Title
The dental and skeletal effects of the cetlin appliance

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Publication Date
2005

Peer reviewed|Thesis/dissertation

THE DENTAL AND SKELETAL EFFECTS OF THE CETLIN APPLIANCE

by

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THESIS

Submitted in partial satisfaction of the requirements for the degree of

MASTERS OF SCIENCE

in

ORAL AND CRANIOFACIAL SCIENCES

in the

GRADUATE DIVISION

of the

UNIVERSITY OF CALIFORNIA

San Francisco

[redacted]

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ACKNOWLEGEMENT

The support and encouragement of many people has made it possible for me to complete this project. I would like to extend my appreciation to all.

Dr. Nelson originally planted the idea for this project in my head. He has helped me develop this into a great clinical study and provided me with guidance whenever questions arose. I would like to thank him for being a great mentor, not only with this project, but also throughout the residency.

I would also like to thank Drs. Kasrovi and Meyer for the insight they have provided in creating the design of this project and for their continued involvement as this project evolved. I am grateful to the doctors and staff at Berkeley Orthodontics and Orinda for all the effort they have put in toward collecting the records for this study and allowing me the use of them.

Dr. Vargervik played a critical role in making this project into a scientifically solid study. She challenged me constantly with the hypotheses, design and results of this project, and has been crucial in the final editing of this thesis.

Dr. Huang has been a friend as well as a mentor. He was always there to discuss any questions I had and helped me to focus the question of this study.

I would also like to thank Dr. Miller for all the moral support, encouragement and

dedication he has shown to us. He readily gave up his time to go over the design and statistical analysis throughout the study and has been crucial in keeping me on time in writing this thesis.

Finally, I would like to thank my parents, family and friends for the love and support they have shown me all my life. I would not be the person I am without them.

ABSTRACT

The purpose of this study was to evaluate the dental and skeletal effects of the Cetlin appliance used in conjunction with a transpalatal arch in the modified Cetlin approach and also to evaluate if eruption of the maxillary second molars affected the treatment response.

Pre-treatment (T1) and post-Cetlin appliance (T2) lateral cephalograms of 45 subjects were assessed. The appliance was activated until a super-Class I molar relationship was achieved. The cephalograms were evaluated by general and maxillary superimposition analysis using the structural method.

The maxillary first molars were distalized 2.29mm, erupted 1.06mm and tipped distally 9.86° on average in the general cephalometric analysis. The anchoring maxillary incisors moved labially 4.08mm and tipped labially 8.96° on average. However, no correlation was found between the movements of the maxillary first molars and incisors. A statistically significant mandibular plane opening resulted from the use of the Cetlin appliance. The mandibular plane opened 1.24° relative to SN on average and the anterior facial height increased by 3.8mm. Although the degree of opening was not clinically significant, it would be prudent to avoid using the Cetlin appliance on patients with an open bite tendency. In general, the

presence of the maxillary second molars erupted did not have any significant effect on the dental and skeletal movements achieved by the Cetlin appliance. However, when the dental changes were measured within the maxilla, the maxillary incisors proclined significantly more in the subjects with the maxillary second molars erupted.

In conclusion, the Cetlin appliance is effective in distalizing the maxillary first molars even when the second molars have erupted. However, it is not advisable to use the Cetlin appliance in patients where vertical increase is undesirable.

TABLE OF CONTENT

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

The nature of a Class II malocclusion is related to many different factors, such as facial structure, maxillary and mandibular growth patterns, and dentoalveolar development. The individual variations of these factors have to be considered in relation to treatment procedures to correct the malocclusions. [1]

In cases where the mandible and the mandibular dentition are found to be in a normal position, a common method of correcting a Class II molar relationship is through distal movement of the maxillary molars into a functional relationship with the mandibular molars. The amount of skeletal discrepancy, the amount of dental protrusion, the amount of crowding, and differences in individual facial profile would play an important role in deciding whether distal movement of the maxillary dentition would suffice in obtaining an optimal occlusion with an esthetic result.

Several methods of correcting Class II malocclusion have been proposed over the years. It is of some value to review the different methods to recognize the applications and limitations of each. In order to interpret the dental and skeletal affects of such treatment modalities, it is necessary to understand the natural growth and development of the dentition and the skeletal base.

Normal Growth of the Craniofacial Structures

Several researchers have studied the growth concept of the craniofacial structures over a long period of time, mostly using sequential lateral cephalograms, either of animals or humans. Prior to studies utilizing implants, it was commonly thought that the corpus of the bone remained unchanged and that the matrix changed its form through simple remodeling. However, implant studies showed that the craniofacial bones underwent intra-matrix rotation as well as matrix rotation, and through remodeling of the bony surfaces, the true skeletal changes were masked.[2] Thus, when growth is evaluated only through serial lateral cephalograms, what is observed may not be the real phenomenon that is occurring.

Normal growth of the maxilla

According to Enlow,[3] as the maxilla grows downward and forward from the cranium, its anterior surfaces are remodeled and bone is removed from most of the anterior surface. The anterior part of the alveolar process is a resorptive area, so removal of bone from the surface will cancel some of the forward growth that otherwise would occur by translation of the entire maxilla. However, Bjork[4] showed through his studies using implants, that the anterior surface of the maxilla is not affected by this remodeling in certain area, especially the anterior surface of the zygomatic arch.

From Bjork's[5,6] study, maxillary height was found to increase through sutural lowering at the frontal and zygomatic sutures, and deposition at the alveolar processes. There is concurrent resorption on the nasal floor and apposition on the orbital floor at a ratio of 3:2. The lowering of the nasal floor is greater anteriorly than posteriorly. Varying degrees of vertical rotation was noted in the sample group. However, the inclination of the nasal floor to the anterior cranial base is maintained as a result of compensatory differentiated modeling.[7]

Whereas Scott[8] believed that the anterior surface of the maxilla contributes to the increase in maxillary length in conjunction with growth due to the cartilage of the nasal septum, Bjork[5,6] found that the maxilla is carried forward by sutural growth toward the palatine bone, and is lengthened through apposition at the tuberosities. However, the anterior aspect of the maxilla stays quite constant in the sagittal dimension throughout remodeling in the vertical direction.

The midpalatal suture has been known to be an active growth site of the maxilla. Through his implant studies, Bjork[4,6,7] found that the maxilla, comprised of two maxillae, rotate toward each other in the transverse plane, with more growth in the posterior aspect of the median suture than the anterior part. The length of the maxilla at the median suture decreased considerably with growth and more mesial movement of the molars is noted than the incisors. The timing of the midpalatal suture pubertal growth spurt coincides with the growth in body height, but the sutural growth terminates earlier, around 17 years of age.

In Bjork's study, the maxillary dentition was found to be displaced forward and downward in relation to the maxillary corpus and the cranial base, increasing in prognathism. However, the amount of forward molar movement was approximately twice as great as the incisor movement on average, contributing to dental crowding. There was slight widening of the intercanine and intermolar width from the mixed dentition stage to the adult dentition, of approximately 1 mm. [5,7,9]In growth studies by Ricketts, the maxillary dental arch was found to erupt down and forward by about 0.2 mm to 0.3 mm per year and the mandibular molars tended to erupt straight up by about 0.8mm per year.[10]

Normal growth of the mandible

The growth concept of the mandible can be essentially divided into two concepts: the downward and forward growth of the chin in relation to the cranium, and upward and backward growth of the condyle in relation to this translation. Enlow[3] explained the growth occurring in the mandible as the "Principle of the V", with the inner surface of the area facing the direction growth undergoing resorption and the outer surface undergoing apposition.

Bjork[2,11-13] found that the growth of the mandible essentially occurs at the condyles, and the direction of the condylar growth dictates the direction of mandibular growth in patients with no pathoses. Remodeling of the mandibular border, including resorption of the lower posterior border and apposition under the lower anterior border varied among individuals depending on growth pattern. In addition to the linear growth of the mandible, longitudinal growth changes involve rotational displacement of the mandible. He showed that the mandible rotates around different fulcrum points, depending on the type of growth and malocclusion. The direction of dental eruption also differed among the different growth patterns. The forward rotators tended to have a more forward eruption path whereas the backward rotators tended to have a more vertical eruption path of the mandibular dentition. Opening of the mandibular plane was noted in cases where the amount of dental eruption vertically exceeded the amount of vertical condylar growth.

Rickett's concept of arcial growth of the mandible developed from a trial and error procedure using longitudinal cephalometric records.[14] He postulated that the normal human mandible grows by superior-anterior apposition at the ramus on a curve or arc which is a segment formed from a circle. The radius of this circle is determined by using the distance from the mental protuberance (Pm) to a point at the forking of the stress line at the terminus of the oblique ridge on the medial surface of the ramus. In his study, an average mandibular growth of 2.5mm was determined as the annual growth.

These findings help us differentiate between the dental and skeletal changes produced by treatment from that of normal growth.

Literature Review of Class II Treatment Methods – Molar Distalization

Historically, extraoral traction (headgear) has been used to distalize the maxilla and the maxillary dentition. Angle, an advocate of non-extraction treatment, used extraoral traction of many different designs.[15,16] Kloehn showed successful results of Class II treatment with headgears and invented the facebow design that we use today, attaching the bows to the inner arch with a soldered union in the incisor area.[16] He advocated early treatment as an advantage to guide the growth of the maxilla and used the headgear as "a gentle force to move the teeth that need to be moved". The aim of the treatment was to move the maxillary teeth distal into the correct functional relationship with the mandibular teeth.[17]

A number of studies have shown the effectiveness of headgear treatment. Klein[18] showed that the maxillary molars distalized with the use of headgear, and that the direction of tipping could be controlled by the practitioner manipulating the appliance. Taner[19] showed that the headgear distalized the maxillary first molars with some degree of tipping and the incisors were not affected significantly.

However, studies of long-term stability of headgear effects have shown conflicting results. Weislander and Buch[20], in a 9-year follow-up study, concluded that the posterior movement of the maxillary molars, the basal maxillary changes and the surrounding anatomic structures were relatively stable. Melsen[21], on the other hand, through an implant study that followed up headgear treatment for 7 to 8 years, found that the effect of headgear on the growth pattern of the facial skeleton appeared reversible and temporary. In fact, during post-treatment growth, the direction of growth of the maxillary complex was more forward, on average, than would be expected in an untreated population.

The center of resistance of a molar tooth has been found to lie at approximately the trifurcation of the root.[19]The force vector ideally should pass close to the centre of resistance of the tooth for pure translatory movement to take place.[22,23] If the force vector passes either occlusal or apical to the center of resistance, crown tipping is encountered. Because of skeletal variations, the importance of headgear force direction has been emphasized by numerous clinicians. Worms[23] explained that altering the direction of the outer bow of the headgear will affect the direction the maxillary first molars are tipped. Melsen[24] found that the type of tooth movement during the headgear period clearly reflected the line of action of the force.

Cetlin and Ten Hoeve[25] recognized the tipping effect of distalization on maxillary first molars and combined part-time extra-oral force with a full-time intra-oral removable plate to prevent the tipping. Their theory was that a constant force by the removable plate tips the crown of the first molars distally while the headgear controls root position, resulting in bodily movement of the molars. The maxillary second molars erupt normally without impaction and the second premolars follow the first molars distally. A recent study by Ferro,[26]in which patients were treated with the Cetlin removable plate, headgear and lip bumper, found bodily distalization of the maxillary molars in only 9% of the patients. Distal tipping of the molars was seen in 70% of the patients, whereas in 21% of the patients, a mesial-crown tipping occurred. They attributed this to the force vector of the headgear. Labial displacement and proclination of the maxillary incisors was found in 81% of the patients, leading to an increase in overjet.

Wilson[27] devised an intra-oral method of distalizing molars with a maxillary bimetric distalizing arch, a lower three-dimensional lingual arch and the use of intermaxillary Class II elastics. He reported an average treatment time of 6 to 10 months to bodily distalize Class II maxillary first molars into Class I molars without the use of headgears or removable appliances. The use of elastic load reduction principle preserves mandibular anchorage and maxillary incisor position. Rana and Becher,[28] in a study that used the Wilson biometric distalizing arch, reported 1 mm distal movement of the maxillary molars with 2° of distal tipping in conjunction with 3.5° flaring and 2.7 mm extrusion of maxillary anterior teeth. Muse[15] reported 2.16 mm of molar distalization with substantially increased distal tipping.

Although headgears, removable plates and intra-oral appliances with the use of elastics have been shown to be effective for molar distalization, they are very dependent on patient cooperation. In a recent survey by Sinclair,[29] all responding orthodontists used molar distalization, and nearly all indicated that patient cooperation was the most significant problems encountered in distalizing maxillary molars. Many clinicians found this factor to be a major obstacle to achieving the necessary results and proposed several ways of eliminating the patient cooperation factor from treatment.[30]

Many noncompliance fixed appliances have been developed to apply a distal force to the maxillary molars. In 1988-89, Gianelly[31] described a new intra-arch molar distalizing method by means of samarium-cobalt repelling magnets. Rapid distal movement of the maxillary molars have been noted but with distal tipping and rotation.[32] Anchorage loss of approximately 20% was found in a study by Gianelly.[31] Due to the size and cost of the magnets, and the fast force deterioration with increased distance, they have lost popularity over the years.[16,30,33] Because of these drawbacks, along with the necessity of frequent recall reactivation, Darendeliler[34] has concluded that magnets offer no advantage over conventional systems in molar distalization.

Gianelly also developed another distalizing appliance using nickel-titanium superelastic coil springs. Bondemark[35] found the Ni-Ti coin spring to be more efficient in force delivery than the magnets. The open coils produce a more constant force, while the magnet forces drop rather quickly with increased distance between the poles as a result of physical properties. The superelastic coil springs were also found to produce less molar tipping than the magnets. As well as the coils, Gianelli[36] also described placing a compacted nickel titanium wire between maxillary first premolars and first molars with crimpable stops.

The Jones Jig is an open nickel titanium coil spring delivering 70-75 g of force over a compression range of 1-5mm to the molars.[37] Gulati[38] reported significant hinge opening of the mandible that resulted from excessive extrusion of the maxillary molars. In a comparison with headgears by Haydar, the Jones Jig was found to produce more distal tipping of the molars and significant anterior movement of the anchorage unit.[37]

The distal jet, a lingual distalizing appliance with nickel titanium coil springs, has been shown to distalize molars with less distal tipping since the force is delivered closer to the center of resistance of the molars. It can also be easily converted into a Nance holding arch to maintain the position of the distalized molars.[39,40] Bolla[41] examined 20 subjects and found that the maxillary first molars were distalized 3.2 mm on average into Class I molar relationship with distal tipping of 3.1°. However, they noted that the amount of tipping was influenced by the state of eruption of the maxillary second molars.

In 1992, Hilgers[42] developed the pendulum appliance made of beta-titanium springs embedded in a Nance button. It was later noted that expansion of the maxilla may be necessary with molar distalization and a midline screw was added to the appliance to produce the Pend-X appliance. Hilgers[42] stated that it is typical to see approximately 5mm of distal molar movement in a 3 to 4 month period of time. He has estimated that 20% of the space opening can be ascribed to anterior anchorage loss. Ghosh and Nanda[33] evaluated 41 subjects and found that 57% of the maxillary space created was from molar distalization of 3.37mm and the remaining from anchorage loss measured at the maxillary first premolars and anterior teeth. An average of 8.4° of molar distal tipping was also noted. Others have shown varying degrees of molar movement, tipping and anchorage loss.[16,19,30,43] Due to the substantial amount of distal tipping and the concern for undesirable bite opening, Bussick and McNamara[30] suggested that the pendulum appliance would be most effective when the appliance is constructed with anchorage support from maxillary second deciduous molars and when maxillary permanent second molars are unerupted. However, Keles and Sayinsu[44] claimed that through activation of the springs which incorporate the expected side-effects of the molars, bodily distalization can be achieved without tipping or extrusion.

Most recently, studies have been directed towards the use of osseointergrated implants as anchorage units. However, most of the patients presenting for orthodontic treatment have a complete dentition; thus, alternative anatomic sites are required. Midpalate, buccal plates, retromolar areas and alveolar bone between roots have been used as implant sites.[45] Keles[45] described successful bodily distalization of molars with absolute anchorage using titanium screws in the palatal region. Kyung[46] described the use of a midpalatal miniscrew to distalize maxillary molars without side-effects to the anterior teeth or the molars.

More studies with long-term treatment outcomes are being done with positive results.

Limitations of molar distalizing appliances

Despite the effectiveness of many of these appliances in moving posterior teeth distally, they all produce a certain amount of anterior anchorage loss; mesial movement of anchoring teeth and proclination of maxillary incisors leading to possible lip protrusion.[30,33,47] In addition, they also tend to produce some distal tipping of the maxillary molars, rather than pure bodily movement, because the path of the force vector does not pass through the center of resistance of the molars in most cases.[19,26,33,43,47] The molar roots would be tipped mesially, and unless a supplemental force system is used to provide a moment that torques the root distally, a significant amount of anchor loss may occur as the molars relapse to an upright position.[48] Extrusion of maxillary first molars have also been noted, which clinicians believe contribute to increases in anterior face height and mandibular plane angle, therefore exacerbating the Class II appearance.[30] These limitations introduce inefficiencies into the Class II correction, specifically, "round tripping" of the incisors and posterior anchorage loss during the retraction of the other maxillary teeth.[43] Bolla[41] et al found that if the recovery from tipping of both molars and premolars is subtracted from the total space generated by distalization, the effective space for the pendulum, distal jet with brackets, and distal jet alone was estimated to be about the same. They concluded that appliances that produce more tipping may introduce more inefficiency into the system.

Increase in facial height

Some clinicians believe that molar distalization is contraindicated for hyperdivergent patients.[49] This admonition is based on the assumption that, when maxillary molars are distalized "into the wedge" of the occlusion, they will open the bite. This effect, combined with a backward rotation of the mandible, is said to increase the vertical dimension, especially in high angle cases.[33,38,43,50] . However, contradicting results have been noted with different or even the same kind of molar distalizing appliances.[26,30,33,43,48,49] Ngantung[40] noted no significant increase in mandibular plane angle nor in lower face height with the use of the distal jet appliance. On the other hand, Bussick and McNamara[30] found that the mandibular plane and lower anterior face height increased significantly in relation to the Frankfort horizontal plane with the use of the pendulum appliance. However, they did not find any statistically significant difference in the amount the lower facial height increased between patients with different mandibular plane angles. In a preliminary study done by Fortini[47] with the first class appliance, they also noted no significant differences in intermaxillary vertical relationship changes between different facial types. Bolla[41] noted an insignificant increase in lower anterior facial height with no significant difference among subjects with high, neutral, or low pretreatment mandibular plane angles. Ghosh and Nanda[33] noted that there was not a statistically significant difference in increase in mandibular plane angle between different facial types with the pendulum appliance. However, they did find that the increase in lower face height as a result of molar distalization was statistically greater in the high-angle subjects compared to the normal and low- angle subjects. Ferro[26] found that backward rotation of the mandible took place without differences between facial types with the Cetlin approach. Toroglu[51] found that there was significantly more tipping and distalization of the upper first molars in high mandibular angle patients. These patients also had more mesialization of the upper incisors with the pendulum appliance. However, there was no significant inter-group difference in anterior facial height increase. In reality, other elements such as the cant of the occlusal plane, the condyle to molar distance, and occlusal forces may be more important risk factors for molar distalization than the amount of distalization if opening the vertical dimension is a concern.[43]

Presence of maxillary second molars

It was commonly thought that the presence of second molar would hinder the distal movement of the maxillary first molars.[31] Gianellly[36] found it easier to move first molars distally before the eruption of second molars. Ten Hoeve,[52] Jeckel and Rakosi,[53] and Gianelly[54] concluded that distalization of the first molars is impacted by the degree of breakthrough of the second molars and recommended distalization before second molar eruption. However, in several studies, the presence of maxillary second molars did not correlate with the rate of maxillary first molar movement, magnitude of movement, or in some cases, the amount of tipping that occurred.[15,33,43,47] Bussick and McNamara[30] concluded in their studies using the pendulum appliance, that maxillary molar distalization can be accomplished before or after the eruption of the second molars with no appreciable or significant differences in dentoalveolar outcomes, although a light increase in extrusion of first molars was noted in cases where the second molars were present. However, they did note that the presence of upper second molars was associated with significant increases in mandibular plane angle and lower anterior facial height. Ghosh and Nanda[33] noted no significant difference in maxillary first molar movement, as well as anchorage loss between the groups with and without erupted maxillary second molars with the use of the pendulum appliance. Fortini[47] also found no differences in dental movement or an increase in mandibular plane angle between the two groups with the first class appliance. Muse[15] found that the presence of maxillary second molars does not correlate significantly with the amount of maxillary first molar tipping. Interestingly, Bolla[41] noted more favorable changes, including less distal tipping of the first molar and less anchorage loss and extrusion, in subjects treated with the distal jet after the eruption of the second molar.

Normally, the center of resistance of the maxillary first molar is close to the trifurcation of the roots, but when the germ of the second molar is an obstacle to distal movement, the center of resistance tends to move apically and may lead to greater tipping of the first molars.[43] Kinzinger[55] also found that the position rather than the existence of the tooth germ of the second or the third molars affected the amount of tipping of the maxillary first molar during distalization. There was more distal tipping of the upper first molar when the upper second molar was still in the budding stage. When the upper second molar was fully erupted into the arch, there was less tipping of the first molar. Graber[56] noted that when using extraoral traction on the maxillary first molar, with the second molar not yet erupted, the first molar tips distally and does not routinely distalize bodily. . Worms[23] found that the presence of upper second molars tended to shift the center of resistance of the first molar, requiring the clinician to adjust the direction of the outer bow of the headgear if translation is needed.

Cetlin Treatment Protocol

In the 1970s, Bernstein[57,58] described the ACCO (acrylic resin cervico-occipital) appliance, a cross between the removable plate-type appliance with pendulum springs and cervical or occipital headgear. In the early 1980s, Norman Cetlin[25] introduced his nonextraction method for Class II division 1 treatment. The protocol uses an upper removable plate in conjunction with a headgear, usually a cervical pull, and a lip bumper. The plate has an anterior biteplate that caps the upper incisors, which is designed to disclude the posterior teeth during distalization and prevent labial tipping of the anterior teeth. Adams clasps are adapted to the first premolars for retention and springs are designed to distalize the first molars with activation. The force direction and the line of action plane of the headgear vary according to the facial type of the patient. To control the root inclination of the upper molars, the outer bow should be adjusted to deliver force apical to the center of resistance of the molars. Extra-oral traction is to be worn 10 to 12 hours a day or more for orthopedic affects and produce a force of 150 to 200g per side. In the mandibular vestibule, the lip bumper eliminates tight cheek and lip muscle pressure, promoting functional expansion, arch flattening and bite opening.

Since the introduction of the full Cetlin treatment protocol, modifications have been made to make treatment more efficient. In this study, the treatment protocol used includes a modified Cetlin plate worn with a transpalatal arch, in conjunction with full fixed appliances on the lower dentition. After the molars have been distalized to super-Class I relationship, the plate is discontinued, and a headgear is worn to retain the molar position and upright the roots for 3 months. Upper full fixed appliances may be started during or after the headgear phase.

Recent studies have shown that in more than 70% of patients with Class II molar relationships, the Class II molar relationship is due to a mesial rotation rather than a mesial position of the molars because the lingual cusp of the maxillary molar is in the central fossa of the mandibular molar.[24] According to Liu and Melsen,[59] the buccal molar relationships are not consistent with their corresponding lingual relationships in 90% of the conventionally diagnosed Class II cases. Rotation of maxillary molars contributes to the arch length deficiency or protrusion of maxillary anterior teeth that are found in dentoalveolar Class II patients. By correction of these rotations, 1 or 2mm of arch length per side and partial Class II correction can be achieved.[60]

The transpalatal arch is another effective method of molar distalization if it is activated one side at a time.[16] Haas and Cisneros[61] reported that the transpalatal arch is able to correct Class II malocclusion as a result of disto-buccal rotation and distal tipping of the activated molars. Thus, the transpalatal arch used with the Cetlin plate would enhance the correction of Class II molar relationship . through molar distalization and derotation.

As previously mentioned, the vector of force can be adjusted through the outer bow in a headgear to produce the desired effect. The force of the headgear is not used to actively distalize the molars in this study, but to maintain the crown position while allowing the premolars to drift distally and to improve the inclination of the molars. Thus it can be worn for less than the 10 to 12 hours originally proposed or only at night time. This factor would be suggested to improve patient cooperation with headgear wear. Also, since the headgear is not used to produce the initial distal movement of the maxillary first molars, the term of headgear use is reduced.

PURPOSE AND HYPOTHSES

The purpose of this study was to evaluate the dental and skeletal effects of the Cetlin plate used in conjunction with a transpalatal arch in the modified Cetlin approach and also to evaluate the differences in treatment response to the eruption of the maxillary second molars.

The following null hypotheses were tested:

1. There is no movement of the maxillary first molars with the use of the Cetlin appliance.
2. There is no movement of the maxillary incisors with the use of the Cetlin appliance.
3. There is no opening of the mandibular plane angle with the use of the Cetlin appliance.
4. There is no correlation between the maxillary first molar and incisor movements.
5. The presence of the maxillary second molars in the arch does not have any effect on the dental and skeletal changes.

MATERIALS AND METHODS

Sample

The sample studied consisted of 45 patients (25 males, 20 females) with the mean age of 12.84 ± 1.16 years ranging from 11 to 15.52 year (Table 1). The patients had been consecutively treated with a nonextraction approach using a Cetlin plate for bilateral distalization of the maxillary first molars in conjunction with lower full fixed appliances at a group orthodontic office in the San Francisco Bay area. The patients were treated by several clinicians, all of whom follow the same treatment protocol. The patients selected met the following criteria:

1) Diagnosed with mild Class II malocclusion, ranging from Class II tendency to half-cusp Class II molar with mild crowding
2) Treated with the modified Cetlin approach as described previously (Figure 1)
3) Had two good quality lateral cephalograms taken, one prior to treatment (T1) and one immediately after discontinuation of the Cetlin plate (T2)

Of the 45 subjects, 33 had maxillary second molars erupted into the arch and 12 did not.

Table 1 Sample distribution

	N	*Age at T1 (year)*				*Treatment time (month)*			
		Mean	*SD*	*Maximum*	*Minimum*	*Mean*	*SD*	*Maximum*	*Minimum*
Total	45	12.84	1.16	15.52	11.00	8.04	3.63	21	2
Male	25	12.85	1.20	15.52	11.00	8.20	4.35	21	4
Female	20	12.82	1.13	15.25	11.25	7.85	2.56	12	2
Erupted 7's	33	12.97	2.22	15.52	11.00	7.73	3.22	21	2
Unerupted 7's	12	12.48	0.91	14.08	11.00	8.92	4.62	21	4

Appliance Design

The molar distalizing Cetlin plate is designed with a labial bow that wraps around the maxillary incisors, Adams clasps to the first premolars and springs that contact the mesial surface of the maxillary first molars. There is acrylic palatal coverage with an anterior bite plane that extends incisally to approximately 90% of the lingual surface of the maxillary incisors. The springs are activated to the mesiobuccal cups of the maxillary first molars from the occlusal view and are set gingivally so that they engage under the height of contour when placed in position. A transpalatal bar is placed to derotate and expand the maxillary first molars when necessary, as is often the case in Class II malocclusion. The Cetlin plate is activated every 4 to 6 weeks until super Class I molar relationship is achieved, when the progress lateral cephalograms were taken. Conventional orthodontic bands and brackets are placed on the mandibular dentition to level and align.

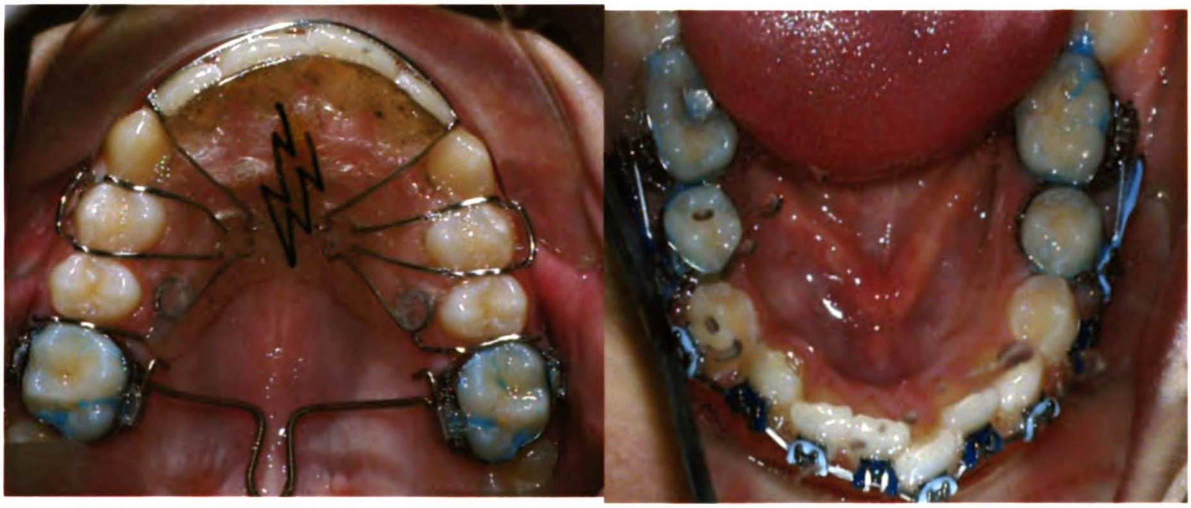


Figure 1. Modified Cetlin plate and TPA with lower full fixed appliances. (Courtesy of Dr. Gerald Nelson.)

Cephalometric Analysis

Lateral cephalograms were obtained before the initiation of treatment and at the time of discontinuation of the Cetlin plate use. The lateral cephalograms had been taken on two different x-ray machines. The magnification was adjusted to 10% for all the lateral cephalograms. The cephalograms were traced using a 0.5mm lead pencil and overlapping outlines of bilateral structures were bisected. The tracing was done by one examiner and the measurements were made to the nearest 0.5mm or 0.5 degree. Twenty seven angular and linear measurements, both horizontal and vertical, were used to evaluate the skeletal and dentoalveolar movements (Table 2 and figure 2).

On the initial lateral cephalogram, a reference line was constructed, consisting of Sella-Nasion (NS) line and Sella-Nasion perpendicular at Sella (SNP). The T1 and T2 lateral cephalograms were superimposed on the stable anterior cranial base structures and the reference lines were transferred to the latter film.

The maxillae were superimposed separately to determine the amount of tooth movement that occurred in the maxillary skeletal base independent of the general growth. The anterior-superior surface of the zygomatic process was superimposed at a plane where the apposition of the orbital floor and resorptive lowering of the nasal floor was 1:1 as described by Bjork[62]. The T1 and T2 occlusal planes were bisected and all linear measurements were taken to this line. The long axis of the maxillary first molar was constructed by drawing a line through the central fossa and the center of the bifurcation of the root. The long axis of the incisor was constructed through the incisal tip and root apex. The angular differences were measured as the angles between the long axes of each tooth. (Table 3 and figure 3)

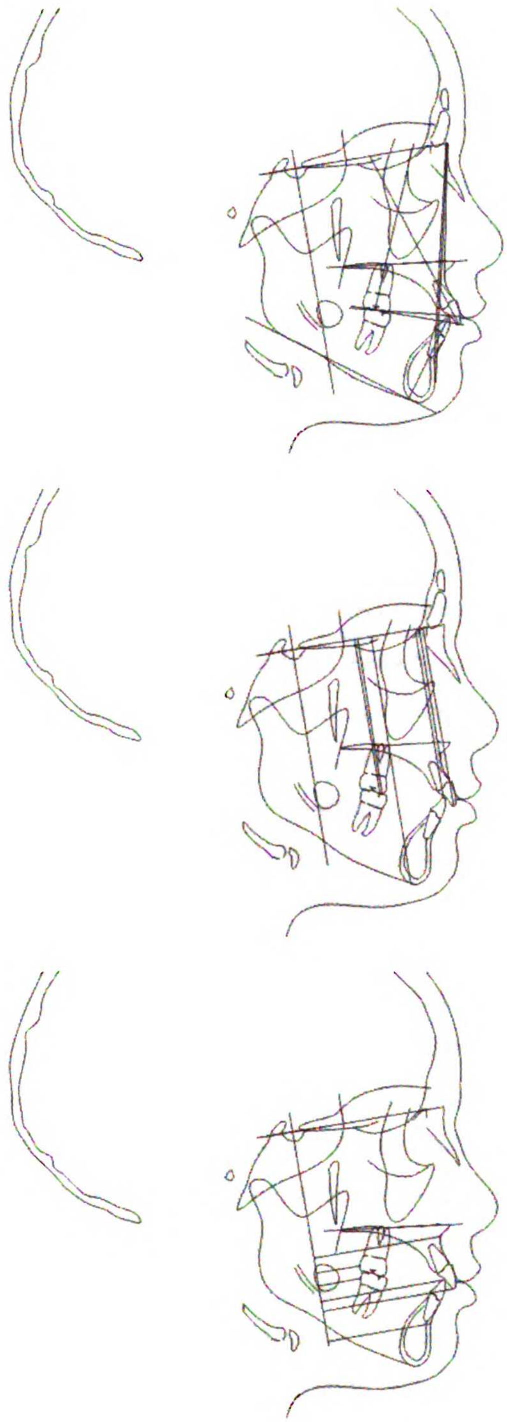


Figure 2. Diagram of reference lines and angles used for measurements on the lateral cephalograms

Table 2. Description of general cephalometric measurements

Measurement	*Description*
SNA (°)	Angle between Sella-Nasion and Nasion-A point
SNB (°)	Angle between Sella-Nasion and Nasion-B point
SNPog (°)	Angle between Sella-Nasion and Nasion-Pogonion
ANB (°)	Angle between A point-Nasion and Nasion- B point
ANPog (°)	Angle between A point-Nasion and Nasion- Pogonion
SNP-A(mm)	Distance from Sella-Nasion-perpendicular line to A point
SNP-B(mm)	Distance from Sella-Nasion-perpendicular line to B point
SN-A(mm)	Distance from Sella-Nasion to A point
SN-Me(mm)	Distance from Sella-Nasion to B point
SN to ML (°)	Angle between Sell-Nasion and Mandibular plane
SN to PP (°)	Angle between Sella-Nasion and palatal plane
PP to ML (°)	Angle between palatal plane and mandibular plane
SNP-U1(mm)	Distance from Sella-Nasion perpendicular line to upper incisor tip
SNP-L1(mm)	Distance from Sella-Nasion perpendicular line to lower incisor tip
.*SNP-U6(mm)*	Distance from Sella-Nasion perpendicular line to upper first molar distal most prominent surface
SNP-L6(mm)	Distance from Sella-Nasion perpendicular line to lower first molar distal most prominent surface
SN-U1(mm)	Distance from Sella-Nasion line to upper incisor tip
SN-L1(mm)	Distance from Sella-Nasion line to lower incisor tip
SN-U6(mm)	Distance from Sella-Nasion line to upper first molar mesial tip
SN-L6(mm)	Distance from Sella-Nasion line to lower first molar mesial tip
SN to U1 (°)	Angle between Sella-Nasion line and axis of upper incisor
SN to U6 (°)	Angle between Sella-Nasion line and axis of upper first molar
ML to L1 (°)	Angle between mandibular plane and axis of lower incisor
PP to Ops (°)	Angle between palatal plane and upper occlusal plane
ML to Opi (°)	Angle between mandibular plane and lower occlusal plane
OB (mm)	Vertical distance between upper and lower incisor tips
OJ (mm)	Horizontal distance between upper and lower incisor tips

Table 3. Description of maxillary measurements

Measurement	*Description*
H6 (mm)	Net horizontal movement of the upper fist molar along the mean oclusal plane
	(+) Mesial movement (-) Distal movement
H1(mm)	Net horizontal movement of the upper incisor along the mean oclusal plane
	(+) Mesial movement (-) Distal movement
V6 (mm)	Net vertical movement of the upper first molar in relation to the mean occlusal plane
	(+) Intrusion (-) Extrusion
V1 (mm)	Net vertical movement of the upper incisor in relation to the mean occlusal plane
	(+) Intrusion (-) Extrusion
Inc 6 (°)	Net angular change of the upper first molar
	(+) Mesial tipping (-) Distal tipping
Inc 1 (°)	Net angular change of the upper incisor
	(+) Mesial tipping (-) Distal tipping

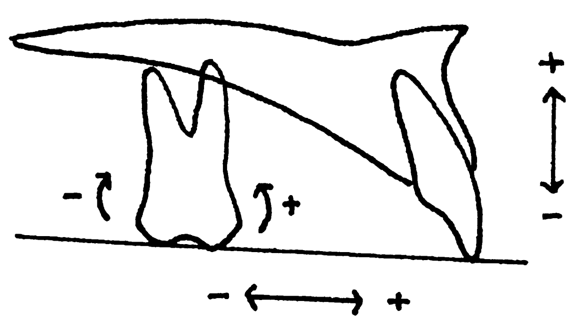


Figure 3. Diagram of measurements for the maxillary dentition in the maxillary superimposition

Statistical Analysis

The data were analyzed with a commercial statistical package (Statview, Statview, Inc, CA). Lin's concordance and Pearson's product correlation was used to assess intra-rater reliability. Ten randomly selected lateral cephalograms were traced twice by the same investigator, separated by a time interval of two weeks.

Descriptive statistics (mean and standard deviation) were calculated for each of the general cephalometric measurements at T1 and T2. The difference in T1 cephalometric measurements between males and females, and between those with erupted and unerupted maxillary second molars were analyzed using unpaired t-test. Paired t-test was used to analyze the differences between T1 and T2 measurements. Post hoc tests (Tukey and Fisher's PLSD) were used to determine significant differences of treatment changes between groups based on whether the maxillary second molars were erupted or not. Pearson product moment correlation coefficient and bivariate regression plots were used to determine the relationship between maxillary dental movements. The significance was set at a level of $P<0.05$.

RESULTS

Intra-rater reliability

Evaluation of tracing error produced Pearson's product correlation of above 0.9 indicating excellent reliability. 25 of 27 measurements had Lin's concordance of above 0.9, corresponding to excellent reliability. SN-Me and angle of upper first molar to SN had Lin's concordance of above 0.8, which would indicate good reliability (Table 4).

Table 4. Lin's concordance and Pearson's correlation for intra-rater reliability of cephalometric measurements

Measurement	*Lin's concordance*	*Pearson correlation*
SNA (°)	0.973	0.982
SNB (°)	0.986	0.988
SNPog (°)	0.983	0.989
ANB (°)	0.911	0.912
ANPog (°)	0.946	0.954
SNP-A(mm)	0.919	0.937
SNP-B(mm)	0.970	0.977
SN-A(mm)	0.977	0.980
SN-Me(mm)	0.858	0.928
SN to ML (°)	0.995	0.998
SN to PP (°)	0.991	0.992
PP to ML (°)	0.988	0.989
SNP-U1(mm)	0.964	0.965
SNP-L1(mm)	0.903	0.934
SNP-U6(mm)	0.950	0.960
SNP-L6(mm)	0.967	0.970
SN-U1(mm)	0.988	0.996
SN-L1(mm)	0.996	0.997
SN-U6(mm)	0.988	0.990
SN-L6(mm)	0.988	0.990
SN to U1 (°)	0.944	0.971
SN to U6 (°)	0.896	0.930
ML to L1 (°)	0.948	0.986
PP to Ops (°)	0.960	0.960
ML to Opi (°)	0.982	0.988
OB (mm)	0.950	0.963
OJ (mm)	0.934	0.937

Analysis of Pre-treatment Measurements

At the initial time point, measurements SNP-A, SN-A, Sn-Me, SNP-U1, SNP-L1, SN-U1, SN-L1, and SN-U6 distance were statistically different between males and females with both mandibular and maxillary lengths larger for males (Table 5). Riolo[63] found dental and skeletal linear measurements to be consistently larger in males than females at all ages. Also in this sample, the males had larger craniofacial structures than the females, but the skeletal and dental relationships were similar. Thus, all the subjects are expected to respond similarly to treatment. In addition, as the mean and distribution of age and treatment time, which could affect the treatment response, were comparable between males and females, gender differences were not taken into consideration.

The initial time point measurements were also compared between subjects who had maxillary second molars erupted and those who had not (Table 6). There were no measurements that were significantly different between the two groups. Hence, all subjects were pooled into one group for evaluation.

Table 5. Descriptive analysis of the differences between genders at T1

	T1								
		Male			*Female*		*Difference*	*P value*	
Measurement	*N*	*Mean*	*SD*	*N*	*Mean*	*SD*	*Female-Male*		
SNA (°)	25	81.96	2.57	20	82.75	3.03	0.79	0.3491	*NS*
SNB (°)	25	78.36	2.14	20	78.49	3.05	0.12	0.8827	*NS*
SNPog (°)	25	79.70	2.49	20	79.58	3.27	-0.13	0.8850	*NS*
ANB (°)	25	3.64	1.58	20	4.28	1.37	0.64	0.1627	*NS*
ANPog (°)	25	2.34	1.94	20	3.18	1.91	0.84	0.1557	*NS*
SNP-A(mm)	25	67.50	3.55	20	63.08	6.72	-4.43	0.0069	*S*
SNP-B(mm)	25	53.30	5.51	20	56.00	4.07	-2.70	0.0653	*NS*
SN-A(mm)	25	60.34	4.38	20	57.18	3.51	-3.17	0.0119	*S*
SN-Me(mm)	25	117.90	6.67	20	111.30	5.64	-6.60	0.0010	*S*
SN to ML (°)	25	28.80	4.56	20	30.15	4.86	1.35	0.3432	*NS*
SN to PP (°)	25	7.52	2.73	20	7.43	2.42	-0.10	0.9036	*NS*
PP to ML (°)	25	21.36	4.38	20	22.68	4.74	1.32	0.3397	*NS*
SNP-U1(mm)	25	68.00	3.70	20	64.75	5.23	-3.25	0.0189	*S*
SNP-L1(mm)	25	64.68	3.75	20	61.73	5.68	-2.96	0.0420	*S*
SNP-U6(mm)	25	27.16	3.14	20	25.53	4.86	-1.64	0.1794	*NS*
SNP-L6(mm)	25	25.86	3.29	20	23.88	5.74	-1.99	0.1522	*NS*
SN-U1(mm)	25	84.52	4.89	20	80.08	5.26	-4.45	0.0054	*S*
SN-L1(mm)	25	78.82	4.70	20	75.48	3.92	-3.35	0.0144	*S*
SN-U6(mm)	25	73.54	4.26	20	69.35	4.23	-4.19	0.0020	*S*
SN-L6(mm)	25	73.54	4.33	20	69.33	4.26	-4.22	0.0021	*S*
SN to U1 (°)	25	102.84	6.85	20	103.48	6.47	0.64	0.7531	*NS*
SN to U6 (°)	25	70.02	3.83	20	67.73	5.25	-2.30	0.0972	*NS*
ML to L1 (°)	25	95.92	5.42	20	98.08	5.05	2.16	0.1793	*NS*
PP to Ops (°)	25	10.50	3.52	20	10.25	3.15	-0.25	0.8055	*NS*
ML to Opi (°)	25	17.28	3.28	20	16.78	3.39	-0.51	0.1654	*NS*
OB (mm)	25	4.96	1.69	20	4.25	1.64	-0.71	0.1633	*NS*
OJ (mm)	25	4.74	1.26	20	4.80	1.48	0.60	0.8839	*NS*

Table 6. Descriptive analysis of differences between groups with maxillary second molar eruption versus non-eruption at T1

	T1								
		7's			*No 7's*		*Difference*	*P value*	
Measurement	*N*	*Mean*	*SD*	*N*	*Mean*	*SD*	*7's - no 7's*		
SNA (°)	33	82.50	2.74	12	81.79	2.94	0.71	0.4558	*NS*
SNB (°)	33	78.49	2.55	12	78.21	2.68	0.28	0.7522	*NS*
SNPog (°)	33	79.76	2.80	12	79.33	3.02	0.42	0.6619	*NS*
ANB (°)	33	4.05	1.56	12	3.58	1.36	0.46	0.3691	*NS*
ANPog (°)	33	2.74	1.99	12	2.63	1.93	0.12	0.8606	*NS*
SNP-A(mm)	33	65.49	6.28	12	65.67	3.24	-0.18	0.9245	*NS*
SNP-B(mm)	33	54.89	4.90	12	54.54	5.09	0.35	0.8338	*NS*
SN-A(mm)	33	59.21	4.63	12	58.17	3.16	1.05	0.4747	*NS*
SN-Me(mm)	33	115.59	7.31	12	113.25	6.01	2.34	0.3268	*NS*
SN to ML (°)	33	29.97	4.59	12	27.83	4.82	2.14	0.1796	*NS*
SN to PP (°)	33	7.88	2.66	12	6.38	2.01	1.50	0.0824	*NS*
PP to ML (°)	33	22.15	4.37	12	21.38	5.14	0.78	0.6172	*NS*
SNP-U1(mm)	33	66.76	4.99	12	66.00	3.86	0.79	0.6368	*NS*
SNP-L1(mm)	33	63.23	5.22	12	63.75	3.97	-0.52	0.7545	*NS*
SNP-U6(mm)	33	26.52	4.30	12	26.21	3.35	0.31	0.8244	*NS*
SNP-L6(mm)	33	25.32	4.79	12	24.04	4.07	1.28	0.4164	*NS*
SN-U1(mm)	33	82.80	5.99	12	81.83	3.83	0.97	0.6051	*NS*
SN-L1(mm)	33	77.52	4.98	12	76.83	3.66	0.68	0.6677	*NS*
SN-U6(mm)	33	71.79	5.01	12	71.38	3.89	0.41	0.7977	*NS*
SN-L6(mm)	33	71.74	5.07	12	71.46	3.92	0.28	0.8614	*NS*
SN to U1 (°)	33	103.03	7.11	12	103.38	5.28	-0.35	0.8793	*NS*
SN to U6 (°)	33	69.24	5.09	12	68.33	2.99	0.91	0.5643	*NS*
ML to L1 (°)	33	96.38	5.76	12	98.25	3.67	-1.87	0.3015	*NS*
PP to Ops (°)	33	10.26	3.56	12	10.75	2.67	-0.49	0.6657	*NS*
ML to Opi (°)	33	17.52	3.52	12	15.79	2.27	1.72	0.1223	*NS*
OB (mm)	33	4.74	1.74	12	4.38	1.57	0.37	0.5246	*NS*
OJ (mm)	33	4.89	1.41	12	4.42	1.13	0.48	0.2984	*NS*

Analysis of Overall Treatment Changes

Descriptive statistics of the subjects at T1 and T2, and the differences between the two time points are presented in Table 7. The mean treatment time of the Cetlin appliance was 8.04 ± 3.63 months.

Skeletally, the maxilla and mandible moved forward and downward, with some backward rotation of the mandible. There was a statistically significant decrease in SNB by 0.48 ± 1.38° and in SNPog by 0.64 ±1.47°, with a concurrent increase in the sagittal jaw discrepancy by 0.48 ± 1.27°. A point moved statistically significantly anteriorly by 0.86 ± 1.72mm, whereas B point moved slightly posteriorly. Menton moved inferiorly 3.8 ± 2.54mm and A point also moved inferiorly by 0.79 ± 2.34mm. The mandibular plane angle increased statistically significantly relative to both the palatal plane and SN, 1.11 ± 1.48° and 1.24 ± 1.38°, respectively.

Dentally, there was statistically significant molar distalization and labial displacement of the incisors, with tipping in opposite directions. The maxillary incisors moved anteriorly 4.08 ± 2.93mm and tipped labially 8.96 ± 6.03°. Incisor proclination and labial displacement were noted in 43 out of 45 subjects (Fig 4). Minimal inferior displacement of the maxillary incisors was noted. The maxillary first molars moved distally 2.29± 1.76mm and inferiorly 1.06 ± 1.91mm with 9.86 ± 5.21° of distal tipping. The molars were distalized in 37 out of 45 subjects and tipped distally in 43 subjects (Fig 4). The mandibular incisors also moved inferiorly and labially from the reference line, and tipped labially 2.14 ± 4.65°. The mandibular molars moved inferiorly by 1.87 ± 1.83mm. The movements of the mandibular dentition is due to a combination of the effect of the full fixed appliances and the effect of the dentition being carried downward and forward with the skeletal base. The upper occlusal plane angle to the palatal plane decreased significantly by 3.34 ± 3.14°. Overbite decreased significantly by 4.08 ± 1.91mm and overjet increased significantly by 1.58 ± 2.41mm from a combination of maxillary and mandibular incisor movements.

Table 7. Descriptive analysis of cephalometric measures and differences at and between T1 and T2

	T1			T2			ΔT2-T1			P	
Measurement	N	Mean	SD	N	Mean	SD	N	Mean	SD		
SNA (°)	45	82.30	2.80	45	82.20	3.00	45	-0.14	1.61	0.5508	NS
SNB (°)	45	78.40	2.60	45	77.90	2.70	45	-0.48	1.38	0.0239	S
SNPog (°)	45	79.60	2.80	45	79.00	3.00	45	-0.64	1.47	0.0051	S
ANB (°)	45	3.90	1.50	45	4.20	1.60	45	0.31	1.17	0.0839	NS
ANPog (°)	45	2.70	1.90	45	3.20	2.10	45	0.48	1.27	0.0153	S
SNP-A(mm)	45	65.50	5.60	45	66.40	6.00	45	0.86	1.72	0.0017	S
SNP-B(mm)	45	54.80	4.90	45	54.40	4.80	45	-0.36	2.34	0.3103	NS
SN-A(mm)	45	58.90	4.30	45	59.70	4.60	45	0.79	2.34	0.0287	S
SN-Me(mm)	45	115.00	7.00	45	118.80	7.60	45	3.84	2.54	<0.0001	S
SN to ML (°)	45	29.40	4.70	45	30.60	4.60	45	1.24	1.38	<0.0001	S
SN to PP (°)	45	7.50	2.60	45	7.40	2.80	45	-0.07	1.50	0.7662	NS
PP to ML (°)	45	21.90	4.50	45	23.10	4.80	45	1.11	1.48	<0.0001	S
SNP-U1(mm)	45	66.60	4.70	45	70.60	4.60	45	4.08	2.93	<0.0001	S
SNP-L1(mm)	45	63.40	4.90	45	64.40	4.70	45	1.08	2.60	0.0080	S
SNP-U6(mm)	45	26.43	4.03	45	24.14	4.27	45	-2.29	1.76	<0.0001	S
SNP-L6(mm)	45	25.00	4.60	45	24.80	4.70	45	-0.20	2.29	0.5609	NS
SN-U1(mm)	45	82.50	5.50	45	82.80	5.40	45	0.30	1.80	0.2707	NS
SN-L1(mm)	45	77.30	4.60	45	81.00	5.40	45	3.67	2.42	<0.0001	S
SN-U6(mm)	45	71.70	4.70	45	72.70	5.50	45	1.06	1.91	0.0006	S
SN-L6(mm)	45	71.70	4.70	45	73.50	5.40	45	1.87	1.83	<0.0001	S
SN to U1 (°)	45	103.12	6.62	45	112.08	7.95	45	8.96	6.03	<0.0001	S
SN to U6 (°)	45	69.00	4.61	45	59.14	6.10	45	-9.86	5.21	<0.0001	S
ML to L1 (°)	45	96.90	5.30	45	99.00	4.50	45	2.14	4.65	0.0034	S
PP to Ops (°)	45	10.40	3.30	45	7.00	3.90	45	-3.34	3.14	<0.0001	S
ML to Opi (°)	45	17.10	3.30	45	16.30	3.70	45	-0.74	3.14	0.1189	NS
OB (mm)	45	4.60	1.70	45	0.60	2.20	45	-4.08	1.91	<0.0001	S
OJ (mm)	45	4.80	1.30	45	6.30	2.50	45	1.58	2.41	<0.0001	S

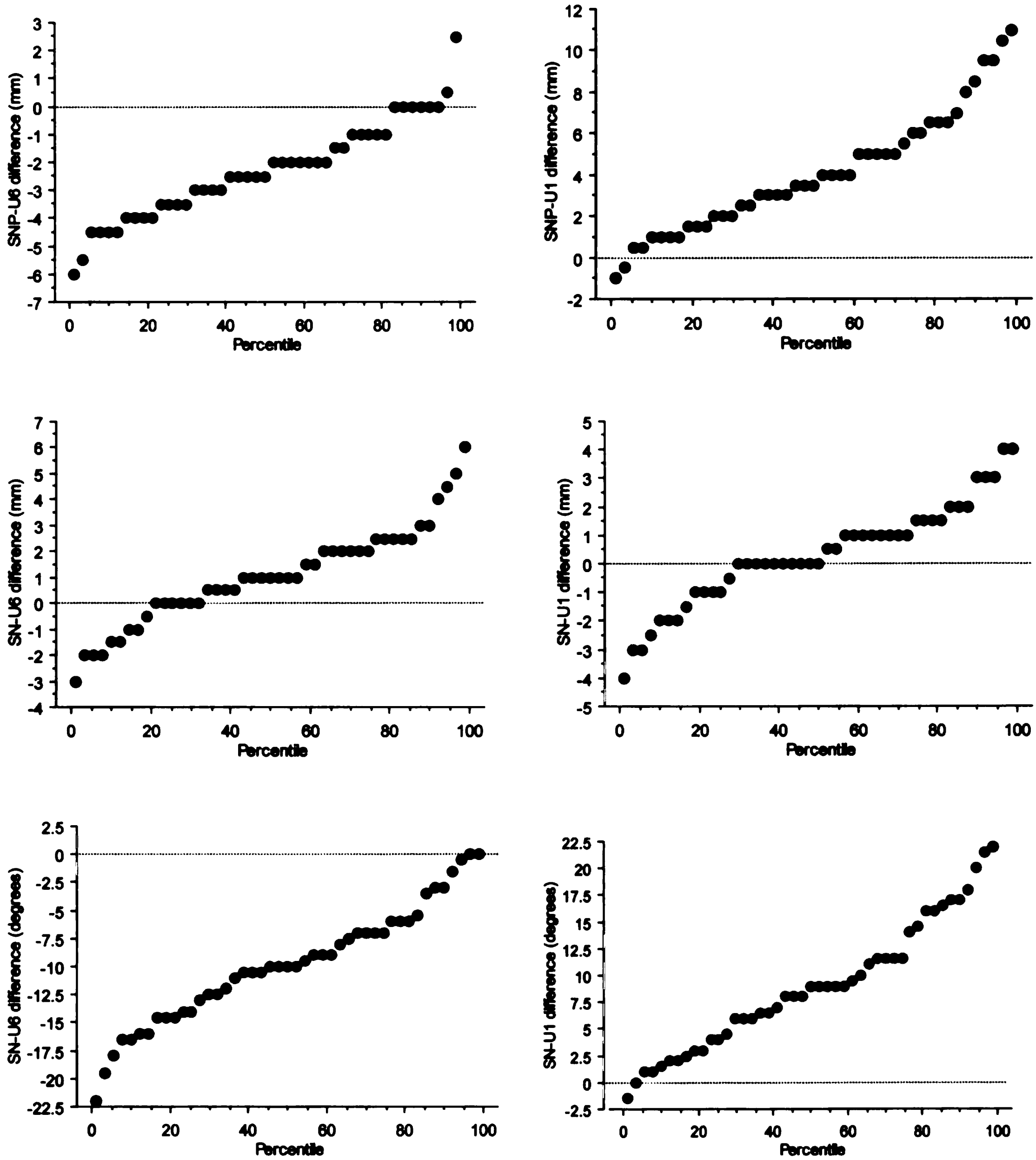


Figure 4. Percentile plots of maxillary dental movements in the general superimposition

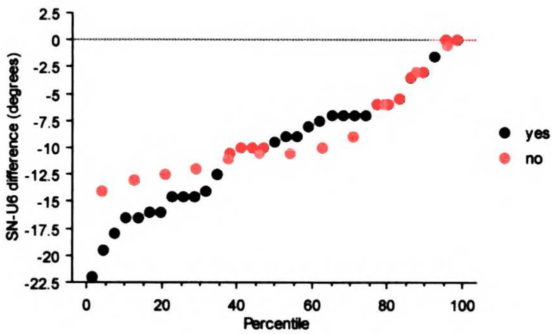
Analysis of the effect of the eruption of the maxillary second molars on treatment changes

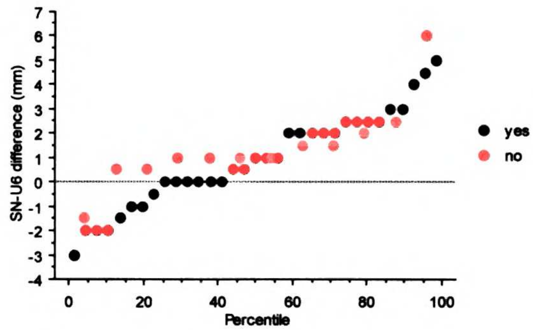
There were no statistically significant differences in the treatment response between the groups of subjects who had maxillary second molars erupted into the arch and those whose maxillary second molars had not erupted (Table 8). Percentile distributions of some of the dental and skeletal changes seen in the general analysis are plotted in Figure 5. No significant difference in the distribution is seen between the two groups.

Although not statistically significant, the mandibular plane angle increased 0.8° more in the subjects without erupted maxillary second molars and meton descended 0.49mm more in this group. The maxillary first molars distalized by 0.96mm and extruded by 0.49mm more on average in the group without upper second molars. The maxillary incisor tip moved more labially by 0.97mm in the group without the maxillary second molars erupted in the arch. However, the maxillary incisors proclined more by 1.47° in the subjects with the maxillary second molars erupted.

Table 8. Differences in cephalometric measures between subjects with maxillary second molar eruption versus non-eruption

	ΔT2-T1								
	7's			No 7's			Differences	P	
Measurement	N	Mean	SD	N	Mean	SD			
SNA (°)	33	-0.23	1.42	12	0.08	2.12	0.31	0.5735	NS
SNB (°)	33	-0.55	1.37	12	-0.29	1.45	0.26	0.5859	NS
SNPog (°)	33	-0.77	1.50	12	-0.29	1.37	0.48	0.3367	NS
ANB (°)	33	0.29	1.18	12	0.38	1.21	0.09	0.8225	NS
ANPog (°)	33	0.55	1.31	12	0.29	1.18	-0.25	0.5594	NS
SNP-A(mm)	33	0.70	1.49	12	1.29	2.25	0.60	0.3098	NS
SNP-B(mm)	33	-0.47	2.29	12	-0.04	2.55	0.43	0.5903	NS
SN-A(mm)	33	0.65	2.58	12	1.17	1.50	0.52	0.5198	NS
SN-Me(mm)	33	3.73	2.66	12	4.17	2.24	0.44	0.6129	NS
SN to ML (°)	33	1.03	1.38	12	1.83	1.25	0.80	0.0833	NS
SN to PP (°)	33	-0.20	1.55	12	0.29	1.34	0.49	0.3379	NS
PP to ML (°)	33	1.03	1.62	12	1.33	1.05	0.30	0.5498	NS
SNP-U1(mm)	33	3.82	2.51	12	4.79	3.89	0.97	0.3292	NS
SNP-L1(mm)	33	1.05	2.49	12	1.17	3.00	0.12	0.8919	NS
SNP-U6(mm)	33	-2.55	1.63	12	-1.58	1.96	0.96	0.1048	NS
SNP-L6(mm)	33	-0.30	1.93	12	0.08	3.16	0.39	0.6223	NS
SN-U1(mm)	33	0.29	2.00	12	0.33	1.17	0.05	0.9414	NS
SN-L1(mm)	33	3.73	2.73	12	3.50	1.37	-0.23	0.7849	NS
SN-U6(mm)	33	0.92	1.98	12	1.42	1.74	0.49	0.4509	NS
SN-L6(mm)	33	1.85	1.83	12	1.92	1.91	0.07	0.9134	NS
SN to U1 (°)	33	9.35	6.38	12	7.88	5.04	-1.47	0.4748	NS
SN to U6 (°)	33	-10.05	5.60	12	-9.33	4.13	0.71	0.6900	NS
ML to L1 (°)	33	2.77	5.01	12	0.42	3.00	-2.36	0.1354	NS
PP to Ops (°)	33	-3.30	3.03	12	-3.46	3.54	-0.16	0.8851	NS
ML to Opi (°)	33	-0.86	3.54	12	-0.42	1.68	0.45	0.6778	NS
OB (mm)	33	-4.14	2.03	12	-3.92	1.61	0.22	0.7372	NS
OJ (mm)	33	1.42	2.42	12	2.00	2.42	0.58	0.4848	NS


SN-U6 difference (degrees)
2.5
0
-2.5
-5
-7.5
-10
-12.5
-15
-17.5
-20
-22.5
0
20
40
60
80
100
Percentile
yes
no


SN-U6 difference (mm)
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6
5
4
3
2
1
0
-1
-2
-3
-4
0
20
40
60
80
100
Percentile
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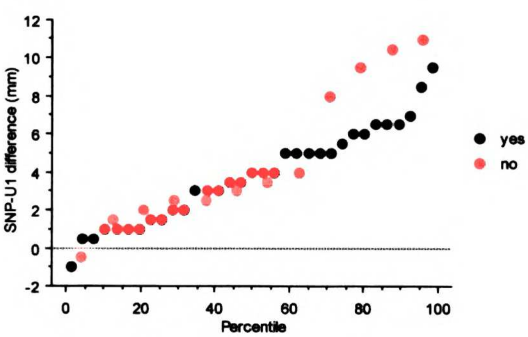
no


SNP-U1 difference (mm)
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8
6
4
2
0
-2
0
20
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80
100
Percentile
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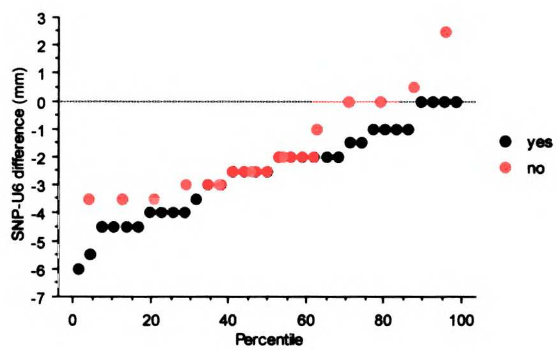
no


SNP-U6 difference (mm)
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2
1
0
-1
-2
-3
-4
-5
-6
-7
0
20
40
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80
100
Percentile
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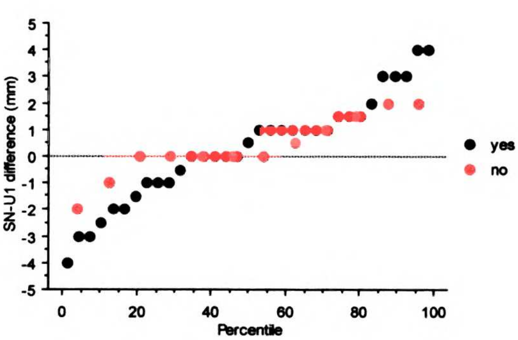
SN-U1 difference (mm)
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4
3
2
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-1
-2
-3
-4
-5
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100
Percentile
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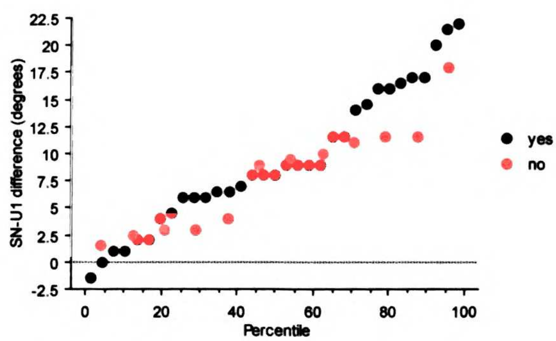
SN-U1 difference (degrees)
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20
17.5
15
12.5
10
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0
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40
60
80
100
Percentile
yes
no

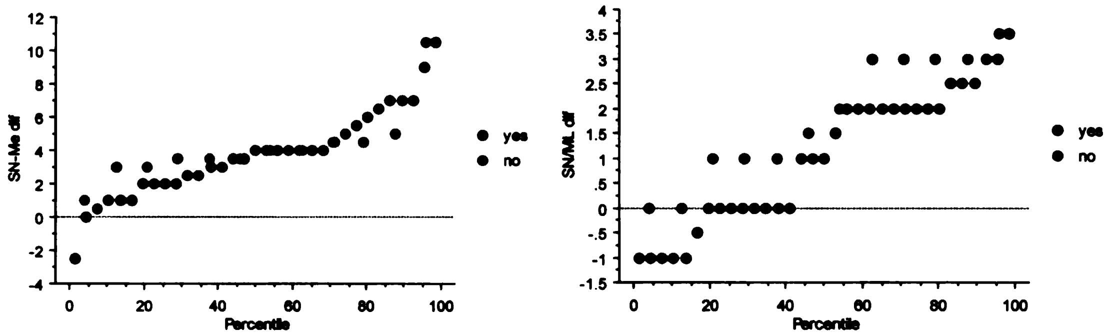


Figure 5. Percentile plots of dental and skeletal movements in the general superimposition
Red: group with the maxillary second molars not erupted into the arch
Blue: group with the maxillary second molars erupted into the arch

Analysis of maxillary dental changes

The mean differences in maxillary incisor and molar positions and angulation are presented in Table 9. The percentile distributions of the movements are plotted in Figure 6.

The maxillary first molars were distalized 2.8 ± 1.3mm and extruded 1.7 ± 1.2mm on average with distal tipping of 11.5 ± 4.9°. The molars distalized in all the subjects and distal tipping was seen in 44 out of 45 subjects. The upper incisor moved labially 3.3 ± 2.1mm and intruded 0.7 ± 1.5mm, in conjunction with some proclination of 8.2 ± 5.7° on average. The incisors moved labially in 41 subjects and proclined in 42 out of 45 subjects.

Table 9. Descriptive analysis of dental changes in the maxilla

Measurement	*N*	*Mean*	*SD*	*Maximum*	*Minimum*
H6	45	-2.80	1.30	-0.5	-5.5
H1	45	3.30	2.10	8.0	0.0
V6	45	-1.70	1.20	1.0	-4.0
V1	45	0.70	1.50	3.5	-2.5
Inc 6	45	-11.50	4.90	0.0	-20.0
Inc 1	45	8.20	5.70	19.5	0.0

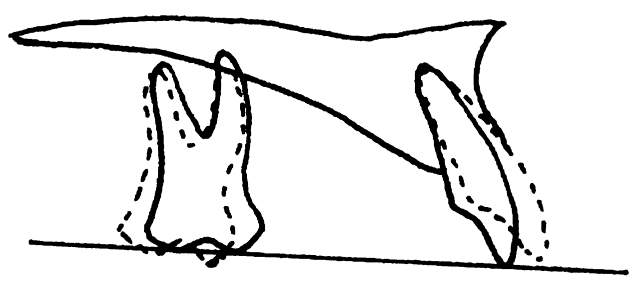


Figure 6. Diagram depicting the average movement of the maxillary dentition within the maxilla

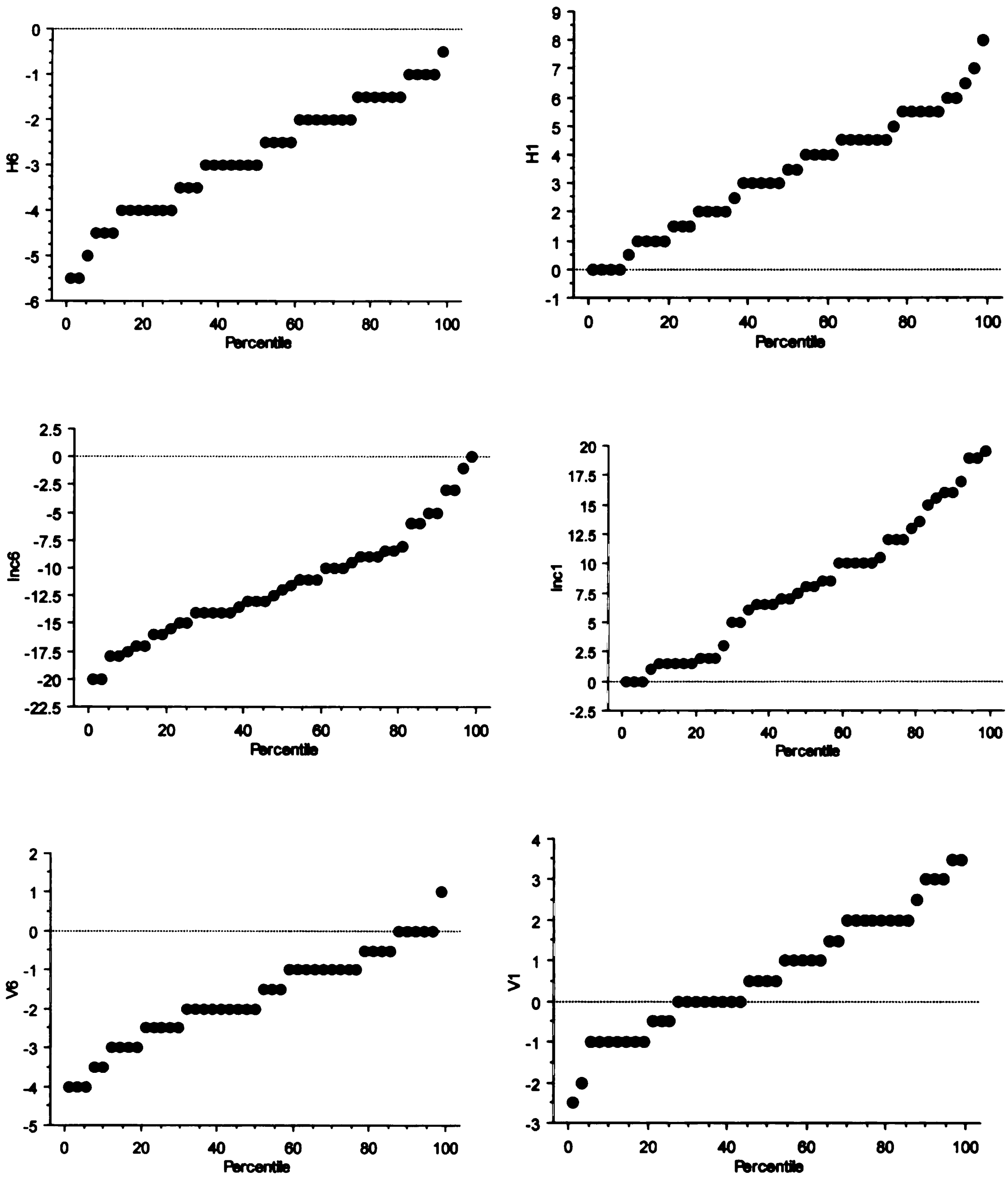


Figure 7. Percentile distribution of maxillary dental changes measured within the maxilla

Correlation between dental movements in the maxilla

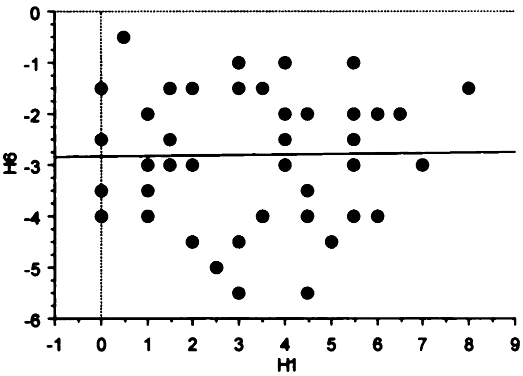
Most of the dental movements had weak or no correlation to each other. The strongest correlation was found between the inclination and horizontal change of the maxillary incisors at 0.766. There were also significant correlations between the vertical change of the maxillary incisor with its inclination change, and between the vertical and horizontal changes of the maxillary incisors. Of the maxillary first molar measurements, the only significant correlation was between the horizontal distance and the inclination change.

Table 10. Pearson's product moment correlation coefficient between maxillary dental measurements

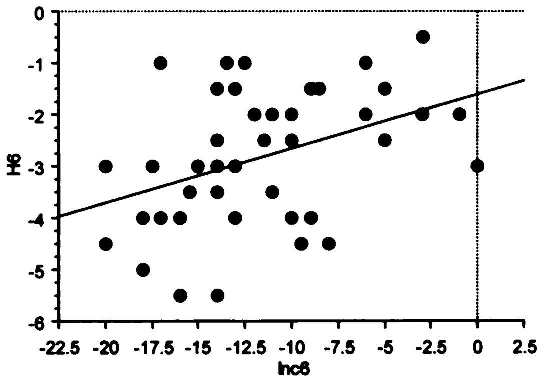
	H6	*H1*	*V6*	*V1*	*Inc 6*	*Inc 1*
H6	1.000	0.016	-0.071	0.001	0.400*	0.030
H1	0.016	1.000	-0.240	0.367*	-0.197	0.766*
V6	-0.071	-0.240	1.000	0.050	0.258	-0.156
V1	0.001	0.367*	0.050	1.000	0.051	0.495*
Inc 6	0.400*	-0.197	0.258	0.051	1.000	-0.157
Inc 1	0.030	0.766*	-0.156	0.495*	-0.157	1.000

- *P< 0.05*

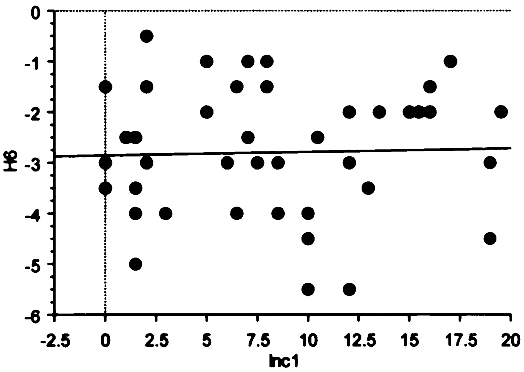
The coefficient of determination, R^2, which is used to determine the percentage of observed variability explained by the relationship, was quite small in most of the comparisons. The biggest coefficient of determination was between upper incisor inclination and horizontal distance change, at 0.587.



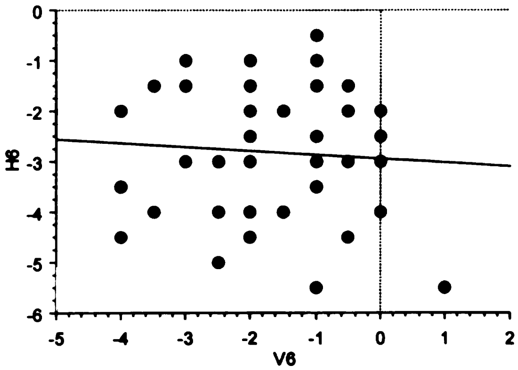
H6 = -2.843 + .01 * H1; R^2 = 2.409E-4



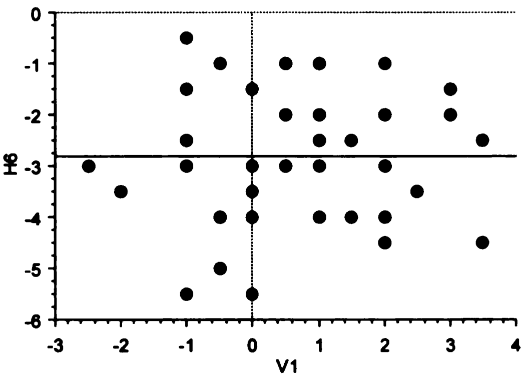
H6 = -1.594 + .106 * Inc6; R^2 = .16



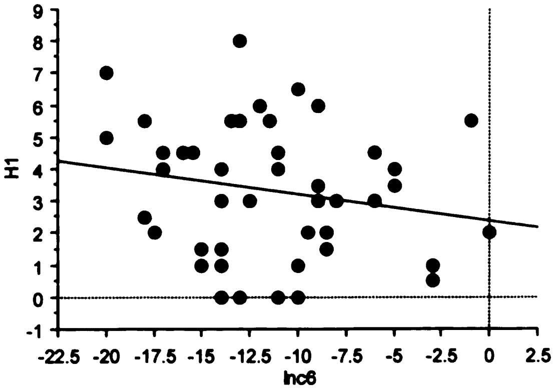
H6 = -2.867 + .007 * Inc1; R^2 = .001



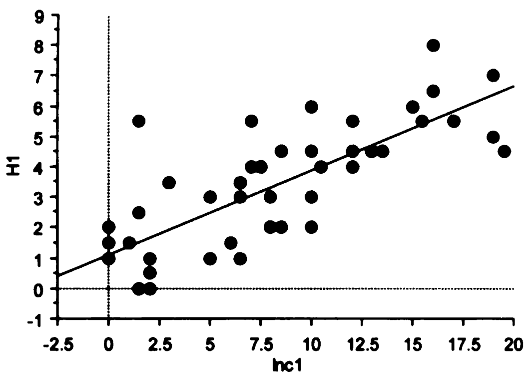
H6 = -2.938 - .075 * V6; R^2 = .005



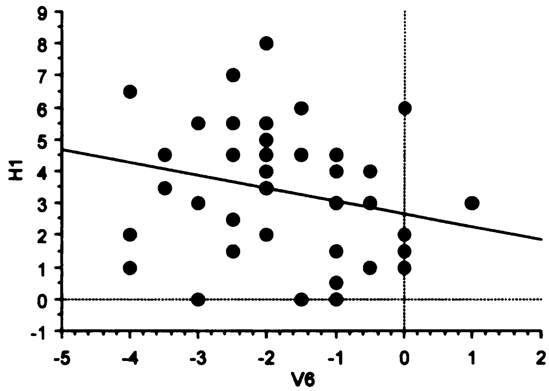
H6 = -2.811 + .001 * V1; R^2 = 3.553E-7



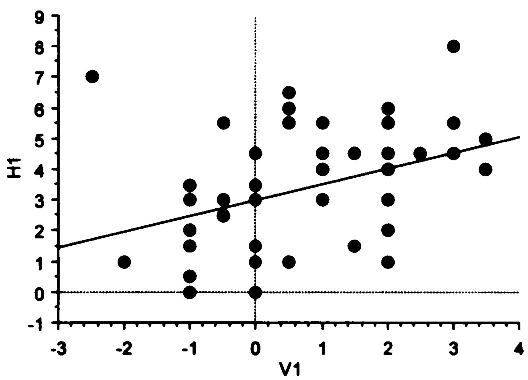
H1 = 2.381 - .084 * Inc6; R^2 = .039



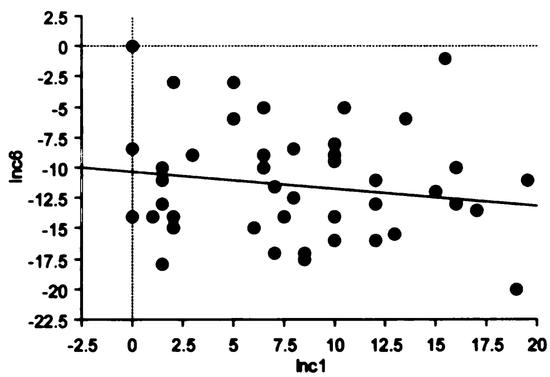
H1 = 1.076 + .278 * Inc1; R^2 = .587



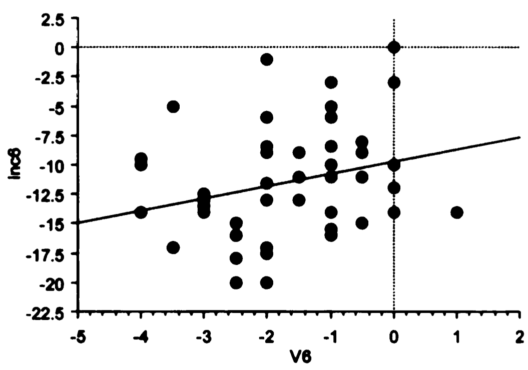
H1 = 2.656 - .408 * V6; R^2 = .058



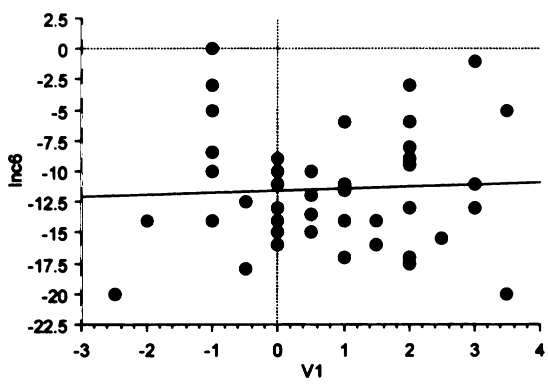
H1 = 2.985 + .514 * V1; R^2 = .135



Inc6 = -10.395 - .134 * Inc1; R^2 = .025



Inc6 = -9.743 + 1.034 * V6; R^2 = .067



Inc6 = -11.606 + .168 * V1; R^2 = .003

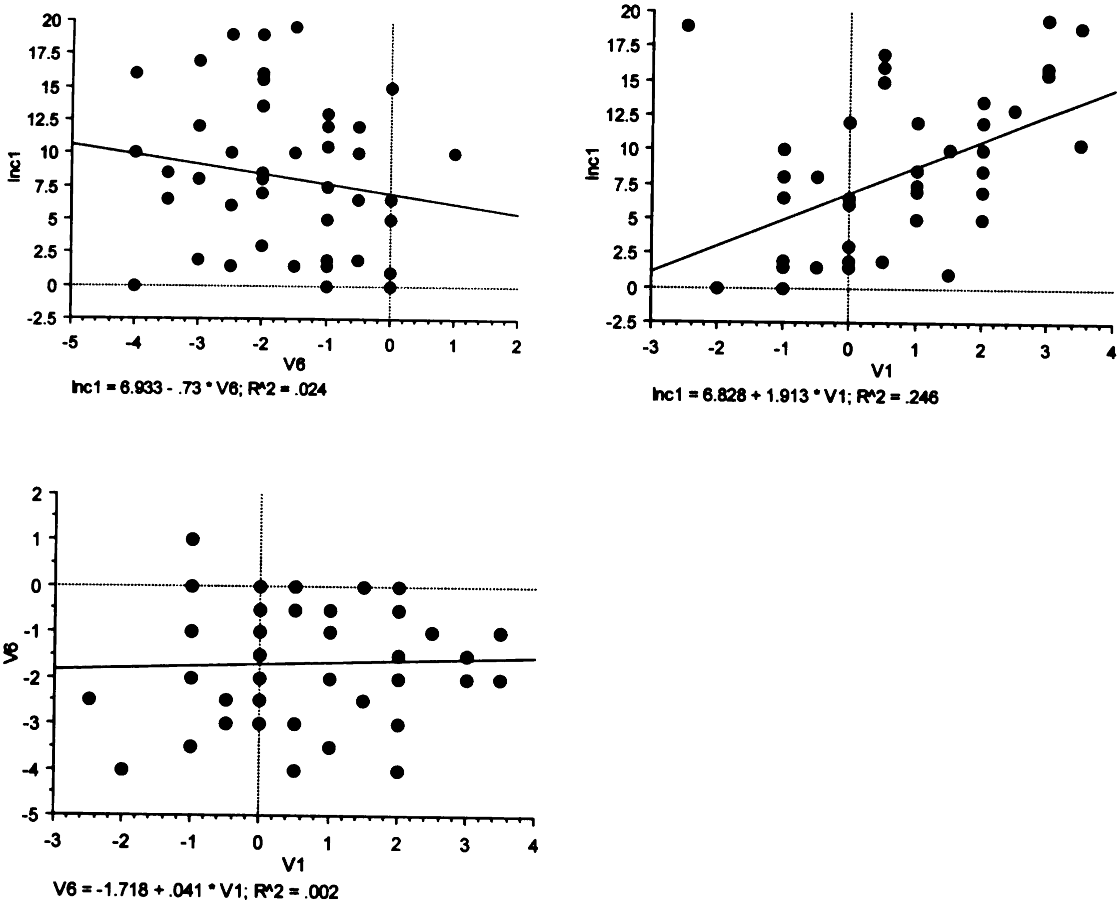


Figure 8. Regression plot of maxillary dental movements measured within the maxilla

Analysis of the effect of second molar on maxillary dental movements

The dental changes within the maxilla were compared between subjects who had the maxillary second molars erupted into the arch and those who did not. The only variable that was statistically different between the two groups was the maxillary incisor inclination. The maxillary incisor inclination change was greater in the subjects with the maxillary second molars erupted into the arch by 4.15° than those without.

Table 11. Differences in maxillary dental changes between subjects with maxillary second molar eruption versus non-eruption

		7's			*No 7's*		*Difference*		
Measurement	*N*	*Mean*	*SD*	*N*	*Mean*	*SD*	*7's- No 7's*	*P*	
H6	33	-2.92	1.31	12	-2.50	1.23	-0.42	0.335	*NS*
H1	33	3.62	1.96	12	2.58	2.27	1.04	0.139	*NS*
V6	33	-1.74	1.21	12	-1.63	1.21	0.12	0.774	*NS*
V1	33	0.89	1.59	12	0.08	1.02	-0.81	0.107	*NS*
Inc 6	33	-11.30	5.32	12	-12.00	3.47	0.70	0.676	*NS*
Inc 1	33	9.27	5.84	12	5.13	4.18	4.15	0.029	*S*

A. Pre-treatment Cephalogram

B. Post-Cetlin appliance Cephalogram

C. Pre-treatment intra-oral photographs

D. Post-Cetlin appliance intra-oral photographs

Figure 9. Example of modified Cetlin appliance treatment result (Courtesy of Dr. Nelson)

DISCUSSION

One of the major difficulties in treating patients with a Class II molar relationship is the need for distalization of the maxillary molars into a Class I relationship. Several studies have been done to evaluate the effects of appliances used in molar distalization including headgears, pendulum appliance, Wilson arch, distal jet, Jones jig, magnets and others.

The current clinical study examines 45 patients with mild Class II malocclusion treated with the modified Cetlin appliance. The age of the subjects ranged between 11 and 15.52 years, with no statistically significant difference between genders or the eruptive stages of the maxillary second molars. The range in the treatment time was large, between 2 and 21 months. However, since the treatment is continued until a desired molar relationship is achieved, treatment time should not be a critical variable. Also, there was no statistically significant correlation found between treatment time and the dental movements within the maxilla (Table 12). It could be speculated that treatment would take longer in patients who are older. However, statistical analysis showed that there was no significant correlation between age and treatment time in this sample (r=0.1).

Table 12. Pearson's correlation coefficient between Cetlin appliance treatment time and maxillary dental movements within the maxilla

	H6	*H1*	*V6*	*V1*	*Inc 6*	*Inc 1*
.*Treatment time*	0.117	0.087	-0.009	0.160	-0.116	-0.021

Movement of the maxillary first molars- hypothesis 1

In the general cephalometric analysis, the maxillary first molars were distalized 2.29mm and tipped distally 9.86° on average. They also dropped inferiorly by 1.06mm. In the Cetlin study by Ferro,[26] the maxillary first molars were noted to have been distalized an average of 2.20mm, a similar amount as the current study. In our sample, 37 subjects had distal movement of the maxillary first molar, whereas 6 had no change and 2 had mesial movement (Fig 4). The mesial movement or lack of movement of the maxillary molars is counter-intuitive when the Cetlin appliance was used to distalize the molars. However, since these measurements were taken from a reference line created to the stable structures of the anterior cranial base, the movements would be an additive measurement of the skeletal and dental movements. The maxilla moves downward and forward with normal growth, carrying the maxillary dentition with it. If the maxillary movement is subtracted from the maxillary molar movement seen in this study, the absolute distal movement of the maxillary first molars would be greater. The dental movements within the maxillary skeletal base will be discussed later.

The amount of distalization achieved with the Cetlin plate as well as other appliances is variable. However, the absolute distance that the molars distalized is not a critical factor since the treatment was carried out until the desired molar position was achieved. Also, the superimposition methods and the reference lines that were used are different between studies, making relative comparisons between studies difficult.

In the general cephalometric analysis, 43 out 45 subjects showed distal tipping of the maxillary first molars, ranging from -1.5 to -22°. Since the line of delivery of the distalizing force was not through the center of resistance of the maxillary first molars, some degree of distal tipping was expected. However, this is a somewhat larger percentage compared to the result in the Ferro study, where he found distal tipping in 70% of the subjects. The difference could be explained by the fact that headgears that would have helped to upright the molars had not been incorporated at the time the progress lateral cephalograms were taken in this study.

The stability of the distally tipped molars is questionable, especially when they are used as anchorage to retract the anterior teeth. The molar position is usually retained after distalization with a headgear, while the premolars are allowed to drift distally under the influence of the transseptal fibers. The use of the headgear to upright the molars may help in preparing the posterior anchor unit better for retraction of anterior teeth later in treatment and also in retaining the space gained through distalization of the molars. It would be valuable to study the patients after the stabilization period with the headgear in order to isolate the effect of the Cetlin plate from the headgear effect, and also evaluate the spontaneous change in the inclination of the maxillary first molars and incisors.

The maxillary first molars moved inferiorly by a significant amount. This could be due to the posterior disclusion that the anterior bite plate provided. Although there was only approximately 1mm of inferior displacement of the maxillary molars, this would have had a significant bite opening effect anteriorly. The extrusion of the molars also contributed to a significant flattening of the upper occlusal plane in relation to the palatal plane. Siatkowski[64] states that correction of Class II molar relationship by steepening the occlusal plane will not be stable.

In a headgear study, Worms[23] found that the upper first molars moved mesially and occlusally in subjects without treatment. The crown moved more mesially than the apex while the tooth erupted and the direction of the movement was always constant although the rate was not. Bjork[5,7,9] also found that the maxillary dentition is displaced forward and downward in relation to the maxillary corpus and the cranial base, increasing in prognathism. However, the amount of molar forward movement was approximately twice as great as the incisor movement on average, contributing to dental crowding. In growth studies by Ricketts,[10] the maxillary dental arch was found to erupt down and forward by about 0.2 mm to 0.3 mm per year. In comparison with these studies, it can be concluded that the distal movement of the maxillary molars that were achieved in this study are effects of the Cetlin appliance. The amount of eruption of the maxillary first molars that was found in this study may was more than the amount found by Ricketts. However, the occlusal movement of the maxillary molars was in the direction of normal tooth eruption. The amount of maxillary molar eruption shown in this study would have been a combination of the normal eruptive movement of the maxillary first molars and idiopathic eruption from the disclusion caused by the anterior bite plane.

When the maxillae are superimposed within the stable maxillary structures, it is possible to assess the dental movements that occur within the maxilla, without the influence of growth and treatment effects on the skeletal base.

Within the maxilla, the maxillary first molars distalized 2.8 mm and extruded 1.7mm, with 11.5° of distal tipping. When compared to the dental changes found in the general superimpositions, the numbers are relatively close. However, it should be noticed that the amount of molar distalization, extrusion and distal tipping is greater when the movements are assessed within the maxilla. Also, whereas there were 8 subjects who had no distalization of the maxillary first molars when viewed from the general superimposition, all 45 subjects showed distalization of the maxillary first molars in the maxillary superimposition. This shows that the true dental movements that occurred with treatment were masked by the effects of the treatment on the skeletal base, such as rotation, and by natural growth, which is in the forward and downward direction.

Movement of the maxillary incisors – hypothesis 2

Although ideally the maxillary incisors should not move, the distalizing force of the Cetlin appliance has a reciprocal action on the anchor unit, the maxillary premolars and incisors. The maxillary incisors proclined statistically significantly by 8.91°, and the incisal edge moved labially by 4.08mm in the general cephalometric analysis. Within the maxilla, the upper incisors moved labially by 3.3mm, intruded 0.7mm and proclined 8.2°. Again, the normal growth of the maxilla accounts for the slight differences between the measurements in the general cephalometric analysis and maxillary analysis. However, over 90% of the subjects had labial movement with proclination in both analyses, which is greater than the 81% found in the study by Ferro. The amount of "anchorage loss" is also greater than the amount found in the Ferro study, 0.72mm labial displacement and 4.78° of labial tipping of the maxillary incisors.[26] However, the Cetlin plate design that was used in this study did not have acrylic capping on the labial surface of the maxillary incisors and no elastics were used on the labial surface of the maxillary incisors to prevent labial displacement. These differences in design could have contributed to the larger degree of incisor movement. The lack of headgear use in this study, which could have influenced the maxillary incisors as well as the maxillary skeletal base, could also explain the greater degree of incisor labial movements.

In order to correct or reverse the forward movement of the maxillary incisors, subsequent orthodontic mechanics with Class II elastics is recommended.[15,54] In a recent study by Bondemark,[48] it was shown that forward movement of the maxillary incisors associated with distal movement was totally reversed and eliminated by inter-maxillary Class II elastics. Concurrent use of headgear or Class II elastics may reduce the amount of incisor movement seen with the use of the Cetlin appliance alone. On the other hand, in subjects with retroclined upper incisors, with a Class II division 1 malocclusion, the reciprocal effect of forces can be utilized for proclination of the incisors.

Change in the mandibular dentition

The lower dentition was treated with full fixed appliances in conjunction with the upper Cetlin appliance. There was a mild degree of crowding in both the maxillary and mandibular arches at the outset in most of the patients. There was a statistically significant labial movement of the mandibular incisors of 1.08mm with labial tipping of 2.14°. This would be expected with the leveling and aligning of the lower dentition. The mandibular incisors and first molars moved significantly inferiorly by 3.67 and 1.87mm, respectively. This inferior movement could be explained by the growth direction of the mandible that was seen during treatment. It was noted that the mandible moved downward with a significant amount of counter-clockwise rotation, which would increase the vertical distance of mandibular incisors from the anterior cranial base more than the mandibular molars.

From the combination of the maxillary and mandibular incisor movements, there was a significant increase in the overjet by 1.58mm and a decrease in the overbite by 4.08mm.

Skeletal movement – hypothesis 3

With the Cetlin appliance, an increase of 0.48° in the sagittal jaw relationship was noted, although it was a clinically insignificant amount. The maxillary linear measurements increased in the vertical and horizontal planes. The maxilla came forward by 0.86mm and positioned inferiorly by 0.79mm. These increases could be attributed to the normal growth of the maxilla, which is in the downward and forward direction.[4,6,7] Since there was no restriction in the maxillary growth, normal direction of growth was expected. However, the horizontal position of the A point could have been influenced by the labial tipping of the maxillary incisors.

There was an increase in the vertical distance from the cranial base to the mandible by 3.84mm, and an opening of the mandibular plane by 1.24°, indicating counter-clockwise rotation of the mandible. This is also in accordance with the decrease in the sagittal mandibular measurements.

Riolo[63] has shown that the sagittal jaw discrepancy between the maxilla and mandible stay nearly constant or decreases slightly over time in normal growth. The increase that is seen in this study could be attributed to the opening of the mandibular plane, secondary to the inferior positioning of the maxillary first molars. However, the increase in the vertical distance from SN to the mandible would have some normal growth contributing to it, since the patients in the sample were at an actively growing age. Harvold and Ricketts[10,14] stated that the mandible grows an average of 2.5mm per year in children.

Either from the extrusion of the maxillary first molars or from the growth pattern of the subjects, there was a significant increase in the mandibular plane angle and anterior facial height in this study[3,10,14]. The mandible moves downward with normal growth, with concomitant increase in the anterior face height[3,13]. Bjork[12] found that the mandible rotates counter-clockwise if the amount of molar eruption is greater than the amount of condylar growth. In this study, the maxillary molars were shown to erupt slightly more than the average amount of 0.2 – 0.3mm stated by Ricketts and this could have caused the counter-clockwise rotation seen in the results. Whereas Ferro[26] found that some backward rotation of the mandible took place with the Cetlin treatment, Ngantung[40] found no significant increase in either the mandibular plane or anterior facial height with the distal jet. With the pendulum appliance, Bussick and McNamara[30] found a significant increase in the mandibular plane angle and lower anterior height in relation to the Frankfort horizontal plane. Ghosh and Nanda[33] found only insignificant changes with the pendulum appliance. With these contrasting results, it can be assumed that the design of the appliances and the method of activation would play an important role in the amount of bite opening. More extrusion and hence more increase in mandibular plane angle and anterior face height would be expected with the Cetlin appliance, since the maxillary first molars are brought out of occlusion with the appliance design. On the other hand, appliances such as the pendulum could be activated to distalize the maxillary first molars and also incorporate an intrusive vector to the springs. When using the Cetlin appliance, clinicians should be cautious to use it in patients who can tolerate some bite opening.

Correlation between movements of the maxillary first molars and incisors – hypothesis 4

Statistical analysis was performed to evaluate the correlation between the dental movements within the maxilla. The strongest correlation was found between the labial tipping and labial movement of the maxillary incisors at r= 0.766. A moderate correlation was found between the labial inclination and the vertical positioning of the maxillary incisors (r= 0.495) and between the vertical and horizontal movement of the maxillary incisors (r= 0.367). A significant correlation was found between the amount of distalization and distal tipping of the maxillary first molars (r= 0.4). This is similar to the findings of Muse,[15] where the tipping of the maxillary first molar (-7.8 degrees) correlated with the distance the maxillary first molar moved distally (r= 0.647). Ghosh and Nanda[33] also found a modest significant correlation between the amount of distalization and the amount of first molar tipping (r= 0.488).

Although there were some significant correlations within the incisor movements and within the first molar movements, the extent to which the variability in the movements can be explained by the relationships was not so great. A clinically useful r^2 should be over 0.5. The relationship between the labial tipping and labial movement of the maxillary incisors had an r^2 value of 0.587. There was no significant correlation found between the maxillary incisors and maxillary first molars, indicating that the amount of anchorage loss will not necessarily be correlated to the amount of molar distalization.

The effect of the eruption of the maxillary second molars – hypothesis 5

There were no measurements that were significantly different between the subjects that had maxillary second molars erupted into the arch and those who did not in the general cephalometric analysis. This is in accord with the findings of Ghosh and Nanda,[33] Fortini,[47] and Muse.[15] Bussick had found no significant difference in the dentoalveolar measurements in patients with second molars erupted into the arch. However, they did note that the presence of upper second molars was associated with significant increases in mandibular plane angle and lower anterior facial height.

Although not statistically significant, there was a tendency for greater increase in mandibular plane angle and anterior face height in subjects who did not have the maxillary second molars erupted into the arch. The maxillary incisors had proclined more but moved less labially in subjects with erupted maxillary second molars. However, when the maxillary dental movements were evaluated within the maxilla, the maxillary incisors proclined significantly more by 4.15° in the subjects with the maxillary second molars erupted in the arch. The maxillary first molars distalized more and tipped more distally, but extruded less in subjects with erupted maxillary second molars. The increase in mandibular plane angle and anterior face height could be explained by the greater amount of maxillary first molar extrusion in the group without the maxillary second molars in the arch.

The findings above do not give an intuitive picture of the changes that occurred in subjects in different dental stages. When divided into two groups, the number of subjects in each group may not have been enough to give a powerful analysis of the differences in the dental and skeletal changes. The inconclusive findings also demonstrate how individual responses can vary widely with the same treatment. Contrary to the beliefs of some clinicians[30,31,52,53] who believe that distalization of maxillary first molars is dependent on the stage of eruption of the maxillary second molars and that maxillary first molar distalization should be accomplished before the second molars are erupted, it can be concluded from this study that the eruptive stages of the maxillary second molars does not

CONCLUSION

Hypothesis 1: There is no movement of the maxillary first molars with the use of the Cetlin appliance.

- This null hypothesis is rejected. The maxillary first molars distalized 2.29mm, erupted 1.06mm and tipped distally by 9.86° in general. The Cetlin appliance can effectively distalize molars, although bodily movement was not achieved in this study.

Hypothesis 2: There is no movement of the maxillary incisors with the use of the Cetlin appliance.

- This null hypothesis is rejected. An adverse effect of the molar distalization was movement of the anchor unit, the maxillary incisors, in the opposite direction. The maxillary incisors moved labially 4.08mm and tipped labially 8.96° in general while the maxillary first molars were distalized with the Cetlin appliance. It may be useful to use headgears or Class II elastics concomitantly to prevent excessive amounts of adverse incisor movements.

Hypothesis 3: There is no opening of the mandibular plane angle with the use of the Cetlin appliance.

- This null hypothesis is rejected. A statistically significant amount of mandibular plane opening was noted with the use of the Cetlin appliance. The mandibular plane opened 1.24° relative to SN on average and the anterior facial height increased by 3.8mm. These increases could be the result of normal growth as well as the eruption of the maxillary first molars. Although the degree of opening is not clinically significant, it would be prudent to avoid using the Cetlin appliance on patients with an open bite tendency.

Hypothesis 4: There is no correlation between the movements of the maxillary first molars and incisors.

- This null hypothesis cannot be rejected. No significant correlations were found between the movements of the maxillary incisor and first molars that occurred with the Cetlin appliance. Hence, no prediction can be made regarding the amount of movement of one unit, either the incisors or the first molars, based on the other. However, there were significant correlations between the movements within the incisors and within the molars.

Hypothesis 5: The presence of the maxillary second molars in the arch does not have any effect on the dental and skeletal changes.

- In general, the presence of the maxillary second molars erupted in the arch did not have any significant effect on the dental and skeletal movements of the Cetlin appliance. However, the maxillary incisors proclined significantly more in the subjects with the maxillary second molars erupted when the dental movements were measured within the maxilla.

In conclusion, the Cetlin appliance is an effective method of distalizing the maxillary first molars regardless of the presence of the maxillary second molars. However, the maxillary first molars show extensive distal tipping which needs to be corrected while maintaining the position of the crowns. Also, the proclination and labial movement of the maxillary incisors need to be addressed during subsequent treatment with full fixed appliances without protracting the first molars that have been distalized. Unlike the pendulum appliance where the maxillary premolars are used as anterior anchorage against the distal movement of the molars, the premolars were retracted spontaneously during first molar distalization with the Cetlin appliance. The lack of need to retract premolars as well as the anterior teeth puts less protraction force on the molars that have been distalized. Although the amount of mandibular plane opening was not clinically significant, it would be prudent to avoid using the Cetlin appliance in patients where increase in the vertical dimension is undesirable. Further investigation is needed to evaluate the dental movements such as relapse of molar distalization and relapse of maxillary incisors during the molar uprighting stage with headgear use and the subsequent full fixed appliances stages.

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