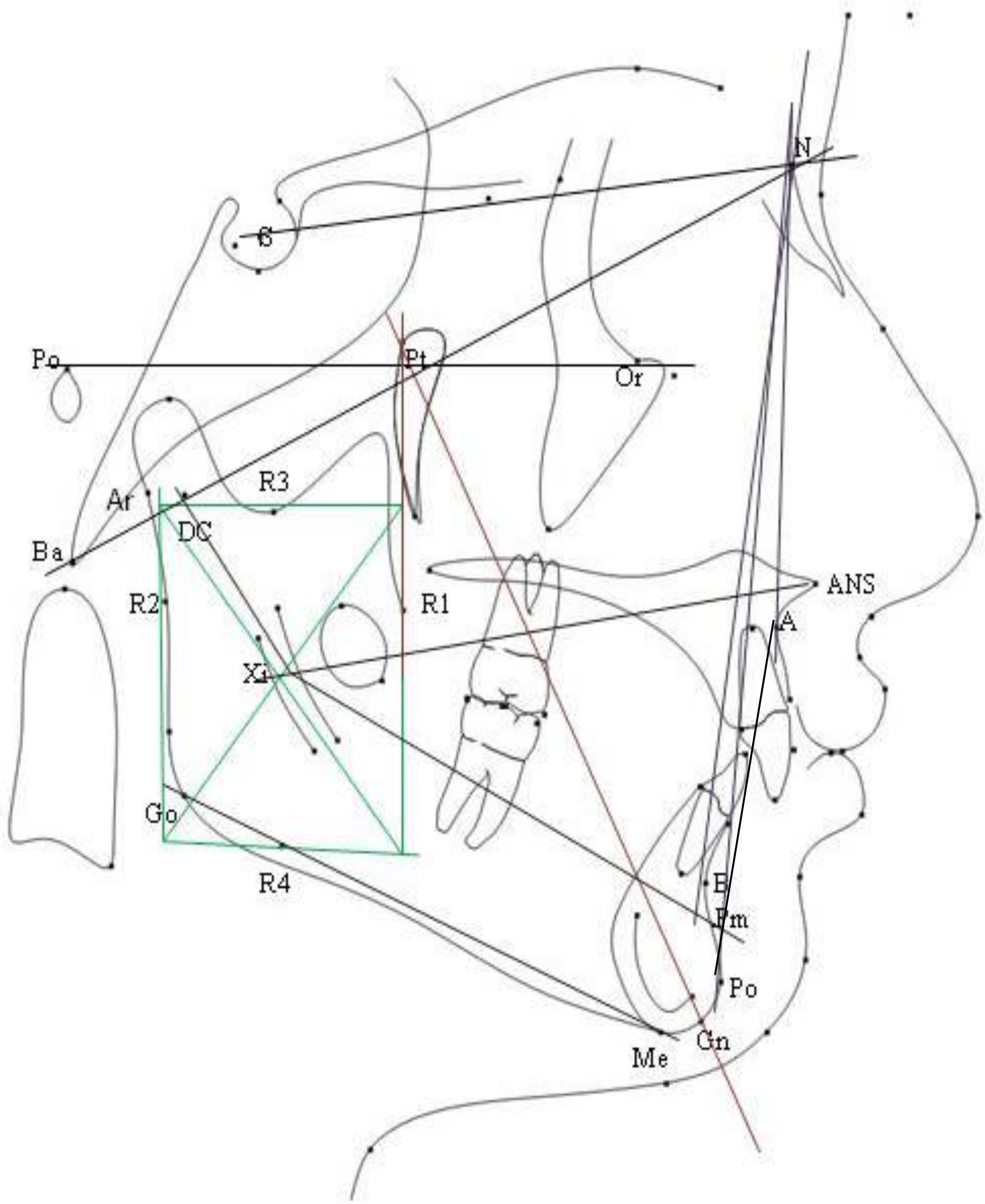

Figure 1 **Cephalometric landmarks and planes**

3.4 Measurement Error

Reproducibility of the primary investigator in tracing lateral cephalometric radiographs was evaluated by tracing 20 lateral cephalometric radiographs at two different time points. The measurements were compared using paired t-test. No significant differences were found between measurements at two different time points.

Cephalometric radiographs of the treated sample were uploaded and digitally traced using Dolphin Imaging version 11.5 (Chatsworth, CA, USA). They were all calibrated using ruler calibration.

In order to calibrate the images of the control group, each lateral cephalometric radiograph has four fiducial registration marks with unique camera file that records the coordinates of those four peripheral marks on each image, the values of the camera file coordinate for each study was supplied (Appendix M), this calibration method was described by Baumrind and Miller (1980).

In addition to intra-examiner reliability test, a Transfer Structure Method was performed using Dolphin Imaging software, where lateral cephalometric radiographs were superimposed for each subject between the studied two time points. This method ensured that all reference lines and planes had the same orientation in both T1 and T2, and minimized errors in landmark identification per subjects at two different time points.

A template was also developed for each group at both observation periods (Appendices; E-L), T1 and T2, using the Dolphin Imaging software average function. These templates were constructed to resemble the average tracing of each group. These templates were then superimposed on anterior cranial base and registered on Sella to evaluate growth changes within groups and between both groups at the two different time points. All the developed templates have 1:1 ratio, which enabled visualization of the actual growth changes in both groups, and helped us to interpret the statistical findings.

3.5 Statistical Analyses

A Shapiro-Wilk test was carried out to confirm the normal distribution of measurements in both groups. Independent Samples t-Test was performed to compare the two groups at initial and final observations. Paired t-test was performed to compare the changes within each group at the different time points. Finally, the changes in each measurement between T2 and T1 were calculated for each group and compared using Independent Samples t-test, since most of those changes were not normally distributed.

3. RESULTS

4.1 Descriptive Statistics

Descriptive statistics for the untreated control group and the treated group at T1 (Initial observation) and T2 (final observation) are reported in Appendices A and B, respectively.

4.2. Normality Tests

Shapiro-Wilk test was performed on the measurements evaluated. All measurements in both groups were normally distributed except for ANB angle, Facial Angle (FA), Facial Convexity (NA-Apo), Frankfort Mandibular Plane Angle (FMA), the distance between maxillary first molar and Pt Vertical (U6-PtV), and the Overjet.

Shapiro-Wilk test was also done on the mean differences in the cephalometric measurements between initial observation (T1) and final observation (T2) between both groups. The resultant measurements were normally distributed except for age and facial angle axis (FAx).

Non-parametric tests were also done to evaluate the changes in the aforementioned measurements; the results were similar to the results shown in the parametric tests. Therefore, it was agreed to use parametric tests on all variables.

4.3 Intergroup Comparisons

4.3.1 Comparison at T1

Table I shows the independent samples t-test between the treated group and the control group at initial observation (T1). The mean age of the control group was 20 months younger than the treated group ($p < 0.05$). The Facial Axis Angle (FAx) was also significantly greater in the control group ($p<0.05$). There was no statistically significant difference in any of the other skeletal measurements at T1.

As for the dental measurements, the upper incisor to APog plane was significantly less in control group by 2.34 mm ($p<0.05$). Lower incisor to APog plane was also significantly less in control group by almost 2 mm ($p<0.05$).The lower incisor to NB plane was significantly less by 2.6 mm in control group ($p<0.05$). Lower incisor angulation to NB plane is significantly greater in treated group by 5.7 degrees ($p<0.05$).The inter-incisal angulation was significantly greater in the control group ($p<0.05$).

TABLE I

STATISTICAL COMPARISON (INDEPENDENT SAMPLES T-TEST) BETWEEN CLASS II TREATED GROUP AND CLASS II CONTROL GROUP AT T1.

Cephalometric Measurements	Control, n=18		Treated, n= 17		Difference (Cx-Tx)	P-value
	Mean	SD	Mean	SD		
Age	93.33	6.74	113.59	22.91	-20.25	0.00*
Cranial Base						
FH - SN^{O}	9.03	2.09	9.47	2.50	-0.44	0.57
Anteroposterior						
SNA^{O}	81.48	2.96	83.06	3 .27	-1.58	0.14
SNB^{O}	74.98	2.83	75.94	3.27	-0.96	0.36
ANB^{O}	6.48	1.79	7.12	2.24	-0.64	0.36
FA^{O}	84.77	2.05	85.59	3.00	-0.82	0.35
NA-APo^{O}	12.32	4.39	14.78	4.99	2.46	0.13
Vertical						
FAx^{O}	89.7	2.13	87.15	2.79	2.52	0.01*
MP - SN^{O}	35.65	3.70	36.99	3.54	-1.34	0.28
FMA^{O}	26.62	2.31	27.36	3.21	-0.74	0.44
OP-SN^{O}	18.51	3.79	19.82	3.83	-1.31	0.32
LFH^{O}	44.11	3.01	45.44	1.96	-1.32	0.14
Mandibular						
MA^{O}	31.51	3.75	30.54	4.46	0.97	0.49
Co-Gn (mm)	103.47	5.35	105.21	6.10	-1.75	0.37
Dental						
U6-PtV (mm)	13.77	11.60	14.01	3.70	-0.25	0.57
Overjet (mm)	6.66	1.70	6.46	2.98	0.19	0.91
Overbite (mm)	1.15	-2.50	2.23	2.41	-1.08	0.16
U1-NA (mm)	2.40	2.27	3.47	1.86	-1.07	0.14
U1-APog (mm)	6.62	2.23	8.96	2.39	-2.34	0.01*
L1-NB (mm)	4.25	2.59	6.82	1.93	-2.57	0.00*
L1-APog (mm)	-0.06	3.01	2.11	1.87	-2.17	0.02*
U1-L1^{O}	131.66	10.4	124.60	7.66	7.06	0.03*
U1-NA^{O}	20.17	6.08	20.88	6.85	-0.72	0.75
L1-NB^{O}	21.69	7.71	27.41	4.65	-5.71	0.00*

4.3.2 <u>Comparison at T2</u>

Table II shows the Independent Samples t-test between the treated group and the control group after treatment (T2). Facial Axis Angle was significantly greater in the control group by 3.0 degrees ($p<0.05$). The Frankfort Mandibular plane angle in treated group was significantly greater by 2 degrees ($p<0.05$). None of the other skeletal measurements were statistically significant.

As for the dental measurements, lower incisor to APog plane was significantly greater in treated group by 1.9 degrees ($p<0.05$). None of the other dental measurements were statistically significant.

TABLE II

STATISTICAL COMPARISON (INDEPENDENT SAMPLES T-TEST) BETWEEN CLASS II TREATED GROUP AND CONTROL GROUP AT T2.

Cephalometric Measurements	Control, n=18		Treated, n= 17		Difference (Cx-Tx)	P-value
	Mean	SD	Mean	SD		
Age	137.67	6.06	139.88	21.58	-2.22	0.69
Cranial Base						
FH - SN^{O}	9.22	2.58	9.42	2.33	-0.20	0.81
Anteroposterior						
SNA^{O}	81.31	2.35	82.45	3.64	-1.15	0.27
SNB^{O}	75.82	2.35	76.76	3.23	-0.95	0.33
ANB^{O}	5.48	1.70	5.61	1.65	-0.13	0.82
FA^{O}	86.32	3.31	86.55	2.18	-0.22	0.82
NA-APo^{O}	9.23	4.29	11.49	4.05	2.26	0.12
Vertical						
FAx^{O}	91.03	3.04	88.01	2.56	3.03	0.00*
MP - SN^{O}	34.12	3.94	36.68	3.73	-2.56	0.06
FMA^{O}	24.91	3.78	27.25	2.97	-2.34	0.05*
OP-SN^{O}	16.81	3.67	18.51	4.65	-1.71	0.24
LFH^{O}	42.92	3.98	44.58	2.07	-1.65	0.14
Mandibular						
MA^{O}	34.23	4.29	32.16	4.41	2.07	0.17
Co-Gn (mm)	111.07	4.78	110.62	4.92	0.45	0.79
Dental						
U6-PtV (mm)	17.86	2.59	16.36	3.86	1.50	0.29
Overjet (mm)	7.35	2.54	5.74	1.74	1.61	0.06
Overbite (mm)	3.12	2.23	2.51	1.49	0.62	0.35
U1-NA (mm)	3.47	1.86	3.82	1.89	0.67	0.39
U1-APog (mm)	8.96	2.39	8.16	2.01	-0.28	0.71
L1-NB (mm)	6.82	1.93	6.30	2.44	-1.42	0.09
L1-APog (mm)	0.45	3.09	2.38	2.34	-1.93	0.05*
U1-L1^{O}	127.63	10.26	124.61	9.15	3.03	0.37
U1-NA^{O}	23.30	6.37	23.22	7.21	0.08	0.97
L1-NB^{O}	23.61	6.48	26.55	6.13	-2.94	0.18

4.3.3 Comparison of Measurements Changes per Group

Paired Samples t-test was used to evaluate the changes in cephalometric measurements in the control untreated group during the observation period.

As reported in Table III, there was a significant increase in SNB angle, Facial angle (FA), facial axis (FAx), mandibular arc (MA), and mandibular length (Co-Gn), ($p<0.05$). There was a significant decrease in ANB angle of 1.0 degrees group within the observation period and a significant decrease in convexity angle (NA-APo), ($p<0.05$).there was also a significant decrease in occlusal plane to SN (OP-SN), Frankfort mandibular plane angle(FMA), and Mandibular plane to anterior cranial base ($p<0.05$).

Dentally, there was a significant increase in the following measurements: U6-PtV, Overjet, Overbite, U1-NA (mm), U1-APog, and L1-NB (degrees), ($p<0.05$).

Paired samples t-test was used to evaluate the changes in cephalometric measurements in the treated group during the observation period.

As shown in table IV, there was a significant increase in Facial angle (FA), and mandibular length (Co-Gn), ($p<0.05$). There was also a significant decrease in ANB angle, facial convexity (NA-APo) and Frankfort Mandibular plane angle (FMA), ($p<0.05$). Dentally, there was an increase in U6 to PtV by 1.7 mm ($p<0.05$). There is a significant decrease in Overjet by 0.99 mm ($p<0.05$) within the observation period.

TABLE III

CEPHALOMETRIC CHANGES IN CLASS II UNTREATED CONTROL GROUP OVER THE OBSERVATION PERIOD (PAIRED SAMPLES T-TEST)

Cephalometric Measurements	Initial Observation T1		Final Observation T2		Mean Difference	SD of Change	P-Value
	T1	SD	T2	SD			
Age	93.33	6.74	137.67	6.06	-44.33	7.68	0.00*
Cranial Base							
FH - SN^{O}	9.03	2.09	9.22	2.58	-0.19	2.59	0.75
Anteroposterior							
SNA^{O}	81.48	2.96	81.31	2.35	0.17	1.93	0.71
SNB^{O}	74.98	2.83	75.82	2.35	-0.84	1.47	0.03*
ANB^{O}	6.48	1.79	5.48	1.70	1.00	1.40	0.00*
FA^{O}	84.77	2.05	86.32	3.31	-1.55	2.73	0.00*
NA-APo^{O}	12.32	4.39	9.23	4.29	3.09	3.25	0.00*
Vertical							
FAx^{O}	89.7	2.13	91.03	3.04	- 1.3	1.95	0.01*
MP - SN^{O}	35.65	3.70	34.12	3.94	1.53	2.03	0.01*
FMA^{O}	26.62	2.31	24.91	3.78	1.71	2.57	0.00*
OP-SN^{O}	18.51	3.79	16.81	3.67	1.71	2.10	0.00*
LFH^{O}	44.11	3.01	42.92	3.98	1.19	2.19	0.03*
Mandibular							
MA^{O}	31.51	3.75	34.23	4.29	-2.72	3.62	0.01*
Co-Gn (mm)	103.47	5.35	111.07	4.78	-7.60	2.44	0.00*
Dental							
U6-PtV (mm)	13.77	11.60	17.86	2.59	-4.09	2.39	0.00*
Overjet (mm)	6.66	1.70	7.35	2.54	-0.69	1.71	0.00*
Overbite (mm)	1.15	-2.50	3.12	2.23	-1.97	2.17	0.00*
U1-NA (mm)	2.40	2.27	3.47	1.86	-2.08	2.35	0.00*
U1-APog (mm)	6.62	2.23	8.96	2.39	-1.26	1.68	0.01*
L1-NB (mm)	4.25	2.59	6.82	1.93	-0.63	1.33	0.06
L1-APog (mm)	-0.06	3.01	0.45	3.09	-0.51	1.6	1.97
U1-L1^{O}	131.66	10.04	127.63	10.26	4.03	7.77	0.04*
U1-NA^{O}	20.17	6.08	23.60	6.37	-3.13	6.88	0.07
L1-NB^{O}	21.69	7.71	23.60	6.48	-1.92	3.79	0.05*

TABLE IV

CEPHALOMETRIC CHANGES IN CLASS II TREATED SUBJECTS. (PAIRED SAMPLES T-TEST)

Cephalometric	Initial Observation T1		Second observation		Mean	SD of	P-
Measurements	T1	SD	T2	SD	Difference	Change	Value
Age	113.59	22.91	139.88	21.58	-26.29	7.22	0.00*
Cranial Base							
FH - SN^{O}	9.47	2.50	9.42	2.33	0.05	1.17	0.87
Anteroposterior							
SNA^{O}	83.06	3.27	82.45	3.64	0.61	2.47	0.33
SNB^{O}	75.94	3.27	76.76	3.23	-0.83	2.13	0.13
ANB^{O}	7.12	2.24	5.61	1.65	1.51	2.17	0.00*
FA^{O}	85.59	3.00	86.55	2.18	-0.96	2.37	0.00*
NA-APo^{O}	14.78	4.99	11.49	4.05	-3.29	5.04	0.00*
Vertical							
FAx^{O}	87.15	2.79	88.01	2.56	-0.86	2.45	0.16
MP - SN^{O}	36.99	3.54	36.68	3.73	0.32	1.79	0.48
FMA^{O}	27.36	3.21	27.25	2.97	0.11	2.28	0.00*
OP-SN^{O}	19.82	3.83	18.51	4.65	1.31	3.33	0.13
LFH^{O}	45.44	1.96	44.58	2.07	0.86	1.88	0.08
Mandibular							
MA^{O}	30.54	4.46	32.16	4.41	-1.62	3.52	0.08
Co-Gn (mm)	105.21	6.10	110.62	4.92	-5.41	5.08	0.00*
Dental							
U6-PtV (mm)	14.01	3.70	16.36	3.86	-1.71	3.61	0.00*
Overjet (mm)	6.46	2.98	5.74	1.74	0.99	2.24	0.00*
Overbite (mm)	2.23	2.41	2.51	1.49	0.38	2.23	0.50
U1-NA (mm)	3.47	1.86	3.82	1.89	-0.35	2.61	0.59
U1-APog (mm)	8.96	2.39	8.16	2.01	0.80	2.20	0.15
L1-NB (mm)	6.82	1.93	6.30	2.44	0.52	1.62	0.20
L1-APog (mm)	2.11	1.87	2.38	2.34	-0.28	1.91	0.56
U1-L1^{O}	124.60	7.66	124.10	9.15	-0.01	11.8	0.10
U1-NA^{O}	20.88	6.85	23.22	7.21	-2.34	9.33	0.32
L1-NB^{O}	27.41	4.65	26.55	6.13	0.86	5.33	0.52

4.3.4 <u>Comparison in Measurement Changes</u>

Independent Samples t- test was used to compare the measurement changes between the two groups.

As reported in Table V, there was a significant difference in age between both groups in which the age range in control untreated group is significantly larger when compared with the treated group (19.6 months, $p<0.05$) . There was no statistical differences between both groups with respect to the skeletal cephalometric measurements, ($p<0.05$).

There was a significant change in the dental measurements; The U6 to PtV was significantly greater in the control group. Overjet and overbite significantly decreased in the treated group. The upper incisor distance to NA and APog planes was significantly less in treated group and the lower incisor distance to NB plane was also significantly less in the treated group ($p<0.05$). There was no statistical significance in the remaining dental angular measurements.

Change in the mandibular length per the observation periods was also evaluated; Shapiro-Wilk was performed and the variables were normally distributed. An independent samples t-test was used to evaluate the mandibular length change over the observation periods in each group. The results showed no statistical difference between the groups.

TABLE V

INDEPENDENT SAMPLES T-TEST ON CEPHALOMETRIC MEASUREMENT CHANGES BETWEEN CLASS II TREATED AND UNTREATED GROUP IN TWO DIFFERENT TIME POINTS.

Cephalometric Measurements	Control Group		Treated Group		Mean Difference	Independent T-Test
	Mean	SD	Mean	SD		
Age	-44.33	7.68	-26.29	7.22	18.04	0.00*
Cranial Base						
FH - SN^{O}	-0.19	2.59	0.05	1.19	0.22	0.74
Anteroposterior						
SNA^{O}	0.17	1.93	0.61	2.48	0.45	0.55
SNB^{O}	-0.84	1.47	-0.83	2.12	0.00	1.00
ANB^{O}	1.00	1.40	1.51	2.16	0.48	0.44
FA^{O}	-1.55	2.73	-0.96	2.37	0.61	0.49
NA-APo^{O}	3.09	3.25	3.29	5.03	0.16	0.91
Vertical						
FAx^{O}	-1.33	1.95	-0.82	2.44	-0.47	0.53
MP - SN^{O}	1.53	2.03	0.32	1.79	-1.19	0.08
FMA^{O}	1.71	2.57	0.11	2.23	-1.58	0.163
OP-SN^{O}	1.71	2.10	1.31	3.27	-0.43	0.65
LFH^{O}	1.19	2.19	0.86	1.82	-0.35	0.61
Mandibular						
MA^{O}	-2.72	3.62	-1.62	3.51	1.06	0.38
Co-Gn (mm)	-7.60	2.44	-5.41	5.07	2.19	0.12
Dental						
U6-PtV (mm)	-4.09	2.39	-1.71	3.61	2.38	0.00*
Overjet (mm)	-0.69	1.71	0.99	2.24	1.69	0.00*
Overbite (mm)	-1.97	2.17	0.38	2.23	2.35	0.00*
U1-NA (mm)	-2.08	2.35	-0.35	2.61	1.74	0.05*
U1-APog (mm)	-1.26	1.68	0.80	2.20	2.06	0.00*
L1-NB (mm)	- 0.63	1.33	0.52	1.62	1.15	0.03*
L1-APog (mm)	0.51	1.61	0.28	1.91	0.24	0.70
U1-L1^{O}	4.03	7.80	-0.01	11.85	-2.99	0.24
U1-NA^{O}	-3.13	6.90	-2.34	9.4	0.76	0.79
L1-NB^{O}	-1.92	3.79	0.86	5.38	2.80	0.08
GR	0.17	0.06	0.18	0.18	0.01	0.79

5. DISCUSSION

It has been suggested that spontaneous correction of Class II malocclusion occurs in patients who undergo maxillary expansion, most notably six months after expansion (McNamara, 2002). The reason for this spontaneous correction was attributed to mandibular release from maxillary constraints allowing it to grow to its full potential.

The effect of orthodontic treatment in general and maxillary expansion in particular on mandibular growth is one of the controversial issues in orthodontics. After a careful literature review few studies were found which investigated mandibular growth trends after expansion, none of which had a control group with which to compare the results.

5.1 Investigated Treatment Protocol

The investigated treatment protocol consisted of maxillary expansion using Quad-Helix appliance in addition to bite opening utility arches.

The Quad-Helix is a fixed, slow maxillary expander. In the treated sample, expansion was recommended to every patient with a maxillary width less than 52 mm, measured from buccal junction of the first molar crown and gingival margins. The expander was activated every 40 days and was stabilized for three months after achieving the desired expansion.

Maxillary and mandibular utility arches were used for the purpose of intruding the incisors during treatment. No Class II mechanics or inter-arch correctors were used in the treated sample.

5.2 Study Design and Limitations

The focus of this study is the skeletal relationship. Therefore, subject inclusion was based solely on skeletal characteristics of both groups. Whereas other studies relied on Angle's classification of malocclusion, there are few related studies that incorporated the malocclusion with the skeletal pattern.

This is the first known study that used skeletal patterns to evaluate the mandibular growth response to expansion. The study design is based on comparing the growth changes in the mandible seen in treated Class II skeletal subjects with an untreated group with a similar skeletal pattern within a specific observation period.

ANB angle was chosen at least to be 4.5 degrees based on a longitudinal study done by Walker and Kowalski (1971), in which they concluded that the mean value of ANB angle of normal Class I subjects was 4.0 degrees.

In order to eliminate subjects with an increased vertical growth tendency, Total Facial Height Angle was used. Subjects with a total facial height of more than 60 degrees were excluded from this study. These measurements were taken from the Ricketts Analysis and norms (Ricketts, 1960; Ricketts et al., 1972).

Although all subjects included in this study were growing individuals, there were large disparities in age in both treated and control group. Due to the limited sample size, the initial age of both groups was not matched. The control group was significantly younger than the untreated group. In the treated group, treatment did not start at a specific age but rather over an age range (9.5-11.7 years of age). This resulted in a significant difference in the mean age at initial observation between both groups, and the overall observation period. The control group, at the time of initial observation was significantly younger than the treated group with a mean difference of year and a half. This statistical difference may not play a major role on the study objectives since Class II skeletal pattern mostly predetermined at an early developmental stage and is maintained through development (Ngan et al., 1997; Baccetti et al., 1997; Stahl et al., 2008). The growth spurt period is considered to be in a range between 12 and 15 years old (Bishara et al., 1997). Hence, there might have been growth changes that were not measured in this study. This can be considered a limitation of the present study since both samples did not include the growth peak.

The control group consisted of 11 males and 7 females, whereas the treated sample consists of 8 males and 9 females. This could have also affected the results, since growth pattern and rate is different between genders (Bishara et al., 1997).

The control group was taken from different growth studies, which predominantly included Caucasians. The treated group was taken from a single private orthodontic office, where the main population was also Caucasian. Patients with African American ethnicity were excluded in both groups.

5.3 Study Findings

5.3.1 Growth in Untreated Subjects

Figure 2 shows the average of cephalometric tracing of the control group at T1 and T2, registered on Sella and superimposed at anterior cranial base, as produced by Dolphin imaging.

The untreated group in this study had a Class II skeletal pattern and retrusive mandible with a normal vertical relationship. Dentally, individuals had an increased overjet with normally angulated and positioned upper and lower incisors. The distance between Pterygoid Vertical to maxillary first molar was slightly increased from the norms.

After an average of three and a half years, a significant decrease in ANB angle (1.0 degrees) and Convexity angle was noticed, indicating an improvement of the maxillary and mandibular relationship in the sagittal plane. This decrease in ANB angle was also noticed in the Ngan et al sample (1997) of Class II individuals although this change was not statistically tested. According to their study there was no statistical difference in ANB angle during growth in Class II division 1 subjects when compared to subjects with Class I malocclusion.

In this studied sample, there was a significant increase in SNB angle and Facial Angle which indicates an improvement in mandibular position in relation to the cranial base.

Throughout the literature of Class II growth pattern, studies that compared the ANB angle change between subjects with Class II div 1 malocclusion and subjects with normal occlusion agreed on the following: there are different morphological variations in the dentofacial complex in Class II div 1 subjects (Fisk et al., 1953); the skeletal growth of Class II subjects is established early and maintained through puberty (Ngan et al, 1997); and both types of malocclusions have similar growth trends where ANB did not show any significant difference between both groups but they differed in the overall growth magnitude in which was described as an overall decrease in mandibular total length and mandibular ramus height in Class II div 1. This decrease was mostly seen at the pubertal growth spurt (Stahl et al. (2008), Ngan et al. (1997)). Bishara et al (1997) had a similar finding where a significant decrease in mandibular length was noticed but in the early dentition rather than during the growth spurt. They further stated that at a later stage of development the mandible caught up.

In the studied sample, there was also a significant decrease in the Frankfort Mandibular Plane angle, Mandibular plane to SN plane, Lower Facial Height angle, Occlusal plane to SN angle and Facial Axis, in which all indicated an improvement in the skeletal vertical relationship.

The mandibular arc and mandibular length changes indicated a significant growth of the mandible during the observation period. Mandibular arc, which measures the angle between the corpus and condylar axes, describes the condylar growth direction. The significant increase in the measured angle (2.7 degrees), indicated a forward and upward inclination of the condyle relative the mandibular body. Baccetti et al. (1997) showed that there is a more backward and downward inclination of the condyle relative to the mandibular body in Class II individuals when compared to individuals with Class I malocclusion leading to less decrement in gonial angle. In our study gonial angle was not measured. In regard to mandibular length, there was a significant increase in total mandibular length during the observation period. This favorable change may contribute to the improvement seen in antero-posterior maxillary-mandibular relationship. Ngan et al. (1997) showed that the main characteristics of Class II individuals is the decreased mandibular length and corpus length when compared to Class I individuals.

The maxillary position in relation to the anterior cranial base did not significantly change during the observation period, while the skeletal convexity decreased. This may indicate that the overall improvement in skeletal trend is due to the significant mandibular growth. This finding disagree with Baccetti et al.(1997), who found that the growth trend in Class II malocclusion shows significantly greater increments in maxillary protrusion. Ngan et al. (1997) showed a further decrease in maxillary protrusion in Class II subjects during the pubertal growth period.

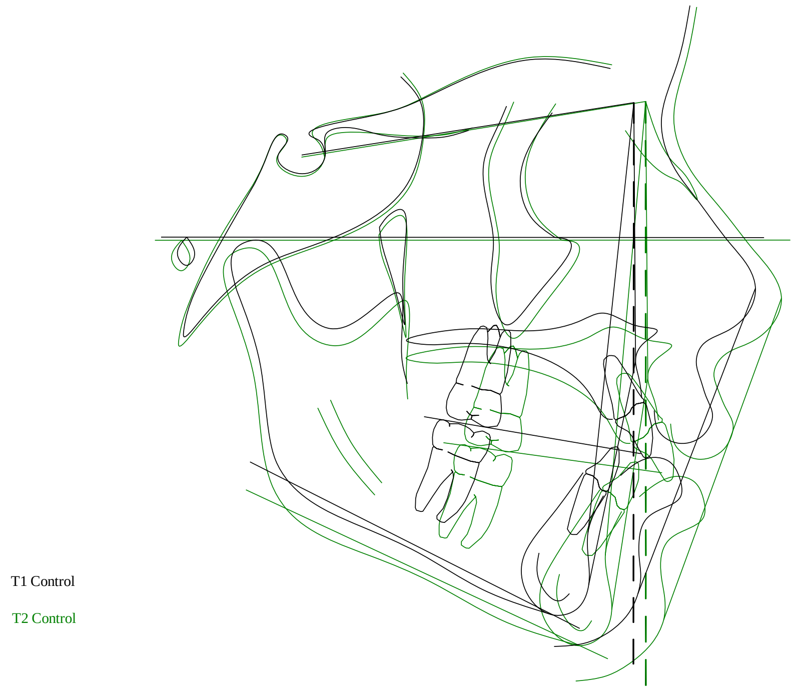

Figure 2. Average tracing of control group at T1 and T2, registered on Sella and superimposed on anterior cranial base.

5.3.2 **Growth in Treated Subjects**

Figure 3 shows the average of cephalometric tracing of the treated group during the observation period between T1 and T2, registered at Sella and superimposed on the anterior cranial base. Prior to treatment, the studied sample had a Class II skeletal pattern with retrusive mandible and normal skeletal vertical relationship but with more vertical component when compared to the control group (FAx). Dentally, subjects had an increased overjet with a protrusive upper incisor to APog plane, and lower incisors were protrusive in relation to NB plane.

The distance between Pterygoid Vertical to the distal of maxillary first molar was increased by one and a half millimeters when compared to the norms. This suggests that the maxillary first molar is positioned in a more forward position when compared to subjects with a normal malocclusion at the same age.

The results indicated an overall improvement in the Class II skeletal pattern after treatment (Figure 3). A statistically significant decrease in ANB angle (1.5 degress) and convexity angle was noticed along with a significant increase in Facial Angle which all indicated an improvement in the antero- posterior skeletal relationship. There was also a significant improvement in the vertical relationship reflected by a decrease in Frankfort Mandibular Plane angle. This decrement is so small, it has no clinical relevance. Additionally, mandibular length showed a significant increase within the observation period.

In agreement with the finding of this study, Farronato et al. (2011), found a significant decrease in ANB angle in subjects with Class II malocclusion after maxillary rapid expansion, the change in ANB angle in their sample was slightly greater (by 0.2 degrees) than the studied sample.

SNB angle did not change significantly during the observation period, while Farranato et al (2011) showed a significant increase in SNB angle in their Class II sample. Lima Filho et al. (2007) also found a significant increase in SNB angle after rapid maxillary expansion. However, a control group was not included in their study.

A statistically significant decrease in the Frankfort mandibular plane angle was noted during the observation period. The amount of this change is almost 0.1 degree, which can be considered as not a significant clinical finding. Lima Filho et al. (2007), found no statistically significant change in FMA. Our finding may indicate that the vertical dimension was maintained throughout the treatment and treatment protocol. In other words, maxillary expansion and incisor intrusion did not affect the vertical dimension and did not cause clockwise mandibular rotation.

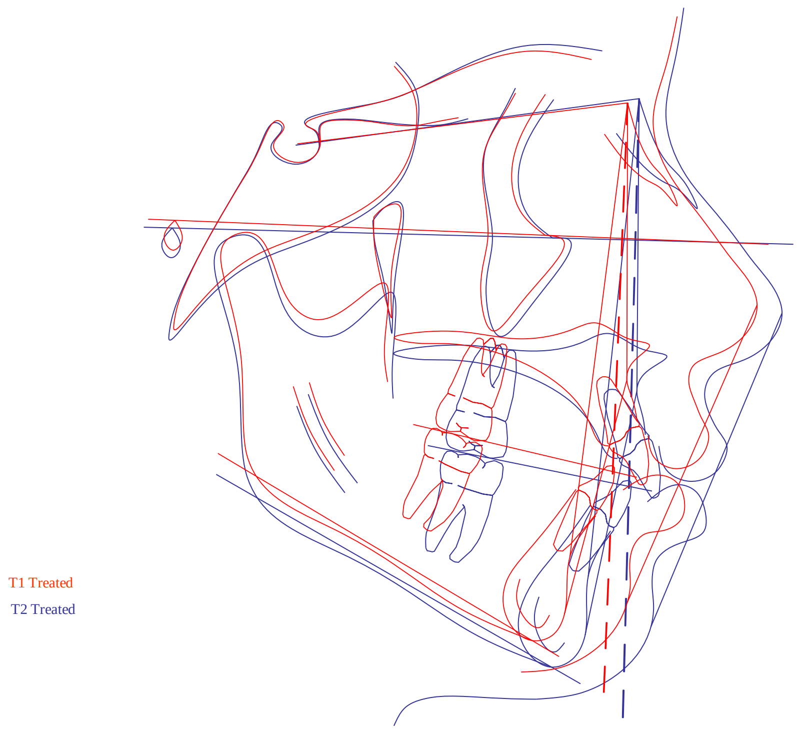

Figure 3 Average tracing of treated group at T1 and T2, registered on Sella and superimposed on anterior cranial base.

5.3.3 <u>Comparison between Both Samples</u>

Similarity at T1:

Both groups were statistically tested for similarity at initial observation. The statistical analysis showed that both groups were similar in skeletal characteristics except for Facial axis. Facial axis describes the facial height; in this sample the treated group had a significantly smaller facial axis indicating a more vertical growth pattern. A clockwise mandibular rotation is usually seen in individuals with vertical growth pattern. Thus, a vertical control should be considered in treatment planning to prevent molar extrusion and consequently clockwise mandibular rotation and worsening of Class II skeletal relationship. A superimposition of average tracings of each group demonstrates the similarity of the two groups at T1 (Figure 4).

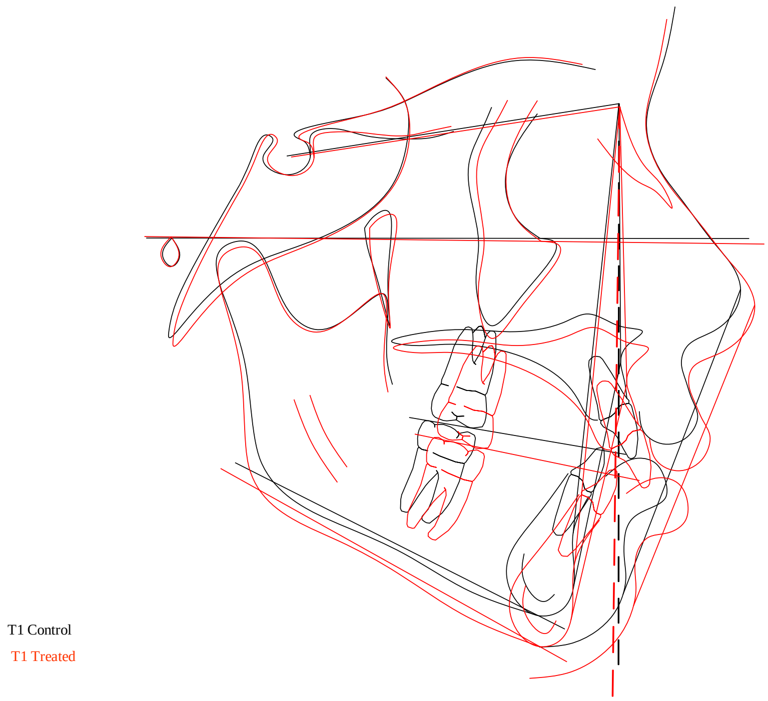

Figure 4 Average tracing of control and treated at T1, registered on Sella and superimposed on anterior cranial base.

Similarity at T2

Statistical analysis of both groups at final observation was also done. A significant decreased facial height (Fax) was still present in the treated group. Frankfort Mandibular Plane angle was significantly greater in the treated group; these two significant measurements may indicate an increased vertical growth pattern in the treated group when compared to the control group. Although the treated group had a more vertical component in their growth pattern, they had a significant improvement in anteroposterior dimension during the observation period similar to what was found in the untreated group. The direction of growth in the treated subjects had a more downward backward growth compared to the control group (Figure 5).

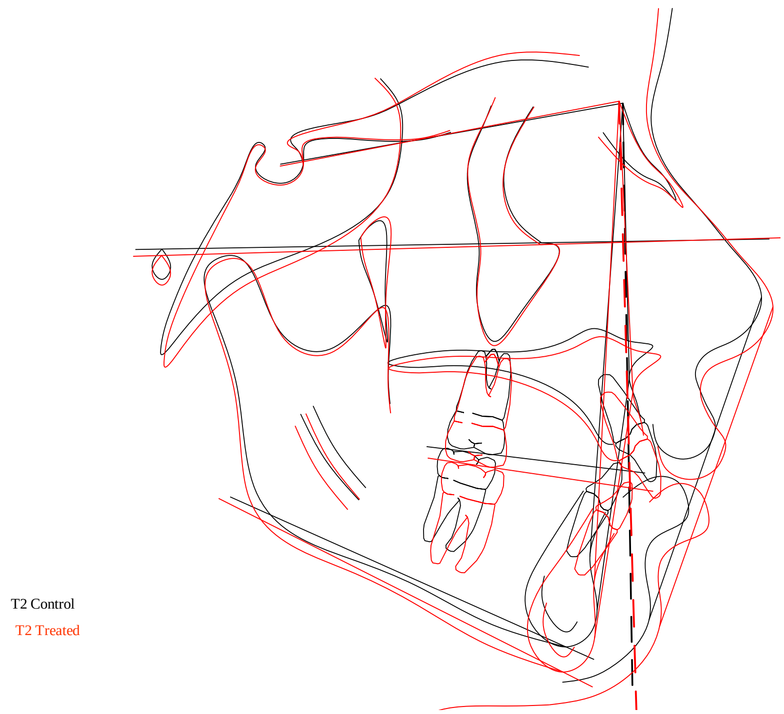

Figure 5 Average tracing of control and treated groups at T2, registered on Sella and superimposed on anterior cranial base.

5.3.4 Observed Changes in Both Groups:

There was no statistical difference in skeletal growth changes during the observation period between the two groups. However, the observation period in the untreated group was significantly longer by 18 months; the control group was younger by an average of 20 months at initial observation. This might indicate that the growth changes seen in the treated subjects were similar to those seen in the control group but occurred in a shorter period of time.

Since both groups had different observation periods, growth rate, rather than amount, had been used to evaluate if the difference in the observation periods would affect the resultant amount of change. The mandibular length was divided by the observation period. The results showed no statistical difference between the two groups, indicating similar changes in mandibular length over the same period of time.

In regards to skeletal vertical growth pattern, there was no statistical significance in the amount of change in facial height (FAx) and Frankfort Mandibular plane angle between both groups. This indicates that the growth direction did not change in the treated group and was maintained throughout the observation period.

5.4 Further Investigation

Further investigation had been carried out to evaluate the dental cephalometric measurements in both groups. In the control group the upper incisors initially were more protrusive when compared to their position in the treated group, and this protrusion gradually increased during the observation period, and since there was no change in the lower incisor position, the above dental changes caused a significant increase in overjet.

The maxillary first molar showed a significant mesial movement in relation to the PtV plane. This measurement was significantly increased at initial observation in this sample, which indicated a Class II malocclusion with a mesially positioned molar. The increase in this distance during growth may indicate that Class II malocclusion remained constant and it did not improve.

The significant increase in lower incisor angulation in relation to NB plane may be contributed to the forward movement of B point during growth.

While the distance between Pterygoid Vertical to distal of maxillary first molar was significantly increased in the treated subjects, the amount of mesial movement was not as much as seen in the control group. This change in the first molar position was then divided by the observation period of each group to evaluate the influence of time on the amount of mesial movement of upper first molar. The insignificant result may show us that the main reason for the lesser mesial molar movement was due to the shorter observation period the treated group had.

The upper incisors did not show any significant forward movement as did in the control group. Thus, overjet significantly decreased in the treated group, especially when viewed in light of the fact that the treated group started with a more protrusive upper incisor position at initial observation.

The treated subjects showed a significant decrease in overjet due to preventing further mesial movement of upper incisors. The absence of bite deepening was also noted during the observation time.

In conclusion, the treatment protocol had a significant favorable dental effect on the upper incisors position in relation to the denture plane, which contributed to the significant decrease in overjet and preventing further bite deepening during growth.

5.5 Clinical Implications:

The findings of the study suggest that utilizing maxillary expansion with utility arches did not affect mandibular growth and did not contribute to Class II skeletal correction when compared to the studied untreated group. However, treatment show favorable Class II dental correction by maintaining vertical control, reduction of overjet and overbite, and holding maxillary 1st molar mesial movement which naturally will get worse (as in the control group). Furthermore, the use of this treatment protocol may be justified in individuals with posterior crossbites and /or deep traumatic overbites or in order to facilitate other aspects of mechanotherapy

Interestingly, the treatment protocol did not negatively affect the vertical dimensions or produce clockwise rotation of the mandible which could be attributed to the young age at which treatment started.

5.6 **Recommendations**

The limitation of this study, as discussed earlier, warrants further research to confirm the findings. Based on the methodology used, the followings are recommendations for future research:

1- Larger sample size with preferably patient of the same gender.

2- Matching the groups based on skeletal development rather than chronological age. Cervical vertebral maturation method and/or hand and wrist films (Fishman, 1878) may be utilized.

3- Similar vertical growth pattern in both groups.

4- Including occlusal anaylsis utilizing study models

5- Analyzing growth over multiple timepoints including growth spurts.

6. CONCLUSIONS

Within the limitations of the study, both the control and treated groups showed a significant improvement in their antero-posterior skeletal relationship during the observation period, but this improvement was not sufficient to reach a Class I skeletal pattern.

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APPENDIX A

UNIVERSITY OF ILLINOIS
AT CHICAGO

Office for the Protection of Research Subjects (OPRS)
Office of the Vice Chancellor for Research (MC 672)
203 Administrative Office Building
1737 West Polk Street
Chicago, Illinois 60612-7227

Determination Notice
Research Activity Does Not Involve "Human Subjects"

February 28, 2011

Tamara Oweis, BDS
Orthodontics
801 S. Paulina Street, Room 131
M/C 841
Chicago
Phone: (312) 476-9347

RE: Research Protocol # 2010-1112
"Mandibular growth changes in Class II subjects treated with palatal expansion: A retrospective Cephalometric study"

Dear Tamara Oweis:

The above proposal was reviewed on February 26, 2011 by OPRS staff/members of IRB #3. From the information you have provided, the proposal does not appear to involve "human subjects" as defined in 45 CFR 46. 102(f).

The specific definition of human subject under 45 CFR 46.102(f) is:

> *Human subject* means a living individual about whom an investigator (whether professional or student) conducting research obtains
>
> (1) data through intervention or interaction with the individual, or
> (2) identifiable private information.
>
> *Intervention* includes both physical procedures by which data are gathered (for example, venipuncture) and manipulations of the subject or the subject's environment that are performed for research purposes. *Interaction* includes communication or interpersonal

contact between investigator and subject. *Private information* includes information about behavior that occurs in a context in which an individual can reasonably expect that no observation or recording is taking place, and information which has been provided for specific purposes by an individual and which the individual can reasonably expect will not be made public (for example, a medical record). Private information must be individually identifiable (i.e., the identity of the subject is or may readily be ascertained by the investigator or associated with the information) in order for obtaining the information to constitute research involving human subjects.

All the documents associated with this proposal will be kept on file in the OPRS and a copy of this letter is being provided to your Department Head for the department's research files.

If you have any questions or need further help, please contact the OPRS office at (312) 996-1711 or me at (312) 355-2908. Please send any correspondence about this protocol to OPRS at 203 AOB, M/C 672.

Sincerely,

Charles W. Hoehne, B.S., C.I.P.
IRB Coordinator, IRB # 3
Office for the Protection of Research Subjects

cc: Carlotta A. Evans, Orthodontics, M/C 841
Budi Kusnoto, Orthodontics, M/C 841

APPENDIX B

DESCRIPTIVE STATISTICS FOR CEPHALOMETRIC MEASUREMENTS IN CLASS II CONTROL GROUP

Cephalometric Measurements	Control Group n= 18							
	First Observation T1				Second Observation T2			
	Mean	SD	Max.	Min.	Mean	SD	Max.	Min.
Age	93.33	6.74	107.00	84.00	137.67	6.06	148.00	129.00
Cranial Base								
FH - SN^{O}	9.03	2.09	11.90	4.80	9.22	2.58	16.20	5.70
Anteroposterio								
SNA^{O}	81.48	2.96	86.60	77.30	81.31	2.35	84.60	76.30
SNB^{O}	74.98	2.83	80.20	71.10	75.82	2.35	79.70	71.90
ANB^{O}	6.48	1.79	9.90	4.50	5.48	1.70	10.10	3.60
FA^{O}	84.77	2.05	90.20	82.20	86.32	3.31	95.00	82.90
NA-APo^{O}	12.32	4.39	20.9	5.8	9.23	4.29	21.8	3.1
Vertical								
FAx^{O}	89.70	2.13	92.7	86.0	91.03	3.04	94.80	85.2
MP - SN^{O}	35.65	3.70	41.80	30.30	34.12	3.94	42.00	28.40
FMA^{O}	26.62	2.31	30.00	22.00	24.91	3.78	31.20	17.00
OP-SN^{O}	18.51	3.79	26.60	14.20	16.81	3.67	24.20	9.00
LFH^{O}	44.11	3.01	48.90	38.30	42.92	3.98	51.10	34.80
Mandibular								
MA^{O}	31.51	3.75	41.40	24.00	34.23	4.29	40.70	25.70
Co-Gn (mm)	103.47	5.35	114.50	96.90	111.07	4.78	120.80	104.10
Dental								
U6-PtV (mm)	13.77	1.76	22.20	11.60	17.86	2.59	19.00	13.50
Overjet (mm)	6.66	3.24	13.80	1.70	7.35	2.54	16.50	4.50
Overbite (mm)	1.15	2.04	7.70	-2.50	3.12	2.23	4.20	-0.50
U1-NA (mm)	2.40	2.27	5.00	-1.80	3.47	1.86	7.40	0.20
U1-APog (mm)	6.62	2.23	9.30	1.70	8.96	2.39	12.30	4.30
L1-NB (mm)	4.25	2.59	9.00	-2.10	6.82	1.93	10.20	2.80
L1-APog (mm)	-0.06	3.01	6.20	-8.30	0.45	3.08	5.40	-7.50
U1-L1^{O}	131.66	10.04	152.60	111.70	127.63	10.26	149.80	106.20
U1-NA^{O}	20.17	6.08	28.60	8.90	23.30	6.37	10.06	39.50
L1-NB^{O}	21.69	7.71	37.40	0.10	23.60	6.48	37.90	9.00

APPENDIX C

DESCRIPTIVE STATISTICS FOR CEPHALOMETRIC MEASUREMENTS IN CLASS II TREATED GROUP

Cephalometric Measurements	Treated Group n= 17							
	First Observation T1				Second Observation T2			
	Mean	SD	Max	Min	Mean	SD	Max.	Min.
Age	113.6	22.91	113.59	154.00	139.88	21.58	188.00	103.00
Cranial Base								
FH - SN^{O}	9.47	2.50	13.90	5.00	9.42	2.33	13.50	6.00
Anteroposterior								
SNA^{O}	83.06	3.27	89.60	78.20	82.45	3.64	89.20	76.90
SNB^{O}	75.94	3.27	82.20	75.94	76.76	3.23	82.30	72.00
ANB^{O}	7.12	2.24	11.00	4.50	5.61	1.65	8.90	2.30
FA^{O}	85.59	3.00	92.00	81.7	86.55	2.18	90.40	83.20
NA-APo^{O}	14.78	4.99	23.5	5.7	11.49	4.05	19.00	3.4
Vertical								
FAx^{O}	87.15	2.79	92.10	82.20	88.01	2.56	91.80	82.40
MP - SN^{O}	36.99	3.54	42.30	29.80	36.68	3.73	42.70	28.80
FMA^{O}	27.36	3.21	33.00	17.60	27.25	2.97	31.90	20.90
OP-SN^{O}	19.82	3.83	26.90	10.80	18.51	4.65	26.40	9.80
LFH^{O}	45.44	1.96	49.20	42.3	44.58	2.07	48.50	41.90
Mandibular								
MA^{O}	30.54	4.46	41.00	22.3	32.16	4.41	40.50	25.00
Co-Gn (mm)	105.21	6.10	116.90	97.00	110.62	4.92	121.30	101.90
Dental								
U6-PtV (mm)	14.01	7.80	3.70	20.60	16.36	3.86	22.60	7.50
Overjet (mm)	6.46	2.90	2.98	12.50	5.74	1.74	8.70	3.30
Overbite (mm)	2.23	-1.10	2.41	5.90	2.51	1.49	6.50	0.40
U1-NA (mm)	3.47	1.86	7.40	0.20	3.82	6.20	-1.00	1.89
U1-APog (mm)	8.96	2.39	12.30	4.30	8.16	11.30	4.30	2.01
L1-NB (mm)	6.82	1.93	10.20	2.80	6.30	10.10	1.60	2.44
L1-APog (mm)	2.11	1.87	7.10	- 0.80	2.38	2.34	7.00	-1.80
U1-L1^{O}	124.60	7.66	143.30	112.30	124.1	9.15	149.30	110.10
U1-NA^{O}	20.88	6.85	38.00	11.60	23.22	7.21	34.80	8.20
L1-NB^{O}	27.41	4.65	35.80	16.30	26.55	6.13	37.20	16.10

APPENDIX D

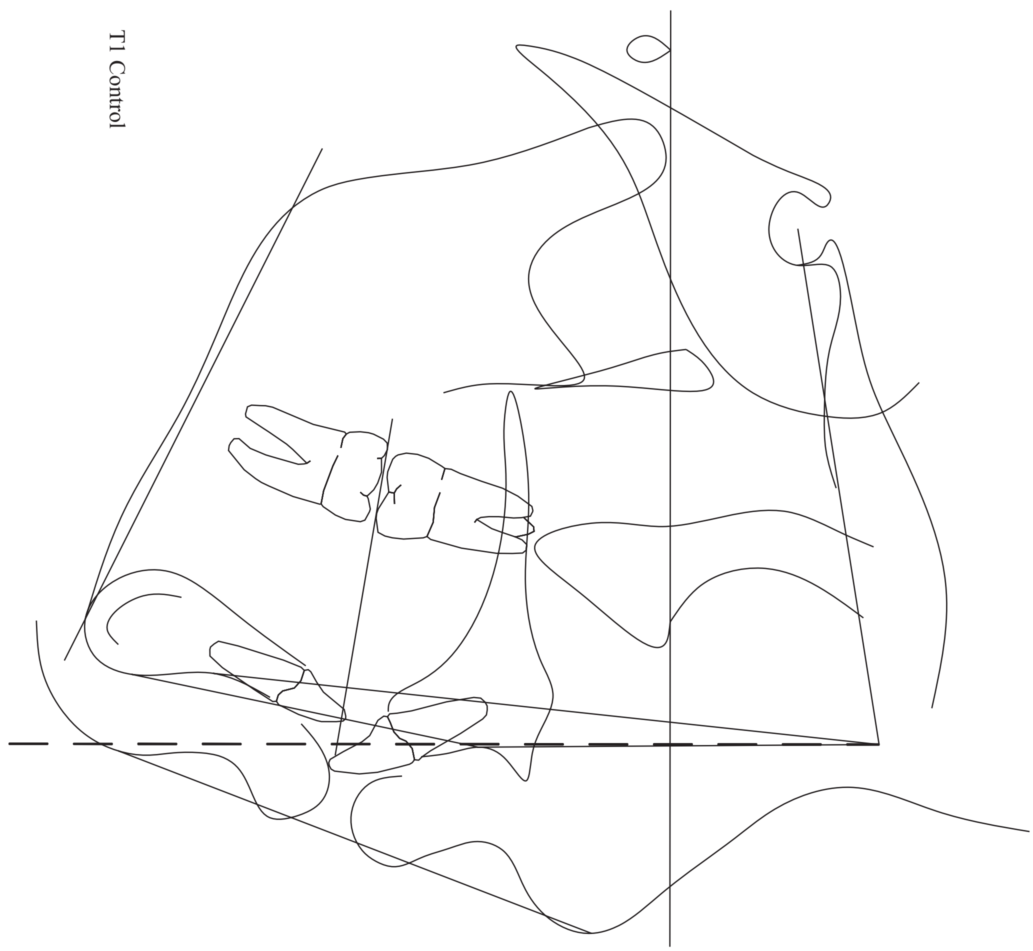
INDEPENDENT SAMPLE T-TEST (VARIABLE/OBSERVATION PERIOD)

Cephalometric Measurements	Group I, n=18		Group II, n= 17		Difference (Cx-Tx)	P-value
	Mean	SD	Mean	SD		
Observation period	44.33	7.68	26.29	7.22	18.04	0.00*
PtV	4.09	2.39	1.71	3.61	2.38	0.00*
Co-Gn	7.60	2.44	5.41	5.07	2.19	0.12
Variable/Observation period(OP)						
PtV/ OP	0.03	0.02	0.04	0.06	-0.01	0.67
Co-Gn/ OP	0.17	0.06	0.18	0.18	0.01	0.79

P<0.05

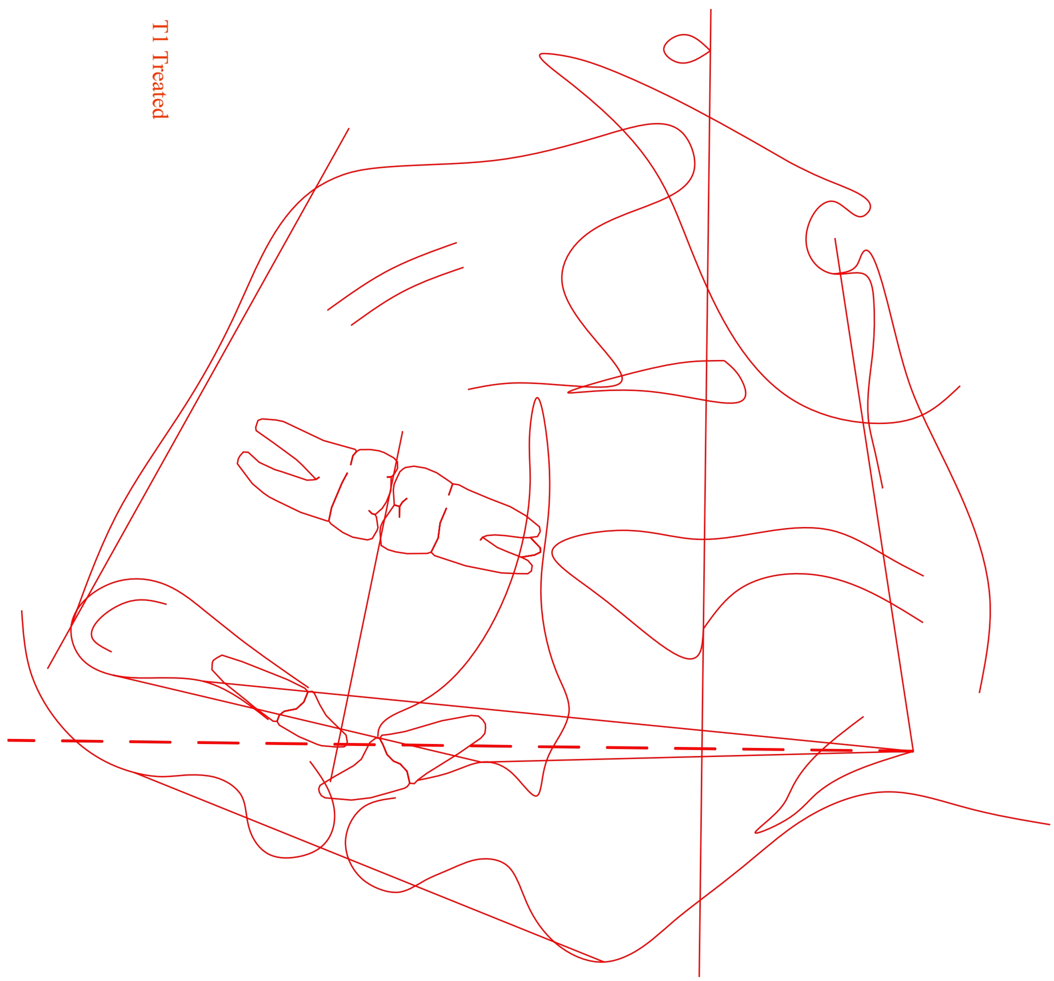
APPENDIX E

AN AVERAGE CEPHALOMETRIC TRACING OF THE CONTROL SAMPLE AT INITIAL OBSERVATION, T1.



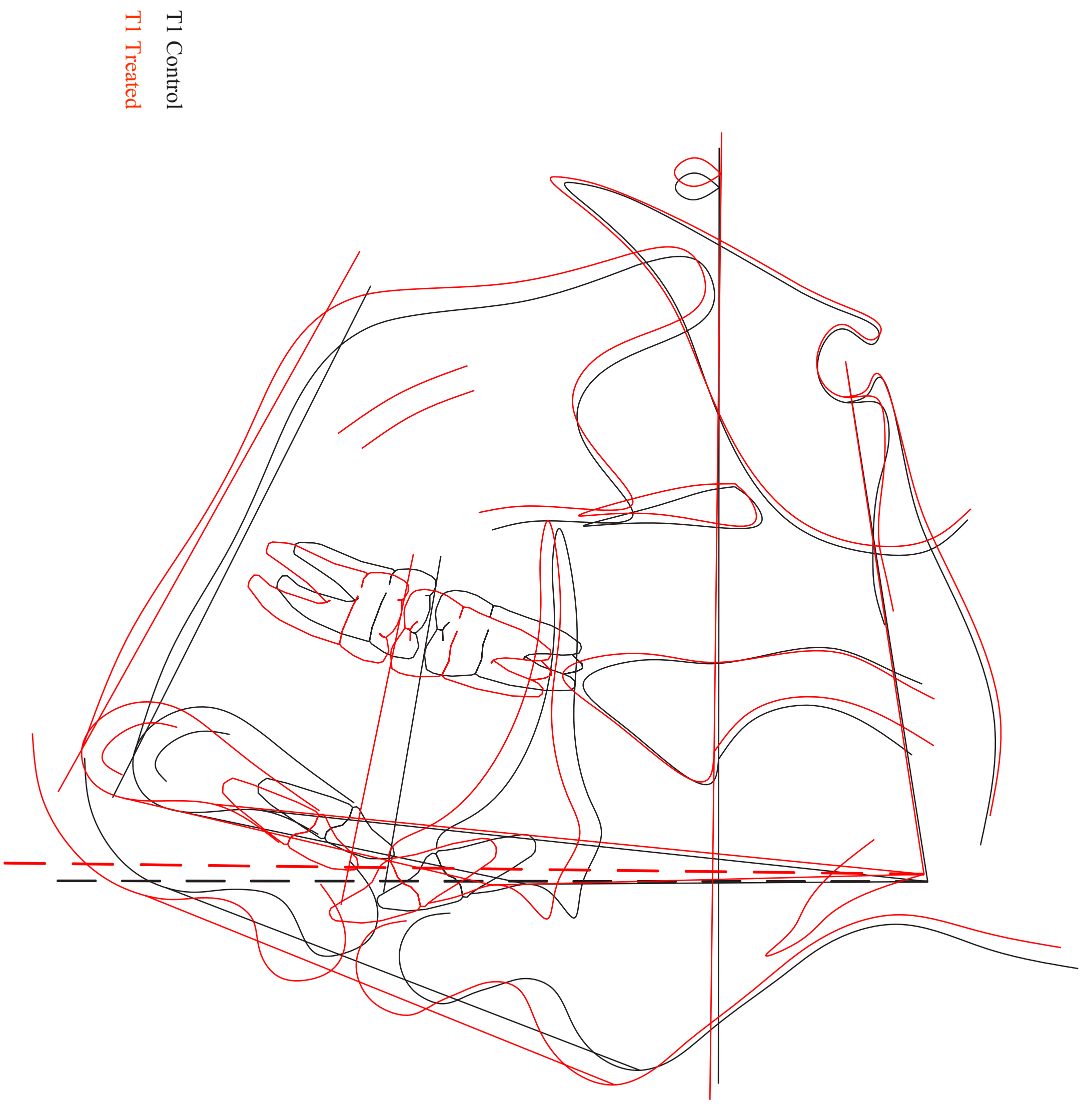
APPENDIX F

AN AVERAGE CEPHALOMETRIC TRACING OF THE TREATED SAMPLE
AT INITIAL OBSERVATION, T1.



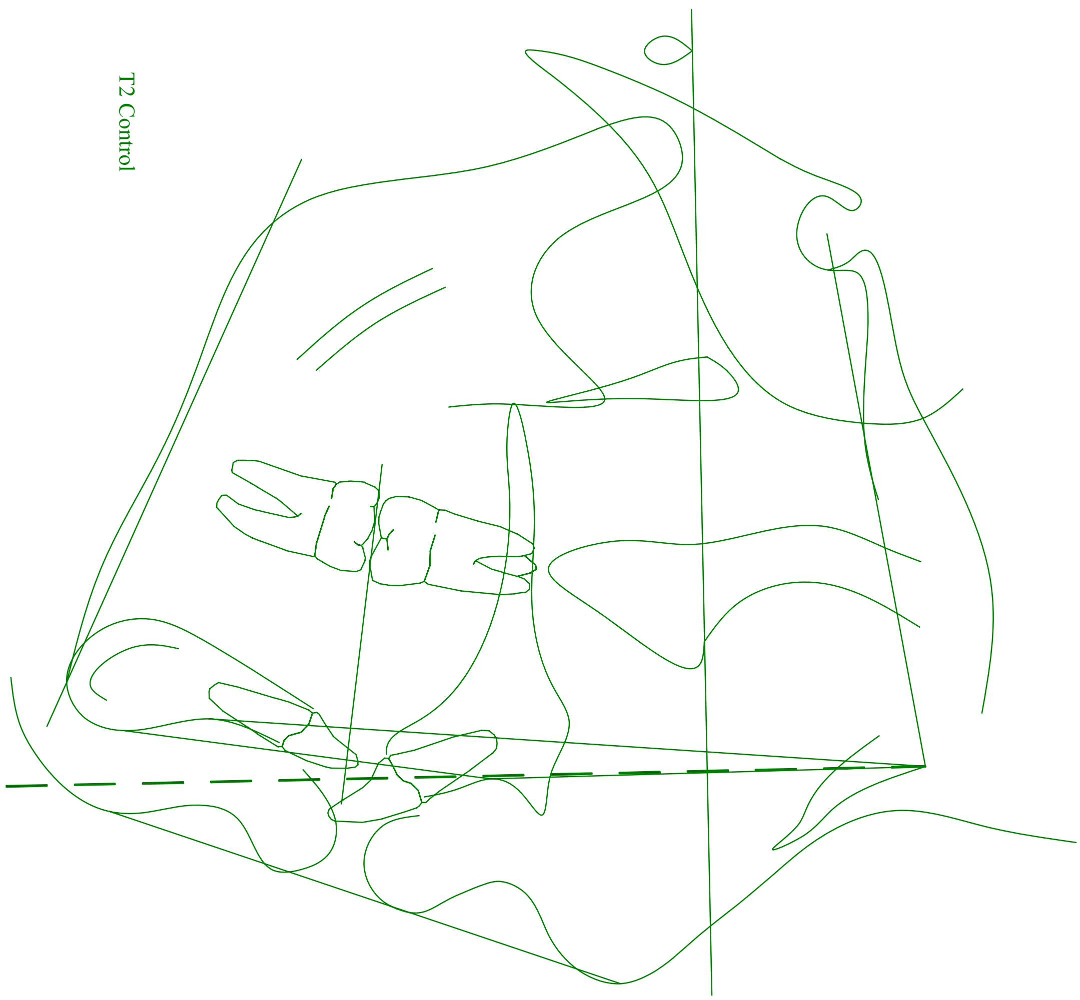
APPENDIX G

A SUPERIMPOSITION OF THE AVERAGE CEPHALOMETRIC TRACING OF THE TREATED AND CONTROL SAMPLES AT THE TWO STUDIED TIME POINTS, T1 AND T2, REGISTERED ON SELLA AND SUPERIMPOSED ON THE ANTERIOR CRANIAL BASE



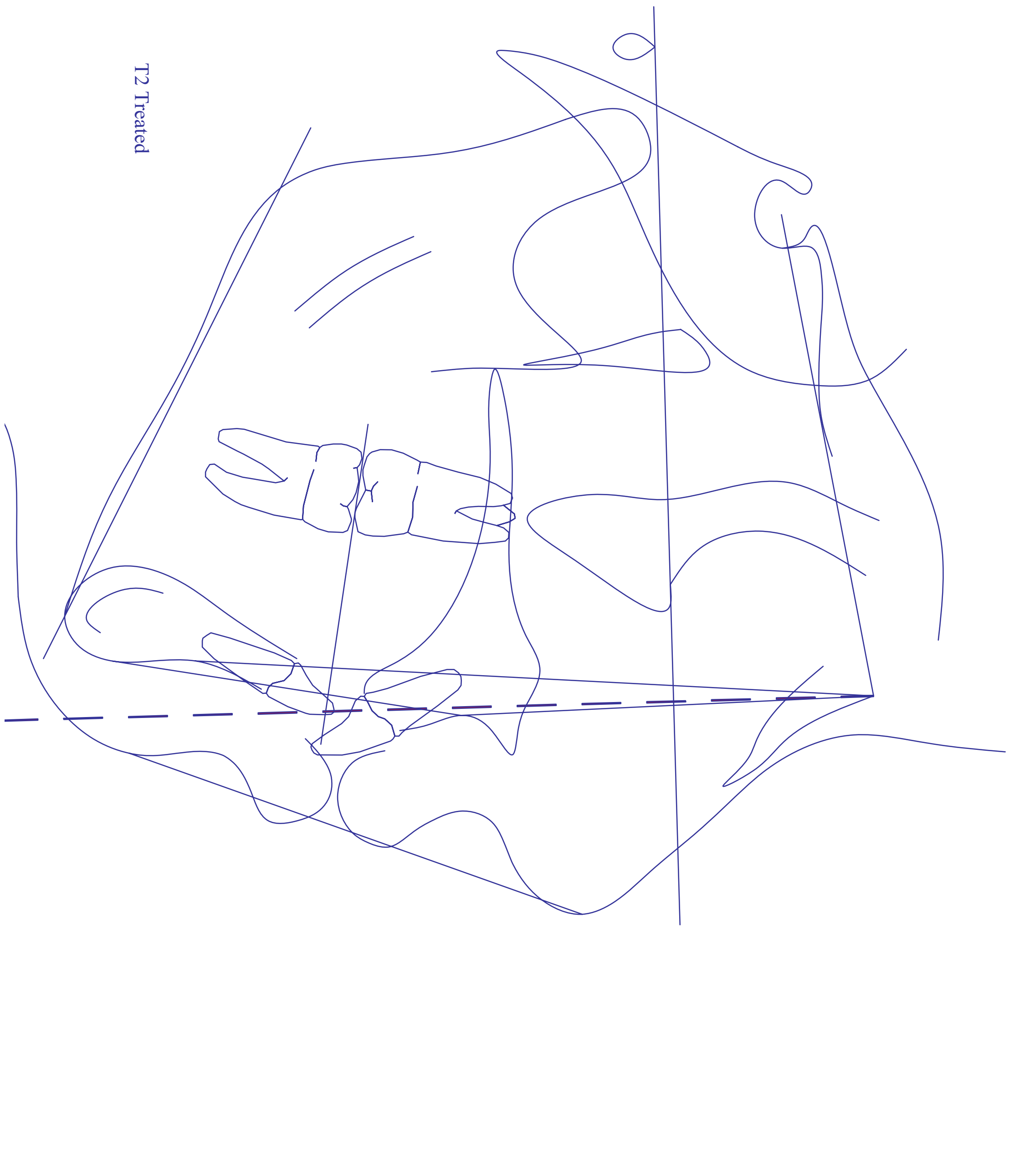
APPENDIX H

AN AVERAGE CEPHALOMETRIC TRACING OF THE CONTROL SAMPLE AT FINAL OBSERVATION, T2



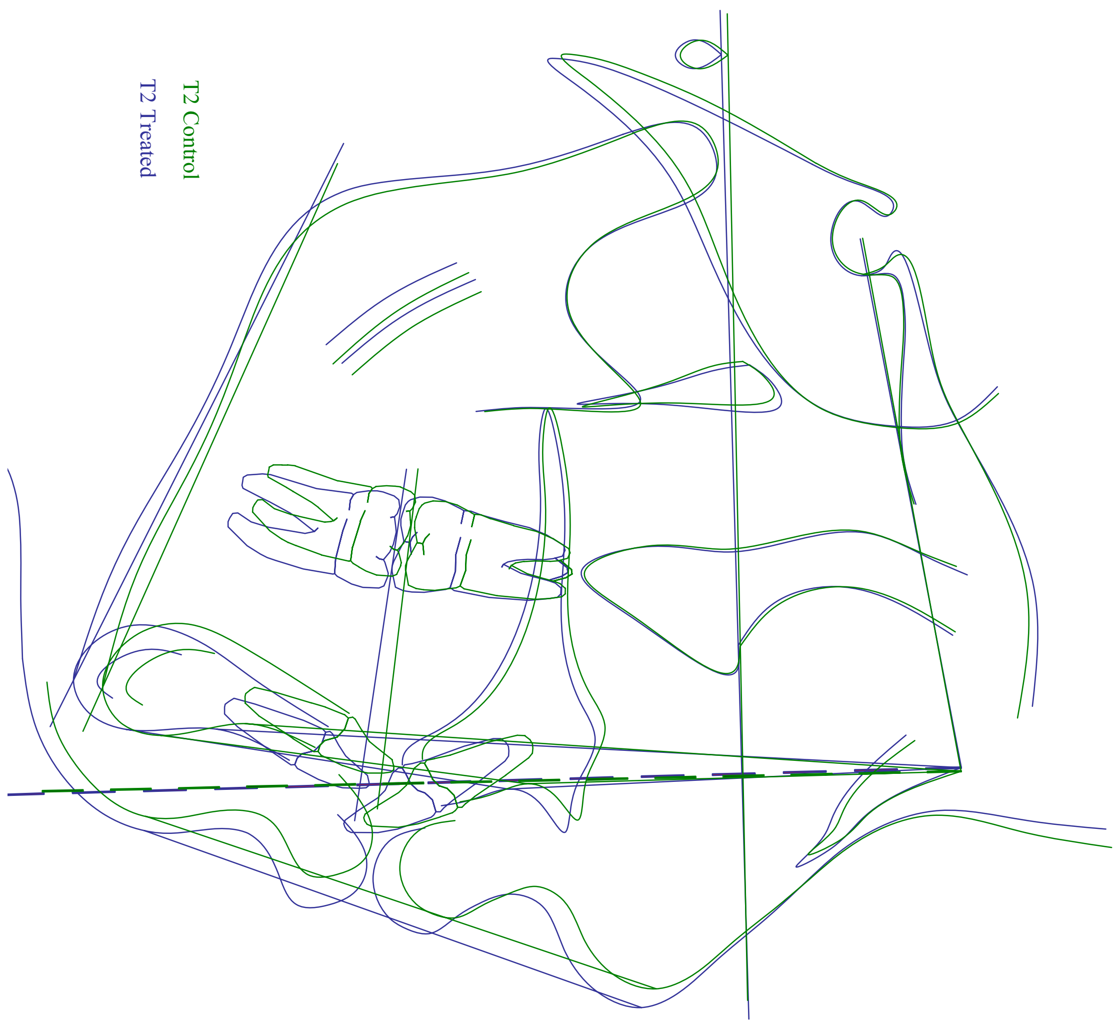
APPENDIX I

AN AVERAGE CEPHALOMETRIC TRACING OF THE TREATED SAMPLE AT FINAL OBSERVATION, T2



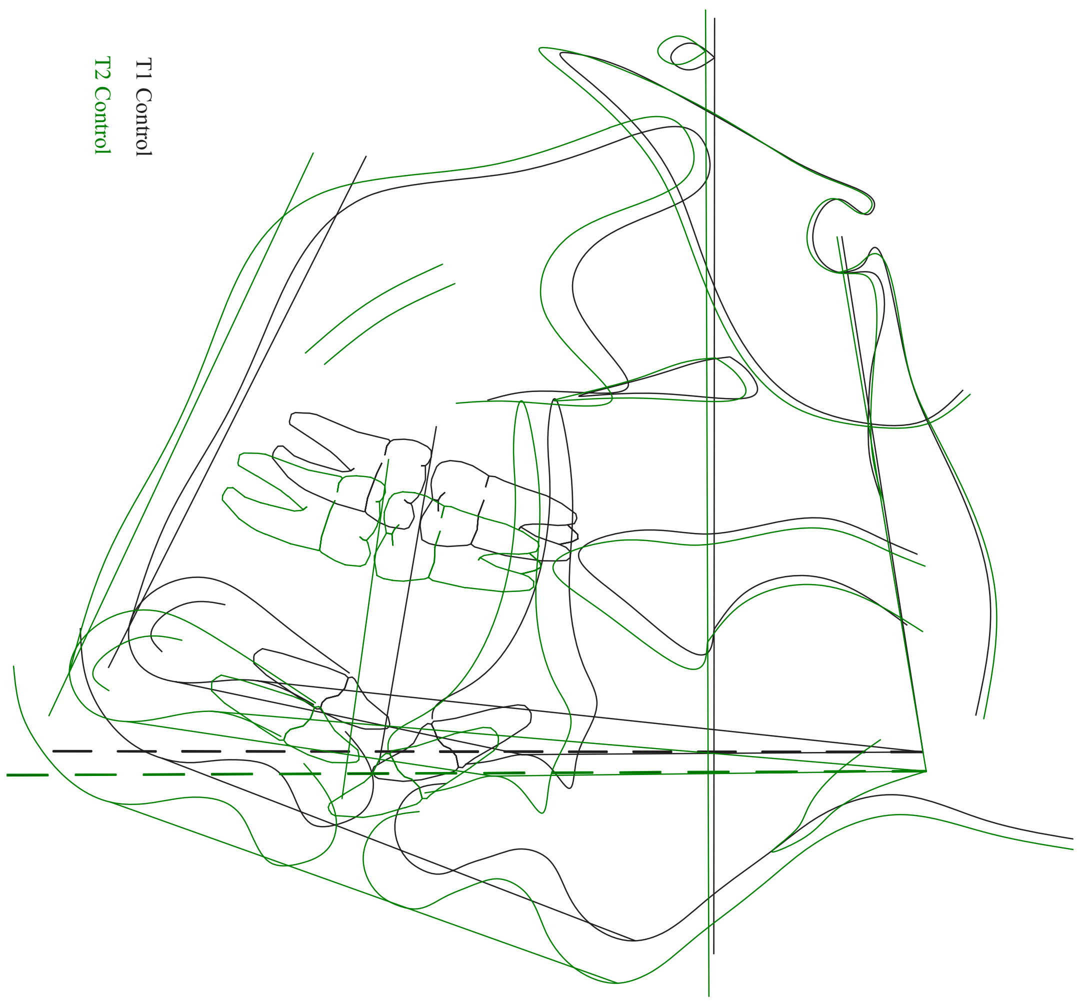
APPENDIX J

AN AVERAGE CEPHALOMETRIC TRACING OF THE CONTROL AND TREATED SAMPLES AT FINAL OBSERVATION, T2, REGISTERED ON SELLA AND SUPERIMPOSED ON THE ANTERIOR CRANIAL BASE.



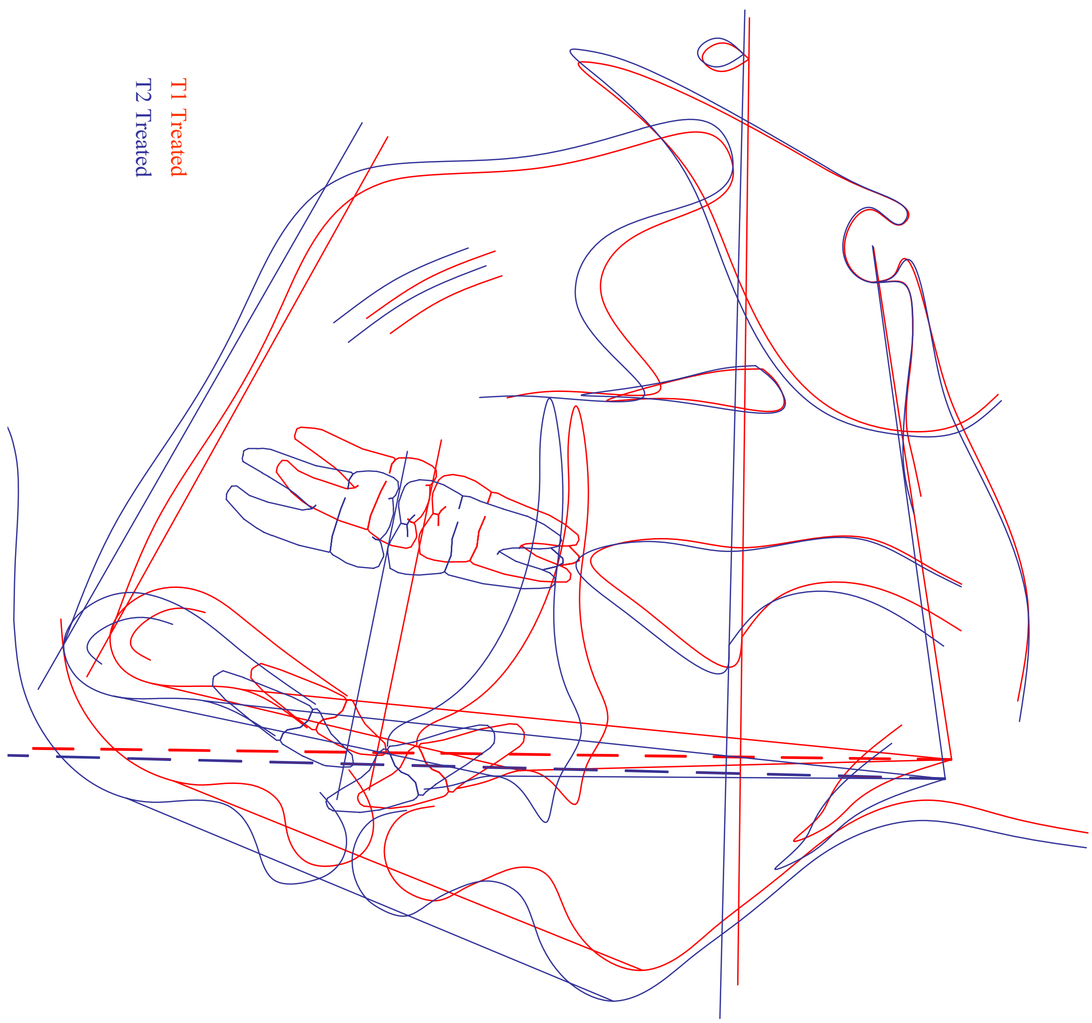
APPENDIX K

A SUPERIMPOSITION OF THE AVERAGE CEPHALOMETRIC TRACING OF THE CONTROL SAMPLE AT THE STUDIED TWO TIME POINTS , REGISTERED ON SELLA AND SUPERIMPOSED ON THE ANTERIOR CRANIAL BASE.



APPENDIX L

A SUPERIMPOSITION OF THE AVERAGE CEPHALOMETRIC TRACING OF THE TREATED SAMPLE AT THE STUDIED TWO TIME POINTS , REGISTERED ON SELLA AND SUPERIMPOSED ON THE ANTERIOR CRANIAL BASE.



APPENDIX M

AAOF CAMERA FILES WITH LINEAR VALUES OF FIDUCIARY LINES

Collection	Fiducials	X Coord	Y Coord
Bolton	801	6.106667	-158.69
	802	0	0
	803	177.4883	0
	804	183.8133	-151.147
Michigan	801	38.9	23.05
	802	38.4	175.75
	803	215.6	176.05
	804	215.4	16.25
Burlington	801	11.9	4.3
	802	11.1	279.6
	803	233.7	279.9
	804	234.9	4.5
Mathew	801	-0.36	-152.57
	802	0	0
	803	178.17	0
	804	177.74	-159.43
Oregon	801	-2.84	-132.82
	802	0	0
	803	265.98	0
	804	262.92	-139.89
Forsyth	801	0.3	-152.47
	802	0	0
	803	177.1	0
	804	176.94	-159.64
Denver	30mm ruler		
A: 801	Lower left fiducial		
B: 802	Upper Left fiducial		
C: 803	Upper Right fiducial		
D:804	Lower Right fiducial.		

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	Badran, D., Duaibis, R., Al-Ali, M., Oweis, T., Amin, W.: Health Status of the Clinical Dental Students in the Jordanian Universities. J. Clin. Med. Res. 1; 45-49:2009.