A COMPUTER AIDED INVESTIGATION OF THE CEPHALOMETRIC CHANGES RESULTING FROM KLOEHN CERVICAL HEADGEAR

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ABSTRACT

The purpose of this retrospective study was to examine the effects of Kloehn cervical headgear therapy. A group of Class II patients who were successfully treated nonextraction was drawn from the treatment files at the OHSU Graduate Orthodontic Clinic. A group of untreated Class II individuals was drawn from the Oregon Child Development Study. By closely matching the individuals for sex, age, time of observation, and Class II malocclusion it was hoped an increased understanding of the effects of Kloehn headgear could be gained.

Pretreatment and posttreatment cephalometric radiographs were digitized and various measurements were evaluated using Quick Ceph Image.™ The experimental and control groups exhibited very similar skeletal and dental malocclusions at the time of the initial radiograph. Both groups were then observed for equal periods of time. The differences between the groups at posttreatment was assumed to be the result of cervical anchorage combined with full orthodontic therapy.

The results of this investigation indicate that:

1.Kloehn cervical headgear coupled with full orthodontic treatment exerts a profound effect on maxillary protrusion, limiting the forward growth of both the maxilla and the maxillary dentition. This effect tends to improve the Class II skeletal and molar relationship, and the overjet. This does not occur in untreated subjects.

2.The untoward vertical side effects of cervical traction were smaller in this study than previously demonstrated. There was an insignificant tendency for increased growth in all the vertical linear measurements. It is possible that comprehensive orthodontic treatment may have decreased the eruption of the maxillary first molar and the subsequent vertical side effects of cervical traction. It is also possible that the use of a Class II control more accurately evaluates the vertical differences between the treated and untreated subjects.

3.An unfavorable effect on the horizontal position of the mandible and pogonion following cervical headgear treatment was not demonstrated in this study. Perhaps the use of a Class II control more accurately evaluates the possible projection of the mandible.

4.A small but statistically significant increase in mandibular plane was detected in this study. However, one degree of mandibular plane rotation may not be clinically relevant.

5.The use of Kloehn headgear proved effective in correcting the Class II molar relationship for the patients evaluated in this study. However, the experimental patients were selected on the basis of successful treatment. For this group of treated patients, the vertical side effects of cervical traction was small and little change in expected mandibular growth was detected. Both of these previously discussed side effects of cervical traction were probably not clinically significant. These results indicate that cervical traction can be an effective appliance for the correction of Class II malocclusions.

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Introduction

Individuals with an Angle Class II malocclusion comprise a significant percentage of the patients seeking orthodontic therapy. Treatment of both dental and skeletal Class II has consumed a great deal of clinical effort dating back at least as far as Kingsley in the late 1800's.[1] He was amongst the first to utilize extraoral traction in an attempt to correct these anteroposterior malocclusions. Many orthodontists continue to employ extraoral anchorage therapy in an attempt to modify the downward and forward growth of the maxilla and maxillary dentition. One of the most frequently used extraoral traction devices is the cervical headgear to a facebow attached to maxillary molars which was reintroduced to the orthodontic profession by Kloehn in 1953.[2]

Kloehn headgear therapy proved effective for correction of Class II malocclusion and shortly after its introduction, the use of cervical anchorage in orthodontic treatment became widespread. As its clinical utilization increased, researchers began to examine the effects of the Kloehn appliance system on the growth and development of the maxilla and dentoalveolar process. However, investigations of treatment and side effects of force systems have proven difficult in this and other areas of orthodontic therapy.[3] The most significant problem with clinical orthodontic research is, that out of necessity, it generally involves individual patients who present for treatment. This makes finding a well matched sample very difficult. The great variation between patients regarding initial malocclusion, treatment timing, individual growth and compliance are but a few of the many complicating factors surrounding clinical research.[4] Many previous experimental studies have even included both extraction and nonextraction cases in the same sample. The extraction cases will require space closure and likely some forward movement of the maxillary first molar. By including extraction and nonextraction cases in the same group the actual effect of Kloehn traction on the maxillary first molar may be misunderstood.

The second major problem of clinical research is that it involves a long term orthodontic treatment process. During the two or more years that a patient is undergoing therapy, decisions are made every appointment which subtly alter the original treatment plan. Different mechanical approaches to the headgear application and whether it is used alone or in conjunction with comprehensive edgewise therapy further complicate the clinical research. Variations in the use of auxiliaries including biteplanes and elastics also present difficulties. These factors combine to ensure that a truly well matched treatment group is almost impossible to find.

Since growth modification is the objective of extraoral anchorage therapy, it is necessary to compare the results of treatment with the growth of an untreated control group. While locating a well matched group of treated patients is difficult, finding a group of untreated patients to act as a control is even more difficult. The treated patients begin with a Class II malocclusion indicating that some degree of dysplasia is present. The use of Class II subjects with a similar skeletal and dental dysplasia as a control would allow for stronger conclusions.[4] However, longitudinal records of the growth and development of individuals with a Class II malocclusion are not common. One way to gather such a group would be to delay orthodontic treatment of Class II individuals presenting for therapy until the end of their active growth period. However, since some growth modification is often used during treatment, this would limit their potential treatment outcome. Therefore the only access to the records of Class II growth must be found in the few organized growth studies that were carried out earlier in the 20th century.

The difficulty in gathering both uniformly treated patients and well matched Class II control subjects is apparent during an examination of the literature describing the effects of Kloehn headgear.[4] Because of these problems, the experimental groups are often small and untreated Class I individuals are often used as the control. Nevertheless, numerous clinical studies of Kloehn headgear have been conducted and their results published in the orthodontic literature. Despite the volume of clinical research published, differences related to experimental design and treatment mechanics persist and tend to obscure a thorough understanding of the effects of Kloehn cervical anchorage. Thus it was perceived that if some of the previous obstacles to clinical research could be overcome, further research evaluating the effects of Kloehn anchorage would be warranted.

The Oregon Child Development Study located at the Oregon Health Sciences University contains a group of almost thirty untreated individuals with a Class II malocclusion who have been serially examined over several years. Orthodontic records including models and cephalometric radiographs were taken annually from early childhood until late adolescence or adulthood on many of these subjects. These records could provide a suitable control group with which to compare the effects of Kloehn cervical therapy for the correction of a Class II malocclusion.

The treatment records at the Oregon Health Sciences University Department of Orthodontics Graduate Clinic contains a group of Class II patients treated primarily with cervical headgear in conjunction with comprehensive edgewise therapy. Several of these patients were treated without extractions during their active growth period. The records of these former patients could comprise an experimental sample for evaluation of the effects of Kloehn headgear on the growth and development of the maxilla. The purpose of this study is to compare the treatment results and effects of a group of Class II patients undergoing Kloehn cervical headgear therapy with a well matched group of Class II untreated patients.

Literature Review

In 1947, Kloehn[5] presented two major tenets that formed the basis for the introduction of cervical traction therapy. First, Kloehn reiterated that teeth placed in correct functioning relationships did not result in increased bone growth as had been proposed by Angle. The placement of orthodontic appliances under the pretense of stimulating growth of the mandible was demonstrated as incorrect. Kloehn then restated the results of the initial cephalometric studies by Broadbent and Brodie demonstrating the constancy in pattern of facial development regardless of growth or orthodontic therapy. The realization of the orthodontic profession of these tenets led many practitioners to discontinue mixed dentition treatment. This resulted in the initiation of extraction therapy as the primary solution for many malocclusions. Kloehn suggested that bicuspid extraction does not change the underlying skeletal relationship but rather changes the relationship of the teeth to the skeletal bases. He proposed stopping the forward growth of the maxillary teeth and alveolar process with a headcap appliance until the forward growth of the mandible yielded a normal relationship of the teeth. Kloehn demonstrated the potential for headcap treatment with several case reports of successful correction of Class II malocclusion utilizing it rather than extraction therapy.

By 1953, Kloehn[2] promoted the philosophy that Class II malocclusion was largely hereditary in origin and that the jaw malrelation had a direct inhibitory effect on normal mandibular development. His treatment goal was to restore the normal relationship between the maxilla and mandible. He thought this would promote improved growth. Treatment was started early, during the mixed dentition, and the appliance was directed at those teeth that were in an abnormal position without disturbing those in good position. The face bow and cervical strap appliance was described as the mechanism for slowing the growth of the maxilla and the maxillary teeth. The mandible and mandibular dentition were allowed to continue their normal forward growth which eventually resulted in balance between the two jaws. The appliance was to be worn during the evening and while sleeping, ten to twelve hours per night. Relative to a headcap which attatched to the archwire and tended to cause undesirable distal tipping of the molar, the face bow, because it inserted into molar tubes, had the advantage of permitting better control of the axial inclinations of the applied force. Combination of the headgear and the archwire also helped control axial inclinations. Kloehn bent the face bow downward if distal crown tipping was desired, but when distal root movement was required the outer bow was bent above the archwire. In combination with the cervical strap and face bow, a bite plane was often used to help unlock the occlusion and stimulate vertical growth to decrease overbite and permit maximum mandibular growth. Kloehn again displayed several successful case results which demonstrated the potential for Class II correction using an extraoral appliance designed for guiding growth toward a more normal relationship.

Following the reintroduction of extraoral traction to the orthodontic specialty, its use became widespread and it was advocated for the correction of many malocclusions. The earliest research into the effects of cervical headgear therapy involved comparisons of cephalometric radiographs taken before and after treatment. No control group was used. Graber,[6] in 1955, was one of the first to comment on the limitations of cervical headgear and to delineate its most effective use. A sample of 100 Class II, Division 1 cases, ranging in age from 3 to 19 years, with acceptable lower arches was treated with extraoral traction. A cervical headgear was attached via continuous loops at the canines to a .045" stainless steel labial arch wire with vertical spring loops at the molar bands. Bite plates were used in some cases as was elastic traction when necessary. Examining the results with the use of cephalometric radiographs, Graber concluded that marked improvements in basal relationships could be obtained with the use of extraoral force, but he also found excessive distal tipping of maxillary first molar crowns, and difficulty in controlling excessive overbite. He commented that growth is the primary factor in the correction and demonstrated that results were superior in the group treated during their pubertal growth spurt. Graber held there was no evidence that maxillary growth was affected, but rather perceived that it was only maxillary alveolar growth that was influenced.

King[7] (1957) was also amongst the first to use superimposed cephalometric radiographs taken before and after treatment to examine the results of extraoral anchorage. Fifty Class II, Division 1 patients in the late mixed or permanent dentition, ranging in age from 9 year, 5 months to 18 years, 9 months were studied. Treatment with full or partial edgewise appliances was carried out in conjunction with the cervical anchorage but neither the exact mechanics of the attachment nor the use of biteplane were specified. Nearly half the cases also involved the extraction of four bicuspids. King concluded that extraoral anchorage does restrict the forward growth of the first molar and maxillary denture area relative to the forward growth of the face. Further, he felt that tipping of the maxillary first molar was controlled because edgewise appliances were in place. However, King reported that vertical growth exceeded forward growth in his sample. While the changes in both the occlusal and mandibular plane angles were small and not significant, King did note that the cases which exhibited the most vertical growth had the poorest response at pogonion. He also summarized that in general the treatment response with respect to forward growth at pogonion was disappointing.

Using a similar study design, Klein[8] (1957) evaluated cervical traction as proposed by Kloehn on a consecutive sample of 24 successfully treated Class II, Division 1 cases. The average age at the start of treatment was 8 years, 6 months. The facebow in this study was extended to a point anterior to the ear and bite planes were used in some instances. Klein concluded that distal movement of the maxillary first molar was possible and that tipping could be controlled by the force exerted by the facebow. Also noted was a vertical displacement of the upper first molar averaging 2.3 mm, however this was found to be correlated with the vertical growth of the mandible, the thought being that the growth of the mandible allowed the maxillary first molar to erupt. The occlusal plane was found to be stable, exhibiting little change on average. Relative to the Bolton plane the Y axis was found to increase on average 1 degree over the course of treatment. Facial convexity decreased by an average of 2.8 degrees, however in some cases the chin appeared to be less prominent. Finally, SNA decreased an average of 1.3 degrees and the palatal plane demonstrated a tendency to rotate clockwise, 1.75 degrees on average, causing Klein to conclude that the growth of the maxilla had been altered. In agreement with King,[7] Klein described some cases in which excess unfavorable mandibular rotation occurred and speculated that the headgear may have the unfavorable effect of increasing the mandibular plane angle. He called for a serial investigation of untreated Class II cases to help determine the patterns of growth in Class II cases.

Blueher,[9] in 1959, also compared before and after cephalometric radiographs in his study of thirty four Class II, Division 1 or Class II tendency cases. An early treatment group of 12 children, average age 10 years, started with the cervical headgear alone followed by full treatment after the eruption of permanent teeth while an older group of 22 children, average age 13 years, was treated with simultaneous neck strap and edgewise appliance. Neither the mechanics of the face bow nor the use of biteplanes was specified. Blueher found that forward growth of the maxillary anterior alveolar process was restricted as evidenced by decreases in both the SNA and linear distance SA along the Frankfurt plane. The palatal plane angle increased in 25 out of 34 cases; only 6 out of 34 cases exhibited a decrease. The mandibular findings were variable as SNB and SNPo remained constant in some patients, increased in some and decreased in others. An almost universal decrease in the angle of convexity averaging almost 5 degrees was observed. The bite opening tendency of the cervical appliance was again noted as the angle NSGn increased in two thirds of the patients but the mandibular plane angle showed more variable change, increasing in some while decreasing in an equal number of others. Blueher commented that wide variation in both growth and treatment response prohibit prediction of individual reaction based on the average response.

Hanes,[10] later in 1959, compared cephalometric changes in a group treated with cervical traction with those in a group treated with intermaxillary elastics. The cervical traction group included thirty two patients, average age 9 years, 9 months, and the appliance varied from headgear and a biteplane only to complete edgewise. The elastic group included thirty eight cases, average age 12 years, 3 months, many of whom also wore cervical headgear in combination with Class III elastics during anchorage preparation. Extractions were required in 4 of the headgear group and in nearly all, 26 of 38, of the elastic group. Using before and after superimposed cephalometric radiographs, Hanes found the groups to be very similar pretreatment except for the two and a half year age discrepancy. Despite the difference in treatment very similar changes resulted in both groups. Maxillary measures SNA and linear measures to A both showed significant decreases in both groups. Intermaxillary measures ANB and linear measure between A-B also decreased similar amounts in both groups. The mandibular measure SNB tended to decrease or worsen slightly in both groups but the linear measure to pogonion decreased in the headgear group while moving slightly forward in the elastic group. Also, the mandibular plane angle increased 2 degrees in the cervical traction group, but only .8 degrees in the elastic group. Hanes concluded that Class II treatment can effect distal positioning of the point A and that cervical anchorage with a bite plate has a significant effect increasing the mandibular plane angle.

Ricketts[11] examined the influence of orthodontic treatment on facial growth in a large study, published in 1960, using both treated and untreated patients. Five groups of fifty patients each were compared including 1) untreated Class I patients, average age 8.1 years, including both protrusive and normal dentition, 2) untreated Class II patients, average age 8.6 years, including both Division 1 and 2 cases, 3) Class II patients treated only with extraoral anchorage, primarily Kloehn headgear, average age 8.8 years, 4) Class II patients treated solely with intermaxillary elastics, average age 11.7 years, 5) Class II patients treated with a combination of Class II correction mechanics including extraoral and intraoral traction, average age 11.0 years. In all the Class II groups both Division 1 and 2 patients were included. Extractions were employed on 4 headgear only patients, and on 15 from each of the other treatment groups. Using superimposed cephalometric radiographs, Ricketts found the cranial base remarkably stable on average in all the patients, although individual cases did show some variable small angular and linear changes, both increases and decreases. Summarizing the effect of treatment on the mandible, he stated that both cervical headgear and intermaxillary elastics tend to open the Y axis and mandibular plane and lengthen the face faster than occurs with normal growth. More importantly this trend was more significant in already retrognathic cases while more prognathic cases showed less vertical development. As an aside, Ricketts noted that some of the retrognathic cases treated with high pull headgear tended to improve. Ricketts also found that facial convexity decreased slightly with growth, more with intermaxillary elastic treatment, but significantly more when extraoral anchorage was used. Similarly, point A and the palatal plane were constant in the control and elastic group but extraoral anchorage caused the point A to move down and backward and the palatal plane to be tipped clockwise. Ricketts speculated that since both ANS and the palatal plane were altered that the whole middle face was affected by extraoral anchorage. Significant dental effects were also shown, including significant retraction of the maxillary incisors in the extraoral anchorage groups. Headgear also caused backward movement of the maxillary molar versus forward drift in the control sample. Ricketts concluded that the maxillary growth can indeed be altered and that dramatic movement of teeth can be accomplished with extraoral force. However, while the total amount of mandibular growth is probably not affected he sensed the direction could be unfavorably influenced vertically by orthodontic therapy.

Perhaps frustrated at the volume of conflicting literature that had been presented regarding the effects of cervical anchorage with which his name was synonymous, Kloehn[12] published again in 1961. He commented that variations in sample size, age, method and direction of force application, and cephalometric analysis made it very difficult to draw conclusions from the literature. Furthermore, he observed that a great degree of individual variation results from identical force application in different individuals. While Kloehn did not use cephalometrics to evaluate his cases, explaining that facial balance was acceptable evidence, he stated that he had not found elongation of molars nor opening of the bite a problem in his cases. Rather, he stated that many Class II malocclusions have a deepbite and require an increase in vertical dimension. He did note that certain open bite cases do require an alteration in treatment planning and appliance therapy but did not elaborate.

Wieslander[13], in 1963, was one of the first to explore the possibility that the direct effect of extraoral force may extend beyond the alveolus and the maxilla. He compared a sample of 30 Class II malocclusions treated with Kloehn cervical headgear and comprehensive orthodontic therapy with a sample of 30 children with normal occlusion. Justifying this control sample, he stated that previous studies of growth indicated that the general growth patterns in persons with Class II malocclusions are not significantly different from those seen in untreated normal subjects. The groups were closely matched for age, sex and time of observation which averaged three and one half years. Biteplane use and outer bow angulation were not specified. Rather than simply report means and differences, Wieslander reported t-scores and statistically proved the significant effects of Kloehn cervical anchorage treatment. He noted that in general the maxilla followed a downward forward growth pattern relative to the cranial base. The pterygomaxillary fissure moved inferior and anterior in the control, but showed posterior and significantly more inferior movement in the headgear group. ANS was affected similarly with significantly less anterior movement in the treated group. The overall length of the maxilla was unchanged between the two groups indicating that maxillary position was altered down and possibly back in the headgear group. The maxillary molar exhibited forward movement in the control but moved distal and more inferiorly in the headgear group. The effect of headgear treatment on the mandible was to significantly increase lower face height, possibly due to steepening of the mandibular plane. Examining the cranial base, Wieslander found that an inferior and anterior change had occurred in the position of basion following treatment. This proved to be a result of superimposing on the spheno-ethmoidal plane. In reality what had been shown was that a clockwise rotational effect on the sphenoid bone occurred during cervical headgear therapy. Wieslander had shown not only a change in the growth of the dentoalveolar area, but also a change in the direction of growth of the maxilla and adjacent craniofacial complex following cervical headgear therapy.

Schudy's three publications in 1964,[14] 1965,[15] and 1968[16] emphasized the role of vertical relations in orthodontic treatment. He noted that the absolute growth of the mandible was not as significant as the direction of that growth and that the vertical and anteroposterior components should be considered as opposing rather than allied forces. Schudy stated that condylar growth results in the forward component of chin position while the vertical elements of facial growth are responsible for the downward components of chin position. Growth increments affecting the vertical dimension are found at (1) the mandibular condyles, (2) the body of the maxilla, which has the effect of lowering the palatal plane, (3) the posterior dentoalveolar process of the maxilla and (4) the posterior dentoalveolar process of the mandible. These growth increments can be used to explain and describe mandibular growth rotations, their cause and how they affect both the overbite and the position of the chin. Counterclockwise rotation is the result of greater condylar growth than the combined posterior facial vertical growth. It results in increased overbite, a more horizontal position of the chin and less increase in the anterior face height. Clockwise rotation, conversely, is the result of greater vertical growth in the posterior dentoalveolar region than at the condyle. The effect is to reduce vertical overbite, and through occlusal contact push the mandible down and back, resulting in less horizontal growth of the chin and an increase in anterior face height. Thus, anteroposterior growth, which is actually excess condylar growth, tends to bring pogonion forward, while excess facial or dentoalveolar vertical growth tends to move pogonion down. Further, Schudy considered the vertical movement of the maxillary first molar the most important factor in establishing facial height, accounting for 70 percent of the total vertical growth of the face. Because of the noted vertical side effects of cervical headgear, Schudy along with Creekmore developed and recommended a high pull face bow to be used in open bite and high mandibular plane angle cases.

By 1970 when Ringenburg[17] published, certain effects of cervical headgear therapy had come to be known as a Kloehn reaction and were accepted as truths by many in the orthodontic profession. They included both favorable results such as inhibiting the forward growth of both the maxilla and maxillary first molar and reducing the SNA angle, and unfavorable side effects such as downward tipping of the occlusal plane, extrusion of maxillary first molars resulting in clockwise rotation of the mandible, increases in mandibular plane angle and a reduction in the SNB angle. Ringenburg studied a group of 30 Class II, Division 1 patients treated with a cervical headgear and a maxillary appliance only and compared them to a group of untreated Class II, Division 1 patients. The groups had very similar age ranges and means. Mechanically, the outer bow of the facebow was elevated placing a distal torqueing effect on the maxillary first molar roots and an intrusive force on the incisors. No bite planes were used in treatment. Ringenburg reported similar maxillary results as other studies, reduced SNA, tipping of the palatal plane, and a decreased linear measure to Ptm all indicating a growth retardation of the maxilla. However, contrary to many other findings, Ringenburg found the extrusion of the maxillary first molar was not significantly greater than the control, and that neither the occlusal plane, facial height, nor the FMA increased significantly. Rather, a significant decrease in mandibular plane angle was reported in the female group along with normal forward movement of B point. Ringenburg concluded that the normal downward and forward growth of the mandible was unaffected by proper use of cervical traction to the maxillary arch.

Wieslander[18] further evaluated the effects of force on craniofacial development in his 1974 paper. He commented that many previous studies of Class II treatment had simply compared the measurements of the same patients before and after treatment. Furthermore, those studies that compared treatment effects to untreated samples nearly always used children with normal occlusions as the control group. Wieslander remarked that because of the great individual variation of growth and development that an untreated Class II sample would serve as the best control group for the investigation of treatment results. Such a control group was located at the University of Oregon Child Study Clinic. The Class II treated sample consisted of 28 cases who began treatment in the mixed dentition from the University of Washington. The Class II control was closely matched for developmental age, sex, length of time of observation, and finally severity of Class II relationship. The treatment consisted primarily of cervical facebows, although biteplanes and incisor brackets were used when necessary. The headgears were worn 12-14 hours per day with 10-15 ounces of force. The average treatment time was 2 years 8 months. The results of cephalometric superimposition revealed that the maxilla had grown in a more inferior-posterior direction in the cervical traction group. Statistically significant findings included a reduction in the ANB of 3 degrees, a 1 mm more inferior position of ANS, slight clockwise tipping of the palatal plane, and posterior positioning of Ptm by 2 mm in the treatment group. The distance from Ptm to ANS remained constant. As Wieslander had shown earlier the base of the sphenoid bone rotated clockwise 1.5 degrees. The maxillary molars were found on average 5 mm more distal in the treated group than in the control; 2 mm of this was thought due to the traction effect on the maxilla while the remainder due to tooth movement within the dentoalveolar area. Slightly, but not statistically significant, more extrusion of the maxillary molar was demonstrated in the treatment group. The resulting effect of the maxillary change on mandibular position was a slight clockwise rotation including a significant increase of the mandibular plane of 1.5 degrees and a more inferior position of menton of 2 mm. Average differences of less than 1 mm were detected, but not significant, in the projection of pogonion and B point.

In 1975, in an effort to evaluate the physiologic response following cervical headgear treatment, Wieslander and Buck,[9] followed this group of treated and untreated patients until the age of 18. Twenty three of the original 28 treated patients were recorded at age 18 while only 12 of the control Class II sample remained untreated and were recorded. The individuals were closely matched for age, sex, and time of observation. The original study demonstrated the more posterior-inferior maxillary growth direction in the cervical traction treatment group. After treatment, both groups showed an equal tendency for downward and forward maxillary growth. Similar intergroup differences between posttreatment and age 18 measurements were found for the position of A point, ANB reduction, and for posterior positioning of the Ptm. Interestingly, the maxillary molar showed an increased difference more posteriorly relative to the untreated group postretention than posttreatment. While the slight tipping of the palatal plane and the more inferior position of ANS caused by treatment were less evident after retention, Wieslander concluded that the spatial change in position of the maxilla appeared to be stable. The clockwise rotation of the mandible effecting an increase in mandibular plane continued posttreatment but there was no statistically significant difference in the position of pogonion in the cervical traction group.

Because much of the literature evaluating cervical pull headgear had shown an unfavorable mandibular rotation, many orthodontists began using high pull forces. In 1976, Badell[20] published an evaluation of combined high-pull and cervical traction to the maxilla. The study sample consisted of 30 patients (13 males, 17 females, average age of 11 years, 2 months; 20 Class II, Division 1 patients, 3 Class II, Division 2 patients and 7 Class I patients). The patients were treated without extractions and each wore a combination high-pull headgear adjusted to apply 24-36 ounces and a cervical pull adjusted to apply 16 ounces. The outer bow of the facebow was short and bent upwards 15 degrees. The patients also wore appliances on the maxillary and mandibular first molars and incisors. The average time span between cephalograms taken before and after headgear wear was 122 days. In order to evaluate long term effects of the treatment, another cephalogram was taken an average of 3 years 2 months later. The statistically significant changes included the movement of the maxillary first molar 2.3 mm posteriorly, .1 mm superiorly, along with 10.6 degrees of distal tipping. In addition, the mandibular first molar moved .4 mm distally, .9 mm superiorly, and uprighted 3.5 degrees. The occlusal plane increased 1.2 degrees relative to the Frankfurt horizontal. No statistically significant orthopedic changes were detected in any of the linear and angular measurements of the maxilla, including point A, ANS and palatal plane. Badell proposed that the short period of extraoral treatment may have been the cause of this. A slight, .8 degrees, increase in the mandibular plane angle was also noted. During the 3.2 year posttreatment period the maxillary molar tended to upright, and move downward and forward, yet the Class I result was maintained. Also, the mandibular plane rotated counterclockwise 2.4 degrees posttreatment lending credence to the theory that the original increase was due to dental interferences. The results of this study and others like it stimulated the use of a more vertical direction of extraoral force in the treatment of patients with vertical growth patterns.

Melson,[21] in 1978, commented that the lack of reliable reference points in the maxilla make it difficult to accurately assess the effect of the extraoral force. In order to differentiate dental changes from a shift in the entire maxilla, Melson used four metallic implants placed in the maxilla and five placed into the mandible according to the Bjork technique. The dual purpose of the study was to analyze the influence of the tilt of the extraoral bow and to evaluate growth following completion of extraoral therapy. Twenty mixed dentition patients, average age 9.5 years, were equally divided into groups of 10. Group I received a cervical headgear with the outer bow tilted 20 degrees up relative to the occlusal plane while the outer bow for the group II headgear was angled 20 degrees below the occlusal plane. The force applied was 400 gm and all patients wore the headgear 12 hours per day. Head films were taken at the beginning of treatment, after 8 months of headgear wear and then following the completion of growth as determined by a hand wrist film. The differences between the groups after the 8 months headgear study period included significantly more distal movement of the maxillary molar in group II (downward outer bow-3.5 mm versus upward bow-1.5 mm), however, this was due to profound distal tipping on average of over 7 degrees. The group I molar axial inclination showed no significant change. Also, group I exhibited a significantly greater decrease in maxillary prognathism. Both groups demonstrated similar amounts of maxillary molar extrusion. Melson remarked that perhaps the occlusal forces and contacts influenced the extrusive forces. The clockwise posterior rotation of the maxilla relative to the implants was greater than that relative to the cranial base indicating that some local remodeling of the palate was occurring. Both groups exhibited similar posterior rotation of the mandible relative to both the implants and the cranial base and mandibular prognathism (SNPg) decreased in both groups.

By following both groups until the completion of facial growth, Melson was able to evaluate the long term effects of cervical traction relative to the stable implants. She observed that the growth of the maxilla and mandible changed dramatically back, to a more downward and forward direction following completion of the headgear treatment. Melson concluded that the influence of traction is only temporary and that following therapy the maxillary complex will catch up and recover normal growth. The mandible showed similar results rotating forwards in all but two cases. The stability of the orthodontic treatment was thus dependent on the dentoalveolar remodeling resulting from cervical traction.

In 1978, Baumrind et al[22-27] began reporting on an extremely large undertaking that set out to compare the effects of various forms of maxillary retraction therapy including both extraoral and intraoral force delivery systems. The total sample consisted of 303 Class II patients in the early to mixed dentition undergoing the phase 1 of a two phase treatment. The force systems evaluated were 1) cervical traction to a facebow (104 patients), 2) straight-pull headgear to J-hooks (16 patients), 3) high-pull headgear to a facebow (53 patients), 4) combination headgear to a facebow (15 patients), and 5) an intraoral functional appliance consisting of a modified activator (61 patients) and 54 control subjects. Records were gathered from the offices of several local clinicians. It is extremely important to note that the selection of treatment mechanics for individual patients was not based on pretreatment findings or diagnosis, but rather, determined by each individual practitioner's appliance of choice for the correction of Class II malocclusions. Because of the number of treatment modalities involved and the ethics of maintaining an untreated Class II control, it proved impossible to obtain a completely matched sample for either group size or pretreatment parameters. The groups were not particularly well matched for age at initial cephalogram. The straight pull group averaged approximately one year less (at 8 years, 10 months) and the control group a further 5 months younger (8 years, 5 months) than the other treatment groups (9 years, 10 months). However, all the groups were fairly well matched for both severity of Class II molar relationship and mandibular plane angle. Baumrind concluded that sample was suitable to assess differences between controls and various treatment modalities. Each group was then evaluated to determine if the Class II molar relationship improved during the course of the study. While the average severity of the Class II molar relationship of the control group was unchanged, all the treatment groups experienced significant improvements and usually the Class I treatment goal was achieved.

In evaluating the treatment effects on the maxilla, Baumrind et al[23] concluded first that forces applied to retract the maxilla do produce substantial orthodontic and orthopedic effects. The orthodontic effect of the retraction systems were evaluated by the movement of the maxillary first molar while the orthopedic effect was evaluated by the position of ANS. The high pull force system, which used the highest force, produced the greatest change both orthodontically and orthopedically despite being used for the shortest period of time. The lower force system used with the cervical headgear caused nearly as much orthopedic change but significantly less orthodontic tooth movement of the maxillary first molar. While it was not proven that lower forces result in a greater orthopedic effect, the data was certainly contrary to the conventional hypothesis that heavy forces result in greater orthopedic effects and that lighter forces result in more orthodontic tooth movement. Both the high pull and cervical tended to increase the cant of the palatal plane. The cervical pull force system tended to cause extrusion and greater downward displacement of the anterior maxilla while the high pull system appeared to intrude the posterior palate.

On examining the mandibular plane changes during these various forms of maxillary retraction therapy, Baumrind[22,24] found only very slight differences between force systems. The range of all the mean changes including both treatment and control was less than one degree and the increment of change from start to finish of treatment was less than .5 degrees for all the groups. The control group showed a small but statistically significant tendency for the mandibular plane to decrease. The intraoral group experienced an insignificant decrease while all the extraoral treatment groups experienced slight increases in the mandibular plane angle. The high-pull group caused the smallest increase followed by the straight-pull, combination, and finally the cervical but the differences were not significant. Baumrind concluded that the effect on mandibular plane of each appliance is too small to be considered a major factor in the selection of a treatment for an individual case. Further, by analyzing numerous correlations of both pretreatment measurements and treatment mechanics to the resultant outcomes, Baumrind found very little predictive power in any of the criteria, including initial mandibular plane angle.

Baumrind[25] then evaluated the annual changes in various facial dimensions associated with each force system. The sample was restricted to patients with less than 3.5 years between initial and final cephalograms (261 patients). The statistically significant differences included a tendency for increased lower anterior face height in the cervical traction group. This was unexpected because the mandibular plane angle changes were so similar, however the cervical group also experienced significantly more ramus height increase allowing increased vertical dimension without increasing the mandibular plane angle. Interestingly, both the cervical traction group and the intraoral group demonstrated increased condyle to pogonion distance, but, it was the control group that experienced the largest mandibular body length increase.

Research evaluating the effects of various extraoral traction mechanics has continued even until the present. In 1988, Cangialosi et al[27] discussed the effects of edgewise Class II nonextraction treatment with extraoral force. They reported on a treatment sample that included 43 Class II, Division 1 patients with an average age of 11 years, 11 months at the beginning of treatment (30 girls, mean age 10-4, 12 boys mean age 12-2). The average treatment time was 2 years, 8 months. Nonextraction edgewise treatment combined with cervical anchorage was used on all patients. No control group was used, rather the final results were compared to the pretreatment status. The statistically significant findings included a decrease in SNA of 1.1 degree, mean reduction of ANB of 1.6 degrees, and 1 degree clockwise tipping of the palate, all suggestive that the forward progress of the maxilla had been impeded. As would be expected in treatment of a Class II, Division 1, the maxillary incisors were retracted and their proclination decreased. An insignificant .5 degree increase in the SNB, and a small reduction in the mandibular plane were also detected. However, despite the lack of increase in the MP, the Y axis did exhibit a significant opening of .77 degrees. Because no control group was used, neither the linear vertical nor horizontal effect of the treatment could be evaluated because all of these values normally increase during this period of active growth.

Because of the many suggested side effects of the cervical headgear, Firoux et al[28] (1992) evaluated the effect of high pull headgear in the treatment of Class II, Division 1 patients. Twenty four Class II patients with skeletal ages between 9.5 and 12.5 years, all with increased lower face height were divided into equal groups. Twelve patients received Interlandi high pull headgear, 500 gm per side, to be worn 12 hours per day, and a transpalatal arch to minimize rotations. The remaining patients acted as a control. The two groups were compared after 6 months of treatment. In the treatment group there was significant distal displacement of the maxillary molars (2.6 mm distal versus .5 mm mesial in the control), and significant intrusion (.2 mm versus .2 mm eruption in the control). This movement tended to be displacement rather than tipping and served to correct the Class II molar relationship. The anteroposterior and vertical position of the maxilla was also affected. Significant distal (.3 mm) movement was observed in the headgear group versus .5 mm forward movement in the control. As well, the maxilla grew down less than half as much in the treated group. No statistical changes were observed in either the palatal plane, mandibular plane, or skeletal convexity. Firoux concluded that high pull headgear can produce significant distal movement to aid Class II correction and reduce the normal downward growth of both the maxillary molar and maxilla.

A recent study by Hubbard et al,[29] in 1994, reported on the effects of cervical headgear as used by Kloehn himself. This was accomplished by using records from his orthodontic practice. A sample of 85 (38 males, 47 females) Class II, nonextraction patients were chosen. The average age at the start of treatment was 12.1 years (range 9.2-15.6). A long outer bow was used and 1.5 pounds of force delivered to each side. The bows were alternately bent down very low to tip the maxillary first molar back, then severely upwards to upright the roots. Following achievement of a Class I molar conventional edgewise orthodontics were begun. Pretreatment and posttreatment cephalograms were superimposed and the differences compared to the standards from University of Michigan Growth Study of normal (Class I) untreated children. Contrary to many other studies, Hubbard found no increase in maxillary molar extrusion compared to the control. Over the course of the study the molars migrated mesially (1.6 mm versus 3.6 mm for normals). Both these results were thought possibly due to the continuity of full edgewise therapy with the completion of the headgear. The occlusal plane and palatal plane rotated clockwise significantly 2 and 1.6 degrees respectively. While the SNA was found to decrease a significant 2.1 degrees relative to no change in the control, all the linear measures reflecting the horizontal and vertical position of the maxilla showed changes nearly identical to those exhibited in the control. Hubbard concluded that the findings did not support the observations of others that that the normal downward and forward growth of the maxilla had been altered by the extraoral traction. Further, no significant change in the mandibular plane was shown, even in a group of patients that began with an increased FMA. The Y axis did tend to increase by 1.0 degrees while SNB and SNPg showed small (less than .6 degrees) anterior movement.

Despite the efforts of previous researchers, there remains a lack of consensus on several of the specific effects of extraoral traction on the development of the dentofacial complex. It has been demonstrated by King,[7] Baumrind[23] and is fairly well agreed upon by many others[8,13,21,25,29] that a cervical face bow appliance can effect either distal movement or decreased mesial movement of maxillary first molars. However, Klein,[8] Wieslander,[13] Melson,[21] and Baumrind[25] have also reported increased vertical displacement of the maxillary molars while Ringenburg[17] and Hubbard[29] have found no significant extrusion relative to controls. There is also strong consensus that cervical traction restricts the forward movement of the maxilla especially with respect to changes occurring at the anterior maxilla.[7-11,13,17,18,21,23,27] Several researchers including Blueher,[9] Wieslander[13,18] and others[11,17,23,27] have demonstrated that the palatal plane generally tips clockwise during cervical traction. But, there is not universal agreement regarding other structures associated with the maxilla. Only a few researchers including Wieslander[13,18] and Ringenburg[17] have demonstrated decreased anterior movement of Ptm. While some investigations have shown an increased occlusal plane, others have demonstrated it to be stable.[7,8] The effects of cervical traction on the mandible have proven even more controversial. A number of studies including those by King,[7] Hanes[10] and Melson[21] have demonstrated a poor mandibular response to traction including clockwise rotation resulting in a decreased pogonion projection, an increased Y axis[8,9,11,27] and increased lower face height.[11,13,18,25] Research by Ringenburg[17] has disputed this and shown no increase in lower face height and others have measured improvements in the mandibular position.[9,29] Finally, the effect of cervical anchorage on the mandibular plane angle remains controversial with studies by Ricketts,[11] Wieslander[13,18] and others[8,10] demonstrating increases during therapy while research by Blueher,[9] Baumrind[22] and others[7,17,27] showed no significant increase.

Constraints on sample size, group equality, comparable treatment mechanics, and lack of an adequate control continue to plague research designs. Conclusions are often limited by the research design, such as a lack of a Class II control. Only a few evaluations of Kloehn headgear therapy concurrent with edgewise therapy utilizing a well matched Class II control have been published.[18] Since the results of previous research remain controversial and since access to a Class II untreated population is available at Oregon Health Sciences University, it was decided that further investigation into the effects of cervical anchorage is warranted. The purpose of this study is to locate and match a group of Class II patients treated with a cervical headgear and comprehensive edgewise therapy with a group of untreated Class II individuals available from the Oregon Child Development Study. By closely matching the individuals for sex, initial age of observation, length of observation, and mandibular plane angle it is hoped that a better understanding of the effects of Kloehn headgear as utilized at OHSU will be achieved.

Materials and Methods

Patient Selection

The materials used for this investigation were drawn from the longitudinal records of individuals participating in the Oregon Child Development Study and from the patient records at the Oregon Health Sciences University (OHSU) Graduate Orthodontic Clinic. The cephalometric radiographs were taken using a Broadbent-Bolton cephalometer according to the technique described by Broadbent.[30] In order to eliminate magnification differences as a source of error, only patients with all their cephalometric radiographs taken in the same manner on the same cephalometer were included. The participants were all Caucasians and were primarily of Northern European ancestry.

The experimental group was gathered by evaluating pretreatment and posttreatment records of all the potential patients treated since 1977 at the OHSU Graduate Orthodontic Clinic. Since this time, pretreatment and posttreatment cephalometric radiographs have been taken using the same Broadbent-Bolton cephalometer used in the Child Growth Study. The following criteria were used to select the experimental sample:

1. Class II, Division 1 malocclusion at pretreatment.
2. Successful nonextraction orthodontic therapy primarily utilizing Kloehn cervical anchorage to achieve a Class I relationship, concurrent with or followed by comprehensive fixed appliance therapy.
3. Treatment beginning during the active period of growth.
4. No missing teeth or significant asymmetry present.
5. Treatment time less than 3 years, 6 months.
6. Availability of good quality pretreatment and posttreatment radiographs.
7. Availability of a matching Class II patient in the control sample.

Using these criteria 23 subjects (10 females and 13 males) were identified as suitable for inclusion in the present study.

The control group was gathered by evaluating longitudinal orthodontic records obtained during the Oregon Child Development Study. By assessing the orthodontic models of all the individuals with a Class II malocclusion, it was determined whom had undergone orthodontic therapy. The following criteria were used to select the control sample:

1. Class II, Division 1 malocclusion present in the transitional or early permanent dentition.
2. No orthodontic treatment or extraction of permanent teeth undertaken previous to or during the period of comparison with the treatment sample.
3. No missing teeth or significant asymmetry present.
4. Availability of good quality pretreatment and posttreatment cephalometric radiographs for the period of comparison with the treatment sample.

The subjects in the control group were matched as closely as possible to those in the experimental group for sex, age at the initiation of treatment / observation, length of treatment / observation, steepness of mandibular plane angle, and as much as possible for severity of initial Class II presentation. Chronologic age was used as an indicator of maturation because the available records did not provide a means for determining skeletal age. The result was an equal number of subjects (10 females and 13 males) in the control sample.

Appliance Design

A Kloehn cervical headgear was used as the primary mechanism of Class II correction in all subjects in the treated sample. Forces used with the headgear were not documented but the clinicians supervising the cases recommended 12 - 16 oz per side. The inner bow of the face bow was inserted into the buccal tube of the maxillary first molars. The clinicians supervising the cases instructed that the outer bow of the facebow be angled up 10 - 20 degrees relative to the occlusal plane. This was done in order to effect as pure a translational force as possible. The patients were instructed to wear their headgears 12 -14 hours per day but no diaries were kept. Chart entries were used to evaluate patient compliance which was acceptable in all the patients included. Bite planes were used in 4 out of the sample of 23 treated patients. Class II elastics were used during the finishing stages of treatment for a maximum of 6 months and an average of 3.5 months in 18 of the 23 patients.

Analysis of the Cephalometric Data

The lateral cephalometric radiographs were photographed and captured, then enhanced and digitized using Quick Ceph Image™ running on a Macintosh Power PC.™ The Frankfurt horizontal plane was constructed on the pretreatment or initial radiograph using anatomic porion and orbitale. This plane was then transferred to the posttreatment or final observation radiograph using the anterior cranial base for superimposition. Nineteen skeletal points and 9 dental points were digitized on the monitor screen for each cephalogram and are presented in Figure 1. When right and left images were not superimposed, a midpoint between the two images was used. The identification of the landmarks was based upon the classic definitions found in the literature.[31-34] All the landmarks were identified by one investigator. The landmarks were all reevaluated for accuracy by the same investigator several days after the initial entry. Four subjects, selected randomly one from each group, male and female, control and experimental, had their initial and final radiographs retraced to evaluate the error in data capture and digitization. (Tables 6,7, and 8)

Using the digitized landmarks, various linear and angular anteroposterior and vertical measurements were made. The anteroposterior position of the maxilla was evaluated by the angular measurements SNA and by the maxillary depth angle (Frankfurt horizontal - NA). The linear A-P position of the maxilla was assessed by the position of A point relative to a Frankfurt horizontal perpendicular (FHP) through Nasion. The length of the maxilla was established by the midfacial length from hinge axis to A point and the length of the palate was measured from ANS to PNS. The vertical changes in the maxilla were examined using linear distances from N-ANS and S-PNS measured perpendicular to Frankfurt horizontal. The cant of the palatal plane was measured relative to SN.

The anteroposterior position of the mandible was evaluated using the facial angle and SNB. Linear changes in the A-P position of the mandible were measured by the position of pogonion relative to a Frankfurt horizontal. Other linear measurements were used to describe the components of the mandible. Articulare - gonion was used to measure ramus height; gonion - pogonion measured the corpus length while the overall mandibular length was determined from hinge axis to pogonion.

Vertical changes in the mandibular position were assessed using Frankfurt horizontal to mandibular plane, SN-MP, and Y axis relative to Frankfurt.

The relationship between the maxilla and the mandible was assessed by the ANB and the Wits analysis. The angle of convexity measured the skeletal profile. The cant of the occlusal plane was measured relative to SN. The vertical changes in the face were established by lower anterior face height from ANS - menton, overall anterior face height from N-menton, and posterior face height from S to gonion.

The position of the maxillary anterior dentition was evaluated by the protrusion of the maxillary central incisor relative to a Frankfurt horizontal perpendicular through A, and by the axial inclination of the incisor relative to Frankfurt. The position of the maxillary first molar crown was measured vertically perpendicular to Frankfurt horizontal and the palatal plane, and horizontally from a pterygomaxillary fissure perpendicular. The position of the mandibular anterior dentition was evaluated by the protrusion of the mandibular central incisor relative to the A-Po line and by the axial inclination of the incisor relative to the Frankfurt horizontal. The vertical position of the mandibular molar was measured as the perpendicular distance from the mandibular plane. The relationship of the maxillary and mandibular dentition to one another was evaluated by the interincisal angle, the incisal overjet and a linear horizontal molar relationship measure.

Soft tissue was not evaluated because of the great variation in cephalometric technique. In many of the radiographs lip strain appeared obvious while in many others it appeared as if something had been placed between the subject's lips.

The initial and final values for each of the cephalometric variables was measured for each subject.(Table 1) The difference or change between the initial and final measurements for each variable was then calculated for each subject.(Table 2) Group means and standard deviations for the initial cephalometric values and for the differences between the initial and final measurements were computed for each variable. These descriptive statistics for the males, females and combined sample are reported in Tables 3, 4, and 5 respectively. The pretreatment equivalence of the experimental and the control groups was tested using analysis of variance to compare the experimental males with the control males and the experimental females with the control females. F-values and the resulting probability or P-values testing pretreatment equivalence are also reported in Tables 3, 4, and 5. Because of the large number of variables examined an alpha level of $p<.01$ was predetermined. An analysis of variance was also used to compare the changes that occurred during treatment/observation. Initially the males and females samples were analyzed separately then combined to achieve greater statistical significance. The F-values and P-values comparing the change over time are reported.(Tables 3,4, and 5) The differences were also compared using a $p<.01$ alpha value.

Error of the Method

Several days following the original data entry and digitization, one subject from each group, chosen randomly, had their pretreatment and posttreatment cephalometric radiographs reentered and redigitized. The cephalometric measurements from the original tracing and from the retracing of these four subjects was compared to evaluate the error in radiograph capture and landmark identification.(Table 6) The errors in tracing (difference between the two tracings of the same radiograph) were thought to occur randomly which would result in an equal number of positive and negative differences and a low mean error. To compensate for this error values were calculated using both real numbers and absolute numbers.(Table 7) The mean real and absolute error and standard deviation was computed for each cephalometric measurement.(Table 8)

As suspected, the measurement errors occurred randomly which resulted in fairly small real mean differences. Almost equal numbers of the real mean differences were positive and negative. The means for the absolute differences were somewhat higher. The mean errors in the angular measurements of the maxilla and mandible relative to the cranial base were low. All the measures had mean differences less than .2 degrees and absolute mean differences less than .8 degrees. The linear maxillary measurements also demonstrated small mean errors of less than .3 mm and absolute mean errors of less than .8 mm. The only exception to this was the ANS - PNS distance which had a mean error of .9 mm and an absolute mean error of 1.2 mm.

In general, the errors in the linear measurements of the mandible were slightly larger. While the mean errors remained fairly low the standard deviations were higher and the means of the absolute differences approached 1 mm for all the mandibular lengths and for the three facial height measurements. The mean absolute error in the position of pogonion relative to a FHP through N was 1.2 mm. The error in the mandibular plane angle measurements were less than 1 degree. The mean and absolute error in the measurements relating the maxilla to the mandible were also small averaging less than 1 degree and 1 mm.

The error in the linear measurements of the dentition was low. The mean real and absolute errors in the linear position of the maxillary and mandibular central incisors and first molars all were less than 1 mm. The mean absolute error in the angular measurements of the maxillary and mandibular central incisors was larger, 2.3 degrees and 1.7 degrees respectively.

Thurow[35] and Baumrind[39] have previously discussed error in cephalometric tracings, landmark identification and superimposition. Thurow[35] commented that blurring, distortion and enlargement error exist in every radiograph. He suggested that the accuracy of tracing is no better than .5 mm. Baumrind[39] found large differences in the magnitude and configuration of the error among different landmarks. Macri[40] found greater error using a mouse to identify landmarks on computer digitized image than digitizing landmarks directly from the film. In this study the majority of cephalometric measurements had errors of less than 1 mm or 1 degree. However larger errors occurred in locating ANS and PNS. The Quick Ceph Image™ program used relies on the Frankfurt horizontal for the orientation of the digitized points to the digitized image. Even a small error in identification of orbitale or porion will result in skewing of the tracing and measurements from the image. As the distance from Frankfurt increases, so too does the magnitude of this skewing. This resulted in a relatively large error measurement for pogonion, a landmark which is fairly easily identified.

Results

Pretreatment Comparison of Experimental and Control Subjects

The descriptive statistics for the pretreatment values for the male and female experimental and the control groups are presented in Tables 3 and 4 respectively. Because of the large number of comparisons, the alpha value for significance was predetermined at $p<.01$. Efforts to closely match each experimental patient with a control subject resulted in few significant differences between the groups. At the time of the initial radiograph, the control males ranged in age from 9.9 - 13.9 years with a mean of 12.0 years while the experimental males ranged in age from 9.4 - 14.2 years also with a mean of 12.0 years. Comparisons of the pretreatment values between the control and experimental males indicate a slight trend toward increased maxillary and mandibular prominence relative to the cranial bases in the control. However, the midfacial, mandibular and ANS-PNS length were all marginally larger in the experimental group. The treated group also exhibited a slightly larger pretreatment palatal plane angle. None of these trends were statistically significant. Means for the mandibular plane angle and the various facial height measurements showed little variation between the two groups. Measurements of the relationship between the maxilla and the mandible were very similar indicating that similar skeletal discrepancies existed in both groups. Dental measurements also varied little. Both the experimental and control group exhibited similar pretreatment positions of the maxillary and mandibular central incisor and first molar.

The age range in the control females at the time of the initial radiograph was 10.0 - 12.9 years with a mean of 11.4 years while the range in the treated group was 9.5 - 13.3 years with a mean of 11.5 years. Comparison of the pretreatment values between the experimental and control groups of females revealed few differences. There was a slight trend toward increased maxillary and mandibular prominence relative to the cranial base and maxillary and mandibular length in the experimental group of females. None of these trends approached statistical significance. Means for the mandibular plane and the various facial height measurements varied little between the two groups. The measures of the relationship between the maxilla and the mandible were also very similar indicating that similar skeletal discrepancies existed in both the control and the treated samples. Differences between the pretreatment values of the maxillary incisor measurements approached statistical significance. Flaring and protrusion of the maxillary central incisor and incisal overjet were somewhat increased in the treated group. However, only the interincisal angle was statistically different pretreatment. The experimental group exhibited a pretreatment interincisal angle of 127 degrees versus 116 degrees in the control group. The remainder of the dental measurements reflecting the position of the maxillary first molar, and the mandibular central incisor and first molar demonstrated very little difference between the two groups.

Comparison of the Changes Between the Treated and Nontreated Subjects

The comparison between the treated and the nontreated subjects was performed by subtracting the initial values from the final values and then comparing the differences using an analysis of variance. (Tables 3,4,5) Males and females were initially evaluated separately and then grouped together to increase the size of the sample in order to gain significance. Because of the large number of measurements used and evaluated, a $p<.01$ was predetermined as the level of statistical significance.

Treatment Time

The treatment time (interval between initial and final radiographs) for the male experimental group ranged from 1.75 - 3.7 years averaging 2.7 years while the time of observation for the male control group ranged from 1.9 - 3.7 years and also averaged 2.7 years. The treatment time for the experimental female group ranged from 1.7 - 3.1 years averaging 2.3 years while the time of observation for the female control group ranged from 1.9 - 3.1 years and averaged 2.4 years.

Maxillary Position

Comparison of the changes that occurred during the time of observation indicate that the headgear treatment had some significant effects. All the measurements of the maxilla relative to the cranial base showed statistically significant decreases in both the male and female treatment groups while staying relatively constant or increasing in the controls. In the male treated sample the maxillary depth decreased an average of 2.0 degrees while the SNA decreased 1.9 degrees, and the position of A relative to a Frankfurt horizontal perpendicular (FHP) through nasion decreased 2.1 mm. In contrast, the male control sample exhibited no change in the maxillary angle, a .1 degree increase in the SNA and a .2 mm advancement in the position of A. The female groups demonstrated similar changes. The female treated sample exhibited a 2.6 degree decrease in both the maxillary depth angle and the SNA and a 2.5 mm decrease in the position of A relative to the FHP through N. The female control groups exhibited .4 degree increases in both maxillary depth and SNA and a .5 mm advancement of A point.

The treatment groups also demonstrated a significant decrease in the midfacial length. The distance from hinge axis to A point increased by 1.6 mm during the treatment period in the male experimental group while increasing 4.2 mm in the control. In the female experimental group the midfacial length increased only .7 mm versus 3.3 mm in the untreated control. The distance from PNS - ANS continued to increase similarly in all four groups (males and females, experimental and control) regardless of treatment.

While the changes in the horizontal position of the maxilla were profound, the effect of the cervical traction therapy on the vertical position of the maxilla was less significant. The untreated control group demonstrated a downward and forward pattern of maxillary growth. The vertical distance from N - ANS along a FHP increased slightly but not significantly more in the treated groups than in the nontreated controls, 3.7 mm increase in the former versus 2.7 mm in the latter. The vertical distance from S - PNS was also not significantly different between the experimental and control groups. The male treated group exhibited slightly increased vertical displacement of the posterior palate following headgear treatment, 3.7 mm versus 3.1 mm. Interestingly, the female treated group exhibited a smaller vertical increase in the posterior maxilla than the control, 1.7 mm versus 2.1 mm. In the female treated subjects, the combination of increased vertical displacement in the anterior maxilla and decreased vertical displacement in the posterior maxilla resulted in a statistically significant 2 degrees of clockwise tipping of the palatal plane. The female control group exhibited only .1 degree of clockwise palatal plane tipping. The male experimental group demonstrated no significant trends in the palatal plane cant relative to the control group. When the males and females were combined no significant difference in the palatal plane following headgear treatment was detected between the experimental and the control groups.

Mandibular Position

The effect of cervical headgear on maxilla is readily understandable because of its point of attachment there. However, many previous researchers have also demonstrated an effect on the mandible following Kloehn headgear therapy. The male experimental and control group exhibited no significant differences in the horizontal position of the mandible relative to the cranial base as measured by the facial angle, SNB, and the projection of pogonion relative to a FHP through N. The differences between the two groups for these measurements were very small. The mandibular length and pogonion - gonion length also exhibited almost identical changes regardless of treatment. The ramus height showed a slight tendency for increase in the treated sample growing 6.1 mm relative to 5.1 mm in the control group.

Changes to the mandibular position following cervical anchorage therapy also failed to reach significance in the female groups. However some nonsignificant trends were noticed. Whereas both male groups demonstrated continued forward growth of the mandible during headgear therapy or observation, a small trend for less forward movement of the mandible was detected in the female experimental group. The facial angle increased .8 degrees in the control group but only by .1 degrees in the treated group. A similar trend in the SNB angle was shown, with the control group exhibiting an increase of .5 degrees relative to a decrease of .3 degrees in the treated group. Despite the decreased projection of the mandible, the experimental group actually exhibited a slightly increased mandibular length growth of 6.3 mm relative to the control group's growth of 5.1 mm. Insignificant differences between female groups were also demonstrated between the gonion - pogonion length and the ramus height. When the male and female experimental and control groups were combined no further significant data resulted for the horizontal position or various lengths of the mandible.

The angular measurements of the mandible were evaluated to determine if the cervical anchorage therapy had an effect on the vertical position of the mandible. The male and female control samples both exhibited decreases of 1 degree in the mandibular plane relative to FH and to SN during the course of observation. The male treatment sample exhibited a similar closure of the mandible but to a lesser extent, between .4 - .5 degrees. In contrast, the female treated group demonstrated an increase of 1 degree in both the mandibular plane measures. When the male and female experimental groups were combined the female tendency for opening and the males tendency for decreased closure resulted in the entire group exhibiting a small but significant opening of the mandibular plane angle relative to the control. A similar trend existed in the Y axis measurement. Both control groups exhibited a slight increase, .3 degrees, during the period of observation; the male experimental group showed a larger increase, .8 degrees, and the female experimental group an even larger increase of 1.3 degrees. However, the changes in the Y axis did not prove significant.

Facial Height

In addition to the angular measurements of facial height, the vertical growth of the face was evaluated by measuring various linear facial heights. While none of the vertical measure differences reached significance they did demonstrate a tendency for increased vertical growth of the face during treatment. The lower anterior and total anterior face height increased 4.5 mm and 8.6 mm in the treated subjects compared to 3.5 mm and 6.5 mm in the control groups. The posterior face height grew slightly less in the female treated sample but slightly more in the male treated sample relative to the control groups.

Maxillary/Mandibular Relationship

The group of measurements reflecting the relationship between the maxilla and the mandible demonstrated highly significant changes during treatment. With growth alone, the ANB tended to decrease .5 degrees in the male and remain constant in the female control groups. Cervical traction therapy caused the ANB to decrease 2.3 degrees in both the treated groups. The angle of convexity demonstrated similar changes decreasing only slightly in the controls yet significantly more in the treated sample. The Wits analysis tended to get worse by .3 mm in both untreated groups but improved by more than 2 mm in both the treated groups. The SN occlusal plane angle tended to decrease during observation in both the male and female control groups, 2.0 and .7 degrees respectively. The male experimental group also showed a mean decrease but to a lesser extent decreasing only .8 degrees. The female experimental group demonstrated a 1 degree increase in the OP angle. This resulted in a nonsignificant tendency for increased occlusal plane angles during treatment relative to controls.

Dental Changes

In addition to the cervical anchorage therapy, all the treated subjects underwent comprehensive orthodontic therapy. It was expected that many of the measurements of the dentition would exhibit significant differences between the experimental and control subjects. For the entire treated sample a significant decrease in the protrusion of the maxillary central incisor was demonstrated during the course of therapy. Relative to a FHP through A, the maxillary incisor protrusion reduced more than 2.3 mm in the treated groups relative to the control. The position of the maxillary first molar is very important for the correction of the Class II molar relationship. The mesial movement of the molar crown was significantly decreased in both the treated groups. While the maxillary first molar moved mesial 3.6 mm relative to a Ptm vertical in the control groups, its forward progress was limited to 1.7 mm in the male treated sample and .7 mm in the female treated sample. A nonsignificant trend for approximately 1 mm increased maxillary molar vertical eruption relative to the FH was also demonstrated in the experimental group.

The mandibular anteriors also exhibited significant changes during the course of cervical anchorage therapy. Relative to the APo line the mandibular central incisors protruded by more than 2 mm in the combined experimental group while remaining almost constant in the control. The mandibular central incisor also tended to procline significantly relative to the FH. The FMA decreased by more than 3.5 degrees in the treated sample while uprighting slightly in the control. The vertical position of the mandibular molar exhibited almost no variation between the various groups. The molar relationship improved significantly by 2.8 mm during treatment in the experimental group while improving only .4 mm in the control groups. Likewise the incisal overjet decreased more than 5 mm in the treated subjects while remaining almost constant in the controls.

Discussion

Pretreatment Comparison

Each treated subject was closely matched with a control subject for sex, initial age, time of observation, mandibular plane angle, and severity of Class II malocclusion. The rationale behind matching the subjects was to create experimental groups that initially differed very little from control groups. The initial group means reflected this pretreatment similarity. The mean age at the time of the initial radiograph was equal for both the male groups and for both the female groups. Although there was a wide age range within each group, the ranges were similar. The time of observation was equal between the male control and experimental groups and between the two female groups. This was achieved by matching the length of observation for each control to the length of treatment for the corresponding experimental match.

None of the pretreatment cephalometric measurement means differed significantly between the experimental and control males. It can be inferred that the male experimental and control groups exhibited very similar pretreatment skeletal and dental malocclusions. The female control and experimental groups matched almost as well for their pretreatment cephalometric measurements. The only significant difference was that the experimental sample demonstrated increased maxillary incisor flaring. This can be explained because maxillary incisor flaring is a significant motivator for seeking orthodontic treatment. In contrast, although the control subjects were classified as having Class II malocclusions perhaps their lack of incisor flaring is what resulted in them not seeking treatment and remaining in the Child Development Study. It is likely that many of the Study children with a significant esthetic component to their malocclusion sought orthodontic therapy and thus could not be used as controls. Although the control group exhibited less incisor flaring, the lack of significance in any other pretreatment measurements reflect that both the experimental and control female groups exhibited very similar skeletal and dental malocclusions.

This close matching between the experimental and control groups offered the unique opportunity to evaluate the changes resulting from cervical headgear therapy in conjunction with comprehensive orthodontic therapy. Any differences between the two groups following the treatment / observation period would be thought due to the treatment effect of the headgear and orthodontic therapy.

Comparison of the Changes Between the Treated and Nontreated Subjects

Maxillary Protrusion

Previous investigations of untreated subjects have demonstrated a normal downward and forward direction of growth of the maxilla.[36,37] Measurements of maxillary protrusion relative to both Frankfurt horizontal and SN tend to remain constant during these growth investigations. The results of the control group in this investigation confirm that maxillary protrusion does not decrease during a 2 - 3 year observation period in untreated subjects. In contrast, the marked reduction in the angular and linear measurements reflecting maxillary protrusion in the treated sample must be interpreted as evidence that the the cervical headgear delivered an orthopedic force that affected the forward growth of the maxilla. This compares favorably with the results of previous investigations by King[7], Wieslander,[13,18] Baumrind[23] and others[11,17,21,27] The overall length of the maxilla as measured from condylion to A point increased less in the experimental group but the length of the palate demonstrated equal growth in both treated patients and controls. It has been suggested by Wieslander[13] that headgear treatment does not affect the length of the maxilla, but rather limits the forward component of maxillary growth. The results of this investigation indicate that the use of extraoral Kloehn cervical headgear during the active growth spurt can result in a statistically significant orthopedic effect on the forward growth of the maxilla tending to reduce maxillary protrusion.

Maxillary Rotation

In this investigation the vertical effects of headgear treatment were evaluated by measuring the descent of both the anterior and posterior maxilla and by the angular change of the palatal plane. The untreated control sample confirmed the results of previous growth studies[36,37] demonstrating a parallel descent of the palatal plane during normal growth. Both the male and female experimental groups exhibited an insignificant 1 mm increase in the vertical descent in the anterior maxilla following cervical headgear therapy. This increase was not as great as that shown by Klein,[8] Ricketts,[11] and other researchers[13,17,18,23] who have demonstrated a significant increase in the vertical growth of the anterior maxilla during cervical headgear treatment. Rather, these results are more in accordance with those of Boecler et al.[38] who showed no significant difference in the descent of the anterior maxilla between cervical headgear, combination headgear and no headgear. The posterior maxilla exhibited conflicting results. In the treated male group the posterior maxilla also experienced increased vertical displacement resulting in a parallel palatal descent. In the treated females the posterior maxilla displaced less vertically than the control. This resulted in a significant 2 degree increase in the palatal plane angle in the treated female sample. The increased palatal plane angle in the females is in agreement with research by Ringenburg[17] and Wieslander[13,18] that the palatal plane tips clockwise during cervical headgear therapy. Although some maxillary vertical increases were detected following the application of cervical headgear treatment they were small, on the order of 1 mm, and not statistically significant. It is unlikely such small changes would be clinically detectable, especially given the continued vertical growth each patient is likely to exhibit.[19,21]

Mandibular Response

The effect of cervical headgear therapy on the position of he mandible remains the largest area of controversy regarding its use. Many previous investigators including King,[7] Melson[21] and others[10] have stated that cervical headgear has a negative effect on pogonion projection. In this study no significant differences between the experimental and the control groups were detected in the horizontal position of the mandible following headgear treatment. Both male groups exhibited almost identical forward growth of the mandible while the female treated group displayed slightly less forward mandibular growth than the female control. These results are in agreement with those of Blueher[9] and Hubbard[29] who also showed no significant decrease in mandibular projection following cervical anchorage therapy.

Many previous authors[8,10,11,13,18] have commented on the steepening of the mandibular plane that occurs as a result of cervical headgear treatment. In contrast, Baumrind[22] and others[17,29] have found little or no significant increase in the mandibular plane angle during Kloehn headgear use. The mandibular plane growth direction in the untreated control subjects compared favorably with the results of previous growth studies. On average, the mandibular plane closed 1 degree over the observation period. In contrast, both the treated groups exhibited less counterclockwise rotation. The male experimental group demonstrated only .4 degrees of mandibular closure. The female experimental subjects underwent 1 degree of clockwise rotation which was statistically different than the control. When the male and female experimental groups were combined a small but statistically significant tendency for opening of the mandibular plane during cervical anchorage therapy was detected. This was more noticeable in the female sample. Although the difference was small, the results are in accordance with those of Hanes,[10] Wieslander[13,18] and other previous authors[11] who have shown an increase in mandibular plane angle following cervical traction therapy.

Despite the increase in the mandibular plane, none of the linear mandibular measurements including mandibular length, ramus height, and corpus length demonstrated any significant differences between the experimental and the control groups. The results from this investigation support that Kloehn cervical headgear treatment may increase the vertical displacement of the mandible but do not affect the absolute growth nor the horizontal projection.

Facial Height

Wieslander[18] and Baumrind[25] have demonstrated significant facial height increases over that expected during normal growth during cervical traction therapy. As expected all the measures of vertical growth of the face increased in both the controls and experimental groups during the observation period. However, while treated subjects showed a small tendency for increased vertical growth relative to the controls the difference was not significant. These results are in accordance with Ringenburg[17] and Boecler[38] that cervical headgear therapy does not necessarily create significantly increased vertical growth.

Maxilla/Mandible Relationship

Previous studies of growth have demonstrated that the relationship between the maxilla and the mandible tends to remain constant during growth.[37,38] The results of the untreated control groups in this study confirmed this. Neither the ANB, angle of convexity, nor the Wits analysis varied much during the observation period in the control groups. In contrast, these measures of skeletal discrepancy all improved significantly during the period of headgear therapy. These results are in agreement with those of Klein,[8] Wieslander[13,18] and many other authors[11,27] who have demonstrated improvements in the skeletal discrepancy between the maxilla and the mandible during cervical traction therapy.

Maxillary Dental Response

Much as the maxilla continues to grow downward and forward during the period of active growth, continued eruption of the maxillary dentition is also expected during the growth.[37,38] The maxillary first molar tended to erupt vertically and move mesially relative to the Ptm vertical during the observation period in the control group. Baumrind[23] and others[7,8,11,13,18,29] have shown distalization or at least restriction of maxillary molar mesial movement during headgear traction. The results of this study concur that a significant decrease in the mesial movement of the maxillary molar can be accomplished via Kloehn cervical headgear. However, one side effect of the cervical traction is a tendency for increased vertical eruption of the maxillary first molar.[7,8,13,21] This is thought due to the direction of applied force from the cervical strap. The results of this study demonstrated an insignificant increase in vertical eruption of the maxillary first molar in response to cervical traction. This is in agreement with the results of Ringenburg[17] and Hubbard[29] who showed that significantly increased eruption of the maxillary first molar does not necessarily accompany Kloehn cervical anchorage treatment. It is possible that the concurrent use of comprehensive edgewise therapy may decrease the tendency for increased eruption.

The maxillary anterior dental protrusion tended to remain unchanged during the course of observation in the control groups. In the treated subjects the dental protrusion was significantly reduced. Similar decreases in maxillary dental protrusion have been shown by Ricketts[11] and Cangialosi.[27] In this group of treated patients the cervical traction treatment had a profound effect on the final position of the maxillary dentition as well as the maxilla itself.

Mandibular Dentition

Although there is no direct effect of the cervical headgear on the mandibular dentition, its position was evaluated to determine if changes there helped correct the Class II molar relationship. No increase in vertical eruption of the mandibular first molars was detected in the treated group relative to the control. There was an increase in protrusion of the mandibular anteriors relative to the APo line. However, this is partly due to a more posterior positioning of A point caused by the cervical traction and full orthodontic treatment. The mandibular anteriors also tended to flare significantly relative to Frankfurt indicating that their position may also have been affected by the use of intermaxillary elastics during the finishing stages of treatment.

Correction of Class II

Johnson[41] has described a "Pitchfork" Analysis that utilizes maxillary, mandibular and cranial base superimpositions to evaluate the movement of the buccal segments. While this analysis is not completely analogous to the measurements done in this study, it is possible to comment on how the Class II to Class I correction was achieved. The average molar correction achieved in the treated group was 2.8 mm. The untreated group molar relation tended to improve slightly .4 mm. The restriction in the mesial movement of the maxillary first molar relative to a Ptm vertical averaged 2.4 mm in the treated group relative to the control group. Since 2.4 mm is exactly the difference between the correction achieved in the treated patients versus the untreated subjects, this would indicate that the correction of the Class II molar resulted from a restriction of the forward movement of the maxillary molar. It also must be determined whether the maxillary molar was held or if the forward movement of the entire maxilla was restricted. The linear measurements to A point including A to a Frankfurt perpendicular through Nasion and midfacial length indicate approximately 2.5 mm less mesial maxillary movement in the treated patients than in the control. This would indicate that the primary effect of the cervical headgear treatment is to restrict the forward movement of the maxilla. However, Doppel[42] has demonstrated that many of the reference points in the maxilla including ANS, PNS and A point remodel and are therefore not suitable for maxillary superimposition. A point especially remodels as the roots of the maxillary incisors are moved. The backward remodelling of A point during retraction of the incisors would tend to exaggerate the orthopedic effect of the cervical traction. Although accuracy to the one tenth of a mm is not possible, it can be speculated that the correction achieved using a Kloehn cervical headgear results from a combination of both restriction of the anterior movement of the maxilla and restriction of the mesial movement of the maxillary first molar within the maxilla.

Male versus Female

The male and female experimental subjects demonstrated very similar changes for most of the cephalometric variables considered. However, the female treated subjects did exhibit less counterclockwise rotation of the mandible and less horizontal projection of the mandible. These side effects of cervical headgear treatment have been described by Klein[8] and others[7,11] as a Kloehn reaction. Both the female experimental and the age matched female control sample demonstrated somewhat smaller (approximately 75%) overall increases in all the linear measurements of growth than the male experimental and control groups. However, the females were treated for an average of 4 months less. It is possible that the female groups who began the study with an average age of 11.4 years had already experienced some of their pubertal growth spurt. This would leave less total vertical growth to compensate for any vertical side effects of the cervical anchorage treatment. It is possible that the magnitude of the unfavorable vertical side effects of cervical anchorage is dependent on a patient's remaining vertical growth. If significant growth remains the Kloehn reaction may be hidden in the overall increase in the vertical dimension of the face.

Limitations of the Study

Unfortunately, the majority of clinical research must be done on a retrospective basis. This skews the results of any clinical investigation.[4] During the record gathering for this study, it was noted that many of the cases that started with the goal of correcting a Class II malocclusion with cervical anchorage subsequently required the extraction of bicuspids for the completion of orthodontic treatment. Thus, the experimental subjects who were included in this study were only those who were successfully treated with cervical anchorage. It is difficult to determine what percentage of patients who begin with this treatment plan are successfully treated without extractions. Many factors affect the success of a nonextraction, cervical headgear treatment plan. The two most important variables, patient cooperation and growth are not under the control of the orthodontist. Clinical investigations such as this can only elaborate on what changes will occur in successfully treated cervical headgear patients.

Conclusions

The purpose of this study was to examine the effects of Kloehn cervical headgear therapy. By closely matching groups of treated and untreated subjects for sex, age, time of observation, and Class II malocclusion it was hoped an increased understanding of the effects of Kloehn headgear could be gained. From the findings of this investigation it can be concluded:

1.Kloehn cervical headgear coupled with full orthodontic treatment exerts a profound effect on maxillary protrusion, limiting the forward growth of both the maxilla and the maxillary dentition. This effect tends to improve the Class II skeletal and molar relationship, and the overjet. This does not occur in untreated subjects.

2.The untoward vertical side effects of cervical traction were smaller in this study than previously demonstrated. Although there was a tendency for increased growth in all the vertical linear measurements, no statistically significant change in the vertical displacement of the maxilla, eruption of the maxillary first molar, lower face height, nor anterior face height was demonstrated. It is possible that comprehensive orthodontic treatment may have decreased the eruption of the maxillary first molar. It is also possible that the use of a Class II control more accurately evaluates the vertical differences between the treated and untreated subjects. In cases were no increase in vertical dimension can be tolerated, the use of high pull extraoral forces may be indicated.

3.An unfavorable effect on the horizontal position of the mandible and pogonion following cervical headgear treatment was not demonstrated in this study. Although the female treated sample exhibited slightly less horizontal mandibular projection, it was not statistically significant. Perhaps the use of a Class II control more accurately evaluates the possible projection of the mandible.

4.A small but statistically significant increase in mandibular plane was detected in this study. One degree of mandibular plane rotation may not be clinically relevant.

5.The use of Kloehn headgear proved effective in correcting the Class II molar relationship for the patients evaluated in this study. However, the experimental patients were selected on the basis of successful treatment. For this group of treated patients the vertical side effects of cervical traction was small and little change in expected mandibular growth was detected. Both of these previously discussed side effects of cervical traction were probably not clinically significant. These results indicate that cervical traction can be an effective appliance for the correction of Class II malocclusions.

6.Although the experimental and control groups used in this study were matched as closely as possible, the retrospective design limits the conclusions. A prospective evaluation comparing equivalent pretreatment patients to determine the success rate and mechanism of cervical headgear treatment would be a more powerful design.

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Figure 1

Location of 28 Lateral Landmarks

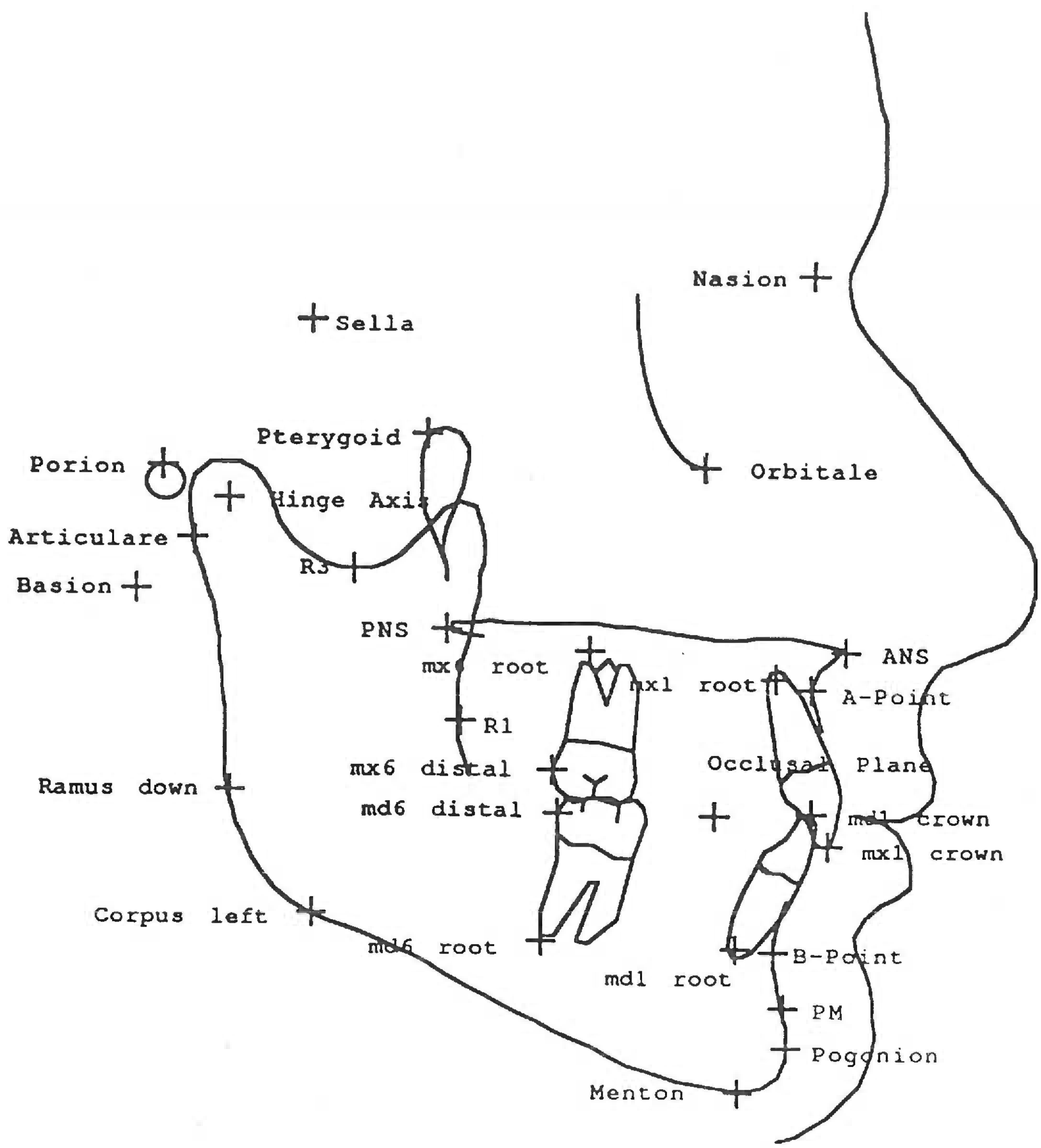

Table 1

	Group	Gender	Age Initial	Age Final	Maxillary Depth (dg)		SNA (dg)		A to N perp FH (mm)		Midfacial Length (mm)		PNS-ANS (mm)		N-ANS (mm)	
					Initial	Final	Initial	Final	Initial	Final	Initial	Final	Initial	Final	Initial	Final
1	Control	Male	12.25	15.00	93.100	92.800	79.200	79.500	3.500	3.500	86.400	89.900	48.800	50.500	54.700	60.700
2	Control	Male	11.50	15.00	95.000	95.000	87.100	87.200	5.300	5.600	87.400	93.000	52.300	55.400	52.600	55.400
3	Control	Male	9.90	13.10	91.000	90.000	75.800	75.500	1.100	0.000	78.500	88.000	44.900	50.500	47.000	52.300
4	Control	Male	12.40	15.00	91.100	91.000	78.100	79.200	1.100	1.100	73.600	77.800	42.800	43.200	48.400	50.900
5	Control	Male	11.00	14.00	90.000	90.300	78.600	79.100	0.000	.400	82.900	85.000	49.500	51.200	48.100	53.000
6	Control	Male	9.90	12.40	89.700	88.700	77.400	76.600	-.400	-1.400	81.200	83.600	49.800	53.000	52.600	55.800
7	Control	Male	12.10	15.20	95.600	94.700	84.700	82.900	5.300	4.900	81.900	84.300	49.500	49.800	47.400	50.900
8	Control	Male	13.00	15.00	92.200	92.500	83.700	83.900	2.500	2.800	84.000	86.200	49.800	51.600	52.600	54.000
9	Control	Male	13.40	16.50	89.300	89.300	79.000	80.400	-.700	-.700	85.100	87.600	54.000	54.700	54.400	55.100
10	Control	Male	13.90	17.00	86.600	87.300	83.300	82.900	-3.200	-2.800	79.700	84.300	49.800	52.300	46.700	51.200
11	Control	Male	13.10	15.20	95.000	96.900	81.000	82.400	4.900	7.400	83.900	90.400	48.100	51.200	49.100	51.200
12	Control	Male	12.50	15.00	96.100	96.600	80.600	81.000	6.000	6.700	82.600	87.000	48.400	50.200	49.800	51.600
13	Control	Male	10.50	12.40	99.200	98.900	81.500	81.200	9.500	9.500	79.800	84.700	46.000	49.100	53.300	54.700
14	Control	Female	10.90	13.40	93.200	93.700	78.500	78.700	3.200	3.900	85.300	89.400	51.600	56.100	49.800	53.000
15	Control	Female	12.00	13.90	93.300	92.400	84.100	84.900	3.200	2.500	80.200	84.800	46.300	50.900	48.400	49.500
16	Control	Female	10.00	13.10	87.300	87.500	79.100	80.200	-2.500	-2.500	79.800	84.800	45.600	46.700	47.400	48.800
17	Control	Female	10.00	12.00	88.500	88.200	76.300	77.200	-1.400	-1.800	75.900	79.600	47.400	50.900	47.700	51.900
18	Control	Female	10.00	13.00	90.000	90.600	78.100	78.400	0.000	.700	83.600	87.500	49.800	52.600	50.200	55.800
19	Control	Female	12.60	15.10	93.700	94.500	80.000	80.600	3.500	4.200	82.700	86.200	48.400	51.200	47.400	48.100
20	Control	Female	12.90	15.00	94.500	94.900	79.300	80.200	4.600	5.300	78.900	79.800	47.000	51.200	54.000	55.800
21	Control	Female	12.75	15.00	89.300	90.300	78.200	77.800	-.700	.400	73.800	75.400	47.400	48.100	52.300	53.000
22	Control	Female	11.30	13.70	94.100	94.300	85.700	85.200	3.900	4.200	88.100	92.200	50.200	55.400	48.800	51.200
23	Control	Female	11.90	14.10	89.000	90.700	79.200	79.700	-1.100	.700	80.700	82.300	50.500	51.900	51.600	53.300
24	Exp	Male	12.20	15.20	92.900	88.500	82.000	77.300	3.200	-1.800	85.400	84.200	52.600	55.800	51.900	56.800
25	Exp	Male	12.20	15.20	91.300	90.300	82.600	81.100	1.400	.400	86.700	90.600	51.600	55.400	50.500	56.500
26	Exp	Male	12.90	15.75	89.000	87.900	77.000	76.000	-1.100	-2.500	88.400	89.300	52.300	55.100	53.000	56.100
27	Exp	Male	9.70	12.20	88.400	86.700	75.300	75.100	-1.400	-3.200	82.200	82.500	52.600	54.700	44.900	48.800
28	Exp	Male	11.90	13.70	87.200	84.700	78.600	75.900	-2.800	-6.000	78.900	77.800	46.300	47.400	49.800	53.300
29	Exp	Male	11.70	14.20	89.600	87.700	80.700	77.600	-.400	-2.500	87.900	90.400	55.100	59.600	52.300	54.000
30	Exp	Male	9.40	13.10	91.400	87.700	76.300	73.300	1.400	-2.500	78.000	82.500	50.200	54.000	48.100	54.700
31	Exp	Male	12.60	14.70	88.700	88.700	76.700	76.300	-1.400	-1.400	84.000	85.200	53.700	54.400	54.700	55.100
32	Exp	Male	13.10	14.90	86.800	84.800	77.400	75.300	-3.200	-5.600	85.300	85.300	51.900	51.600	51.200	53.000
33	Exp	Male	12.40	15.30	92.200	90.000	82.000	80.400	2.500	0.000	85.400	85.300	52.300	54.400	53.000	54.400
34	Exp	Male	12.30	14.75	91.300	88.400	77.500	74.900	1.400	-1.800	84.800	85.900	50.500	52.300	52.600	55.800
35	Exp	Male	14.20	17.10	95.600	94.400	85.000	84.100	5.600	4.900	88.100	91.300	52.300	53.000	51.900	57.500
36	Exp	Male	12.00	15.60	95.400	94.000	81.000	79.700	5.300	4.600	80.700	86.400	46.000	51.200	50.900	56.800
37	Exp	Female	13.10	15.50	99.400	95.500	91.700	87.900	9.100	5.300	87.600	85.500	51.600	53.000	48.800	50.900
38	Exp	Female	10.40	12.40	90.400	88.700	77.600	74.800	.400	-1.400	81.600	81.100	46.000	48.800	53.300	57.900
39	Exp	Female	12.60	14.90	93.100	91.400	87.400	85.400	3.200	1.400	85.800	86.800	50.500	52.600	47.700	52.300
40	Exp	Female	11.75	14.00	94.600	92.900	80.600	78.600	4.600	3.200	85.700	88.600	52.300	55.400	49.800	53.300
41	Exp	Female	12.00	14.40	95.700	93.800	86.900	85.500	6.000	4.200	88.400	87.300	52.600	55.400	49.100	51.900
42	Exp	Female	10.75	13.25	96.000	92.500	82.200	78.500	5.600	2.500	88.500	89.700	55.100	58.600	49.100	52.300
43	Exp	Female	13.30	15.00	91.800	89.300	80.700	78.100	1.800	-.700	85.700	85.500	49.100	50.500	49.800	51.900
44	Exp	Female	9.80	12.90	90.400	87.200	82.300	79.000	.400	-2.800	75.100	76.700	48.100	48.800	44.900	50.500
45	Exp	Female	11.60	13.50	91.800	88.700	76.500	74.900	1.800	-1.400	82.600	86.100	50.200	52.600	53.300	55.800
46	Exp	Female	9.50	12.30	86.000	83.700	81.800	78.800	-3.500	-6.000	81.000	81.700	43.500	47.000	44.900	50.500

Table 1

	S-PNS (mm)		SN-Palatal Plane (dg)		Facial Angle (dg)		SNB (dg)		Pogonion to N perp FH (mm)		Mandibular Length (mm)		Corpus Length (mm)	
	Initial	Final	Initial	Final	Initial	Final	Initial	Final	Initial	Final	Initial	Final	Initial	Final
1	41.700	47.700	9.400	9.000	89.100	89.400	72.800	74.100	-1.800	-1.400	106.700	115.900	76.900	79.100
2	44.900	50.200	5.600	2.800	89.300	91.000	79.800	81.300	-1.400	2.100	106.500	117.900	72.100	76.500
3	37.500	39.300	3.900	8.200	88.100	86.400	71.200	70.800	-3.500	-7.000	95.000	105.800	70.300	76.100
4	41.400	45.300	2.800	1.200	90.400	91.300	75.500	76.000	.700	2.500	95.200	102.900	71.300	80.000
5	38.600	40.300	5.300	8.100	89.000	90.000	75.900	76.600	-1.800	0.000	99.000	104.300	78.400	79.500
6	40.300	42.100	9.000	10.500	84.600	85.200	71.100	71.900	-9.800	-9.500	94.600	103.200	71.300	75.300
7	37.900	40.300	7.600	8.200	89.600	90.600	76.300	76.900	-.700	1.100	98.900	104.500	71.600	76.300
8	44.600	47.000	6.100	4.700	85.700	88.000	76.200	77.800	-8.400	-4.200	99.500	107.400	73.100	75.700
9	43.500	44.900	7.800	7.200	85.200	87.000	73.700	76.700	-9.100	-6.000	99.100	109.400	74.700	79.200
10	46.700	49.500	-1.600	-.200	87.400	88.900	81.400	80.800	-4.900	-2.100	105.700	113.600	74.500	80.800
11	39.300	41.400	5.300	5.100	92.200	93.100	75.500	76.200	3.900	6.000	101.500	109.200	76.700	82.000
12	40.000	42.500	4.900	4.500	93.400	93.300	76.200	76.800	6.300	6.300	102.300	107.600	73.700	77.000
13	36.100	37.900	12.900	12.400	94.200	93.600	76.200	75.800	8.100	7.000	98.500	102.400	71.300	72.900
14	36.500	38.200	9.700	11.100	87.400	87.500	71.600	71.500	-4.600	-4.600	95.900	100.300	72.500	74.500
15	36.800	38.600	10.500	9.900	85.700	85.600	76.600	77.000	-7.000	-7.400	89.500	94.100	65.200	69.400
16	41.000	43.500	3.900	2.600	81.600	80.900	73.100	73.100	-15.100	-17.200	95.100	100.100	70.900	77.300
17	37.200	40.000	7.600	9.800	84.900	85.300	71.500	72.600	-8.800	-8.400	91.600	97.000	67.700	72.300
18	39.300	44.900	8.300	7.600	86.000	87.200	72.900	73.700	-7.400	-5.600	100.600	107.000	76.200	81.100
19	38.600	40.300	5.500	4.500	93.200	94.500	77.400	78.200	5.600	8.100	103.600	109.300	82.400	86.300
20	40.300	42.100	10.400	10.800	91.500	92.200	75.100	76.200	2.800	4.200	99.100	102.200	68.800	68.900
21	40.700	41.000	10.300	10.500	88.100	89.100	75.500	74.600	-3.500	-1.800	95.800	99.000	67.800	68.900
22	45.600	47.700	-.300	.400	88.800	91.200	79.000	79.800	-2.100	2.100	99.700	110.000	74.600	82.100
23	40.300	41.400	9.400	9.400	86.000	87.600	74.500	75.400	-7.400	-4.600	98.000	101.300	74.600	77.700
24	42.800	44.600	5.900	8.600	90.400	91.400	76.100	76.300	.700	2.800	104.600	112.800	69.100	75.200
25	35.800	41.700	13.500	12.100	86.800	87.600	76.000	75.300	-5.600	-4.900	101.300	112.000	72.900	81.100
26	42.100	45.600	6.700	6.000	88.200	90.000	73.200	74.800	-3.500	0.000	106.800	114.000	81.300	87.000
27	29.800	33.700	11.600	11.600	86.000	85.500	71.000	72.300	-6.300	-7.700	92.400	96.200	67.700	73.700
28	43.500	47.000	3.800	3.700	87.000	87.400	75.500	75.800	-5.600	-5.300	103.000	108.000	73.800	75.700
29	40.700	43.500	9.300	7.400	84.700	86.200	74.700	74.600	-9.500	-7.400	100.100	109.200	78.300	85.900
30	35.100	37.900	8.700	12.200	87.600	85.400	71.500	69.300	-4.200	-9.100	93.800	102.000	69.600	73.200
31	41.000	41.000	10.500	10.300	83.100	84.300	68.800	70.000	-14.000	-11.900	102.100	105.500	71.900	69.700
32	39.300	41.000	9.400	9.100	85.900	88.300	73.100	74.700	-7.400	-3.200	102.400	108.700	78.700	81.000
33	47.000	47.400	2.900	4.000	87.900	88.200	76.400	77.300	-4.200	-3.900	104.300	110.200	75.300	78.800
34	37.500	43.900	10.700	7.000	88.200	86.900	73.900	72.300	-3.500	-6.700	104.800	110.600	73.700	78.100
35	40.700	47.000	7.900	6.900	94.100	94.700	81.600	81.900	7.400	9.500	107.000	117.900	82.700	84.700
36	37.500	43.500	9.600	8.800	90.200	93.220	74.700	77.500	.400	6.300	96.400	110.200	73.300	82.400
37	43.900	45.300	3.400	4.200	93.100	94.300	84.200	85.300	5.300	7.400	103.400	107.300	76.700	78.500
38	40.700	41.700	9.200	12.700	87.100	86.600	73.800	72.500	-5.300	-6.700	95.600	99.100	68.300	71.500
39	43.200	44.600	3.000	6.300	89.000	88.900	82.300	81.700	-1.800	-2.100	102.200	107.700	80.800	85.000
40	38.600	38.900	7.500	10.700	90.400	91.500	75.600	74.900	.700	3.200	104.600	117.100	71.000	71.300
41	45.600	47.700	.200	1.500	92.100	90.900	80.700	80.500	3.900	1.800	108.000	110.300	80.800	78.100
42	31.200	34.000	14.100	13.600	91.100	91.200	76.200	75.800	1.800	2.100	98.700	106.500	75.300	79.900
43	38.900	39.600	7.800	9.200	85.600	86.000	73.400	73.600	-7.700	-7.000	96.400	99.900	72.100	74.600
44	38.200	42.100	4.700	6.500	85.700	85.700	77.500	76.700	-7.000	-7.700	89.100	96.500	67.300	72.000
45	37.900	40.000	11.700	12.300	88.600	87.600	72.800	73.000	-2.500	-4.600	98.100	104.900	79.300	83.600
46	38.200	39.300	6.100	10.800	81.800	82.300	76.900	76.500	-13.700	-14.400	95.300	104.900	62.700	70.100

Table 1

	Ramus Height (mm)		Mandibular Plane FH (dg)		Mandibular Plane SN (dg)		Y axis (dg)		Lower Ant Face Height (mm)		Anterior Face Height (mm)		Posterior Face Height (mm)		ANB (dg)	
	Initial	Final	Initial	Final	Initial	Final	Initial	Final	Initial	Final	Initial	Final	Initial	Final	Initial	Final
1	41.000	48.200	27.600	28.200	41.500	41.600	59.000	60.300	68.900	75.300	122.600	135.300	72.200	81.500	6.400	5.400
2	40.600	48.900	25.500	24.600	33.400	32.500	57.000	57.500	62.600	71.800	113.200	126.400	74.000	85.300	7.200	5.800
3	36.800	38.100	22.500	23.200	37.800	37.700	56.400	57.700	67.100	68.000	113.300	119.100	68.500	71.300	4.600	4.700
4	37.800	42.200	19.500	18.100	32.500	29.900	56.100	56.600	61.900	63.400	110.200	114.200	72.000	78.200	2.600	3.300
5	35.200	40.900	20.000	20.900	31.400	32.200	53.400	54.200	61.000	67.900	108.400	120.200	68.200	77.500	2.700	2.500
6	43.700	47.100	19.800	19.300	32.100	31.300	60.100	60.700	65.100	67.700	115.500	121.800	77.200	83.000	6.300	4.800
7	42.700	45.600	19.800	18.500	30.700	30.400	56.300	56.500	58.900	62.600	105.000	112.700	69.700	76.200	8.400	6.000
8	39.500	47.400	30.000	26.400	38.500	35.000	62.400	61.300	69.400	73.800	120.500	127.100	74.100	83.700	7.500	6.100
9	38.500	45.800	26.600	25.300	36.900	34.300	59.600	59.500	65.600	71.200	118.300	125.600	72.300	81.000	5.300	3.700
10	52.200	60.500	22.300	18.900	25.500	23.400	59.200	58.100	71.600	73.100	117.700	123.800	86.000	92.700	2.000	2.000
11	35.600	38.900	20.200	19.600	34.200	34.100	52.300	51.900	59.900	63.700	108.500	114.400	66.300	70.200	5.400	6.200
12	38.400	43.200	19.200	19.700	34.700	34.200	51.300	52.200	60.500	63.000	109.800	114.000	68.500	70.200	4.400	5.300
13	42.300	43.800	18.700	17.500	36.400	35.300	51.900	52.700	60.900	63.200	113.700	117.200	71.400	74.800	5.400	5.400
14	42.000	47.700	14.200	14.000	28.900	28.900	55.200	56.100	59.600	62.800	107.500	113.400	72.800	77.700	6.800	7.100
15	42.500	44.100	21.900	20.900	31.200	28.500	58.300	59.000	55.400	56.500	102.200	103.900	67.600	71.400	7.500	7.900
16	36.500	38.900	30.500	30.400	38.800	37.700	63.400	64.700	64.700	71.600	110.700	119.100	65.500	71.300	5.900	7.100
17	37.100	40.900	22.200	21.400	34.400	32.400	57.800	59.300	57.400	58.900	104.200	109.000	64.300	70.800	4.800	4.500
18	39.400	44.200	22.600	22.200	34.500	34.400	60.200	60.600	65.700	70.900	114.400	125.900	73.000	82.000	5.100	4.700
19	34.900	37.600	18.900	17.400	32.700	31.200	53.200	52.900	60.300	63.600	107.400	111.600	67.400	72.100	2.600	2.500
20	40.400	43.700	24.500	22.600	39.700	37.400	56.800	56.500	65.100	65.300	118.000	120.300	73.300	77.600	4.200	3.900
21	45.300	48.100	24.100	21.400	35.200	33.900	60.400	60.300	62.300	63.700	114.000	116.000	75.000	78.200	2.700	3.100
22	45.400	48.400	13.700	14.300	22.100	23.400	53.100	53.300	57.400	63.000	104.800	112.900	76.900	82.200	6.700	5.400
23	37.600	41.700	25.700	24.000	35.500	35.000	59.500	58.200	59.900	62.300	109.900	114.800	67.400	71.100	4.600	4.400
24	45.300	52.900	21.100	18.300	32.000	29.500	54.800	55.200	62.800	68.000	113.800	124.600	76.700	87.100	5.900	1.000
25	39.600	44.100	22.000	22.000	30.800	31.200	57.500	57.700	57.200	63.900	106.400	119.300	69.500	78.000	6.600	5.800
26	45.300	52.800	16.800	14.900	28.800	26.800	56.100	55.700	66.800	71.500	119.300	127.200	81.200	89.900	3.800	1.200
27	39.400	42.000	15.400	14.900	28.400	26.500	51.900	54.200	54.400	57.900	97.300	105.300	63.200	71.500	4.200	2.800
28	44.200	47.600	22.400	23.300	31.000	32.100	59.700	61.400	64.100	70.000	113.400	123.100	77.000	84.000	3.100	.100
29	43.300	48.500	18.500	18.200	27.500	28.200	58.800	57.900	60.300	66.600	111.000	119.400	76.600	81.700	6.000	3.100
30	33.900	38.300	28.600	33.000	43.800	47.400	55.900	59.100	64.200	69.500	110.300	122.700	59.300	63.500	4.800	4.000
31	40.300	47.100	31.500	29.000	43.500	41.400	62.500	61.500	69.400	72.200	122.200	126.000	69.500	75.800	7.900	6.300
32	46.200	54.800	16.300	15.000	25.700	24.500	57.700	57.300	62.200	66.600	112.400	119.300	79.700	87.300	4.400	.600
33	44.100	49.800	25.200	23.200	35.300	32.800	60.200	60.200	73.500	76.800	125.600	130.800	81.200	87.900	5.600	3.200
34	38.600	44.100	25.700	25.600	39.600	39.100	55.800	59.200	65.500	73.400	117.400	128.700	68.100	78.100	3.600	2.700
35	41.500	51.900	14.200	15.300	24.800	25.600	50.800	53.000	59.600	68.000	110.900	125.300	78.600	90.500	3.300	2.200
36	40.000	47.200	21.200	21.100	35.600	35.400	54.800	54.000	60.700	66.500	110.600	122.800	67.800	76.900	6.200	2.300
37	50.100	53.000	14.000	13.500	21.600	21.100	53.600	53.400	55.900	56.600	103.800	106.700	77.400	80.800	7.500	2.600
38	39.600	42.800	22.700	24.200	35.400	38.100	56.800	59.100	56.900	62.700	109.300	119.600	68.100	73.500	3.900	2.300
39	38.300	42.000	24.800	23.900	30.500	29.900	57.900	59.500	65.700	68.800	111.900	120.300	72.800	80.700	5.100	3.700
40	45.500	55.000	21.400	22.300	35.400	36.600	54.000	55.000	63.100	67.100	112.000	119.700	69.500	77.400	5.000	3.700
41	42.000	47.300	19.800	20.400	28.700	28.700	53.300	55.400	65.200	68.700	113.700	120.000	76.100	82.800	6.200	5.000
42	41.800	43.900	12.400	15.000	26.200	29.000	49.300	50.400	54.100	59.000	101.800	110.200	68.800	72.000	6.000	2.700
43	36.100	36.600	24.300	24.300	35.400	35.500	57.600	57.400	59.900	60.000	108.100	111.100	65.600	67.100	7.200	4.500
44	41.600	43.600	18.400	20.300	26.500	28.500	56.700	58.600	56.000	58.400	98.700	107.900	68.600	74.200	4.800	2.300
45	38.500	41.200	16.900	19.300	32.100	33.100	54.800	57.400	57.500	62.200	110.400	117.200	70.200	74.400	3.700	1.900
46	38.500	39.700	30.100	31.700	34.300	36.500	60.000	61.200	58.500	62.100	102.200	112.000	65.300	68.800	4.800	2.200

Table 1

	Angle of Convexity (dg)		Wits Appraisal (mm)		Occlusal Plane SN (dg)		Mx I to A perp to FH (mm)		Mx 1 to FH (dg)		Mx 6 to Ptm vertical (mm)		Mx6 to FH (mm)	
	Initial	Final	Initial	Final	Initial	Final	Initial	Final	Initial	Final	Initial	Final	Initial	Final
1	9.200	8.000	2.600	1.200	24.100	23.500	3.500	3.900	111.000	114.400	17.900	22.500	39.600	46.700
2	12.700	8.700	3.500	2.800	17.800	13.800	2.800	4.200	111.300	114.000	14.400	21.000	40.700	48.400
3	6.100	7.700	.800	3.100	23.400	21.800	3.500	2.500	109.300	103.500	17.500	20.700	34.000	38.900
4	1.500	-.600	-.600	-1.000	19.200	20.400	6.300	9.500	119.800	124.100	16.800	18.900	39.600	41.000
5	2.200	.700	.600	3.900	17.400	11.300	4.600	6.000	108.900	113.100	22.800	26.700	43.500	50.200
6	11.500	7.400	5.800	3.700	19.800	19.900	.700	3.500	108.000	111.000	12.300	15.100	36.800	41.700
7	12.700	9.300	4.500	3.200	19.300	18.300	2.100	4.200	115.300	119.400	16.800	18.600	37.200	41.400
8	14.800	9.700	4.000	2.500	20.600	17.900	1.100	1.800	107.800	103.200	17.200	21.000	41.000	48.100
9	9.400	4.900	3.400	1.800	19.600	16.100	1.800	4.600	108.200	112.800	17.200	20.300	38.600	44.900
10	-1.600	-3.400	1.200	3.500	9.500	7.000	7.000	8.800	118.500	123.100	20.000	24.600	43.500	47.700
11	6.300	8.500	1.200	4.000	21.000	18.300	8.800	8.800	127.900	130.100	18.900	23.200	36.120	40.000
12	5.700	7.000	.800	3.300	19.200	16.400	9.100	10.500	127.700	131.900	21.000	25.300	37.200	41.000
13	10.800	11.700	-.300	.300	22.100	22.800	7.400	10.500	124.300	128.600	17.200	18.900	35.100	36.100
14	13.400	14.400	4.300	5.600	22.800	21.700	1.800	.400	107.200	111.300	13.000	17.900	33.300	37.900
15	17.700	17.200	4.900	6.400	17.200	16.000	0.000	-1.400	103.500	99.600	12.600	14.400	36.100	38.200
16	11.700	13.700	3.600	5.600	19.500	18.700	6.300	5.300	120.400	116.600	16.800	20.700	36.800	44.200
17	8.000	6.400	1.800	.900	22.400	22.800	1.800	1.400	108.400	104.800	9.800	14.700	34.700	38.600
18	8.500	7.700	1.300	.700	22.900	22.900	3.500	3.200	109.700	109.300	13.000	20.000	35.800	41.700
19	1.200	-.100	-1.300	-.700	19.000	16.500	6.300	7.400	119.400	121.800	24.200	25.300	39.300	40.300
20	6.400	6.100	.700	-.600	20.000	20.600	3.900	2.800	112.500	112.300	17.900	21.800	40.700	41.700
21	2.600	2.800	-.400	.200	19.300	20.100	4.200	4.600	114.400	118.300	15.100	17.500	38.600	40.300
22	12.000	6.900	2.800	2.500	16.900	14.600	.700	.700	109.400	109.200	15.400	17.500	36.800	42.100
23	6.800	6.900	-.500	-.600	23.400	22.600	4.600	3.900	113.900	116.600	13.000	18.600	35.800	37.500
24	6.000	-6.500	3.200	-.600	19.200	16.400	3.500	5.300	116.900	122.300	19.600	20.000	38.600	44.900
25	10.100	6.100	2.200	2.400	20.600	20.800	4.900	3.200	115.500	112.500	14.700	19.600	34.400	40.000
26	1.900	-4.800	4.000	1.100	16.900	15.700	3.900	3.200	112.100	117.300	15.100	17.500	41.400	46.300
27	5.200	2.500	2.400	3.200	20.800	16.700	5.300	2.500	117.300	116.900	15.400	17.900	31.600	37.200
28	.400	-6.100	3.900	-.300	13.300	14.500	7.700	6.700	124.400	123.500	16.100	14.700	38.600	44.900
29	11.200	3.400	5.000	2.200	16.800	17.100	4.900	2.100	122.700	114.400	11.900	14.700	37.900	43.900
30	8.400	5.200	.700	.100	24.800	26.200	3.500	3.500	116.200	115.900	17.900	16.500	31.600	38.900
31	11.900	9.400	5.500	3.300	25.500	24.900	2.100	.700	107.700	110.000	16.100	17.200	39.600	41.700
32	2.200	-8.300	3.800	2.300	17.500	12.400	1.100	3.900	106.000	118.300	10.500	12.300	37.500	44.200
33	9.600	3.900	5.300	1.100	15.400	16.400	7.700	4.900	122.400	120.200	17.900	17.900	43.500	48.400
34	6.800	3.300	1.000	-1.200	20.100	22.700	7.700	4.600	125.600	119.200	19.600	22.500	40.300	44.900
35	3.400	-.700	1.100	-.900	12.400	13.200	5.600	6.000	117.500	119.600	22.100	24.200	42.800	50.900
36	11.400	2.000	2.000	-.500	21.900	17.000	8.100	7.400	124.400	125.100	16.800	21.400	38.200	47.400
37	14.600	2.800	4.600	-3.200	10.700	13.700	9.100	6.000	132.200	120.700	20.000	18.900	40.000	44.200
38	7.400	5.000	1.900	.200	19.100	21.100	4.600	1.100	113.500	105.300	13.300	13.000	38.900	43.500
39	9.200	5.200	-1.100	-1.800	17.600	15.500	7.000	3.900	123.700	111.300	16.500	16.800	34.400	42.100
40	9.000	2.900	2.300	-.900	18.200	22.400	8.400	6.000	124.700	121.000	19.300	21.000	36.800	41.400
41	8.200	6.500	5.300	1.900	11.100	15.400	7.400	0.000	124.500	103.700	18.600	18.900	43.500	44.900
42	11.700	2.900	3.100	-.900	18.100	20.000	8.800	3.900	132.200	120.300	18.600	20.000	36.100	40.300
43	14.300	7.500	4.600	1.200	20.800	21.300	-1.800	0.000	95.100	104.000	15.400	15.800	34.700	37.900
44	10.400	3.300	.500	.600	18.600	15.900	4.600	3.500	120.100	117.300	11.900	14.700	32.600	38.900
45	7.100	2.500	0.000	-3.200	22.700	24.500	8.100	6.700	127.800	126.200	15.800	16.500	35.100	39.600

Table 1

	Mx 6 to Palatal Plane (mm)		Md 1 to APo (mm)		FMIA (dg)		Md 6 to MP (mm)		Interincisal Angle (dg)		Molar Relation (mm)		Incisal Overjet (mm)	
	Initial	Final	Initial	Final	Initial	Final	Initial	Final	Initial	Final	Initial	Final	Initial	Final
1	16.700	18.500	-.600	1.400	56.500	55.500	26.100	27.900	125.500	121.000	-.900	-.600	6.600	4.900
2	12.600	18.500	-2.200	-1.400	60.300	66.900	23.700	27.200	129.000	132.900	.400	.100	7.900	7.300
3	13.000	17.200	1.700	-1.100	63.400	60.400	25.300	29.000	134.100	136.900	5.000	2.900	4.200	6.600
4	14.800	14.900	2.600	3.100	68.700	66.000	25.400	28.300	128.900	121.900	.600	.300	4.300	6.500
5	16.800	22.600	.600	.800	56.500	59.200	22.500	25.200	127.600	126.100	3.300	2.500	5.100	5.300
6	13.000	16.100	-2.800	-1.300	57.800	56.500	29.600	32.800	129.800	125.500	.500	0.000	7.400	8.100
7	15.100	18.800	-3.000	-.800	60.400	61.800	24.400	26.200	125.100	122.400	1.700	.600	7.700	6.700
8	15.800	19.500	0.000	.300	47.100	51.100	24.100	28.200	119.300	127.900	1.700	3.100	5.600	4.400
9	14.700	17.800	.800	1.600	56.300	56.500	24.600	29.100	128.100	123.700	2.400	2.600	4.900	5.400
10	18.300	20.500	1.300	.800	60.300	63.400	29.900	31.900	121.800	120.400	2.500	1.800	6.900	7.900
11	13.300	16.200	-2.100	-2.000	62.400	63.400	22.900	22.800	114.500	113.400	1.500	.600	11.500	11.400
12	13.700	16.600	-.800	-1.600	60.600	62.400	21.700	22.100	112.900	110.500	1.700	2.000	9.900	10.200
13	13.600	13.600	3.000	4.700	60.000	57.100	24.700	27.300	115.700	108.500	-.200	-.300	5.100	7.000
14	11.500	14.500	-2.000	-2.700	61.200	59.200	26.800	28.800	134.000	127.900	3.700	2.500	7.200	6.600
15	15.200	15.900	-1.300	-1.900	57.100	54.700	20.700	22.600	133.600	135.100	1.200	1.600	5.600	4.500
16	12.700	16.800	3.400	4.500	48.900	45.600	25.600	30.400	108.500	109.000	3.600	3.000	7.600	6.900
17	12.200	13.500	.800	-.400	56.100	54.400	23.100	25.900	127.600	129.600	1.700	.100	4.500	5.300
18	14.900	18.100	-.100	-.100	54.200	55.100	27.000	28.500	124.600	125.800	3.200	3.200	7.300	6.800
19	15.200	15.600	.700	1.400	65.200	65.300	25.100	26.700	125.800	123.500	1.600	.700	5.200	4.700
20	16.300	17.500	-.700	-.700	68.500	71.800	23.500	25.300	136.000	139.500	.600	-.600	5.700	4.400
21	17.000	19.400	1.400	.700	60.900	61.300	23.300	24.200	126.400	123.000	-.700	.300	4.500	5.100
22	7.900	11.600	-2.100	-2.700	61.800	58.800	27.100	28.900	132.400	129.600	-.500	0.000	5.900	4.700
23	13.000	15.500	.700	-.500	56.300	56.600	22.900	24.400	122.400	119.700	1.900	.900	7.100	7.100
24	14.100	19.200	-3.500	.300	58.900	60.300	24.200	28.900	122.000	117.900	2.200	-2.600	8.400	3.700
25	15.600	16.100	3.000	2.300	46.700	46.100	24.500	28.900	111.300	113.600	-.100	-2.700	4.900	2.900
26	19.100	21.600	-2.700	-.200	58.600	54.000	26.600	28.700	126.600	116.800	-.800	-1.900	7.800	2.600
27	13.900	16.500	.400	1.900	56.500	52.000	22.700	25.900	119.300	115.100	.700	-1.900	7.300	2.300
28	17.200	20.300	-1.900	1.500	63.000	58.400	24.700	24.700	118.300	114.900	.200	-1.700	11.000	5.200
29	12.900	16.000	-2.400	.700	55.500	57.500	25.800	28.000	112.800	123.100	1.800	-.500	11.000	3.600
30	10.700	14.400	-1.500	3.800	68.900	50.800	21.400	21.100	132.700	114.800	.800	-1.500	7.600	2.700
31	14.700	15.900	-2.500	1.700	58.200	51.000	25.000	29.700	130.600	120.900	2.000	-1.600	9.600	3.000
32	15.400	21.100	-2.800	.800	57.600	51.500	26.200	27.900	131.500	113.200	3.400	-2.100	6.200	2.200
33	20.100	23.100	.200	2.800	58.100	58.300	24.600	28.300	115.600	118.100	.400	-1.800	10.200	3.800
34	18.200	19.300	3.000	5.200	54.500	52.600	22.600	28.600	108.900	113.400	1.500	-1.100	6.700	1.600
35	17.700	20.100	-2.800	2.200	69.100	58.200	24.000	30.400	131.600	118.700	.100	-2.000	7.800	2.200
36	12.900	18.200	.100	3.900	62.300	57.000	24.800	26.200	117.800	111.900	-.100	-2.800	10.300	2.800
37	14.300	15.500	-1.400	1.600	64.700	55.200	23.100	23.600	112.600	114.600	.700	-1.800	11.800	3.600
38	14.500	17.800	1.100	.800	58.800	58.700	20.300	23.500	125.300	133.500	.400	-2.900	6.100	2.700
39	13.300	17.800	1.200	2.700	55.700	58.900	25.100	29.100	112.000	127.600	-.100	-2.500	8.100	2.700
40	14.900	19.300	2.300	2.500	55.600	53.100	22.400	25.200	110.900	112.200	.200	-2.300	7.700	4.000
41	17.000	18.000	-1.200	-1.200	55.700	49.500	21.400	24.800	111.200	125.800	1.900	-2.600	9.400	2.400
42	15.400	17.300	-1.200	.800	63.800	62.700	24.900	24.800	111.600	122.300	1.700	-3.100	11.600	3.400
43	12.100	12.400	-.900	1.000	49.700	45.700	23.600	24.500	134.600	121.600	1.000	-1.300	3.200	2.100
44	11.000	14.700	2.300	2.100	53.100	54.500	23.800	24.300	113.100	117.100	-.700	-2.200	5.500	3.500
45	12.900	15.100	.500	5.500	63.400	53.100	24.700	27.000	115.700	106.900	-.900	-1.500	9.800	2.700
46	12.700	17.700	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Table 2

	Maxillary Depth (dg)	SNA (dg)	A to N perp FH (mm)	Midfacial Length (mm)	PNS-ANS (mm)	N-ANS (mm)	S-PNS (mm)	SN-Palatal Plane (dg)	Facial Angle (dg)	SNB (dg)	Pogonion to N perp FH (mm)	Mandibular Length (mm)	Corpus Length (mm)	Ramus Height (mm)	Mandibular Plane FH (dg)	Mandibular Plane SN (dg)	Y axis (dg)	Lower Ant Face Height (mm)
	Delta 1	Delta 2	Delta 3	Delta 4	Delta 5	Delta 6	Delta 7	Delta 8	Delta 9	Delta 10	Delta 11	Delta 12	Delta 13	Delta 14	Delta 15	Delta 16	Delta 17	Delta 18
1	-.300	.300	0.000	3.500	1.700	6.000	6.000	-.400	.300	1.300	.400	9.200	2.200	7.200	.600	.100	1.300	6.400
2	0.000	.100	.300	5.600	3.100	2.800	5.300	-2.800	1.700	1.500	3.500	11.400	4.400	8.300	-.900	-.900	.500	9.200
3	-1.000	-.300	-1.100	9.500	5.600	5.300	1.800	4.300	-1.700	-.400	-3.500	10.800	5.800	1.300	.700	-.100	1.300	.900
4	-.100	1.100	0.000	4.200	.400	2.500	3.900	-1.600	.900	.500	1.800	7.700	8.700	4.400	-1.400	-2.600	.500	1.500
5	.300	.500	.400	2.100	1.700	4.900	1.700	2.800	1.000	.700	1.800	5.300	1.100	5.700	.900	.800	.800	6.900
6	-1.000	-.800	-1.000	2.400	3.200	3.200	1.800	1.500	.600	.800	.300	8.600	4.000	3.400	-.500	-.800	.600	2.600
7	-.900	-1.800	-.400	2.400	.300	3.500	2.400	.600	1.000	.600	1.800	5.600	4.700	2.900	-1.300	-.300	.200	3.700
8	.300	.200	.300	2.200	1.800	1.400	2.400	-1.400	2.300	1.600	4.200	7.900	2.600	7.900	-3.600	-3.500	-1.100	4.400
9	0.000	1.400	0.000	2.500	.700	.700	1.400	-.600	1.800	3.000	3.100	10.300	4.500	7.300	-1.300	-2.600	-.100	5.600
10	.700	-.400	.400	4.600	2.500	4.500	2.800	1.400	1.500	-.600	2.800	7.900	6.300	8.300	-3.400	-2.100	-1.100	1.500
11	1.900	1.400	2.500	6.500	3.100	2.100	2.100	-.200	.900	.700	2.100	7.700	5.300	3.300	-.600	-.100	-.400	3.800
12	.500	.400	.700	4.400	1.800	1.800	2.500	-.400	-.100	.600	-4E-19	5.300	3.300	4.800	.500	-.500	.900	2.500
13	-.300	-.300	0.000	4.900	3.100	1.400	1.800	-.500	-.600	-.400	-1.100	3.900	1.600	1.500	-1.200	-1.100	.800	2.300
14	.500	.200	.700	4.100	4.500	3.200	1.700	1.400	.100	-.100	0.000	4.400	2.000	5.700	-.200	0.000	.900	3.200
15	-.900	.800	-.700	4.600	4.600	1.100	1.800	-.600	-.100	.400	-.400	4.600	4.200	1.600	-1.000	-2.700	.700	1.100
16	.200	1.100	0.000	5.000	1.100	1.400	2.500	-1.300	-.700	0.000	-2.100	5.000	6.400	2.400	-.100	-1.100	1.300	6.900
17	-.300	.900	-.400	3.700	3.500	4.200	2.800	2.200	.400	1.100	.400	5.400	4.600	3.800	-.800	-2.000	1.500	1.500
18	.600	.300	.700	3.900	2.800	5.600	5.600	-.700	1.200	.800	1.800	6.400	4.900	4.800	-.400	-.100	.400	5.200
19	.800	.600	.700	3.500	2.800	.700	1.700	-1.000	1.300	.800	2.500	5.700	3.900	2.700	-1.500	-1.500	-.300	3.300
20	.400	.900	.700	.900	4.200	1.800	1.800	.400	.700	1.100	1.400	3.100	.100	3.300	-1.900	-2.300	-.300	.200
21	1.000	-.400	1.100	1.600	.700	.700	.300	.200	1.000	-.900	1.700	3.200	1.100	2.800	-2.700	-1.300	-.100	1.400
22	.200	-.500	.300	4.100	5.200	2.400	2.100	.700	2.400	.800	4.200	10.300	7.500	3.000	.600	1.300	.200	5.600
23	1.700	.500	1.800	1.600	1.400	1.700	1.100	0.000	1.600	.900	2.800	3.300	3.100	4.100	-1.700	-.500	-1.300	2.400
24	-4.400	-4.700	-5.000	-1.200	3.200	4.900	1.800	2.700	1.000	.200	2.100	8.200	6.100	7.600	-2.800	-2.500	.400	5.200
25	-1.000	-1.500	-1.000	3.900	3.800	6.000	5.900	-1.400	.800	-.700	.700	10.700	8.200	4.500	0.000	.400	.200	6.700
26	-1.100	-1.000	-1.400	.900	2.800	3.100	3.500	-.700	1.800	1.600	3.500	7.200	5.700	7.500	-1.900	-2.000	-.400	4.700
27	-1.700	-.200	-1.800	.300	2.100	3.900	3.900	0.000	-.500	1.300	-1.400	3.800	6.000	2.600	-.500	-1.900	2.300	3.500
28	-2.500	-2.700	-3.200	-1.100	1.100	3.500	3.500	-.100	.400	.300	.300	5.000	1.900	3.400	.900	1.100	1.700	5.900
29	-1.900	-3.100	-2.100	2.500	4.500	1.700	2.800	-1.900	1.500	-.100	2.100	9.100	7.600	5.200	-.300	.700	-.900	6.300
30	-3.700	-3.000	-3.900	4.500	3.800	6.600	2.800	3.500	-2.200	-2.200	-4.900	8.200	3.600	4.400	4.400	3.600	3.200	5.300
31	0.000	-.400	0.000	1.200	.700	.400	0.000	-.200	1.200	1.200	2.100	3.400	-2.200	6.800	-2.500	-2.100	-1.000	2.800
32	-2.000	-2.100	-2.400	0.000	-.300	1.800	1.700	-.300	2.400	1.600	4.200	6.300	2.300	8.600	-1.300	-1.200	-.400	4.400
33	-2.200	-1.600	-2.500	-.100	2.100	1.400	.400	1.100	.300	.900	.300	5.900	3.500	5.700	-2.000	-2.500	0.000	3.300
34	-2.900	-2.600	-3.200	1.100	1.800	3.200	6.400	-3.700	-1.300	-1.600	-3.200	5.800	4.400	5.500	-.100	-.500	3.400	7.900
35	-1.200	-.900	-.700	3.200	.700	5.600	6.300	-1.000	.600	.300	2.100	10.900	2.000	10.400	1.100	.800	2.200	8.400
36	-1.400	-1.300	-.700	5.700	5.200	5.900	6.000	-.800	3.020	2.800	5.900	13.800	9.100	7.200	-.100	-.200	-.800	5.800
37	-3.900	-3.800	-3.800	-2.100	1.400	2.100	1.400	.800	1.200	1.100	2.100	3.900	1.800	2.900	-.500	-.500	-.200	.700
38	-1.700	-2.800	-1.800	-.500	2.800	4.600	1.000	3.500	-.500	-1.300	-1.400	3.500	3.200	3.200	1.500	2.700	2.300	5.800
39	-1.700	-2.000	-1.800	1.000	2.100	4.600	1.400	3.300	-.100	-.600	-.300	5.500	4.200	3.700	-.900	-.600	1.600	3.100
40	-1.700	-2.000	-1.400	2.900	3.100	3.500	.300	3.200	1.100	-.700	2.500	12.500	.300	9.500	.900	1.200	1.000	4.000
41	-1.900	-1.400	-1.800	-1.100	2.800	2.800	2.100	1.300	-1.200	-.200	-2.100	2.300	-2.700	5.300	.600	0.000	2.100	3.500
42	-3.500	-3.700	-3.100	1.200	3.500	3.200	2.800	-.500	.100	-.400	.300	7.800	4.600	2.100	2.600	2.800	1.100	4.900
43	-2.500	-2.600	-2.500	-.200	1.400	2.100	.700	1.400	.400	.200	.700	3.500	2.500	.500	0.000	.100	-.200	.100
44	-3.200	-3.300	-3.200	1.600	.700	5.600	3.900	1.800	0.000	-.800	-.700	7.400	4.700	2.000	1.900	2.000	1.900	2.400
45	-3.100	-1.600	-3.200	3.500	2.400	2.500	2.100	.600	-1.000	.200	-2.100	6.800	4.300	2.700	2.400	1.000	2.600	4.700
46	-3.300	-3.000	-2.500	.700	2.500	5.600	1.100	4.700	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Table 2

	Anterior Face Height (mm) Delta 19	Posterior Face Height (mm) Delta 20	ANB (dg) Delta 21	Angle of Convexity (dg) Delta 22	Wits Appraisal (mm) Delta 23	Occlusal Plane SN (dg) Delta 24	Mx I to A perp to FH (mm) Delta 25	Mx 1 to FH (dg) Delta 26	Mx 6 to Ptm vertical (mm) Delta 27	Mx6 to FH (mm) Delta 28	Mx 6 to Palatal Plane (mm) Delta 29	Md 1 to APo (mm) Delta 30	FMIA (dg) Delta 31	Md 6 to MP (mm) Delta 32	Interincisal Angle (dg) Delta 33	Molar Relation (mm) Delta 34	Incisal Overjet (mm) Delta 35	Delta Age
1	12.700	9.300	-1.000	-1.200	-1.400	-.600	.400	3.400	4.600	7.100	1.800	2.000	-1.000	1.800	-4.500	.300	-1.700	2.75
2	13.200	11.300	-1.400	-4.000	-.700	-4.000	1.400	2.700	6.600	7.700	5.900	.800	6.600	3.500	3.900	-.300	-.600	3.50
3	5.800	2.800	.100	1.600	2.300	-1.600	-1.000	-5.800	3.200	4.900	4.200	-2.800	-3.000	3.700	2.800	-2.100	2.400	3.20
4	4.000	6.200	.700	-2.100	-.400	1.200	3.200	4.300	2.100	1.400	.100	.500	-2.700	2.900	-7.000	-.300	2.200	2.60
5	11.800	9.300	-.200	-1.500	3.300	-6.100	1.400	4.200	3.900	6.700	5.800	.200	2.700	2.700	-1.500	-.800	.200	3.00
6	6.300	5.800	-1.500	-4.100	-2.100	.100	2.800	3.000	2.800	4.900	3.100	1.500	-1.300	3.200	-4.300	-.500	.700	2.50
7	7.700	6.500	-2.400	-3.400	-1.300	-1.000	2.100	4.100	1.800	4.200	3.700	2.200	1.400	1.800	-2.700	-1.100	-1.000	3.10
8	6.600	9.600	-1.400	-5.100	-1.500	-2.700	.700	-4.600	3.800	7.100	3.700	.300	4.000	4.100	8.600	1.400	-1.200	2.00
9	7.300	8.700	-1.600	-4.500	-1.600	-3.500	2.800	4.600	3.100	6.300	3.100	.800	.200	4.500	-4.400	.200	.500	3.10
10	6.100	6.700	0.000	-1.800	2.300	-2.500	1.800	4.600	4.600	4.200	2.200	-.500	3.100	2.000	-1.400	-.700	1.000	3.10
11	5.900	3.900	.800	2.200	2.800	-2.700	0.000	2.200	4.300	3.880	2.900	.100	1.000	-.100	-1.100	-.900	-.100	2.10
12	4.200	1.700	.900	1.300	2.500	-2.800	1.400	4.200	4.300	3.800	2.900	-.800	1.800	.400	-2.400	.300	.300	2.50
13	3.500	3.400	0.000	.900	.600	.700	3.100	4.300	1.700	1.000	0.000	1.700	-2.900	2.600	-7.200	-.100	1.900	1.90
14	5.900	4.900	.300	1.000	1.300	-1.100	-1.400	4.100	4.900	4.600	3.000	-.700	-2.000	2.000	-6.100	-1.200	-.600	2.50
15	1.700	3.800	.400	-.500	1.500	-1.200	-1.400	-3.900	1.800	2.100	.700	-.600	-2.400	1.900	1.500	.400	-1.100	1.90
16	8.400	5.800	1.200	2.000	2.000	-.800	-1.000	-3.800	3.900	7.400	4.100	1.100	-3.300	4.800	.500	-.600	-.700	3.10
17	4.800	6.500	-.300	-1.600	-.900	.400	-.400	-3.600	4.900	3.900	1.300	-1.200	-1.700	2.800	2.000	-1.600	.800	2.00
18	11.500	9.000	-.400	-.800	-.600	0.000	-.300	-.400	7.000	5.900	3.200	0.000	.900	1.500	1.200	0.000	-.500	3.00
19	4.200	4.700	-.100	-1.300	.600	-2.500	1.100	2.400	1.100	1.000	.400	.700	.100	1.600	-2.300	-.900	-.500	2.50
20	2.300	4.300	-.300	-.300	-1.300	.600	-1.100	-.200	3.900	1.000	1.200	0.000	3.300	1.800	3.500	-1.200	-1.300	2.10
21	2.000	3.200	.400	.200	.600	.800	.400	3.900	2.400	1.700	2.400	-.700	.400	.900	-3.400	1.000	.600	2.25
22	8.100	5.300	-1.300	-5.100	-.300	-2.300	0.000	-.200	2.100	5.300	3.700	-.600	-3.000	1.800	-2.800	.500	-1.200	2.40
23	4.900	3.700	-.200	.100	-.100	-.800	-.700	2.700	5.600	1.700	2.500	-1.200	.300	1.500	-2.700	-1.000	0.000	2.20
24	10.800	10.400	-4.900	-12.5	-3.800	-2.800	1.800	5.400	.400	6.300	5.100	3.800	1.400	4.700	-4.100	-4.800	-4.700	3.00
25	12.900	8.500	-.800	-4.000	.200	.200	-1.700	-3.000	4.900	5.600	.500	-.700	-.600	4.400	2.300	-2.600	-2.000	3.00
26	7.900	8.700	-2.600	-6.700	-2.900	-1.200	-.700	5.200	2.400	4.900	2.500	2.500	-4.600	2.100	-9.800	-1.100	-5.200	2.85
27	8.000	8.300	-1.400	-2.700	.800	-4.100	-2.800	-.400	2.500	5.600	2.600	1.500	-4.500	3.200	-4.200	-2.600	-5.000	2.50
28	9.700	7.000	-3.000	-6.500	-4.200	1.200	-1.000	-.900	-1.400	6.300	3.100	3.400	-4.600	0.000	-3.400	-1.900	-5.800	1.80
29	8.400	5.100	-2.900	-7.800	-2.800	.300	-2.800	-8.300	2.800	6.000	3.100	3.100	2.000	2.200	10.300	-2.300	-7.400	2.50
30	12.400	4.200	-.800	-3.200	-.600	1.400	0.000	-.300	-1.400	7.300	3.700	5.300	-18.1	-.300	-17.9	-2.300	-4.900	3.70
31	3.800	6.300	-1.600	-2.500	-2.200	-.600	-1.400	2.300	1.100	2.100	1.200	4.200	-7.200	4.700	-9.700	-3.600	-6.600	2.10
32	6.900	7.600	-3.800	-10.5	-1.500	-5.100	2.800	12.300	1.800	6.700	5.700	3.600	-6.100	1.700	-18.3	-5.500	-4.000	1.80
33	5.200	6.700	-2.400	-5.700	-4.200	1.000	-2.800	-2.200	0.000	4.900	3.000	2.600	.200	3.700	2.500	-2.200	-6.400	2.90
34	11.300	10.000	-.900	-3.500	-2.200	2.600	-3.100	-6.400	2.900	4.600	1.100	2.200	-1.900	6.000	4.500	-2.600	-5.100	2.45
35	14.400	11.900	-1.100	-4.100	-2.000	.800	.400	2.100	2.100	8.100	2.400	5.000	-10.9	6.400	-12.9	-2.100	-5.600	2.90
36	12.200	9.100	-3.900	-9.400	-2.500	-4.900	-.700	.700	4.600	9.200	5.300	3.800	-5.300	1.400	-5.900	-2.700	-7.500	3.60
37	2.900	3.400	-4.900	-11.8	-7.800	3.000	-3.100	-11.5	-1.100	4.200	1.200	3.000	-9.500	.500	2.000	-2.500	-8.200	2.40
38	10.300	5.400	-1.600	-2.400	-1.700	2.000	-3.500	-8.200	-.300	4.600	3.300	-.300	-.100	3.200	8.200	-3.300	-3.400	2.00
39	8.400	7.900	-1.400	-4.000	-.700	-2.100	-3.100	-12.4	.300	7.700	4.500	1.500	3.200	4.000	15.600	-2.400	-5.400	2.30
40	7.700	7.900	-1.300	-6.100	-3.200	4.200	-2.400	-3.700	1.700	4.600	4.400	.200	-2.500	2.800	1.300	-2.500	-3.700	2.25
41	6.300	6.700	-1.200	-1.700	-3.400	4.300	-7.400	-20.8	.300	1.400	1.000	0.000	-6.200	3.400	14.600	-4.500	-7.000	2.40
42	8.400	3.200	-3.300	-8.800	-4.000	1.900	-4.900	-11.9	1.400	4.200	1.900	2.000	-1.100	-.100	10.700	-4.800	-8.200	2.50
43	3.000	1.500	-2.700	-6.800	-3.400	.500	1.800	8.900	.400	3.200	.300	1.900	-4.000	.900	-13	-2.300	-1.100	1.70
44	9.200	5.600	-2.500	-7.100	.100	-2.700	-1.100	-2.800	2.800	6.300	3.700	-.200	1.400	.500	4.000	-1.500	-2.000	3.10
45	6.800	4.200	-1.800	-4.600	-3.200	1.800	-1.400	-1.600	.700	4.500	2.200	5.000	-10.3	2.300	-8.800	-.600	-7.100	1.90

Table 3

Summary of Male's Data

Variable	Initial Control Mean	Initial Control S.D.	Initial Exper Mean	Initial Exper S.D.	Initial F-Value	Initial P-Value	Delta Control Mean	Delta Control S.D.	Delta Exper Mean	Delta Exper S.D.	Delta F-Value	Delta P-Value
Age (yrs)	11.958	1.280	12.046	1.309	0.03	.8632	2.719	.593	2.700	.503	0.01	.9297
Maxillary Depth (dg)	92.608	2.817	90.754	3.459	2.24	.1471	0.008	1.178	-2.000	.792	25.99	.0001
SNA (dg)	80.768	2.987	79.392	3.222	1.28	.2697	0.138	1.265	-1.931	.897	23.15	.0001
A to N perp FH (mm)	2.685	2.839	0.808	3.471	2.28	.1443	0.162	1.426	-2.146	.879	24.66	.0001
Midfacial Length (mm)	82.077	3.415	84.292	3.656	2.55	.1235	4.215	2.180	1.608	2.127	9.53	.0050
PNS-ANS (mm)	48.746	2.613	51.338	2.929	5.67	.0255	2.231	1.640	2.423	1.443	0.10	.7537
N-ANS (mm)	50.515	2.495	51.138	2.927	0.34	.5646	3.085	2.001	3.692	1.666	0.71	.4084
S-PNS (mm)	40.962	4.380	39.446	3.209	1.01	.3243	2.762	2.187	3.462	1.436	0.93	.3443
SN-Palatal Plane (dg)	6.077	3.027	8.500	3.520	3.54	.0720	0.208	1.864	-0.215	1.908	0.33	.5726
Facial Angle (dg)	89.092	2.778	87.700	2.986	1.51	.2303	0.738	1.431	0.694	1.077	0.01	.9292
SNB (dg)	75.523	3.127	74.346	2.943	0.98	.3329	0.762	1.373	0.431	.967	0.50	.4844
Pog to N perp FH (mm)	-1.723	5.191	-4.254	5.605	1.43	.2440	1.323	2.952	1.062	2.090	0.07	.7965
Mandibular Length (mm)	100.192	4.656	101.462	4.177	0.53	.4715	7.815	3.010	7.562	2.298	0.06	.8111
Corpus Length (mm)	73.531	4.632	74.485	2.562	0.42	.5221	4.192	3.099	4.477	2.093	0.07	.7861
Ramus Height (mm)	40.331	3.485	41.669	4.450	0.73	.4016	5.100	2.179	6.108	2.531	1.18	.2875
Mandibular Plane FH (dg)	22.438	5.257	21.454	3.747	0.30	.5875	-0.885	1.896	-0.392	1.428	0.56	.4618
Mandibular Plane SN (dg)	34.277	6.335	32.831	4.090	0.48	.4959	-1.054	1.795	-0.485	1.272	0.87	.3601
Y axis (dg)	56.538	3.263	56.654	3.498	0.01	.9314	0.323	1.588	0.762	.796	0.79	.3822
Lower Ant Face Ht (mm)	64.108	5.056	63.131	4.125	0.29	.5943	3.946	1.695	5.400	2.470	3.06	.0930
Anterior Face Ht (mm)	113.592	7.158	113.123	5.199	0.04	.8500	7.315	3.162	9.531	3.246	3.101	.0907
Posterior Face Ht (mm)	72.338	7.145	72.954	5.059	0.06	.8021	6.554	2.152	7.985	2.984	1.97	.1737
ANB (dg)	5.246	1.458	5.031	1.986	0.10	.7540	-0.538	1.345	-2.315	1.069	13.90	.0010
Angle Of Convexity (dg)	7.792	3.966	6.808	4.943	0.31	.5805	-1.669	3.200	-6.085	2.511	15.32	.0007
Wits Appraisal (mm)	2.115	1.654	3.085	1.984	1.83	.1888	0.369	1.563	-2.146	1.993	12.82	.0015
Occlusal Plane SN (dg)	19.462	3.996	18.862	3.585	0.16	.6905	-1.962	2.562	-0.862	2.041	1.47	.2377
Mx 1 to A perp FH (mm)	4.515	2.258	5.077	2.908	0.30	.5875	1.546	1.829	-0.923	1.279	15.92	.0005
Mx 1 to FH (dg)	115.231	6.294	117.592	7.612	0.74	.3972	2.400	5.316	0.500	3.464	1.17	.2911
Mx 6 to Ptm vertical (mm)	17.692	3.142	16.438	2.679	1.20	.2844	3.600	1.973	1.746	1.352	7.77	.0102
Mx 6 to FH (mm)	38.686	3.745	38.154	2.983	0.16	.6921	4.860	1.754	5.969	2.109	2.13	.1578
Mx 6 to Palatal Plane (mm)	17.723	2.751	15.577	1.758	0.89	.3551	3.031	1.617	3.023	1.784	0.00	.9909
Md 1 to APo (mm)	-0.115	2.189	-1.031	2.005	1.24	.2772	0.462	1.565	3.100	1.342	21.29	.0001
FMIA (dg)	59.254	5.919	59.069	4.966	0.01	.9321	0.762	5.457	-4.631	2.923	9.86	.0044
Md 6 to MP (mm)	24.992	1.473	24.392	2.437	0.58	.4549	2.546	2.127	3.092	1.356	0.61	.4427
Interincisal Angle (dg)	124.023	8.359	121.462	6.628	0.75	.3952	-1.631	8.609	-5.123	4.471	1.68	.2066
Molar Relation (mm)	1.554	1.177	0.931	1.556	1.33	.2609	-0.354	1.194	-2.792	.844	36.15	.0001
Incisal Overjet (mm)	6.700	1.922	8.369	2.195	4.25	.0502	0.354	1.461	-5.400	1.296	112.88	.0001

Table 4

Summary of Female's Data

Variable	Initial Control Mean	Initial Control S.D.	Initial Exper Mean	Initial Exper S.D.	Initial F-Value	Initial P-Value	Delta Control Mean	Delta Control S.D.	Delta Exper Mean	Delta Exper S.D.	Delta F-Value	Delta P-Value
Age (yrs)	11.435	1.333	11.480	1.167	0.01	.9369	2.395	.415	2.335	.399	0.11	.7455
Maxillary Depth (dg)	91.290	3.729	92.920	2.714	1.25	.2784	0.420	.824	-2.550	.708	74.75	.0001
SNA (dg)	79.850	4.652	82.770	2.864	2.86	.1082	0.440	.850	-2.620	.546	91.80	.0001
A to N perp FH (mm)	1.270	1.126	2.940	.836	1,42	.2493	0.490	.796	-2.510	.726	77.45	.0001
Midfacial Length (mm)	80.900	4.178	84.200	4.254	3.06	.0971	3.300	1.737	0.700	1.413	13.48	.0017
PNS-ANS (mm)	48.420	3.391	49.900	2.002	1.41	.2500	3.080	.955	2.370	1.592	1.46	.2421
N-ANS (mm)	49.760	2.859	49.070	2.265	0.36	.5572	2.280	1.353	3.660	1.609	4.31	.0525
S-PNS (mm)	39.630	4.048	39.640	2.676	0.00	.9949	2.140	1.073	1.680	1.399	0.68	.4202
SN-Palatal Plane (dg)	7.530	4.203	6.770	3.530	0.19	.6667	0.130	1.606	2.010	1.099	9.34	.0068
Facial Angle (dg)	87.320	3.461	88.450	3.326	0.55	.4662	0.790	.799	0.050	.905	3.76	.0684
SNB (dg)	74.720	3.890	77.340	2.492	3.22	.0897	0.490	.666	-0.290	.644	7.09	.0158
Pog to N perp FH (mm)	-4.750	5.882	-2.630	5.920	0.64	.4323	1.230	1.592	-0.170	1.808	3.39	.0826
Mandibular Length (mm)	96.890	5.504	99.140	4.226	1.05	.3188	5.140	3.182	6.280	2.128	0.89	.3588
Corpus Length (mm)	72.070	6.182	73.430	5.092	0.29	.5979	3.780	2.778	3.030	2.289	0.43	.5183
Ramus Height (mm)	40.110	4.088	41.200	3.656	0.39	.5376	3.420	2.550	3.310	1.209	0.01	.9033
Mandibular Plane FH (dg)	21.830	5.338	20.480	5.121	0.33	.5710	-0.970	1.200	1.010	.991	16.18	.0008
Mandibular Plane SN (dg)	33.300	4.782	30.610	5.076	1.49	.2383	-1.020	1.297	1.090	1.215	14.10	.0015
Y axis (dg)	57.790	3.038	55.400	3.300	2.84	.1093	0.300	.966	1.340	.845	6.58	.0196
Lower Ant Face Ht (mm)	60.780	4.078	59.280	3.570	0.77	.3930	3.080	1.802	3.280	2.198	0.05	.8264
Anterior Face Ht (mm)	109.310	5.173	107.190	5.051	0.86	.3661	5.380	2.593	7.280	3.174	2.15	.1599
Posterior Face Ht (mm)	70.320	4.055	70.240	4.363	0.00	.9666	5.120	2.138	4.930	1.693	0.05	.8281
ANB (dg)	5.090	1.280	5.420	1.667	0.25	.6256	-0.030	1.145	-2.330	.660	30.28	.0001
Angle Of Convexity (dg)	8.830	2.687	10.040	5.008	0.45	.5093	-0.630	2.994	-5.920	1.895	22.28	.0002
Wits Appraisal (mm)	1.720	2.151	2.240	2.141	0.29	.5945	0.280	2.340	-2.730	1.097	13.56	.0017
Occlusal Plane SN (dg)	20.340	3.797	17.420	2.395	4.23	.0545	-0.690	2.699	1.010	1.148	3.36	.0834
Mx 1 to A perp FH (mm)	3.310	3.246	6.220	2.187	5.53	.0303	-0.480	2.415	-2.760	.812	8.01	.0111
Mx 1 to FH (dg)	111.880	10.86	121.270	5.324	6.02	.0245	0.100	8.098	-6.710	3.124	6.16	.0232
Mx 6 to Ptm vertical (mm)	15.080	2.666	16.450	3.961	0.82	.3762	3.760	1.083	0.690	1.887	19.91	.0003
Mx 6 to FH (mm)	36.790	3.491	36.440	2.207	0.07	.7918	3.460	1.945	4.840	2.273	2.13	.1619
Mx 6 to Palatal Plane (mm	13.590	1.756	13.810	2.702	0.05	.8315	2.250	1.651	2.750	1.287	0.57	.4599
Md 1 to APo (mm)	0.080	1.679	0.580	1.689	0.44	.5152	-0.320	1.665	1.450	.764	9.33	.0068
FMIA (dg)	59.020	5.606	56.980	5.670	0.65	.4290	-0.740	4.529	-2.930	2.082	1.93	.1817
Md 6 to MP (mm)	24.510	1.547	23.250	2.141	2.27	.1489	2.060	1.563	1.740	1.075	0.28	.6003
Interincisal Angle (dg)	127.130	7.941	115.740	7.985	10.23	.0050	-0.860	9.275	3.750	3.018	2.23	.1523
Molar Relation (mm)	1.630	1.021	0.610	1.561	2.99	.1009	-0.460	1.302	-2.820	.876	22.62	.0002
Incisal Overjet (mm)	6.060	2.716	8.030	1.167	4.44	.0494	-0.450	2.527	-5.090	.720	31.18	.0001

Table 5

Summary of Male and Female Difference Data

Variable	Group				Gender				Interaction
	Control	Exper	F-Value	P-Value	Male	Female	F-Value	P-Value	P-Value
Age (yrs)	2.578	2.541	0.07	.7886	2.710	2.365	5.51	.0237	.8902
Maxillary Depth (dg)	0.187	-2.239	84.49	,0001	-0.996	-1.065	0.06	.8005	.0828
SNA (dg)	0.270	-2.230	82.09	.0001	-0.896	-1.090	0.47	.4972	.0874
A to N perp FH (mm)	0.304	-2.304	75.75	.0001	-0.992	-1.010	0.00	.9540	.2627
Midfacial Length (mm)	3.817	.1213	20.57	.0001	2.912	2.000	2.52	.1198	.9947
PNS-ANS (mm)	2.600	2.400	-.36	,5515	2.317	2.725	0.85	.3612	.3014
N-ANS (mm)	2.735	3.678	3.87	.0558	3.388	2.970	0.69	.4121	.4489
S-PNS (mm)	2.491	2.687	0.06	.8044	3.112	1.910	6.23	.0166	.2352
SN-Palatal Plane (dg)	0.174	0.752	2.11	.1538	-0.004	1.070	4.58	.0381	.0267
Facial Angle (dg)	0.761	0.414	1.42	.2408	0.716	0.429	0.81	.3741	.2976
SNB (dg)	0.432	.0117	3.52	.0674	0.596	0.100	2.81	.1010	.4520
Pog to N perp FH (mm)	1.283	0.526	1.57	.2177	1.192	0.530	0.99	.3241	.3960
Mandibular Length (mm)	6.652	7.004	0.31	.5827	7.688	5.710	6.11	.0175	.3887
Corpus Length (mm)	4.013	3.848	0.09	.7652	4.335	3.405	1.44	.2365	.5076
Ramus Height (mm)	4.370	4.891	0.46	.4988	5.604	3.365	11.58	.0015	.4005
Mandibular Plane FH (dg)	0.922	0.217	8.12	.0068	-0.638	0.020	2.30	.1366	.0939
Mandibular Plane SN (dg)	1.039	0.200	9.85	.0031	-0.769	0.035	3.55	.0665	.0783
Y axis (dg)	0.313	1.013	4.92	.0319	0.542	0.820	0.69	.4092	.3717
Lower Ant Face Ht (mm)	3.570	4.478	1.80	.1870	4.673	3.180	5.87	.0198	.3150
Anterior Face Ht (mm)	6.474	8.552	5.06	.0299	8.423	6.330	5.23	.0273	.8640
Posterior Face Ht (mm)	5.930	6.657	0.80	.3772	7.269	5.025	10.43	.0024	.2502
ANB (dg)	-0.317	-2.322	38.57	.0001	-1.427	-1.180	0.57	.4561	.4300
Angle Of Convexity (dg)	-1.217	-6.013	35.89	.0001	-3.877	-3.275	0.55	.4616	.5921
Wits Appraisal (mm)	0.330	-2.400	26.43	.0001	-0.888	-1.225	0.39	.5346	.6478
Occlusal Plane SN (dg)	-1.409	-0.048	4.51	.0396	-1.412	0.160	5.69	.0217	.6513
Mx 1 to A perp FH (mm)	0.665	-1.722	22.65	.0001	0.312	-1.620	14.99	.0004	.8505
Mx 1 to FH (dg)	1.400	-2.635	7.75	.0080	1.450	-3.305	9.24	.0041	.1240
Mx 6 to Ptm vertical (mm)	3.670	1.287	25.79	.0001	2.673	2.225	0.85	.3606	.2167
Mx 6 to FH (mm)	4.251	5.478	4.30	.0442	5.415	4.150	4.44	.0410	.8225
Mx 6 to Palatal Plane (mm)	2.691	2.904	0.26	.6101	3.027	2.500	1.21	.2777	.5990
Md 1 to APo (mm)	0.122	2.383	28.40	.0001	1.781	0.565	8.64	.0053	.2998
FMIA (dg)	0.109	-3.891	9.98	.0029	-1.935	-1.835	0.01	.9342	.1893
Md 6 to MP (mm)	2.335	2.504	0.06	.8144	2.819	1.900	3.69	.0616	.3707
Interincisal Angle (dg)	-1.296	-1.265	0.07	.7860	-3.377	1.445	5.56	.0231	.0542
Molar Relation (mm)	-0.400	-2.804	57.15	.0001	-1.573	-1.640	0.04	.8340	.9022
Incisal Overjet (mm)	0.004	-5.265	119.00	.0001	-2.523	-2.770	0.27	.6072	.2493

Table 6

	Group	Gender	Maxillary Depth (dg)		SNA (dg)		A to N perp FH (mm)		Midfacial Length (mm)		PNS-ANS (mm)		N-ANS (mm)		S-PNS (mm)		SN-Palatal Plane (dg)
			V1	R1	V2	R2	V3	R3	V4	R4	V5	R5	V6	R6	V7	R7	V8
1	Control	Male	89.30	89.00	79.00	79.00	-.70	-1.10	85.10	84.900	54.00	51.900	54.40	54.400	43.50	43.500	7.80
2	Control	Female	89.30	90.00	78.20	78.20	-.70	.40	73.80	73.400	47.40	45.300	52.30	52.300	40.70	39.600	10.30
3	Exp	Male	88.40	88.40	75.30	75.40	-1.40	-1.40	82.20	81.800	52.60	51.900	44.90	44.900	29.80	28.100	11.60
4	Exp	Female	91.80	90.70	80.70	80.60	1.80	.70	85.70	84.900	49.10	47.000	49.80	48.400	38.90	39.400	7.80
5	Control	Male	89.30	89.70	80.40	79.60	-.70	-.40	87.60	88.700	54.70	53.300	55.10	56.100	44.90	44.600	7.20
6	Control	Female	90.30	91.00	77.80	78.70	.40	1.10	75.40	74.600	48.10	48.400	53.00	53.800	41.00	40.000	10.50
7	Exp	Male	86.70	86.40	75.10	75.70	-3.20	-3.50	82.50	83.200	54.70	55.300	48.80	49.100	33.70	35.100	11.60
8	Exp	Female	89.30	89.00	78.10	78.60	-.70	-1.10	85.50	84.700	50.50	50.900	51.90	52.300	39.60	40.000	9.20

		Facial Angle (dg)		SNB (dg)		Pogonion to N perp FH (mm)		Mandibular Length (mm)		Corpus Length (mm)		Ramus Height (mm)		Mandibular Plane FH (dg)		Mandibular Plane SN (dg)
	R8	V9	R9	V10	R10	V11	R11	V12	R12	V13	R13	V14	R14	V15	R15	V16
1	7.80	85.20	85.20	73.70	74.10	-9.10	-9.10	99.10	99.60	74.70	73.80	38.50	39.90	26.60	26.30	36.80
2	11.30	88.10	89.30	75.50	75.30	-3.50	-1.40	95.80	97.50	67.80	66.30	45.30	46.90	24.10	23.10	35.20
3	12.20	86.00	85.40	71.00	70.90	-6.30	-7.40	92.40	92.00	67.70	68.80	39.40	38.80	15.40	14.60	28.40
4	6.00	85.60	84.40	73.40	72.80	-7.70	-8.10	96.40	98.60	72.10	74.00	36.10	35.90	24.30	24.80	35.40
5	7.80	87.00	87.30	76.70	76.00	-6.00	-5.30	109.40	109.10	79.20	79.60	45.80	47.10	25.30	24.70	34.30
6	10.00	89.10	90.40	74.60	76.00	-1.80	.70	99.00	97.60	68.90	67.80	48.10	49.50	21.40	20.10	33.90
7	10.70	85.50	84.70	72.30	72.20	-7.70	-9.10	96.20	96.10	73.70	73.40	42.00	42.70	14.90	16.20	26.50
8	9.50	86.00	85.50	73.60	73.50	-7.00	-8.10	99.90	100.20	74.60	75.30	36.60	36.40	24.30	25.50	35.50

		Y axis (dg)		Lower Ant Face Height (mm)		Anterior Face Height (mm)		Posterior Face Height (mm)		ANB (dg)		Angle of Convexity (dg)		Wits Appraisal (mm)		Occlusal Plane SN (dg)
	R16	V17	R17	V18	R18	V19	R19	V20	R20	V21	R21	V22	R22	V23	R23	V24
1	36.30	59.60	59.70	65.60	65.80	118.30	118.90	72.30	74.00	5.30	4.80	9.40	8.70	3.40	2.70	19.60
2	35.20	60.40	59.60	62.30	62.10	114.00	113.90	75.00	75.80	2.70	2.90	2.60	2.40	-.40	-.90	19.30
3	27.50	51.90	51.90	54.40	53.90	97.30	97.30	63.20	63.60	4.20	4.40	5.20	6.30	2.40	3.10	20.80
4	35.00	57.60	57.90	59.90	60.10	108.10	107.90	65.60	65.00	7.20	7.70	14.30	13.10	4.60	5.10	20.80
5	34.80	59.50	58.60	71.20	71.20	125.60	126.60	81.00	80.50	3.70	3.60	4.90	5.20	1.80	2.30	16.10
6	30.40	60.30	58.80	63.70	64.80	116.00	115.50	78.20	79.00	3.10	2.80	2.80	1.50	.20	-.50	20.10
7	26.90	54.20	55.30	57.90	58.30	105.30	106.50	71.50	72.30	2.80	3.50	2.50	3.80	3.20	3.70	16.70
8	35.80	57.40	58.30	60.00	60.50	111.10	111.90	67.10	67.50	4.50	5.10	7.50	7.80	1.20	2.20	21.30

Table 6

		Mx I to A perp to FH (mm)		Mx 1 to FH (dg)		Mx 6 to Ptm vertical (mm)		Mx6 to FH (mm)		Mx 6 to Palatal Plane (mm)		Md 1 to APo (mm)		FMIA (dg)		Md 6 to MP (mm)
	R24	V25	R25	V26	R26	V27	R27	V28	R28	V29	R29	V30	R30	V31	R31	V32
1	19.60	1.80	2.90	108.20	110.00	17.20	16.10	38.60	39.70	14.70	15.80	.80	.60	56.30	57.60	24.60
2	20.40	4.20	4.90	114.40	117.20	15.10	16.10	38.60	39.60	17.00	18.80	1.40	1.30	60.90	61.00	23.30
3	20.00	5.30	4.60	117.30	115.60	15.40	15.80	31.60	30.90	13.90	14.10	.40	.50	56.50	56.30	22.70
4	20.30	-1.80	.40	95.10	98.00	15.40	15.40	34.70	36.50	12.10	12.80	-.90	-1.30	49.70	48.10	23.60
5	16.10	4.60	4.90	112.80	115.10	20.30	20.70	44.90	43.90	17.80	18.50	1.60	1.90	56.50	56.60	29.10
6	19.00	4.60	5.30	118.30	115.20	17.50	18.00	40.30	40.00	19.40	19.90	.70	1.90	61.30	62.70	24.20
7	17.30	2.50	1.80	116.90	115.90	17.90	18.20	37.20	38.20	16.50	16.10	1.90	1.00	52.00	50.40	25.90
8	21.30	0.00	.40	104.00	106.70	15.80	17.20	37.90	38.60	12.40	13.90	1.00	.20	45.70	45.00	24.50

		Interincisal Angle (dg)		Molar Relation (mm)		Incisal Overjet (mm)	
	R32	V33	R33	V34	R34	V35	R35
1	24.40	128.10	127.60	2.40	1.30	4.90	6.00
2	24.00	126.40	124.40	-.70	-.30	4.50	4.60
3	22.40	119.30	120.80	.70	.60	7.30	6.90
4	22.90	134.60	132.40	1.00	.60	3.20	4.80
5	27.90	123.70	121.50	2.60	1.60	5.40	5.30
6	24.50	123.00	124.00	.30	.30	5.10	3.80
7	25.90	115.10	114.50	-1.90	-2.10	2.30	3.00
8	24.60	121.60	118.30	-1.30	-1.60	2.10	3.30

Table 7

	Maxillary Depth (dg) Delta 1	SNA (dg) Delta 2	A to N perp FH (mm) Delta 3	Midfacial Length (mm) Delta 4	PNS-ANS (mm) Delta 5	N-ANS (mm) Delta 6	S-PNS (mm) Delta 7	SN-Palatal Plane (dg) Delta 8	Facial Angle (dg) Delta 9
1	-.300	0.000	-.400	-.200	-2.100	0.000	0.000	0.000	0.000
2	.700	-7E-18	1.100	-.400	-2.100	0.000	-1.100	1.000	1.200
3	0.000	.100	0.000	-.400	-.700	0.000	-1.700	.600	-.600
4	-1.100	-.100	-1.100	-.800	-2.100	-1.400	.500	-1.800	-1.200
5	.400	-.800	.300	1.100	-1.400	1.000	-.300	.600	.300
6	.700	.900	.700	-.800	.300	.800	-1.000	-.500	1.300
7	-.300	.600	-.300	.700	.600	.300	1.400	-.900	-.800
8	-.300	.500	-.400	-.800	.400	.400	.400	.300	-.500

	SNB (dg) Delta 10	Pogonion to N perp FH (mm) Delta 11	Mandibular Length (mm) Delta 12	Corpus Length (mm) Delta 13	Ramus Height (mm) Delta 14	Mandibular Plane FH (dg) Delta 15	Mandibular Plane SN (dg) Delta 16	Y axis (dg) Delta 17	Lower Ant Face Height (mm) Delta 18	Anterior Face Height (mm) Delta 19	Posterior Face Height (mm) Delta 20	ANB (dg) Delta 21	Angle of Convexity (dg) Delta 22	Wits Appraisal (mm) Delta 23	Occlusal Plane SN (dg) Delta 24	Mx 1 to A perp to FH (mm) Delta 25	Mx 1 to FH (dg) Delta 26	Mx 6 to Ptm vertical (mm) Delta 27
1	.400	0.000	.500	-.900	1.400	-.300	-.500	.100	.200	.600	1.700	-.500	-.700	-.700	0.000	1.100	1.800	-1.100
2	-.200	2.100	1.700	-1.500	1.600	-1.000	0.000	-.800	-.200	-.100	.800	.200	-.200	-.500	1.100	.700	2.800	1.000
3	-.100	-1.100	-.400	1.100	-.600	-.800	-.900	0.000	-.500	0.000	.400	.200	1.100	.700	-.800	-.700	-1.700	.400
4	-.600	-.400	2.200	1.900	-.200	.500	-.400	.300	.200	-.200	-.600	.500	-1.200	.500	-.500	2.200	2.900	0.000
5	-.700	.700	-.300	.400	1.300	-.600	.500	-.900	0.000	1.000	-.500	-.100	.300	.500	0.000	.300	2.300	.400
6	1.400	2.500	-1.400	-1.100	1.400	-1.300	-3.500	-1.500	1.100	-.500	.800	-.300	-1.300	-.700	-1.100	.700	-3.100	.500
7	-.100	-1.400	-.100	-.300	.700	1.300	.400	1.100	.400	1.200	.800	.700	1.300	.500	.600	-.700	-1.000	.300
8	-.100	-1.100	.300	.700	-.200	1.200	.300	.900	.500	.800	.400	.600	.300	1.000	0.000	.400	2.700	1.400

	Mx6 to FH (mm) Delta 28	Mx 6 to Palatal Plane (mm) Delta 29	Md 1 to APo (mm) Delta 30	FMIA (dg) Delta 31	Md 6 to MP (mm) Delta 32	Interincisal Angle (dg) Delta 33	Molar Relation (mm) Delta 34	Incisal Overjet (mm) Delta 35	Maxillary Depth (dg) AB1	SNA (dg) AB 2	A to N perp FH (mm) AB 3	Midfacial Length (mm) AB 4	PNS ANS (mm) AB 5	N ANS (mm) AB 6	S-PNS (mm) AB 7	SN-Palatal Plane (dg) AB 8	Facial Angle (dg) AB 9
1	1.100	1.100	-.200	1.300	-.200	-.500	-1.100	1.100	.300	0.000	.400	.200	2.100	0.000	0.000	0.000	0.000
2	1.000	1.800	-.100	.100	.700	-2.000	.400	.100	.700	6.9E-18	1.100	.400	2.100	0.000	1.100	1.000	1.200
3	-.700	.200	.100	-.200	-.300	1.500	-.100	-.400	0.000	.100	0.000	.400	.700	0.000	1.700	.600	.600
4	1.800	.700	-.400	-1.600	-.700	-2.200	-.400	1.600	1.100	.100	1.100	.800	2.100	1.400	.500	1.800	1.200
5	-1.000	.700	.300	.100	-1.200	-2.200	-1.000	-.100	.400	.800	.300	1.100	1.400	1.000	.300	.600	.300
6	-.300	.500	1.200	1.400	.300	1.000	-3E-20	-1.300	.700	.900	.700	.800	.300	.800	1.000	.500	1.300
7	1.000	-.400	-.900	-1.600	0.000	-.600	-.200	.700	.300	.600	.300	.700	.600	.300	1.400	.900	.800
8	.700	1.500	-.800	-.700	.100	-3.300	-.300	1.200	.300	.500	.400	.800	.400	.400	.400	.300	.500

Table 7

	SNB (dg)	Pogonion to N perp FH (mm)	Mandibular Length (mm)	Corpus Length (mm)	Ramus Height (mm)	Mandibular Plane FH (dg)	Mandibular Plane SN (dg)	Y axis (dg)	Lower Ant Face Height (mm)
	AB 10	AB 11	AB 12	AB 13	AB 14	AB 15	AB 16	AB 17	AB 18
1	.400	0.000	.500	.900	1.400	.300	.500	.100	.200
2	.200	2.100	1.700	1.500	1.600	1.000	0.000	.800	.200
3	.100	1.100	.400	1.100	.600	.800	.900	0.000	.500
4	.600	.400	2.200	1.900	.200	.500	.400	.300	.200
5	.700	.700	.300	.400	1.300	.600	.500	.900	0.000
6	1.400	2.500	1.400	1.100	1.400	1.300	3.500	1.500	1.100
7	.100	1.400	.100	.300	.700	1.300	.400	1.100	.400
8	.100	1.100	.300	.700	.200	1.200	.300	.900	.500

	Anterior Face Height (mm)	Posterior Face Height (mm)	ANB (dg)	Angle of Convexity (dg)	Wits Appraisal (mm)	Occlusal Plane SN (dg)	Mx 1 to A perp to FH (mm)	Mx 1 to FH (dg)
	AB 19	AB 20	AB 21	AB 22	AB 23	AB 24	AB 25	AB 26
1	.600	1.700	.500	.700	.700	0.000	1.100	1.800
2	.100	.800	.200	.200	.500	1.100	.700	2.800
3	0.000	.400	.200	1.100	.700	.800	.700	1.700
4	.200	.600	.500	1.200	.500	.500	2.200	2.900
5	1.000	.500	.100	.300	.500	0.000	.300	2.300
6	.500	.800	.300	1.300	.700	1.100	.700	3.100
7	1.200	.800	.700	1.300	.500	.600	.700	1.000
8	.800	.400	.600	.300	1.000	0.000	.400	2.700

	Mx 6 to Ptm vertical (mm)	Mx6 to FH (mm)	Mx 6 to Palatal Plane (mm)	Md 1 to APo (mm)	FMIA (dg)	Md 6 to MP (mm)	Interincisal Angle (dg)	Molar Relation (mm)	Incisal Overjet (mm)	
	AB 27	AB 28	AB 29	AB 30	AB 31	AB 32	AB 33	AB 34	AB 35	Input Column
1	1.100	1.100	1.100	.200	1.300	.200	.500	1.100	1.100	
2	1.000	1.000	1.800	.100	.100	.700	2.000	.400	.100	
3	.400	.700	.200	.100	.200	.300	1.500	.100	.400	
4	0.000	1.800	.700	.400	1.600	.700	2.200	.400	1.600	
5	.400	1.000	.700	.300	.100	1.200	2.200	1.000	.100	
6	.500	.300	.500	1.200	1.400	.300	1.000	2.7E-20	1.300	
7	.300	1.000	.400	.900	1.600	0.000	.600	.200	.700	
8	1.400	.700	1.500	.800	.700	.100	3.300	.300	1.200	

Table 8
Reliability

Variable	Difference Mean	Difference SD	Absolute Difference Mean	Absolute Difference SD
Maxillary Depth (dg)	-0.025	0.611	0.475	0.341
SNA (dg)	0.150	0.521	0.375	0.369
A to N perp FH (mm)	-0.013	0.698	0.538	0.396
Midfacial Length (mm)	-0.200	0.723	0.650	0.295
PNS-ANS (mm)	-0.887	1.195	1.213	0.804
N-ANS (mm)	0.137	0.727	0.487	0.528
S-PNS (mm)	-0.225	1.011	0.800	0.590
SN-Palatal Plane (dg)	-0.088	0.930	0.713	0.541
Facial Angle (dg)	-0.037	0.918	0.738	0.472
SNB (dg)	0.000	0.659	0.450	0.450
Pog to N perp FH (mm)	0.162	1.487	1.163	0.835
Mandibular Length (mm)	0.312	1.166	0.862	0.787
Corpus Length (mm)	0.038	1.184	0.988	0.538
Ramus Height (mm)	0.675	0.883	0.925	0.568
Mandibular Plane FH (dg)	-0.125	1.002	0.875	0.385
Mandibular Plane SN (dg)	-0.513	1.302	0.813	1.114
Y axis (dg)	-0.100	0.906	0.700	0.521
Lower Ant Face Ht (mm)	0.213	0.482	0.388	0.336
Anterior Face Ht (mm)	0.350	0.628	0.550	0.434
Posterior Face Ht (mm)	0.475	0.750	0.750	0.421
ANB (dg)	0.163	0.434	0.388	0.217
Angle Of Convexity (dg)	-0.050	0.980	0.800	0.481
Wits Appraisal (mm)	0.162	0.682	0.637	0.177
Occlusal Plane SN (dg)	-0.088	0.718	0.512	0.473
Mx 1 to A perp FH (mm)	0.500	0.946	0.850	0.595
Mx 1 to FH (dg)	0.827	2.389	2.288	0.728
Mx 6 to Ptm vertical (mm)	0.363	0.735	0.638	0.475
Mx 6 to FH (mm)	0.450	0.993	0.950	0.431
Mx 6 to Palatal Plane (mm)	0.763	0.705	0.863	0.558
Md 1 to APo (mm)	-0.100	0.668	0.500	0.414
FMIA (dg)	-0.150	1.143	0.875	0.676
Md 6 to MP (mm)	-0.163	0.590	0.438	0.400
Interincisal Angle (dg)	-1.038	1.683	1.662	0.950
Molar Relation (mm)	-0.338	0.501	0.438	0.403
Incisal Overjet (mm)	0.362	0.965	0.812	0.572