Long-Term Soft Tissue Profile and Incisor Angulation of Class I and II Cases Treated By Tandem Mechanics

BY

SALMA HOSSAMELDIN GHONEIM

B.D.S., King Abdulaziz University, Saudi Arabia, 2009

THESIS

Submitted as partial fulfillment of the requirements

for the degree of Master of Science in Oral Sciences

in the Graduate College of the

University of Illinois at Chicago, 2015

Chicago, Illinois

Defense Committee:

Maria Therese Galang-Boquiren, Chair and Adviser

Carlotta Evans

Marcio da Fonseca, Pediatric Dentistry

Maria Grace Costa Viana

This thesis is dedicated to my parents Lamya Shahin and Hossameldin Ghoneim to whom I am thankful for who I am today. I owe all what I learned in life to them, they taught me the basics of learning and success.

To my husband Omar Al-Tazi who I cannot thank enough for all what he sacrificed to make this project happen. He supported me through every step of this journey. Without his unconditional love and support, this research was not possible.

To my siblings, and my parents in law for their love and prayers.

To my dearest instructor Dr. Rabab Feteih who inspired me to become an orthodontist and guided me through my career.

ACKNOWLEDGEMENTS

I would like to thank my thesis committee, Dr. Maria Therese Galang-Boquiren, Dr. Carlotta Evans, Dr. Marcio Da Fonseca, and Ms. Grace Viana for their support and guidance throughout this project.

I would also like to extend my thanks to Dr. Andrew Haas for being very generous in providing me with the study sample and Dr. Peter Tsay for his thoughts and suggestions that had a great influence on this research.

In addition, I would like to thank Dr. Haas's assistants Irene Williams and Sandra Schweitzer for their help in the sample collection.

Special thanks to my research assistant Fatima Saeed for helping with scanning the x-rays and sorting the charts and the study models. I would also like to thank my friend Erin Dobbins who helped me with inter-examiner reliability testing and Saud Al-Hasawi for providing me with the Class II control radiographs.

SHG

TABLE OF CONTENTS

CHAPTER
Contents **PAGE**

TABLE OF CONTENTS (Continued)

LIST OF TABLES

TABLE **PAGE**

LIST OF FIRGURES

FIGURE **PAGE**

ABBREVIATIONS

A’	Soft Tissue A Point
ANS	Anterior Nasal Spine
B	Point B
B’	Soft Tissue B Point
F	Female
FMA	Frankfort Mandibular Plane Angle
FMIA	Frankfort Mandibular Incisor Angle
G’	Soft Tissue Glabella
Go	Gonion
IPR	Interproximal Reduction
IRB	Institutional Review Board
L 3-3	Lower Canine to Canine
L 4-4	Lower 1st Premolar to 1st Premolar
L 5-5	Lower 2nd Premolar to 2nd Premolar
L 6-6	Lower 1st Molar to 1st Molar
L1	Lower Incisor
L1 root	Lower incisor Root Tip
L1 tip	Lower Incisor Cusp Tip
Li	Labrale Inferius
Ls	Labrale Superious
M	Male
Me	Menton
n	Sample size
N	Nasion
N’	Soft Tissue Nasion
Or	Orbitale
Po	Porion
Pog	Pogonion
Pog’	Soft Tissue Pogonion
Pr	Pronasale
S	Sella
Sig	Significant difference
Sn	Subnasale
StI	Stomium inferius
StS	Stomion superius
TSALD	Tooth-size arch-length discrepancy
T1	Pretreatment time point

ABBREVIATIONS (Continued)

T2	Post-treatment time point
T3	Long-term follow up time point
U1	Upper incisor
U1 root	Upper incisor Root Tip
U1 tip	Upper Incisor Cusp Tip

SUMMARY

This is a retrospective study to evaluate initial, final and long-term follow-up lateral cephalograms and dental study models of 42 growing patients between the ages of 9-14. The objectives are to evaluate the soft tissue profile and incisor angulation changes of Class I and Class II growing children treated with nonextraction tandem mechanics and to compare the changes to age-matched and malocclusion-matched control groups. The soft tissue profile and incisor angulation measurements were recorded for each time point as well as molar classification and lower incisor crowding. The results showed that crowding was no longer evident at an average of 9 years post treatment in 80% of the cases with 12% of patients having only 1-2 mm of crowding. The soft tissue profile of the Class I Tandem-treated cases were similar to the untreated control group. A significant improvement in the soft tissue profile occurred in the Class II Tandem-treated cases. There was no statistically significant difference between upper and lower incisor angulation at the long-term follow up suggesting that the crowding was resolved without proclination of the incisors. Tandem Mechanics can be a valuable treatment alternative to extractions when crowding is a problem in a growing patient.

1. INTRODUCTION

1.1 Background

The soft tissue profile has been the focus of orthodontists for many years. In fact, facial esthetics has been considered one of the most important factors that orthodontists use to determine their method of treatment (Baumrind et al., 1996). Hence, in patients with full soft tissue profiles and proclined incisors, one would prefer extraction treatment over nonextraction to improve the soft tissue profile and avoid further proclination of incisors. Moreover, the interest in the soft tissue profile extends to patients and their parents. A study in 1997 concluded that lay people perceived a difference in the profiles produced by orthodontic treatment and that post treatment profiles were rated as more favorable when compared to the pretreatment profiles (Bishara and Jakobsen, 1997), suggesting that the awareness of facial attractiveness has been rising.

Lower incisor angulation has been given a lot of attention by orthodontists in the past years. Charles Tweed observed that the patients with the most pleasing profiles were those who had lower incisors at 90 degrees to the mandibular plane angle. He studied beautiful faces that never received orthodontic treatment and found that the lower incisors were upright on the basal bone and that the Frankfort mandibular incisor angle (FMIA) values were between 65 to 70 degrees. He developed the Tweed triangle to aid in diagnosis and treatment planning for better facial esthetics (Tweed, 1962). His purpose was to reach a favorable FMIA for each patient. Thus, extractions would be indicated even in cases with minimal crowding to avoid proclination of the lower incisors beyond the angle suggested by Tweed. On the other hand, in recent years, the extraction rate has declined significantly (O'Connor, 1993), with more orthodontists would try to treat without extractions whenever possible. (Luppanapornlarp and Johnston, 1993) stated that nonextraction treatment seems to be more desirable but there is no long-term literature to support that this treatment modality can provide a good alternative to extraction as a solution for the common problems of crowding and protrusion. Tandem Mechanics is a nonextraction treatment alternative performed on growing patients to improve their soft tissue profile and relieve lower incisor crowding by allowing them to drift distally into the deciduous molar spaces (leeway space). Thus, it provides relief of crowding and protrusion without the need for extractions (Haas, 2003). This treatment modality has shown exceptional long-term stability (Sadowsky et al., 1994; Azizi et al., 1999; Yavari et al., 2000) but the effect on the soft tissue profile has not been investigated.

1.2 Objectives

The objective of this study was to evaluate the long term soft tissue profile and upper and lower incisor angulation changes in growing patients treated with nonextraction Tandem Mechanics and to compare these results to age-matched and malocclusion-matched control groups.

1.3 Significance

Studies on Tandem Mechanics assessed its effectiveness in treating the malocclusion and its long term stability but none of them examined long-term profile changes. In other words, while dental and skeletal changes have been documented, changes in the soft tissue profile has not been investigated. There has been an increase in the esthetic demands in the orthodontic field. One of the major goals in orthodontics is to attain and preserve facial attractiveness. This study aimed to investigate the long-term effect of Tandem Mechanics on the soft tissue profile and to investigate whether the profile changes were maintained long-term. In addition, studies on Tandem Mechanics found no significant difference for upper and lower incisor angulation but that may be attributed to the small sample size (Yavari et al., 2000). Thus, this study was aimed to examine the effects of Tandem Mechanics on upper and lower incisor angulation post-treatment and years in retention.

1.4 Hypotheses

The null hypotheses are:

- No statistically significant mean difference exist between initial, final, and long-term soft tissue profile measurements and incisor angulation in Class I Tandem-treated group.
- No statistically significant mean difference exist between initial, final, and long-term soft tissue profile measurements and incisor angulation in Class II division 1 Tandem-treated group.
- No statistically significant mean difference exist between the soft tissue profile measurements and incisor angulation of the initial, final and long-term cephalometric values of the Class I group treated with tandem when compared to untreated age-matched and malocclusion-matched controls.
- No statistically significant mean difference exist between the incisor angulation and soft tissue profile measurements of the initial, final and long-term cephalometric values of the

Class II division 1 group treated with TM when compared to untreated age-matched and malocclusion-matched controls.

2. LITERATURE REVIEW

2.1 <u>The Long-term Effect of Orthodontic Treatment on the Soft Tissue Profile and Incisor Angulation</u>

The long-term changes associated with the soft tissue profile and incisor angulation as a result of various orthodontic treatments have been investigated by several studies. Some concluded that the soft tissue profile is similar between extraction and nonextraction treatments at the long-term follow up, although the extraction group experienced more soft tissue profile and lip change after treatment (Finnoy et al., 1987; Rossouw et al., 1999; Zierhut et al., 2000; Stephens et al., 2005; Erdinc et al., 2007). On the other hand, others showed significantly different soft tissue profiles between extraction and nonextraction groups at the long-term follow up, with the nonextraction group having a flatter profile than the extraction group (Luppanapornlarp and Johnston, 1993) or the nonextraction group having a fuller profile than the nonextraction group (Virkkula et al., 2009). Both groups showed similar post-treatment changes which included further flattening of the profile explained by the normal downward and forward growth of the nose and chin (Luppanapornlarp and Johnston, 1993). Virkkula et al. in 2009 found that the upper lip was more forward in the nonextraction group than in the extraction group when compared 8 years after treatment.

In a sample of Class II division 1 cases with similar pretreatment characteristics (except for more proclined lower incisors in the extraction sample), there was no statistically significant difference between the extraction and non-extraction profiles with an average of 14 years post-retention. The lip position at the post-retention period was flatter than the norms of Ricketts and Steiner but within the average of untreated adults. Furthermore, there was no difference in lower incisor angulation because the proclined incisors in the extraction group were uprighted at the end of treatment, and the non-extraction group did not have significant changes from initial to final and post-retention (Finnoy et al., 1987; Zierhut et al., 2000). In addition, the lower incisor angulation decreased an average of 5 degrees in both treatment groups 14.5 years after treatment. The upper incisors showed statistically significant differences between the two groups, with the extraction group having more upright upper incisors after treatment and the change was maintained in the post-retention follow-up (Paquette et al., 1992). Other studies reported that lower incisors proclined as a result of nonextraction cervical headgear treatment of Class II division 1 cases, and they did not tend to go back to their pretreatment values in a follow up period of 3-5 years as observed in the former studies. The angulation of upper incisors decreased as a result of headgear treatment, which was maintained in the post-retention follow-up (Glenn et al., 1987; Ciger et al., 2005).

2.2 Longitudinal Evaluation of the Soft Tissue Profile in Untreated Subjects

Longitudinal changes of the soft tissue profile in untreated individuals have been an interest to many researchers. In 1959, Subtelny published an article on longitudinal changes of the soft tissue profile in patients 3 months to 18 years of age with normal skeletal profiles. He found that the soft tissue convexity angle measured by soft tissue nasion - subnasale - soft tissue pogonion (N'-Sn-Pog') changed minimally from 6 months to 18 years of age when the nose was excluded from the profile. When the nose was included, the total soft tissue convexity angle measured by soft tissue nasion - tip of the nose - soft tissue pogonion (N'-Pr-Pog') was found to decrease markedly with age, which meant that facial convexity increased with age. The increase was approximately 10 degrees, which was attributed to the continued growth of the nose (Subtelny, 1959).

In 1985, Bishara et al. studied the soft tissue profile changes of untreated subjects with clinically acceptable occlusion. With results similar to Subtelny's, total facial convexity measured from soft tissue glabella (instead of soft tissue nasion) increased significantly from 5 years of age to adulthood. The angle of facial convexity (soft tissue glabella- subnasale- soft tissue pogonion) was found to increase significantly from 5 to 9 years of age, remain stable from 9 to 13 years of age and decrease from 13 to 25 years of age. The net change from 5 years of age to adulthood is very minimal suggesting that the final angle is relatively constant. They also evaluated the change in Merrifield's Z angle. In most of the cases, this angle increased with growth. On the other hand, Holdaway's soft tissue angle (nasion - B point: labrale superior - soft tissue pogonion) decreased with age. They also measured the upper and lower lips to Ricketts' esthetic plane and found that they both decreased with age and that their findings in the adulthood were very much like the numbers suggested by Ricketts (4mm behind the plane for the upper lip and 2 mm behind the plane for the lower lip) (Bishara et al., 1985). It was also found in another study that the upper and lower lips became significantly retruded with age in relation to the Ricketts esthetic plane and that should be taken into consideration when deciding to extract or not to extract in a growing patient (Bishara et al., 1998). The authors warned against treating growing patients to the adult norms.

The soft tissue profile of untreated Class II division 1 individuals hasn't been studied sufficiently due to the fact that most of these patients seek orthodontic treatment because of the unsatisfactory esthetics that accompany this type of malocclusion. There were a few articles that studied untreated Class II subjects longitudinally (Pollard and Mamandras, 1995; Bishara et al., 1997; Stahl et al., 2008; Baccetti et al., 2009) and only one of them studied the soft tissue profile of Class II division 1 cases and compared it to Class I cases at 3 different stages: the deciduous dentition stage, the mixed dentition stage, and the permanent dentition stage. The main conclusion was that growth trends were very similar for Class I and Class II division 1 cases except for having a more protrusive upper lip and a larger facial convexity in the Class II division 1 cases. The soft tissue facial convexity and the upper lip protrusion increased significantly with age in the Class II division 1 group in contrast to the Class I group where the soft tissue convexity decreased and the upper lip became more retruded with age (Bishara et al., 1997).

2.3 Long-term Stability and Lower Incisor Angulation

The lower incisor angulation has been a focus of attention after the Tweed philosophy was introduced to the Orthodontic field. The Tweed philosophy has made orthodontists conscious about the lower incisor angulation and its role in providing a harmonious profile. Tweed followers believe that placing the lower incisor at an angle between 85-95 degrees relative to the mandibular plane helps in long-term stability. On the other hand, it has been reported several times in the literature that extraction of teeth to provide arch length and avoid proclination of the lower incisors, does not insure long term stability. According to Robert Little: “two-thirds of the 1st premolar extraction patients had unsatisfactory lower anterior alignment 10 years post retention (Little et al., 1981). Furthermore in 1988, Little and his colleagues examined premolar extraction cases 10-20 years post retention and found that there was even more increase in crowding and that only a few cases had clinically acceptable incisor alignment (Little et al., 1988). In 2002, Little concluded that premolar extraction was stable in only one-third of the cases 10 years post retention and even less than that 20 years post retention and that they could not relate stability to any pretreatment variable. He found that the most stable cases were the ones treated in the mixed dentition phase where the leeway space was favorable (Little, 2002). Thus, these long-term studies propose that premolar extraction does not necessarily provide long-term stability because lower anterior crowding has been seen in extraction cases, non-extraction cases and untreated individuals (Shields et al., 1985; Little, 1999). These studies conclude that the most stable cases after a single incisor extraction were the ones treated in the mixed dentition stage by arch length management. Table I summarizes lower incisors’ stability following different treatment methods.

TABLE I

STABILITY OF VARIOUS ORTHODONTIC TREATMENTS BASED ON THE IRREGULARITY INDEX

Orthodontic Treatment	Average Post-retention Time	Irregularity index (Mean, SD) mm	Author, Year
Single incisor extraction cases	12 years 9 months	0.62 ± 0.30	Riedel, 1992
Tandem Mechanics	7 years 0 months	1.00 ± 1.00	Yavari et al., 2000
	8 years 2 months	1.70± 0.90	Azizi et al., 1999
	6 years 3 months	2.40 ± 1.69	Sadowsky et al.,1994
Mixed dentition arch length management	9 years 6 months	2.65 ± 2.09	Dugoni et al., 1995
Second premolar extraction cases	16 years 7 months	4.00 ± 1.70	McReynolds and Little, 1991
Serial extraction cases	11 years 3 months	4.39 ± 1.64	Little et al., 1990
First premolar extraction cases	12 years 7 months	4.63 ± 1.91	Little et al., 1981, 1988
Mixed dentition mandibular arch length increase	7 years 7 months	6.06 ± 2.79	Little et al., 1990

2.4 Treatment of Arch Length Discrepancy in the Mixed Dentition

Treatment of arch length discrepancy in the mixed dentition period has been proposed as a treatment option several times in the literature. Preservation of the Leeway space using a passive lingual arch has been the method widely used for this purpose (Eastwood, 1968; Singer, 1974; Wright and Kennedy, 1978; Odom, 1983). In 1961, a different method was proposed for treatment of arch length discrepancy in growing children. Miller used a system of full-time Class III mechanics against a headgear to the maxillary arch to gain adequate space for arch alignment. He believed that treating crowding at a young age by tipping the lower teeth back would help the canines and premolars erupt in a more distal position (Miller, 1961). Haas (1966) described a similar technique for treatment of borderline cases in the mixed dentition. He introduced the word Tandem to describe the simultaneous treatment of the upper and lower jaws (Haas, 1966). Moreover, Philip (1975) presented 4 cases with Class II malocclusion treated with the same mechanics. He suggested this technique as an alternative nonextraction option for borderline cases. Haas (1970) suggested utilizing growth to provide arch length in the mixed dentition stage after he studied the effect of Tandem Mechanics on tooth movement. He concluded that there was a general trend of distal tipping of lower first molars that helped in arch length discrepancy in Class I cases and in anchorage preparation in Class II cases (Haas, 1970).

2.5 Tandem Mechanics and its Long-term Stability

In 2003, Haas published an article about Tandem Mechanics as a treatment for all three dimensions. He believed that Tandem Mechanics offers a nonextraction treatment alternative to patients with crowding in the late mixed dentition. The word “Tandem” implies that both jaws are treated at the same time. The technique involves using a Kleohn-type cervical headgear to the maxillary arch and a mandibular wire with open coil springs supporting a sliding hook that is hooked to Class III elastics whenever the headgear is on. The mandibular arch is secured by steel sling ligature ties to the incisors. According to Haas, this maintains the molars in space and allows the incisors to grow forward with the growth of the jaws. It also utilizes the leeway space to relieve the anterior crowding, thus creating space anterior to the molars on both arches in the growing patient (Haas, 2003).

The long term stability of tandem treatment has been supported in the literature. A study in 1994 evaluated twenty two cases treated with tandem mechanics and found that the cases showed very good mandibular anterior alignment 5 years out of retention. The irregularity index for the maxillary arch had a value of 2 mm, and that of the mandibular arch had a value of 2.4 mm. Overjet and overbite were 5.9 mm and 4.5 mm before treatment with Tandem Mechanics and were improved to be 2.1 mm and 2.6 mm at the end of treatment, respectively. When evaluated 5 years out of retention they were found to be 2.7 and 3.1 mm indicating that very minimal relapse had occurred (Sadowsky et al., 1994). In 1999, another article was published on the long-term stability of tandem mechanics where fifty eight Class I cases were treated with tandem mechanics and were shown to be very stable 8.4 years out of retention. The irregularity index was found to be 1.7 mm at the long-term follow-up which was less than the minimally accepted standards published by Little (Azizi et al., 1999). Furthermore, Yavari et al. showed very similar results for thirty one Class II cases treated with Tandem Mechanics. The irregularity index was 1 mm after 6.4 years post-retention. This study concluded that the stability of Tandem-treated cases was more superior than what other techniques outlined in published literature, suggesting that current treatment philosophies and stability should be revisited (Yavari et al., 2000).

3. MATERIALS AND METHODS

3.1 Study Design

This retrospective study evaluated lateral cephalograms and dental study models of growing patients between the ages of 9-14 who were treated with Tandem Mechanics. Pretreatment, post-treatment and long-term results were examined and then compared to age-matched and malocclusion-matched untreated control groups to verify if the treatment results were due to the treatment provided or were a result of normal growth. The study design is presented in figure 2.

The pretreatment record (T1) was defined as the record taken within a year before orthodontic treatment started. The post-treatment record (T2) was defined as the record taken at the same day or a maximum of 3 months after the removal of the orthodontic appliances. The long-term follow up record (T3) was defined as the record taken at least 3.5 years post-treatment.

3.2 Sample Selection and Inclusion and Exclusion Criteria

The treated sample was taken from the private practice of Dr. Andrew Haas in Cuyahoga Falls in Ohio where the majority of patients were Caucasian. After the approval from the Institutional Review Board at the University of Illinois at Chicago was received, the staff of the private practice were instructed to locate tandem-treated Class I and Class

II division 1 cases that had pretreatment, post-treatment and at least three and a half years follow-up lateral cephalometric radiographs and study models available. The cases were de-identified and given serial numbers to protect the patients' identity and maintain confidentiality. The sample was further studied and the following inclusion criteria had to be met:

- Patients with Angle Class I or Angle Class II division 1 malocclusion with at least end on molar on both sides or a full step molar on one side.
- Female subjects had to be between 9-12 years old.
- Male subjects had to be between 11-13 years old.
- Patients had to be treated with non-extraction Tandem Mechanics.
- Availability of high quality pretreatment, post-treatment and long-term follow-up lateral cephalograms.
- Availability of pretreatment dental casts.
- Availability of follow-up cephalograms at least 3.5 years after treatment.

The following exclusion criteria were applied to the sample:

- Patients who had missing permanent teeth other than the third molars.
- Patients with craniofacial anomalies.
- Patients with hormonal disturbances that could potentially alter normal growth.
- Patients treated with extractions.
- Patients with missing or low quality records.
- Patients with obvious lip strain on the cephalometric radiographs.

- Patients treated with any Class II correctors other than the Kloehn cervical headgear used in Tandem Mechanics.
- Patients given Class II elastics anytime during treatment.
- Non-compliant patients.

The de-identified charts were examined and the following information was extracted from the charts: date of birth, treatment start date, debanding date, active tandem treatment time, headgear time, compliance with headgear wear, upper and lower retention appliances and time, and whether interproximal reduction (IPR) was performed. The compliance with headgear wear was rated by codes from zero to four depending on how many non-compliant notes were written in the chart. Zero having excellent cooperation with no notes about non-compliance and four having poor cooperation with four notes saying that the headgear is not being worn. IPR was given codes from zero to two according to the number of times IPR was done, zero meaning no IPR was done and two meaning it was done twice. Regarding the lower retention appliance, a lower fixed lingual retainer was banded in all cases. The extension of the retainer depended on which teeth were banded in the course of treatment. Four different designs were found and coded according to the following: 1 extended from lower canine to lower canine, 2 extended from lower 1^{st} premolar to lower first premolar, 3 extended from lower 2^{nd} premolar to lower 2^{nd} premolar and 4 extended from lower 1^{st} molar to lower 1^{st} molar .

3.3 Methods

The private practice had cephalometric radiographs taken with 2 x-ray films and a soft tissue shield in one cassette. With one exposure, one radiograph would show the hard tissue structures and the other one that had the soft tissue shield would show the soft tissue profile. The lateral cephalometric radiographs and the profile films for each case at the three time points were scanned by the Epson Perfection Scanner V750-M Pro Scanner at a resolution of 300 dpi and a gray scale of 24 bit .The cases were kept in a folder named Tandem Research and each case had a separate folder within that folder with the three time points. A step was taken to merge the profile film with the cephalometric radiograph in Photoshop version 7.0. For each time point, the cephalometric radiograph and the profile film was opened in Photoshop and superimposed on nasion, ANS, and upper and lower incisors. The opacity of the profile film was reduced to 50% to be able to see the cephalometric radiograph through the profile film and when all four structures overlapped, the merge button was clicked to turn it into one image that was uploaded in the digitizing software later on.

The cases were given file numbers in the Axium software™ and a Dolphin file (Version 11.0.03.37, Chatsworth, CA) was created for each one of them through Axium™. Furthermore, the merged cephalometric radiographs at each time point were uploaded into the Dolphin software™ by clicking on the button “Capture” and naming the time points T1, T2, and T3. Furthermore, a specialized variable list was created in the Dolphin software™ by clicking on Digitize, Settings, and then create variable list. The list was named Tandem Research. The twenty landmarks included in the list are defined in Table II and presented in figure 1.

TABLE II

LANDMARKS USED IN THE STUDY

Digitized Landmarks		
Po	Porion	The uppermost point on the external auditory meatus
Or	Orbitale	The deepest point on the inferior orbital rim.
S	Sella	A structural point in the center of sella turcica
N	Nasion	The point of intersection of the frontonasal and the internasal sutures in the midsagittal plane
G’	Soft tissue glabella	The most prominent point of the forehead on the midsagittal plane at the superior aspect of the eyebrows
Pr	Pronasale	The furthest anterior extention of the nose (tip of the nose)
Sn	Subnasale	The junction between the nose to the upper lip
A’	Soft tissue A point	The most concave point on the contour between subnasale and the upper lip.
Ls	Labrale superious	The most anterior extension of the upper lip at the vermilion border
Li	Labrale inferius	The most anterior extension of the lower lip at the vermilion border
B’	Soft tissue B point	The most concave point on the contour between the lower lip and the chin
Pog’	Soft-tissue pogonion	The most convex point on the soft tissue chin
B	Point B	The most concave point on the mandibular symphysis
Pog	Pogonion	The most convex point on the hard tissue chin
Me	Menton	The lowest point on the mandibular symphysis
Go	Gonion	The most convex point on the inferior border of the mandible
L1 tip	L1incisal tip	The incisal tip of the lower central incisor
L1 root	L1 root	The root apex of the lower central incisor
U1 tip	L1incisal tip	The incisal tip of the upper central incisor
U1 root	U1 root	The root apex of the upper central incisor

3.3.1 <u>Study Variables</u>

The cephalometric variables used to analyze the soft tissue profile and the incisor angulation are defined in Table III and presented in figure 1. Letters refer to the landmarks and numbers refer to the measurements used.

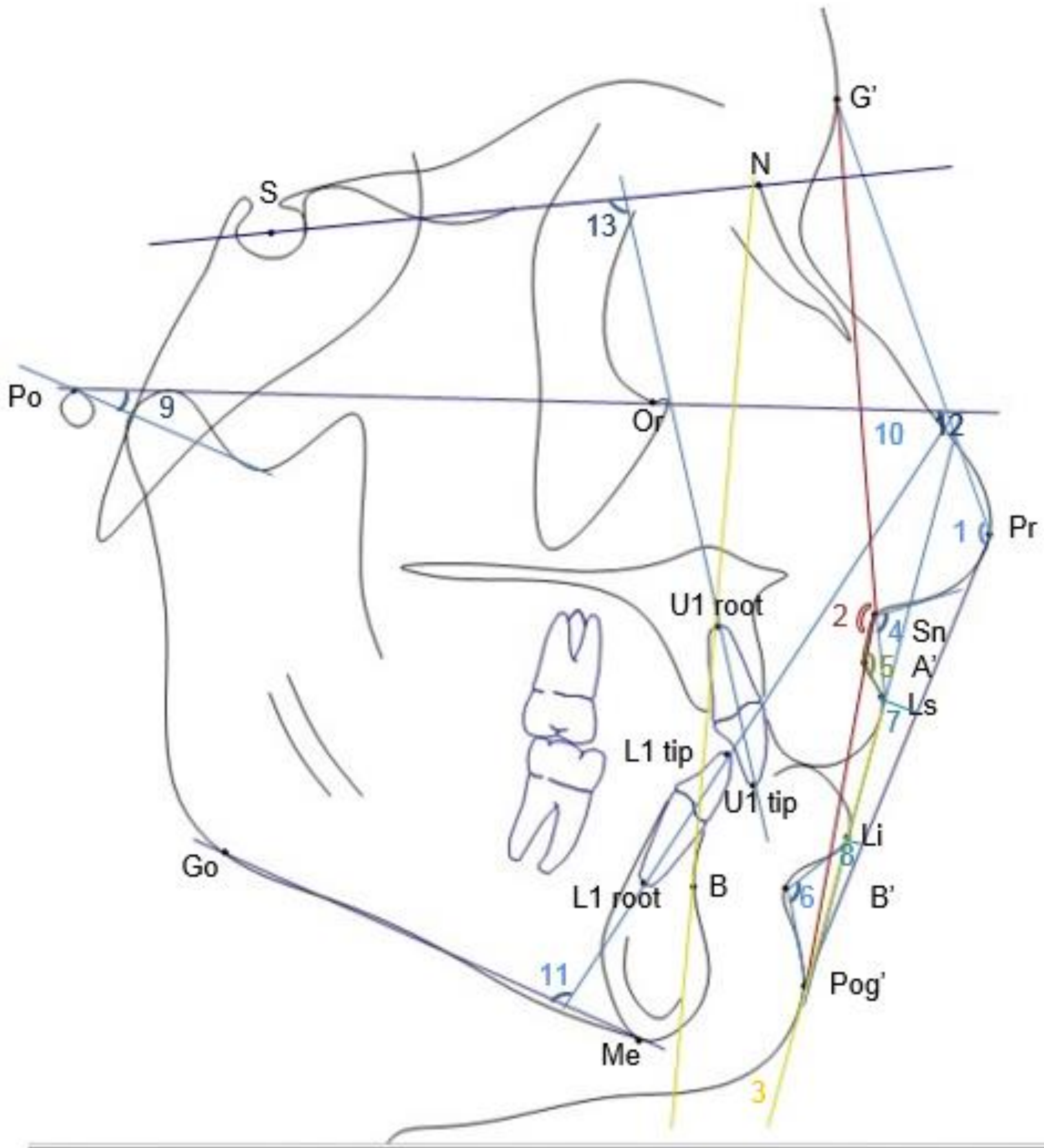

Figure 1. Cephalometric landmarks and variables

TABLE III

THE CEPHALOMETRIC VARIABLES

1	G’-Pr-Pog’(º)	Angle of total facial convexity	The angle of facial convexity including the tip of the nose
2	G’-Sn’-Pg’(º)	Facial convexity angle	The angle of facial convexity excluding the tip of the nose
3	Pog’-LS:NB(º)	Holdaway’s soft tissue angle	The angle formed by the intersection of two lines, the soft tissue pogonion to labrale superious and NB line
4	Col-Sn-Ls(º)	Nasolabial angle	The angle between columela, subnasale and labrale superioris
5	Ls-A’-Sn(º)	Maxillary sulcus contour	Angle formed by subnasale, soft tissue A point, and upper lip anterior
6	Li-B’-Pg’(º)	Mandibular sulcus contour (Mentolabial angle)	Angle formed by the lower lip anterior, soft tissue B point, and soft tissue pogonion when the lips are in repose
7	Ls-E plane (mm)	Upper lip to Ricketts Esthetic Plane	The linear mm distance between the most convex surface on the vermillion border of the upper lip and Ricketts’s Esthetic plane (Pr-Pog’)
8	Li-E plane (mm)	Lower lip to Ricketts Esthetic Plane	The linear mm distance between the most convex surface on the vermillion border of the lower lip and Ricketts’s Esthetic plane (Pr-Pog’)
9	FMA(º)	Frankfort mandibular plane angle	The angle formed by a line tangent to the lower border of the mandible from gonion to menton and the Frankfort horizontal.
10	FMIA(º)	Frankfort mandibular incisor angle	The angle resulting from the intersection between two lines: the long axis of the lower incisor and Frankfort horizontal
11	IMPA(º)	Incisor mandibular plane angle	The angle formed by the long axis of the mandibular central incisor and a line tangent to the lower border of the mandible from gonion to menton
12	Z-angle(º)	Z-angle	The angle resulting from the intersection of Frankfort horizontal plane and a line tangent to the most convex point on the soft tissue chin and the lower lip
13	U1 – SN(º)	Upper incisor to sella nasion	The angle formed by the long axis of the upper incisor and a line passing through sella and nasion

3.4 Treatment Groups

The treatment sample was divided into two groups according to their Angle classification: Group 1 included Class I cases and group 2 included Class II division 1 cases. Males and females were not differentiated in this study.

According to the private practice, the patients were instructed to have their lips lightly touching when taking the lateral cephalometric radiographs. All the cases received the same treatment which included a Kloehn Cervical headgear hooked up to the maxillary first molar bands. The force of the headgear ranged from 6 to 12 ounces per side in Class I cases, 8 to16 ounces per side in dental Class II cases and 16 to 48 ounces per side in skeletal Class II cases. The lower arch involved two lower molar bands and a lower tandem arch which was made out of an 0.022-inch stainless steel wire expanded 10 mm and going through a 0.045-inch lip bumper tube on the mandibular molars to allow free sliding of these teeth. Furthermore, a reverse bayonet bend was placed at the lower molar area to inhibit the distolingual rotation of the lower molars. The lower arch wire was stabilized 1mm anterior to the lower incisors by sling ligature ties. Stainless steel open coil springs (0.010-inch) and a sliding hook distal to lower canines were incorporated on the lower arch and Class III elastics were run from the sliding hooks to the upper molars. The patients were instructed to wear the headgear and the elastics half an hour before they went to bed and to keep them on while sleeping. They were given a cooperation card to mark the number of hours the appliances were worn. The retention protocol included an upper Hawley retainer and a banded lower fixed lingual retainer. In cases with a severe Class II skeletal pattern, a headgear was worn at night during the retention period.

3.5 Control Groups

The Class I control group was taken from several studies because not a single study had all the cephalometric variables and all the time points chosen by this investigator. Whenever a study had grouped the sample into male and female, the male and female means and standard deviations were averaged and then compared to our means. An effort was made to match the age of the untreated control groups at each observation period with the treatment group ages at T1, T2 and T3.

A study in 2014 examined lateral cephalograms of normal untreated subjects at ages 6, 9, 12, 14, 16, and 18 years. For the purpose of this study, ages 12, 14 and 18 years were selected from their sample to represent our T1, T2 and T3 groups because their ages closely matched our sample. The means and standard deviations of the following variables were taken from their study for the 3 time points: the facial convexity angle (G'-Sn-Pog'), nasolabial angle, maxillary sulcus contour, and mandibular sulcus contour (Bergman et al., 2014).

A study by Bishara et al. (1985) examined the longitudinal changes in the soft tissue profile of normal untreated subjects at ages 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, and adults. According to the authors, the cephalograms were taken with no specific instructions for lip position. The time points selected from this study were 12, 14 and adulthood. They did not specify the age range of the adulthood period but they said it varied according to when a cephalogram was available for each patient one time in his adulthood. The following variables were taken from this study: total facial convexity (G'-Pr-Pog'), Merrifield's Z angle, Holdaway's soft-tissue angle, and upper and lower lips to Ricketts E-plane. They also measured the facial convexity angle but they used the superior labial sulcus (SLS) instead of subnasale point so this variable was not used from their study. A study by Bishara et al. (1997) assessed cephalometric changes in untreated Class II division 1 subjects and compared them to untreated Class I. This study had 3 different dental stages: stage I representing the deciduous dentition and the average age of this group was 5 years old, stage II representing the mixed dentition and the average age was 7.7, stage III representing the permanent dentition who were 12 years old on avergae. Only stage III matched our sample's T1 age. U1-SN was used from their study. Another study (Foley and Mamandras, 1992) was used for U1-SN T2, T3 values. The age groups used from their study were 14 and 20 years of age. Two studies by Kowalski and Walker were used for the values of FMA, and IMPA. FMIA was calculated from these two variables based on the fact that the sum of angles of a triangle equals to 180. Thus, FMIA=180 - (FMA+IMPA). The age groups used from their study were 10-12 years which matched our T1 age, 14-16 years which matched our T2 age and 18-26 years which matched our T3 age (Kowalski and Walker, 1971; Kowalski and Walker, 1971). Table IV represents the studies used for the Class I control group.

Class II division 1 control groups were scant in the literature due to the fact that patients having this type of malocclusion usually seek treatment at some point of their childhood or early adulthood so it is hard to find records of untreated Class II patients. Lateral cephalometric radiographs of untreated Class II division 1 cases were taken from the American Association of Orthodontists Foundation Craniofacial Growth Legacy Collection. Only T1 and T2 time points could be found. T3 time point was not available. Eleven cases were selected based on the following criteria:

1. Class II molar relationship with an overjet of 5 mm or more.
2. Age at T1 is similar to the treatment group's average age at T1
3. Age at T2 is similar to the treatment group's average age at T2

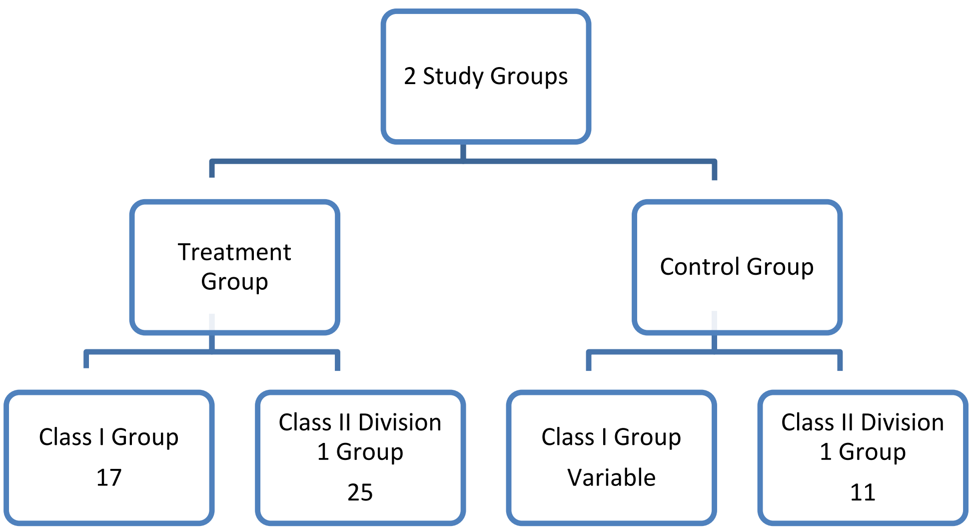

Figure 2. The study design.

TABLE IV

STUDIES USED FOR THE CEPHALOMETRIC VARIABLES OF THE CLASS I CONTROL GROUP

Study	Type of malocclusion	Sample's origin	Cephalometric instructions	Sample size	Age	Variables used	Mean(SD)
(Bergman et al., 2014)	Class I skeletal and dental relationship with ideal overjet and overbite	The Burlington Growth Centre	Lips relaxed or slightly touching. No mentalis strain.	40 (M=20 F=20)	12(T1)	G'-Sn-Pog' (º)	166.00(3.50)
						NLA	107.50(7.00)
						Maxillary sulcus contour	153.00(7.50)
						Mandibular sulcus contour	137.00(9.50)
					14(T2)	G'-Sn-Pog'	166.50(3.00)
						NLA	107.50(7.50)
						Maxillary sulcus contour	154.00(5.50)
						Mandibular sulcus contour	136.00(8.50)
					18(T3)	G'-Sn-Pog'	168.50(4.00)
						NLA	105.00(7.50)
						Maxillary sulcus contour	151.50(6.50)
						Mandibular sulcus contour	134.50(9.00)
(Bishara et al., 1985)	Clinically acceptable occlusion	Facial Growth Study of the	No instructions given in	35 (M=20 F=15)	12(T1)	G'-Pn-Pog' (º)	142.09(3.50)
						Holdaway's soft tissue angle	13.51(4.53)
						Merrifield's Z angle	66.75(8.19)
						Upper lip to E plane	-1.70 (2.06)

		University of Iowa. 97% were Northern Euoropean	regards to lip position			Lower lip to E plane	-0.42 (2.03)
					14(T2)	G'-Pn-Pog' (º)	140.32(5.68)
						Holdaway's soft tissue angle	12.04(5.02)
						Merrifield's Z angle	68.89(7.30)
						Upper lip to E plane	-2.86(2.30)
						Lower lip to E plane	-1.58(2.14)
					A(T3)	G'-Pn-Pog' (º)	139.55(5.54)
						Holdaway's soft tissue angle	8.57(5.73)
						Merrifield's Z angle	73.40(8.01)
						Upper lip to E plane	-5.04(2.64)
						Lower lip to E plane	-3.03(2.24)
(Bishara et al., 1997)	Class I	Facial Growth Study of the University of Iowa. 97% were Northern European	No instructions given in regards to lip position	35 (M=20 F=15)	12.2(T1)	U1-SN (º)	102.20(4.80)
(Foley and Mamandras, 1992)	Skeletal and dental Class I(ANB<4.5 and Angle Class I molars)	Burlington Growth Centre (white)	Lateral Cephs taken in habitual position	37(F)	14(T2)	U1-SN (º)	103.70(4.91)
					20(T3)	U1-SN (º)	103.60(5.20)
(Kowalski and Walker,	Normal dental occlusion	Philadelphia Center	-	267 (M=114 F= 153)	10-12(T1)	FMA	25.50(5.25)
						FMIA	56.56
						IMPA	97.95(4.80)

1971; Kowalski and Walker, 1971)				191 (M= 85 F= 106)	14-16(T2)	FMA	24.07(5.40)
						FMIA	58.66
						IMPA	97.27(5.65)
				36 (M= 22 F= 14)	18-26(T3)	FMA	23.32(6.10)
						FMIA	60.90
						IMPA	95.78(4.30)

3.5.1 Study Model Analysis

The study models were examined for Angle's classification and crowding. The irregularity index was intended to be used as a measure of crowding to be consistent with other studies but a number of cases had primary canines or even exfoliated primary canines so the irregularity index would not be applicable. Thus, crowding was calculated using the tooth-size arch-length discrepancy method (TSALD) where the sum of mesiodistal widths of second premolar to second premolar are deducted from the space available mesial to permanent first molars. Since the study models at T1 were in the mixed dentition stage, the size of permanent canines and premolars were measured from the final casts before any interproximal reduction would have taken place.

3.6 Statistical Analysis

Shapiro-Wilk test was used to test for Normality. Student paired *t*-tests were performed to test the mean paired differences between time points and one sample *t*-tests were used to test the mean differences from the available control groups on each of the dental classification for this study design. Statistical significance was set at $p<0.05$. SPSS version 22.0 (Chicago, IL) was used for data analysis.

4. RESULTS

4.1 The Study Sample

Seventy eight cases were received from the private orthodontic office. Thirty six cases had to be excluded for the following reasons: 16 had the tip of the nose or the soft tissue glabella cut off from the profile film, 4 had Class II elastics due to poor cooperation with the headgear, 5 had the headgear hooked up to the lower jaw in the retention period due to unexpected growth of the lower jaw, and 11 had their post-treatment records less than 3.5 years after treatment.

A total of 42 cases were eligible for this study. The Class I group included 17 cases (6 males and 11 females), and the Class II division 1 group included 25 cases (12 males and 13 females). Study models at each time point were available for all the cases except for 3: 1 Class I case at T2, 1 Class II case at T2, and 1 Class II case at T3.

4.2 Reliability Testing

Ten randomly selected radiographs were digitized by the principal investigator and intra-examiner reliability testing was performed after tracing them twice two weeks apart. In addition, the same ten radiographs were digitized by a second examiner and were compared to the principal examiner. Pearson's correlation coefficient was performed and statistically significant correlations were found showing coefficient of correlation of 0.8 or higher. Reliability testing results are presented in Appendix A.

4.3 <u>Normality Testing</u>

The majority of the variables involved in this study showed normal distribution. Parametric tests were used for the data analysis.

4.4 <u>Descriptive Statistics</u>

The mean age at T1 for the Class I group was 11.98 years and for the Class II group was 11.45 years. The long-term follow-up for the Class I group was 10.4 years on average (minimum of 4.25 and maximum of 29.17 years) after treatment, while it was 8.66 years for the Class II group (minimum of 3.83 and maximum of 25.67 years) after treatment.

Descriptive statistics (mean and standard deviation) of the study sample including age, treatment time, long-term follow-up time, headgear and tandem times, and upper and lower retention times are presented in Table V and the average tracings of the Class I group at the three time points are presented in figure 3.

The frequencies of the following variables: skeletal classification of the cases, the headgear cooperation, the type of lower retainer, and the number of times IPR was done is presented in Table VI. Descriptive statistics for each of the cephalometric variables for the two treatment groups at T1, T2, and T3 are presented in Tables VII and VIII.

TABLE V

DESCRIPTIVE STATISTICS OF THE TREATMENT GROUPS

Variable	Class I Group (Mean, SD)	Class II Group (Mean, SD)
Age at T1 (years)	11.98(2.03)	11.45(1.73)
Age at T2 (years)	14.67(1.62)	14.43(2.04)
Age at T3 (years)	25.06(7.48)	23.09(4.36)
Post-treatment follow up time (years)	10.40(6.84)	8.66(4.32)
Total treatment time (years)	2.69(0.98)	2.98(1.12)
Time in headgear (years)	2.61(0.68)	2.80(1.16)
Time in active tandem treatment (years)	1.13(0.44)	1.19(0.57)
Upper retention time (years)	5.12(1.46)	4.33(1.43)
Lower retention time (years)	7.20(2.12)	7.27(1.44)

TABLE VI

PERCENTAGES OF EACH SKELETAL CLASSIFICATION, HEADGEAR COOPERATION, TYPE OF LOWER RETAINER, AND IPR IN THE TREATMENT GROUPS

Category		Class I Group (%)	Class II Division 1 Group (%)
Skeletal Classification	Class I (ANB 0-4)	64.7	20
	Class II (ANB >4)	35.3	80
Cooperation with headgear	Excellent cooperation (0)	64.7	40
	Very good cooperation (1)	29.4	20
	Good cooperation (2)	0	8
	Fair cooperation (3)	0	28
	Poor Cooperation (4)	5.9	4
Type of lower retainer	L 3-3 (1)	41.2	48
	L 4-4 (2)	5.9	8
	L 5-5 (3)	11.8	4
	L 6-6 (4)	41.2	40
Number of times IPR was done	0	58.8	76
	1	35.3	20
	2	0	4
	3	5.9	0
Crowding at T1 (with conservation of Leeway space)	No crowding < 1mm	47.1	56
	Mild crowding 1-2mm	17.6	20
	Moderate crowding >2-4 mm	29.4	12
	Severe crowding > 4 mm	5.9	12

TABLE VII

DESCRIPTIVE STATISTICS OF EACH VARIABLE FOR CLASS I TREATMENT GROUP AT T1, T2 AND T3 (n=17)

Variable	T1 Mean, SD	T2 Mean, SD	T3 Mean, SD
G'-Pr-Pog' (º)	143.34(3.89)	140.25(4.18)	140.98(3.86)
G'-Sn'-Pg' (º)	164.90(3.67)	164.90(4.25)	168.18(4.32)
Pog'-LS:NB(º)	12.29(3.60)	10.65(3.48)	6.66(4.27)
Col-Sn-Ls (º)	117.04(8.94)	113.81(7.43)	112.90(6.26)
Ls-A'-Sn (º)	132.64(80.7)	145.76(9.87)	144.44(10.8)
Li-B'-Pg' (º)	133.41(8.99)	135.45(6.22)	135.99(7.43)
Ls- E plane (mm)	-2.01(2.89)	-3.83 (2.39)	-6.66 (3.22)
Li- E plane (mm)	-0.68(2.54)	-0.41 (1.65)	-2.80 (2.56)
FMA (º)	26.81(2.96)	28.54(3.86)	26.72(5.87)
IMPA (º)	94.32(7.29)	91.23(7.69)	92.76(7.08)
FMIA(º)	58.87(6.43)	60.23(5.07)	60.52(5.51)
Z-angle (º)	68.67(7.04)	70.03(4.75)	76.71(6.65)
U1 - SN (º)	102.28(9.41)	102.65(2.51)	104.13(3.43)

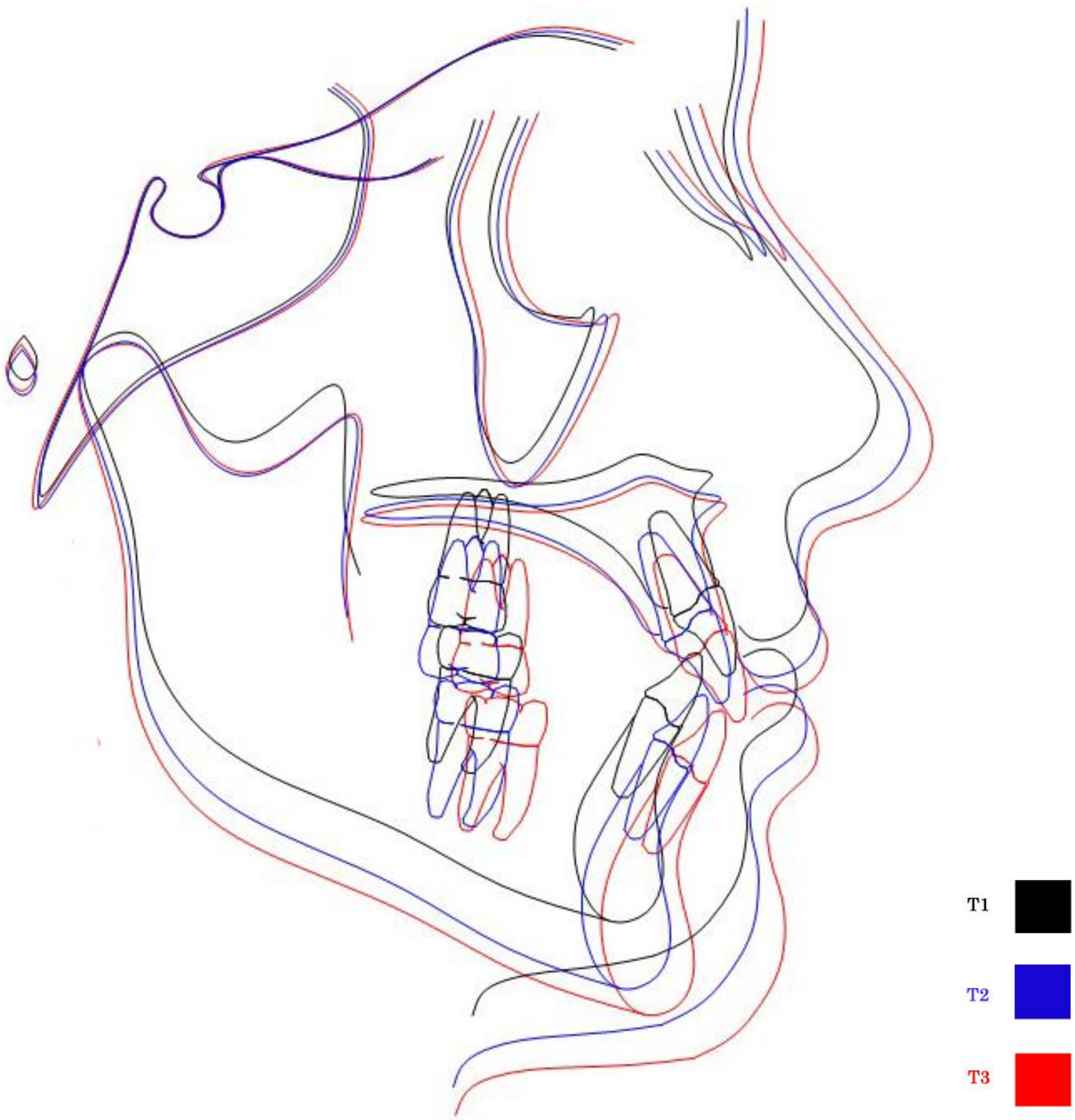

Figure 3. Average tracings of Class I treatment group at T1, T2 and T3.

TABLE VIII

DESCRIPTIVE STATISTICS OF EACH VARIABLE FOR CLASS II DIVISION 1 AT T1, T2, AND T3 (n=25)

Variable	T1 Mean, SD	T2 Mean, SD	T3 Mean, SD
G'-Pr-Pog' (º)	141.68(5.96)	138.67(5.42)	136.02(4.60)
G'-Sn'-Pg' (º)	163.43(5.28)	163.98(4.61)	165.50(5.39)
Pog'-LS:NB(º)	15.13(3.71)	10.28(4.67)	8.07(5.87)
Col-Sn-Ls (º)	111.76(9.20)	116.70(9.04)	114.42(10.6)
Ls-A'-Sn (º)	123.09(90.0)	145.62(11.2)	144.48(11.3)
Li-B'-Pg' (º)	123.90(13.9)	136.65(10.9)	131.36(10.9)
Ls- E plane (mm)	-0.78 (2.30)	-4.35 (2.14)	-6.80(3.53)
Li- E plane (mm)	0.88 (2.34)	-1.64 (2.95)	-2.98(3.90)
FMA (º)	25.61(4.06)	28.09(3.77)	25.07(6.23)
IMPA (º)	96.29(6.25)	93.39(6.01)	95.65(6.45)
FMIA(º)	58.10(5.58)	58.52(5.52)	59.28(7.49)
Z-angle (º)	65.81(6.65)	70.75(7.60)	74.47(10.4)
U1 - SN (º)	103.30(8.24)	100.44(7.70)	100.50(5.49)

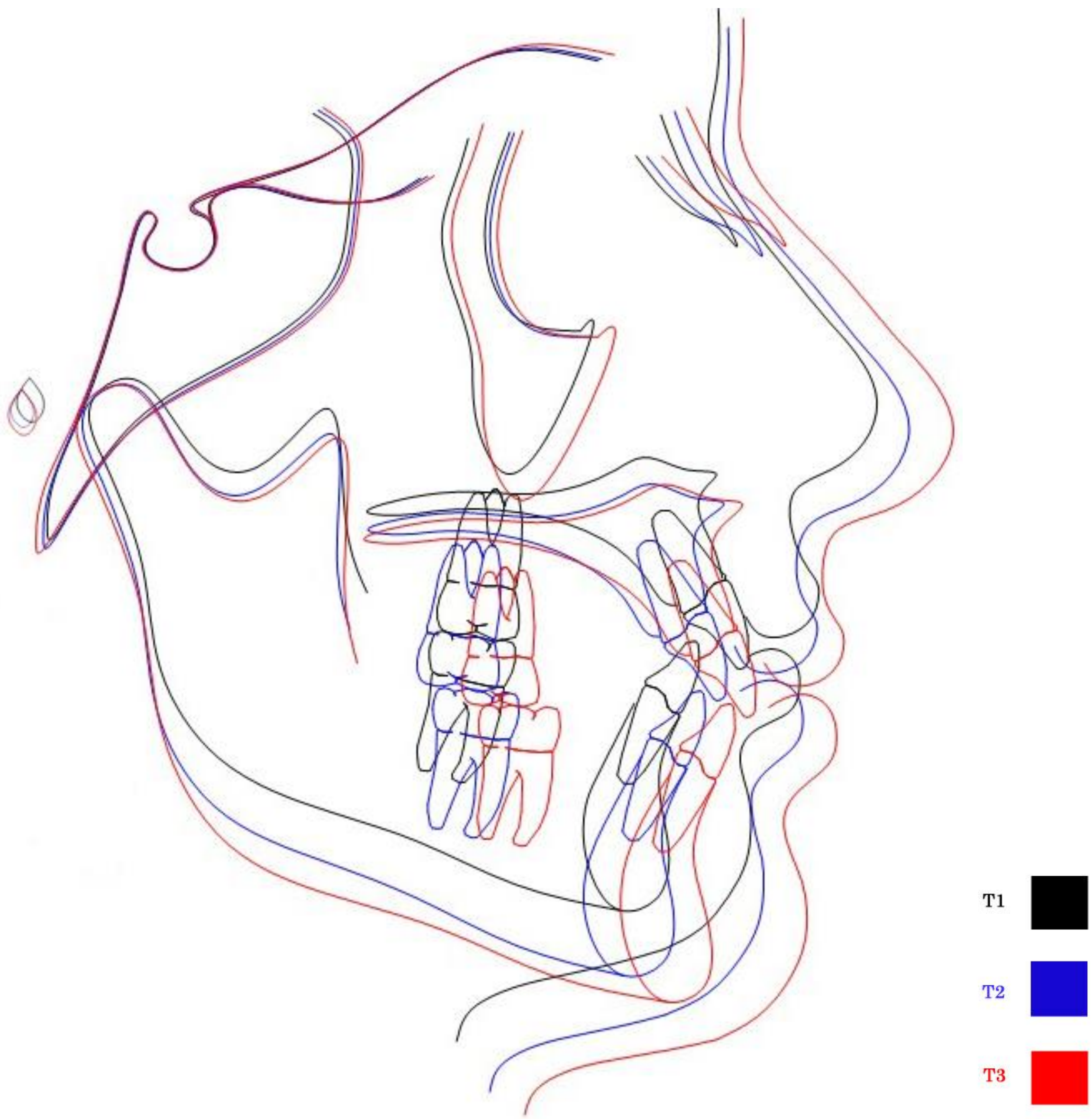

Figure 4. Average tracings of Class II treatment group at T1, T2 and T3.

4.5 Comparison of Treatment Groups at Each Time Point

Treatment (T2–T1), post-treatment (T2–T3), and net changes (T3–T1) of the cephalometric measurements are given in Tables IX and X.

The following variables did not show statistically significant differences at any of the time points: Maxillary sulcus contour, mandibular sulcus contour, U1-SN, IMPA, and FMIA ($P>0.05$).

4.5.1 Class I Treatment Changes (T2-T1)

A comparison was made between the means at T1 and T2 to assess treatment change. The following variables showed a statistically significant decrease: total facial convexity angle, Holdaway's angle, upper lip to E-plane, and lower lip to E-plane (P-value <0.05).

FMA was the only variable that showed a statistically significant increase of 1.74 degrees ($P<0.05$).

Soft tissue convexity angle, NLA, maxillary and mandibular sulcus contour, IMPA, FMIA, Z-angle and U1-SN did not show any statistically significant difference (P-value >0.05).

4.5.2 Class I Long-term Follow-up to Treatment Changes (T3-T2)

The mean differences between the long-term follow-up and the treatment change were compared. There was a statistically significant increase in the soft tissue convexity angle and the Z-angle (P<0.000). There was a statistically significant decrease in Holdaway's angle and upper and lower lips to E-plane (P-value <0.000).

4.5.3 Class I Long-term Follow-Up to Pretreatment Changes (T3-T1)

Comparing the long-term follow-up to the pretreatment values revealed that the total facial convexity's angle, Holdaway's angle, and upper and lower lips to E-plane decreased significantly from T1 to T3 (P <0.05). The soft tissue facial convexity angle, and the Z- angle increased significantly from T3 to T1 (P-value <0.001).

There was no statistically significant difference observed for the following variables: Maxillary and mandibular sulcus contour, FMA, FMIA, IMPA, and U1-SN (P>0.05).

4.5.4 Class II Treatment Changes (T2-T1)

The following variables showed a statistically significant decrease: total facial convexity angle, Holdaway's angle, upper and lower lips to E-plane (P-value <0.001).

The following variables showed a statistically significant increase: NLA, Mandibular sulcus contour, FMA, and Z-angle (P-value <0.01).

The following variables did not change as a result of treatment: soft tissue facial convexity angle, maxillary sulcus contour, IMPA, FMIA, U1-SN (P-value >0.05).

4.5.5 Class II Long-term Follow-up to Treatment Changes (T3-T2)

When the long-term effects were compared to the treatment effects, total facial convexity, Holdaway's angle, mandibular sulcus contour, upper and lower lips to E-plane, and FMA decreased significantly (P-value <0.01). IMPA and Z angle increased (P-value <0.05). The following variables did not show statistically significant differences: soft tissue facial convexity, NLA, maxillary sulcus contour, FMIA and U1-SN (P>0.05).

4.5.6 Class II Long-term Follow-up to Pretreatment Changes (T3-T1)

The following variables decreased significantly from T1 to T3: total facial convexity, Holdaway's soft tissue angle, and upper and lower lips to E-plane (P-value <0.05). The following variables increased significantly from T1 to T3: mandibular sulcus contour and Z-angle (P-value <0.01). The following variables did not show statistically significant difference from T1 to T3: facial convexity angle, NLA, maxillary sulcus contour, FMA, FMIA, IMPA, and U1-SN (P-value >0.05).

TABLE IX

MEAN CHANGE IN CEPHALOMETRIC MEASUREMENTS BETWEEN T1, T3 AND T3 FOR CLASS I TREATMENT GROUP

Variable	T2-T1 (Mean, SD)	P-value	T3-T2 (Mean, SD)	P-value	T3-T1 (Mean, SD)	P-value
G'-Pr-Pog'(º)	-3.09 (2.66)	0.001*	0.73 (2.11)	0.173	-2.36 (2.71)	0.002*
G'-Sn'-Pg'(º)	-0.01 (2.81)	0.993	3.28 (2.76)	0.000*	3.27 (3.33)	0.001*
Pog'-LS:NB(º)	-1.64 (2.78)	0.027*	-3.99 (2.84)	0.000*	-5.62 (3.86)	0.000*
Col-Sn-Ls (º)	-3.23 (6.97)	0.074	-0.91 (7.64)	0.631	-4.14 (8.08)	0.051
Ls-A'-Sn (º)	13.13(83.03)	0.524	-1.34 (11.99)	0.654	11.80(81.73)	0.560
Li-B'-Pg' (º)	2.04 (10.00)	0.412	0.55 (8.07)	0.784	2.59(10.63)	0.330
Ls-E plane mm	-1.82 (2.30)	0.005*	-2.83 (2.00)	0.000*	-4.65 (2.81)	0.000*
Li-E plane mm	-1.09 (1.90)	0.030*	-2.39 (1.76)	0.000*	-3.48 (2.63)	0.000*
FMA (º)	1.74 (2.47)	0.011*	-1.82 (3.75)	0.062	-0.09 (3.79)	0.925
IMPA (º)	-3.09 (7.12)	0.092	1.53 (3.96)	0.130	-1.56 (5.38)	0.248
FMIA(º)	1.36 (6.15)	0.376	0.29 (4.66)	0.798	1.65 (6.68)	0.323
Z-angle (º)	1.36 (4.34)	0.215	6.68 (5.02)	0.000*	8.04 (7.69)	0.001*
U1 - SN (º)	0.38 (8.21)	0.852	1.48 (3.26)	0.080	1.85 (8.79)	0.398

*P-value< 0.05

TABLE X

MEAN CHANGE IN THE CEPHALOMETRIC MEASUREMENTS
BETWEEN T1, T2, AND T3 FOR CLASS II DIVISION 1
TREATMENT GROUP

Variable	T2-T1 (Mean, SD)	P-value	T3-T2 (Mean, SD)	P-value	T3-T1 (Mean, SD)	P-value
G'-Pr-Pog' (º)	-3.01 (3.80)	0.001*	-2.64 (4.33)	0.006*	-5.66 (4.85)	0.000*
G'-Sn'-Pg' (º)	0.55 (3.82)	0.481	1.52 (4.26)	0.087	2.07 (5.10)	0.054
Pog'-LS:NB(º)	-4.86 (3.36)	0.000*	-2.21 (3.53)	0.005*	-7.06 (4.55)	0.000*
Col-Sn-Ls (º)	4.94 (9.67)	0.017*	-2.28 (8.60)	0.198	2.66(11.00)	0.239
Ls-A'-Sn (º)	22.53(91.62)	0.231	-1.14(12.77)	0.658	21.39(91.63)	0.255
Li-B'-Pg' (º)	12.75(12.86)	0.000*	-5.28(11.92)	0.036*	7.47 (13.44)	0.010*
Ls-E plane mm	-3.57 (2.16)	0.000*	-2.44 (2.69)	0.000*	-6.01 (3.21)	0.000*
Li-E plane mm	-2.52 (2.31)	0.000*	-1.34 (2.44)	0.011*	-3.87 (3.68)	0.000*
FMA (º)	2.48 (2.47)	0.000*	-3.01 (3.89)	0.001*	-0.53 (4.26)	0.539
IMPA (º)	-2.90 (7.72)	0.073	2.26 (5.16)	0.039*	-0.64 (6.69)	0.637
FMIA(º)	0.42 (8.37)	0.806	0.76 (6.02)	0.536	1.17 (8.02)	0.472
Z-angle (º)	4.94 (6.57)	0.001*	3.72 (6.79)	0.011*	8.66(10.08)	0.000*
U1 - SN (º)	-2.86 (11.36)	0.221	0.06 (5.67)	0.955	-2.79 (9.07)	0.137

*P-value< 0.05

4.6 Comparison of Treatment and Control Groups

The treated groups were compared to the control groups at T1 to ensure that the two groups matched so that further comparisons could be made at T2 and T3. For this purpose, one sample t-test was used. The one-sample t-test showed that Class I treatment and control groups were not statistically significantly different from each other for all the variables studied, except for the NLA. The mean NLA for the Class I treatment group was 117.04º whereas the NLA of the Class I control group was 107.5º. Further comparison between these two groups was possible, except for the NLA. The comparison between the Class II treatment and Control groups at T1 did not show statistical significance for any of the study variables, so further comparison at T2 was possible. The results of the tests are presented in Tables XI and XII and illustrated in figures 5 and 6.

The comparison of Class I treated and control groups at T2 showed that the maxillary sulcus contour, Lower lip to E-plane, FMA, and IMPA were statistically significant for the two groups. The comparison at T3 showed that only FMA showed statistically significant difference. These results are presented in Table XIII and illustrated in figure 7 and 8.

The comparison of Class II division 1 treated and control groups at T2 revealed that the treatment group was statistically significantly different from the control group in the following variables: Holdaway's angle, NLA, mandibular sulcus contour, upper and lower lips to the E-plane, FMA, and IMPA. These results are presented in Table XIV and illustrated in figure 9 and 10.

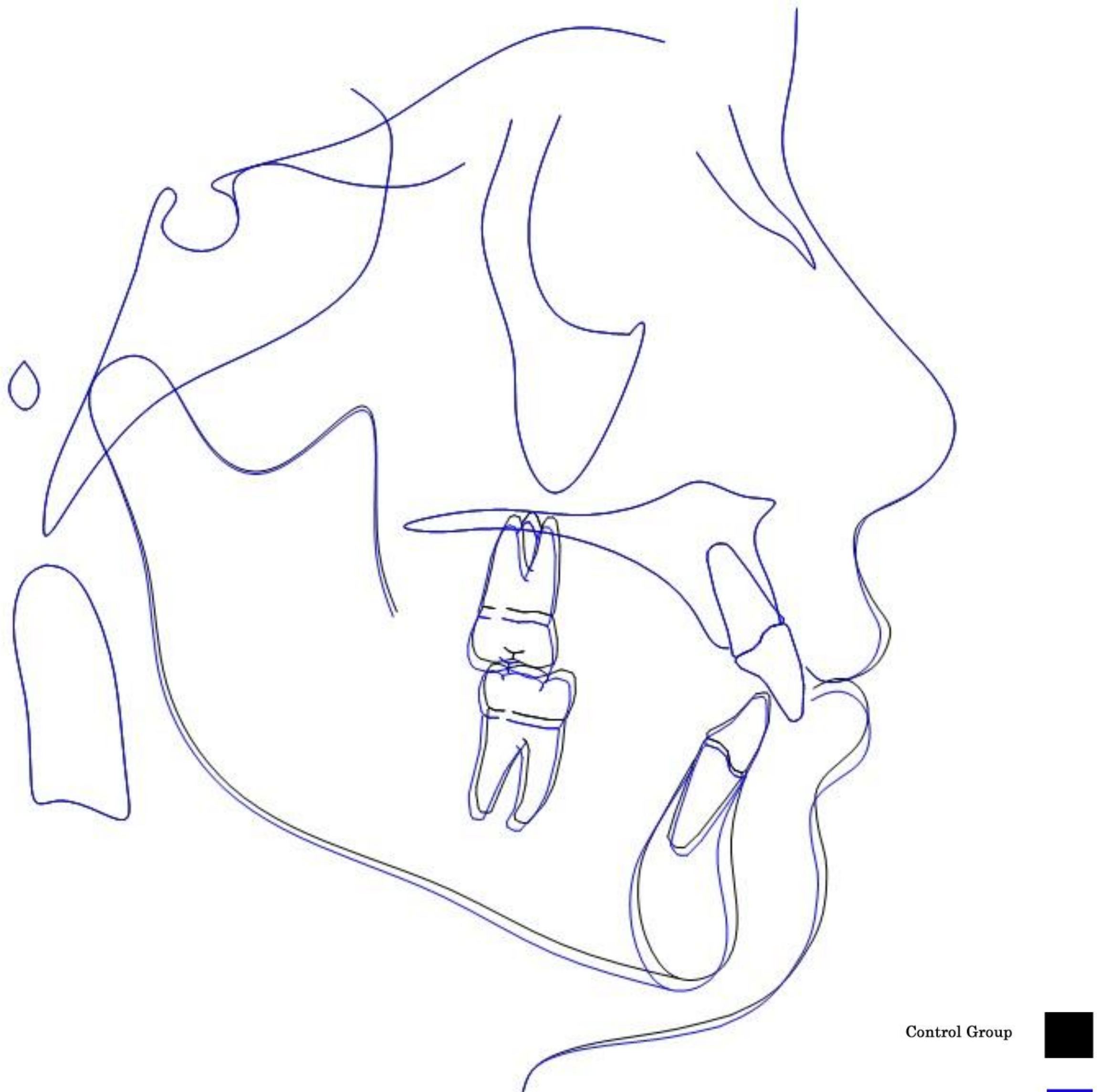

Figure 5. Class I treatment and control at T1.

TABLE XI.

COMPARISON BETWEEN CLASS I TREATMENT AND CONTROL GROUPS T1.

Variable	Sample size	Treatment Group (Mean, SD)	Sample size	Control Group (Mean, SD)	P-value
G'-Pr-Pog' (º)	17	143.34(3.89)	40	142.09(3.50)	0.203
G'-Sn'-Pg' (º)	17	164.90(3.67)	35	166.00(1.80)	0.236
Pog'-LS:NB (º)	17	12.29(3.60)	45	13.51(4.53)	0.181
Col-Sn-Ls (º)	17	117.04(8.94)	40	107.50(7.00)	0.000*
Ls-A'-Sn (º)	17	132.64(80.70)	40	153.00(7.50)	0.314
Li-B'-Pg' (º)	17	133.41(8.99)	40	137.00(9.50)	0.119
Ls- E plane (mm)	17	-2.01(2.89)	35	-1.67(2.06)	0.632
Li- E plane (mm)	17	-0.68(2.54)	35	-0.42(2.06)	0.675
FMA (º)	17	26.81(2.96)	267	25.50(5.25)	0.088
IMPA (º)	17	94.32(7.29)	267	97.95(4.80)	0.057
FMIA(º)	17	58.87(6.43)	267	56.56	0.158
Z-angle (º)	17	68.67(7.04)	35	66.75(8.19)	0.227
U1 - SN (º)	17	102.28(9.41)	35	102.20(4.80)	0.974

*P-value< 0.05

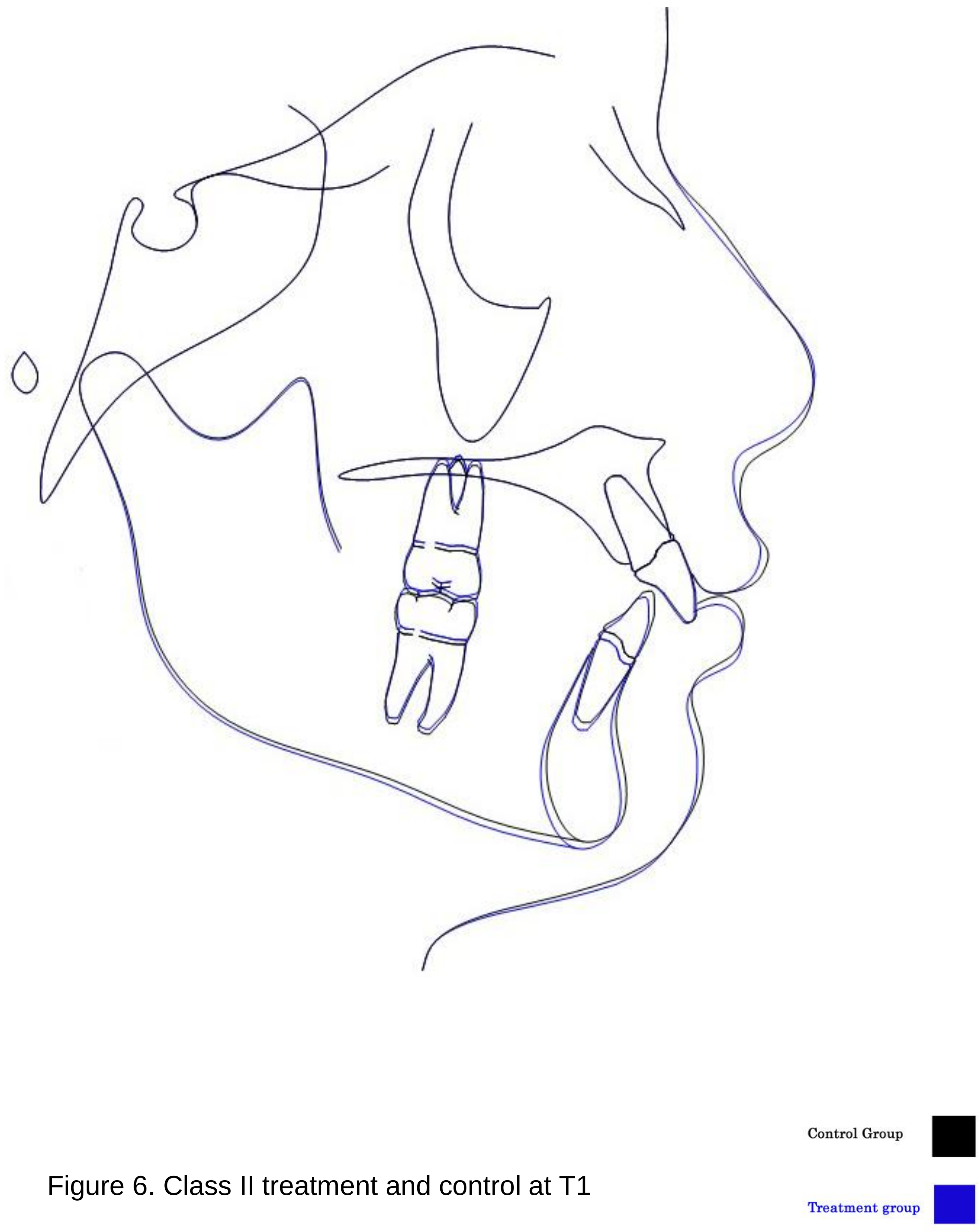

Figure 6. Class II treatment and control at T1

TABLE XII

COMPARISON BETWEEN CLASS II TREATMENT AND CONTROL GROUPS AT T1.

Variable	Treatment Group(n=25) (Mean, SD)	Control Group(n=11) (Mean, SD)	P-value
G’-Pr-Pog’ (º)	141.68 (5.96)	141.16 (4.80)	0.802
G’-Sn’-Pg’ (º)	163.43 (5.28)	161.82 (4.39)	0.383
Pog’-LS:NB (º)	15.13 (3.71)	16.52 (3.45)	0.300
Col-Sn-Ls (º)	111.76 (9.20)	111.01 (6.87)	0.809
Ls-A’-Sn (º)	123.09(90.0)	147.55(13.1)	0.380
Li-B’-Pg’ (º)	123.9 (13.94)	114.88 (12.08)	0.072
Ls- E plane (mm)	-0.78 (2.30)	0.83 (1.93)	0.051
Li- E plane (mm)	0.88 (2.34)	0.18 (2.57)	0.426
FMA (º)	25.61 (4.06)	24.82 (2.89)	0.565
IMPA (º)	96.29 (6.25)	98.71 (5.16)	0.269
FMIA(º)	58.10 (5.58)	56.51 (5.13)	0.424
Z-angle (º)	65.81 (6.65)	68.16 (8.83)	0.383
U1 - SN (º)	103.30 (8.24)	102.81 (9.22)	0.876

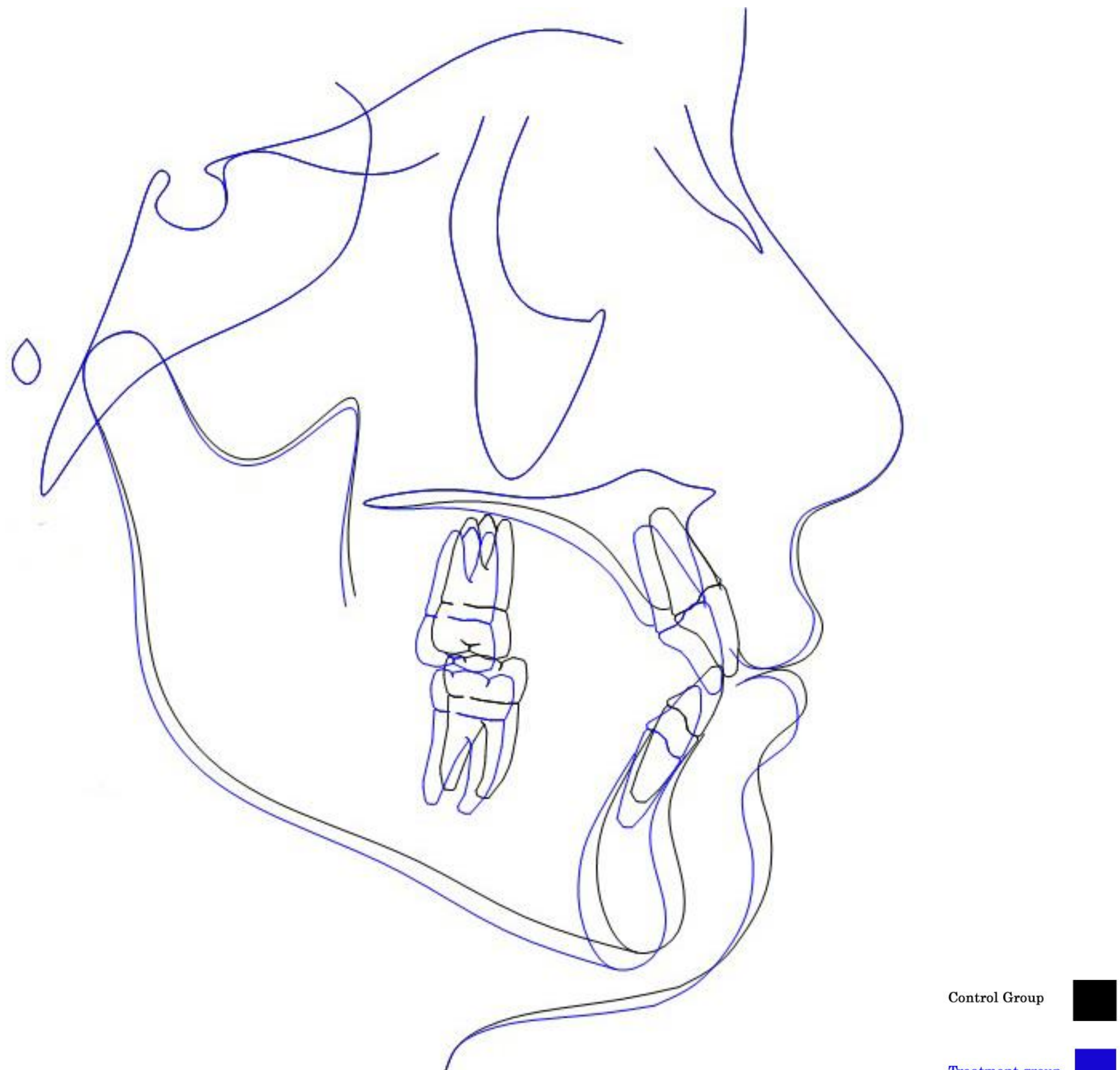

Figure 7. Class I treatment and control at T2

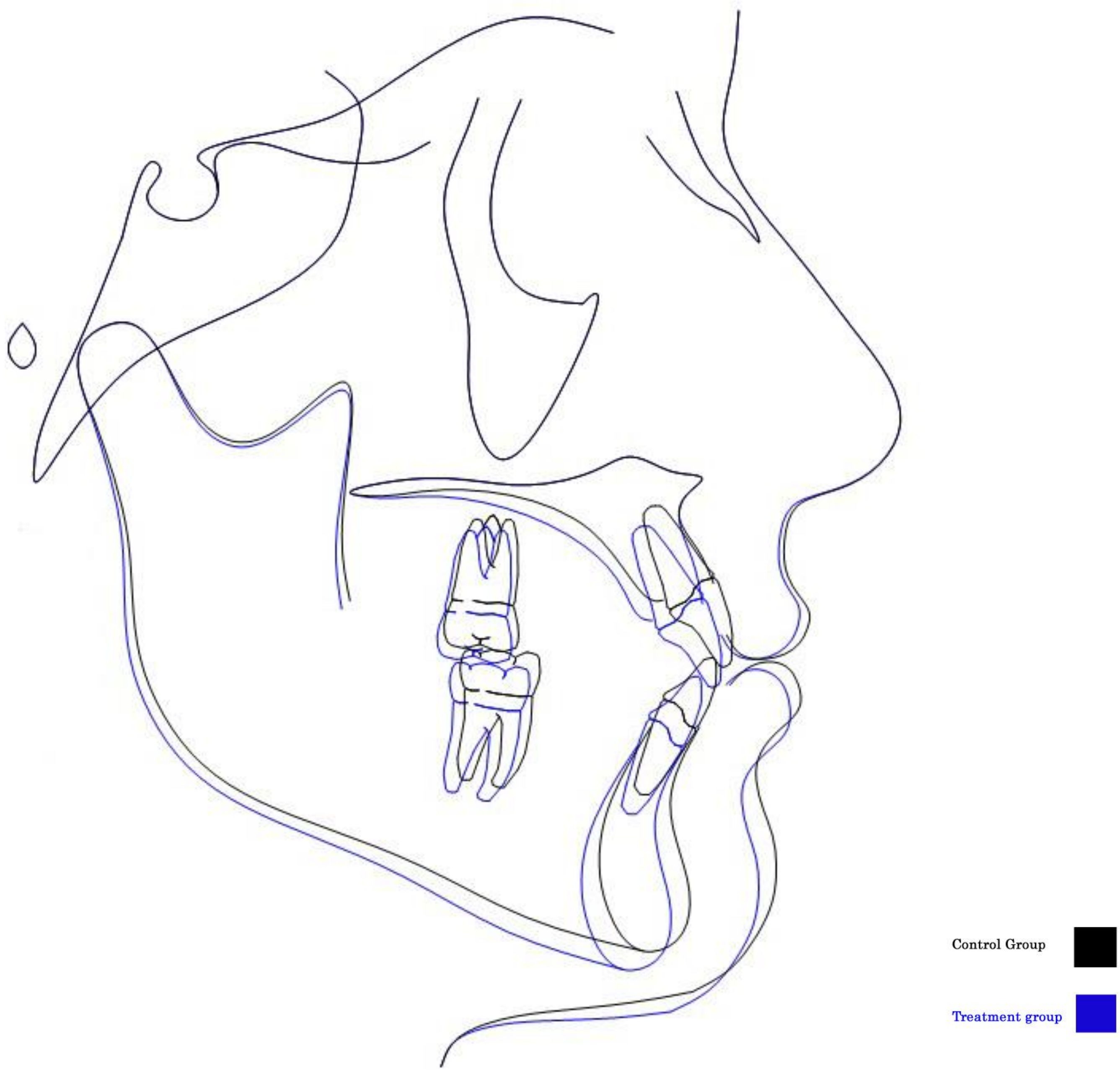

Figure 8. Class I treatment and control at T3

TABLE XIII

COMPARISON BETWEEN CLASS I TREATMENT AND CONTROL GROUPS AT T2 AND T3

Variable	Class I T2 (Mean, SD)	Control T2 (Mean, SD)	P-value	Class I T3 (Mean, SD)	Control T3 (Mean, SD)	P-value
G'-Pr-Pog' (º)	140.25(4.18)	140.32(5.68)	0.948	140.98(3.86)	139.55(5.54)	0.145
G'-Sn'-Pg'(º)	164.90(4.25)	166.50(3.00)	0.140	168.18(4.32)	168.50(4.00)	0.761
Pog'-LS:NB(º)	10.65(3.48)	12.04(5.02)	0.120	6.66(4.27)	8.57(5.73)	0.085
Ls-A'-Sn (º)	145.76(9.87)	154.00(5.50)	0.003*	144.44(10.8)	151.50(6.50)	0.016
Li-B'-Pg' (º)	135.45(6.22)	136.00(8.50)	0.719	135.99(7.43)	134.50(9.00)	0.419
Ls-Eplane mm	-3.83(2.39)	-2.82(2.30)	0.101	-6.66(3.22)	-5.04(2.64)	0.054
Li-Eplane mm	0.41(1.65)	-1.58(2.14)	0.000*	-2.80(2.56)	-3.03(2.24)	0.000*
FMA (º)	28.54(3.86)	24.07(5.40)	0.000*	26.72(5.87)	23.32(6.10)	0.030*
IMPA (º)	91.22(7.69)	97.27(5.65)	0.005*	92.76(7.08)	95.78(4.30)	0.097
FMIA(º)	60.23(5.07)	58.67	0.222	60.52(5.51)	60.90	0.782
Z-angle (º)	70.03(4.75)	68.89(7.30)	0.338	76.71(6.65)	73.4(8.01)	0.057
U1 - SN(º)	102.65(2.51)	103.70(4.91)	0.105	104.13(3.43)	103.6(5.20)	0.533

*P-value< 0.05

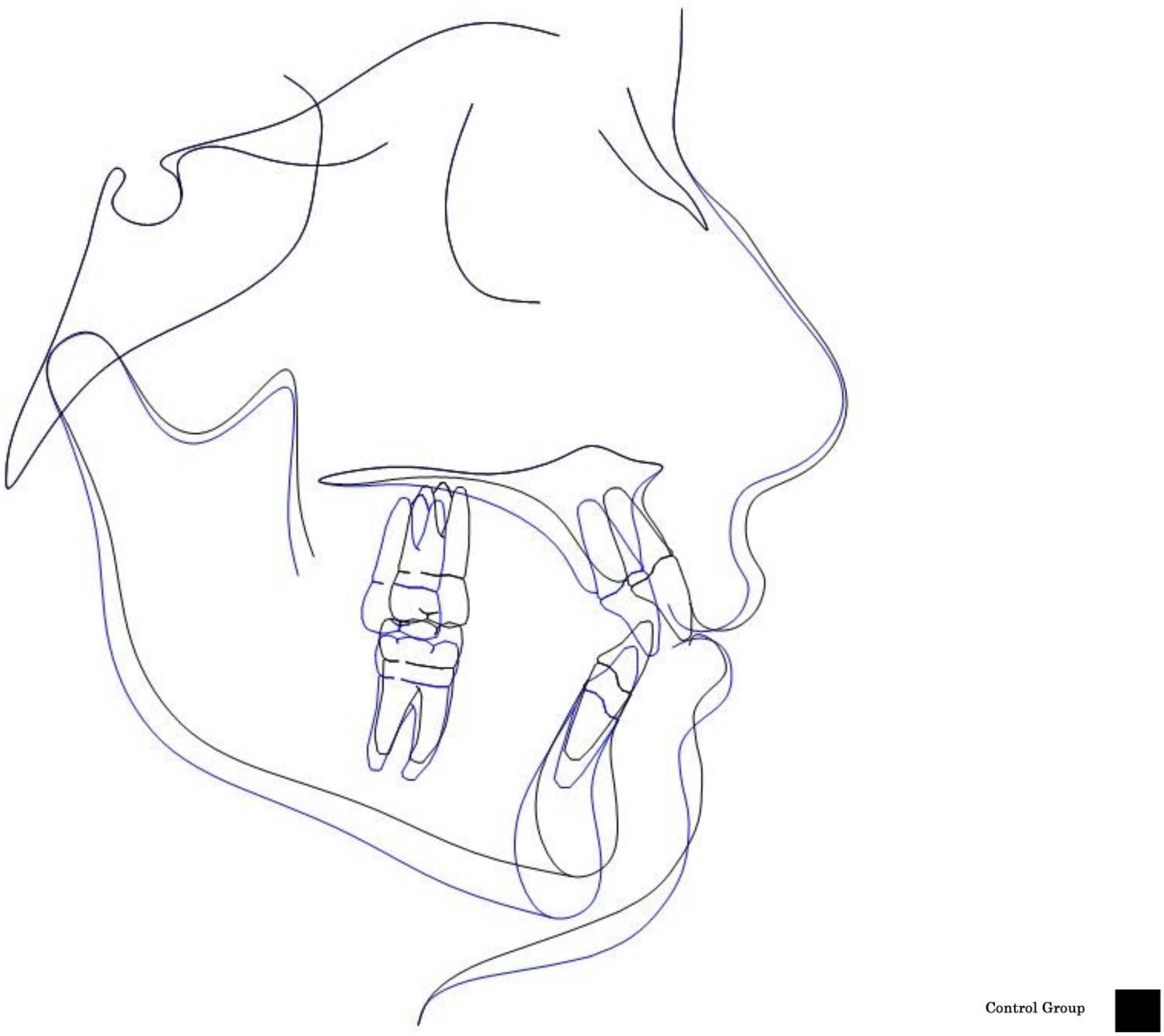

Figure 9. Class II treatment and control at T2

TABLE XIV

COMPARISON BETWEEN CLASS II TREATMENT AND CONTROL GROUPS AT T2

Variable	Class II T2 (Mean, SD)	Control T2 (Mean, SD)	P-value
G'-Pr-Pog' (º)	138.67 (5.42)	136.85 (4.77)	0.346
G'-Sn'-Pg' (º)	163.98 (4.61)	161.97 (3.30)	0.203
Pog'-LS:NB (º)	10.28 (4.67)	14.12 (3.42)	0.020*
Col-Sn-Ls (º)	116.70 (9.04)	107.15(10.57)	0.009*
Ls-A'-Sn (º)	145.62(11.15)	142.66 (9.37)	0.448
Li-B'-Pg' (º)	136.65(10.94)	123.60(14.38)	0.005*
Ls- E plane (mm)	-4.35 (2.14)	-2.35 (2.80)	0.025*
Li- E plane (mm)	-1.64 (2.95)	-2.82 (3.01)	0.000*
FMA (º)	28.09 (3.77)	23.79 (2.71)	0.002*
IMPA (º)	93.39 (6.01)	99.13 (6.27)	0.014*
FMIA(º)	58.52 (5.52)	57.07 (4.77)	0.456
Z-angle (º)	70.75 (7.60)	74.25 (7.43)	0.209
U1 - SN (º)	100.44 (7.70)	103.19 (8.53)	0.346

*P-value< 0.05

4.7 Post-treatment and Long-term Effects on the Study Model Analysis

The study models were available at all time points except for the following: one Class I case at T2, one Class II case at T2, and one Class II case at T3.

Examination of the study models after treatment revealed that all the Class I cases remained Class I molar at T2 and T3, and all the Class II division 1 cases have been treated to a Class I molar relationship which was maintained at the long-term follow-up. Table XV shows the percentage of crowding present at T2 and T3.

TABLE XV

PERCENTAGES OF CROWDING AT T1, T2, AND T3

Category		Class I (%)	Class II Division 1 (%)
Crowding at T1	No crowding < 1mm	47.1	56
	Mild crowding 1-2mm	17.6	20
	Moderate crowding >2-4 mm	29.4	12
	Severe crowding > 4 mm	5.9	12
Crowding at T2	No crowding < 1mm	94.1	96
	Mild crowding 1-2mm	0	0
	Moderate crowding >2-4 mm	0	0
	Severe crowding > 4 mm	0	0
Crowding at T3	No crowding < 1mm	82.4	76
	Mild crowding 1-2mm	11.8	12
	Moderate crowding >2-4 mm	5.9	8
	Severe crowding > 4 mm	0	0

5. DISCUSSION

This is one of a few studies that evaluated the long-term soft tissue and incisor changes as a result of nonextraction orthodontic treatment. The failure to recognize the interaction between the treatment effect and the growth effect may lead to misinterpretation of the treatment effect. In this context, it was important in this study to compare the treatment groups to untreated control groups to evaluate whether the post-treatment effects were a result of treatment or just a phenomenon of normal growth. Nevertheless, crowding measurements of the control groups were not available. Although measuring crowding was not an objective of this study, it was essential to measure the amount of crowding in the treatment groups because Tandem Mechanics is done to relieve crowding. We wanted to assess the soft tissue profile and the incisor angulation provided that the treatment was successful, meaning that the crowding was reduced. The amount of crowding in the treatment groups at T1 seemed very small. Around 52% of the sample had no crowding, 19% had mild crowding, 21% had moderate crowding and 9% had severe crowding. The majority of the cases fell under no to moderate crowding. One can argue that this could be treated without extractions anyway. Why do Tandem? The fact is that the crowding was measured at T1 with the presence of the primary molars which are on average larger than the unerupted premolars by 3.4 mm (Nance,1947). Thus, although the anterior teeth looked very crowded, measuring crowding at that phase under estimated the amount of crowding that would have resulted if posterior teeth were allowed to drift mesially and the leeway space was not utilized, leaving the anterior teeth with severe crowding. In essence, the 52% that had no crowding would have had between 0-4.4 mm of anterior crowding, the 19% that showed mild crowding would have had between 4.5-5.4 mm of anterior crowding, the 21% that showed moderate crowding would have had 5.5-7.4 mm of crowding and the 9% that had severe crowding would have had more than 7.5 mm of crowding. This amount of crowding is usually severe enough to warrant extractions.

5.1 Class I Cases

The effect of headgear on the soft tissue profile of Class I cases has not been studied due to the fact that the headgear is mainly used to treat a skeletal Class II profile to a Class I profile. In this study, headgear has been used on Class I cases together with Class III elastics to alleviate the lower crowding without proclining the incisors, while maintaining a Class I molar and a harmonious profile. The success of this technique would be achieving ideal occlusal results without changing the soft tissue profile in Class I cases. Taking into consideration that the amount of crowding in the control group was not available, the long-term soft tissue changes as result of Tandem Mechanics for treatment of Class I crowding cases is comparable to untreated Class I controls which indicates that Tandem Mechanics relieved the crowding and avoided flaring of the incisors while maintaining the harmonious Class I profile. The maintenance of the lower incisor angulation is confirmed by the absence of the statistical significance for IMPA at T2 and T3. This indicates that Tandem mechanics was successful in resolving the crowding without increasing the proclination of the lower incisors, in contrast to traditional non-extraction treatments with expansion (Basciftci et al., 2014) or Class II elastics (Elms et al., 1996) which increased the proclination of the lower incisors. Likewise, upper incisor angulation did not show statistical changes. This is in agreement with other studies that evaluated the effect of cervical pull headgear and found that the upper incisors angulation were maintained (Glenn et al., 1987; Elms et al., 1996). On the other hand, there were studies that found that the upper incisors uprighted as a result of cervical pull headgear (Fidler et al., 1995; Ciger et al., 2005). In the current study, torque control was a major part of treatment which might explain the maintenance of good upper incisor angulation in the presence of the distalizing force of the headgear. In addition, the design of Tandem Mechanics which includes Class III elastics hooked up to the upper molars whenever the headgear is on might have played a role in minimizing the retroclination of upper incisors resulting in a favorable treatment outcome that was also maintained in the long-term follow-up. There were a few variables that showed statistically significant differences between T1, T2 and T3 but when compared to the control groups, no significant differences were found at T3. These include: G’-Pr-Pog’ (º), G’-Sn’-Pg’ (º), Holdaway’s soft tissue angle, upper and lower lips to E plane, and Z angle. The total facial convexity angle G'-Pr-Pog' decreased significantly from T1 to T2. This means that the face became more convex when the nose was considered, which can be explained as a normal feature of growth as the nose tip tends to grow more forward and downward (Pelton and Elsasser, 1955; Subtelny, 1959; Behrents, 1985; Bishara et al., 1985; Nanda et al., 1990). Furthermore, this variable showed no statistically significant difference between the Class I treatment and control groups which explains that it is truly a characteristic of normal growth. Similarly, the facial convexity angle G'-Sn'-Pg' (º) did not change significantly from T1 to T2 but increased significantly from T2 to T3. There was no statistically significant difference for this angle when compared to the control at any time point. This can be explained by the normal forward projection of the chin (Pelton and Elsasser, 1955; Bishara et al., 1985; Nanda et al., 1990; Bergman et al., 2014). Holdaway's soft tissue angle decreased as a result of treatment and decreased further between T2 to T3. When compared to untreated Class I control, this angle did not show statistically significant difference which is in agreement with a previous study (Bishara et al., 1985). The prominence of the upper and lower lips decreased significantly from T1 to T2 and T2 to T3 in Class I. Virkkula el al. in 2009 found that the upper lip prominence decreased from pretreatment to post headgear treatment but increased in the long-term follow up which was contradictory to our results (Virkkula et al., 2009). According to Ricketts, the upper and lower lips should be positioned 4 mm and 2 mm behind the E-plane in adults, respectively (Ricketts, 1968). In this study, at T3 the upper and lower lips were 6 mm and 3 mm behind the E-plane, respectively, which are a little more retrusive than the norms suggested by Ricketts but comparable to the values found in other studies (Bishara et al., 1985; Nanda et al., 1990; Bishara et al., 1998; Zierhut et al., 2000). Zierhut et al. (2000) found the upper and lower lips to E-plane to be -7.07 mm and -4.93 mm for the extraction group and -7.93 mm and -6.29 mm for the nonextraction group when evaluated approximately 14 years post-retention.

The only variable that showed statistically significant differences in the long-term follow-up between the Class I treatment and control groups was the FMA. Tandem Mechanics increased the FMA 2 degrees from T1 to T2 and then decreased 2 degrees from T2 to T3 so the net change was not significant at the long-term follow up. This is in agreement with other studies which found that the backward rotation of the mandible as a result of nonextraction mechanics tends to return to its initial growth pattern (Glenn et al., 1987; Fidler et al., 1995; Ciger et al., 2005). However, when compared to the control group that had a net change in the FMA of -3 degrees from T3 to T1, statistically significant difference was found but can be considered clinically insignificant.

It can be concluded from the discussion above that Tandem Mechanics was able to maintain the harmonious profile of Class I cases, and that the changes observed in the treatment group between T1, T2 and T3 were mainly as a result of normal growth except for the FMA which increased as a result of treatment but relapsed to the pretreatment value in the long-term follow-up.

5.2 Class II Cases

The effect of Tandem Mechanics on the soft tissue profile of Class II patients was more apparent than on Class I cases. The long-term effects could not be addressed because of the absence of long-term untreated controls. The comparison provided here is between the Class II post-treatment measurements and the 2 year follow-up for the control group. The soft tissue convexity angle G'-Sn-Pog' showed statistically significant increase from T1 to T3 in the Class II group indicating a decrease in the soft tissue convexity as a result of headgear wear which is consistent with another study (Zierhut et al., 2000). On the other hand, when taking the nose into consideration, the soft tissue convexity angle decreased which indicates a more convex face which may be explained by the continued forward and downward growth of the nose (Pelton and Elsasser, 1955; Bishara et al., 1985; Nanda et al., 1990; Bergman et al., 2014). When the soft tissue convexity angles were compared to the untreated control group, there was no statistically significant difference. Holdaway's angle decreased significantly with treatment and further in retention. An earlier study in 1988 found a decrease in this angle as a result of cervical headgear treatment, which was interpreted as decrease in the facial convexity (Cangialosi et al., 1988). The upper and lower lips behaved similarly in Class I and Class II cases. Both lips became flatter with treatment. In comparison to the control group, the Class II treatment group had a straighter profile and flatter upper and lower lips. The lower incisors were upright in the treatment group and proclined in the control group, although they did not have any statistically significant pretreatment differences when compared at T1. There was an increase in the FMA in the treatment group that went back to the pretreatment value in the long-term follow-up, but when compared to the control group at T2, it showed a statistically significant difference. Tandem Mechanics has shown to improve the soft tissue profile and resolve the crowding of Class II cases without proclining the upper and lower incisors. Long-term untreated Class II data is needed to verify if these treatment results are significantly different from untreated subjects long-term.

5.3 Limitations of the Study

The study represented a long-term evaluation of Tandem Mechanics effect on the soft tissue profile and the incisor angulation regardless of the gender of the subjects due to sample size limitation. Another limitation would be using published control data which may contribute to tracing differences between the principal investigator of this study and other authors. In addition, chronologic age was used to describe the sample, but skeletal age would have been more accurate in growing patients.

5.4 Further Research

It would be interesting to conduct a study with a larger sample size to assess gender differences. In addition, comparing the soft tissue profile and the incisor angulation effects of Tandem Mechanics with the preservation of the leeway space in Class I growing children would be of great value. Furthermore, once long-term untreated Class II data becomes available, it would be interesting to compare the long-term effects of Tandem Mechanics on Class II cases.

6. CONCLUSION

Tandem Mechanics is a valuable treatment alternative to extractions in growing patients with crowding. It results in a soft tissue profile in crowded Class I cases similar to untreated class I controls. It resolves crowding while maintaining the angulation of the incisors. In addition, it is very useful in Class II cases as it relieves the soft tissue facial convexity and treats Class II division 1 cases to Neutrocclusion.

CITED LITERATURE

Azizi, M, Shrout, M K, Haas, A J, Russel, C M and Hamilton, E H: A retrospective study of Angle Class I malocclusions treated orthodontically without extractions using two palatal expansion methods. Am J Orthod Dentofacial Orthop. 1;101-7: 1999

Baccetti, T., Stahl, F. and McNamara, J. A., Jr.: Dentofacial growth changes in subjects with untreated Class II malocclusion from late puberty through young adulthood. Am. J. Orthod. Dentofacial Orthop. 2;148-154: 2009

Basciftci, F. A., Akin, M., Ileri, Z. and Bayram, S.: Long-term stability of dentoalveolar, skeletal, and soft tissue changes after non-extraction treatment with a self-ligating system. Korean journal of orthodontics 3;119-127: 2014

Baumrind, S., Korn, E. L., Boyd, R. L. and Maxwell, R.: The decision to extract: part II. Analysis of clinicians' stated reasons for extraction. Am. J. Orthod. Dentofacial Orthop. 4;393-402: 1996

Behrents, Rolf Gordon (1985). Growth in the aging craniofacial skeleton. Ann Arbor, Mich., Center for Human Growth and Development, University of Michigan.

Bergman, R. T., Waschak, J., Borzabadi-Farahani, A. and Murphy, N. C.: Longitudinal study of cephalometric soft tissue profile traits between the ages of 6 and 18 years. Angle Orthod. 1;48-55: 2014

Bishara, S. E. and Jakobsen, J. R.: Profile changes in patients treated with and without extractions: assessments by lay people. Am. J. Orthod. Dentofacial Orthop. 6;639-644: 1997

Bishara, S. E., Jakobsen, J. R., Hession, T. J. and Treder, J. E.: Soft tissue profile changes from 5 to 45 years of age. Am. J. Orthod. Dentofacial Orthop. 6;698-706: 1998

Bishara, S. E., Jakobsen, J. R., Vorhies, B. and Bayati, P.: Changes in dentofacial structures in untreated Class II division 1 and normal subjects: a longitudinal study. Angle Orthod. 1;55-66: 1997

Bishara, Samir E., Hession, Timothy J. and Peterson, Lawrence C.: Longitudinal soft-tissue profile changes: A study of three analyses. Am. J. Orthod. 3;209-223: 1985

Cangialosi, Thomas J., Melstrell Jr, Malcolm E., Leung, Marylyn A. and Ko, Jing Yang: A cephalometric appraisal of edgewise Class II nonextraction treatment with extraoral force. Am. J. Orthod. Dentofacial Orthop. 4;315-324: 1988

Ciger, S., Aksu, M. and Germec, D.: Evaluation of posttreatment changes in Class II Division 1 patients after nonextraction orthodontic treatment: cephalometric and model analysis. Am. J. Orthod. Dentofacial Orthop. 2;219-223: 2005

Eastwood, A. W.: The lingual arch in space control. Dent. Clin. North Am. 383-397: 1968

Elms, T. N., Buschang, P. H. and Alexander, R. G.: Long-term stability of Class II, Division 1, nonextraction cervical face-bow therapy: II. Cephalometric analysis. Am. J. Orthod. Dentofacial Orthop. 4;386-392: 1996

Erdinc, A. E., Nanda, R. S. and Dandajena, T. C.: Profile changes of patients treated with and without premolar extractions. Am. J. Orthod. Dentofacial Orthop. 3;324-331: 2007

Fidler, B. C., Artun, J., Joondeph, D. R. and Little, R. M.: Long-term stability of Angle Class II, division 1 malocclusions with successful occlusal results at end of active treatment. Am. J. Orthod. Dentofacial Orthop. 3;276-285: 1995

Finnoy, J. P., Wisth, P. J. and Boe, O. E.: Changes in soft tissue profile during and after orthodontic treatment. Eur. J. Orthod. 1;68-78: 1987

Foley, T. F. and Mamandras, A. H.: Facial growth in females 14 to 20 years of age. Am. J. Orthod. Dentofacial Orthop. 3;248-254: 1992

Glenn, Gayle, Sinclair, Peter M. and Alexander, Richard G.: Nonextraction orthodontic therapy: Posttreatment dental and skeletal stability. Am. J. Orthod. Dentofacial Orthop. 4;321-328: 1987

Haas, A. J.: The treatment of borderline cases in the mixed dentition. Paper delivered before Great Lakes Society of Orthodontists, Pittsburgh, Pennsylvania 1966

Haas, A. J.: Tandem technique: a treatment for all three dimensions. World J. Orthod. 2;109-118: 2003

Haas, D. G.: An assessment of tandem mechanics. Angle Orthod. 3;234-248: 1970

Kowalski, C. J. and Walker, G. F.: Distribution of the mandibular incisor-mandibular plane angle in "normal" individuals. J. Dent. Res. 4;984: 1971

Kowalski, C. J. and Walker, G. F.: The Tweed triangle in a large sample of normal individuals. J. Dent. Res. 6;1690: 1971

Little, R. M.: Stability and relapse of mandibular anterior alignment: University of Washington studies. Semin. Orthod. 3;191-204: 1999

Little, R. M.: Stability and relapse: early treatment of arch length deficiency. Am. J. Orthod. Dentofacial Orthop. 6;578-581: 2002

Little, R. M., Riedel, R. A. and Artun, J.: An evaluation of changes in mandibular anterior alignment from 10 to 20 years postretention. Am. J. Orthod. Dentofacial Orthop. 5;423-428: 1988

Little, R. M., Wallen, T. R. and Riedel, R. A.: Stability and relapse of mandibular anterior alignment-first premolar extraction cases treated by traditional edgewise orthodontics. Am. J. Orthod. 4;349-365: 1981

Luppanapornlarp, S. and Johnston, L. E., Jr.: The effects of premolar-extraction: a long-term comparison of outcomes in "clear-cut" extraction and nonextraction Class II patients. Angle Orthod. 4;257-272: 1993

Miller, Louis S.: Nonextraction treatment in growing patients, with emphasis on distal movement. Am. J. Orthod. 10;737-757: 1961

Nance, H.: The limitations of orthodontic treatment. Am. J. of Orthod. and Oral Surg. 5; 253-301: 1947

Nanda, Ram S., Meng, Hanspeter, Kapila, Sunil and Goorhuis, Jolande: Growth changes in the soft tissue facial profile. Angle Orthod. 3;177-190: 1990

O'Connor, B. M.: Contemporary trends in orthodontic practice: a national survey. Am. J. Orthod. Dentofacial Orthop. 2;163-170: 1993

Odom, W. M.: Mixed dentition treatment with cervical traction and lower lingual arch. Angle Orthod. 4;329-342: 1983

Paquette, D. E., Beattie, J. R. and Johnston, L. E., Jr.: A long-term comparison of nonextraction and premolar extraction edgewise therapy in "borderline" Class II patients. Am. J. Orthod. Dentofacial Orthop. 1;1-14: 1992

Pelton, Walter J. and Elsasser, William A.: Studies of dentofacial morphology. IV. profile changes among 6,829 white individuals according to age and sex. Angle Orthod. 4;199-207: 1955

Pollard, L. E. and Mamandras, A. H.: Male postpubertal facial growth in Class II malocclusions. Am. J. Orthod. Dentofacial Orthop. 1;62-68: 1995

Ricketts, R. M.: Esthetics, environment, and the law of lip relation. Am. J. Orthod. 4;272-289: 1968

Rossouw, P. E., Preston, C. B. and Lombard, C.: A longitudinal evaluation of extraction versus nonextraction treatment with special reference to the posttreatment irregularity of the lower incisors. Semin. Orthod. 3;160-170: 1999

Sadowsky, C., Schneider, B. J., BeGole, E. A. and Tahir, E.: Long-term stability after orthodontic treatment: nonextraction with prolonged retention. Am. J. Orthod. Dentofacial Orthop. 3;243-249: 1994

Shields, T, Little, R and Chapko, M: Stability and relapse of mandibular anterior alignment: a cephalometric appraisal of first premolar extraction cases treated by traditional edgewise orthodontics. 1985

Singer, J.: The effect of the passive lingual archwire on the lower denture. Angle Orthod. 2;146-155: 1974

Stahl, F., Baccetti, T., Franchi, L. and McNamara, J. A., Jr.: Longitudinal growth changes in untreated subjects with Class II Division 1 malocclusion. Am. J. Orthod. Dentofacial Orthop. 1;125-137: 2008

Stephens, C. K., Boley, J. C., Behrents, R. G., Alexander, R. G. and Buschang, P. H.: Long-term profile changes in extraction and nonextraction patients. Am. J. Orthod. Dentofacial Orthop. 4;450-457: 2005

Subtelny, J. D.: A longitudinal study of soft tissue facial structures and their profile characteristics, defined in relation to underlying skeletal structures. Am. J. Orthod. 7;481-507: 1959

Tweed, Charles H.: Was the development of the diagnostic facial triangle as an accurate analysis based on fact or fancy? Am. J. Orthod. 11;823-840: 1962

Virkkula, T., Kantomaa, T., Julku, J. and Pirttiniemi, P.: Long-term soft-tissue response to orthodontic treatment with early cervical headgear--a randomized study. Am. J. Orthod. Dentofacial Orthop. 5;586-596: 2009

Wright, G. Z. and Kennedy, D. B.: Space control in the primary and mixed dentitions. Dent. Clin. North Am. 4;579-601: 1978

Yavari, J., Shrout, M. K., Russell, C. M., Haas, A. J. and Hamilton, E. H.: Relapse in Angle Class II Division 1 Malocclusion treated by tandem mechanics without extraction of permanent teeth: A retrospective analysis. Am. J. Orthod. Dentofacial Orthop. 1;34-42: 2000

Zierhut, E. C., Joondeph, D. R., Artun, J. and Little, R. M.: Long-term profile changes associated with successfully treated extraction and nonextraction Class II Division 1 malocclusions. Angle Orthod. 3;208-219: 2000

APPENDIX A

RELIABILITY RESULTS

Paired Samples Correlations	N	Correlation	Sig.
S1 Maxillary Sulcus (ULA-A'-Sn) (º) & S2 Maxillary Sulcus (ULA-A'-Sn) (º)	10	0.885	0.001
S1 Mandibular Sulcus (LLA-B'-Pg') (º) & S2 Mandibular Sulcus (LLA-B'-Pg') (º)	10	0.899	0.000
S1 IMPA (L1-MP) (º) & S2 IMPA (L1-MP) (º)	10	0.902	0.000
S1 FMIA (L1-FH) (º) & S2 FMIA (L1-FH) (º)	10	0.960	0.000
S1 Z Angle & S2 Z Angle	10	0.996	0.000
S1 ANB (º) & S2 ANB (º)	10	0.848	0.002
S1 U1 - SN (º) & S2 U1 - SN (º)	10	0.940	0.000
S1 Holdaway Angle (NB to H-line) (º) & S2 Holdaway Angle (NB to H-line) (º)	10	0.996	0.000
S1 Lower Lip to E-Plane (mm) & S2 Lower Lip to E-Plane (mm)	10	0.986	0.000

S1 Upper Lip to E-Plane (mm) & S2 Upper Lip to E-Plane (mm)	10	0.994	0.000
S1 FMA (MP-FH) (º) & S2 FMA (MP-FH) (º)	10	0.988	0.000
S1 Facial Convexity (G'-Sn-Po') (º) & S2 Facial Convexity (G'-Sn-Po') (º)	10	0.989	0.000
S1 Nasolabial Angle (Col-Sn-UL) (º) & S2 Nasolabial Angle (Col-Sn-UL) (º)	10	0.956	0.000
S1 Maxillary Sulcus (ULA-A'-Sn) (º) & E Maxillary Sulcus (ULA-A'-Sn) (º)	10	0.855	0.002
S1 Mandibular Sulcus (LLA-B'-Pg') (º) & E Mandibular Sulcus (LLA-B'-Pg') (º)	10	0.774	0.009
S1 IMPA (L1-MP) (º) & E IMPA (L1-MP) (º)	10	0.758	0.011
S1 FMIA (L1-FH) (º) & E FMIA (L1-FH) (º)	10	0.934	0.000
S1 Z Angle & E Z Angle	10	0.988	0.000
S1 ANB (º) & E ANB (º)	10	0.908	0.000
S1 U1 - SN (º) & E U1 - SN (º)	10	0.921	0.000
S1 Holdaway Angle (NB to H-line) (º) & E Holdaway Angle (NB to H-line) (º)	10	0.983	0.000

S1 Lower Lip to E-Plane (mm) & E Lower Lip to E-Plane (mm)	10	0.978	0.000
S1 Upper Lip to E-Plane (mm) & E Upper Lip to E-Plane (mm)	10	0.992	0.000
S1 FMA (MP-FH) (º) & E FMA (MP-FH) (º)	10	0.966	0.000
S1 Facial Convexity (G'-Sn-Po') (º) & E Facial Convexity (G'-Sn-Po') (º)	10	0.985	0.000
S1 Nasolabial Angle (Col-Sn-UL) (º) & E Nasolabial Angle (Col-Sn-UL) (º)	10	0.983	0.000

APPENDIX B

Determination Notice
Research Activity Does Not Involve "Human Subjects"

December 2, 2013

Salma Ghoneim, BDS
Orthodontics
801 S. Paulina St
Room 131, M/C 841
Chicago, IL 60612
Phone: (773) 629-9184 / Fax: (312) 996-0863

RE: Research Protocol # 2013-1169
"Tweed Cephalometric Analysis of Class I Crowding Cases Treated with Non-extraction Tandem Technique"

Sponsor: None

Dear Dr. Ghoneim:

The above proposal was reviewed on November 30, 2013 by OPRS staff/members of IRB #2. 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.

It is understood that this research involves the analysis of data that has been de-identified by staff at the private practice.
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.
Assistant Director
Office for the Protection of Research Subjects

cc: Carlotta A. Evans, Orthodontics, M/C 841
Maria Therese S. Galang, Orthodontics, M/C 841

VITA

NAME: Salma Hossameldin Ghoneim

EDUCATION: B.D.S King Abdulaziz University, Jeddah, Saudi Arabia 2009
M.S., Oral Sciences, University of Illinois at Chicago, 2015
Certificate, Orthodontics, University of Illinois at Chicago, 2015

HONORS AND AWARDS: Postgraduate Clinical Fellows Clinical and behavioral Science Award, University of Illinois at Chicago Clinic and Research Day 2015
Educational Scholarship, KAU, 2012-2015
International Osteoporosis Foundation Young Investigator Award. Original research (Vitamin D status, Serum Calcium Level, and Bone Mineral Density in Male Patients With Type II Diabetes Mellitus in Saudi Arabia) 2011.
1st place in Youth Development Program research competition held by the Osteoporosis Research Center at King Fahd Research Center. Original research (Vitamin D status, Serum Calcium Level, and Bone Mineral Density in Male Patients With Type II Diabetes Mellitus in Saudi Arabia) 2011.
Exceptional Performance Reports, KAU, 2003-2009

PROFESSIONAL MEMBERSHIP: American Association of Orthodontics
American Dental Association
Chicago Dental Society
Illinois Society of Orthodontics
World Federation of Orthodontists