December 2007

A cephalometric comparison of high mandibular plane angle cases treated with cervical vs. high-pull headgear

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A Thesis submitted to the Department of Orthodontics and
The Advanced Education Committee of the
Oregon Health and Science University School of Dentistry
In partial fulfillment of the requirements
For the degree of Master of Science
December 2007

A Cephalometric Comparison of the Effects of Cervical and High-pull Headgear on High Mandibular Plane Angle Cases

A thesis presented by Gabriela Aranda
In partial fulfillment for the degree of Master of Science in Orthodontics

December 2007

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ACKNOWLEDGEMENTS

I would like to acknowledge and thank all of the people that have helped me throughout this endeavor.

To my mentor Dr. Larry Doyle, thank you for all of the guidance, support, and encouragement throughout this project. Your interest in providing knowledge is contagious.

To Dr. David Covell, thank you for the guidance and input into this project. The motivation that you provided was invaluable.

To Dr. Bruce Fiske, I am very grateful for the time and energy that you put into this thesis. Thank you for all your help with the editing and all of the helpful suggestions that you gave me.

To Dr. Robert Myall, than you for the support that you have always provided. Your willingness to readily participate in this process is admirable.

To Dr. Dave Cruikshank, Dr. Bruce Fiske, Dr. Andrea Laidlaw, and Dr. Daniel Philips thank you for allowing me into your practices and letting me look through your records.

To all of you and the rest of the faculty at OHSU thank you for providing me with some very valuable assets: Knowledge and the reason, and motivation to always keep learning.

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ABSTRACT

The purpose of this retrospective chart review study was to compare the differences that occurred when high mandibular plane angle (MP-SN > 36°) Class II patients were treated with cervical headgear vs. those treated with high-pull headgear. The high-pull sample was gathered from the orthodontic records of Dr. Bruce Fiske, and the cervical headgear subjects from the practice of Dr. David Cruikshank. The treated groups consisted of 28 high-pull headgear subjects (21 females, 7 males) and 34 cervical headgear subjects (18 females, 16 males). Along with headgear, patients were treated with full orthodontic straight wire appliances (.022x.028in.) and Class II elastics as needed. Several patients in the high-pull sample also had a quadhelix palatal expander placed for a short time at the beginning of treatment. No control group was employed since the focus of this study was to determine what happened when experienced clinicians treated patients using techniques of their own choosing. Pretreatment (T1) and posttreatment (T2) lateral cephalometric radiographs were obtained for each of the subjects. The cephalograms were scanned and digitized using QuickCeph Studio 2007 cephalometric software. Cephalometric measurements were recorded and intergroup differences were analyzed by the use of the independent t-test.

Sagittal changes as a result of treatment were not found to be significantly different between the two groups. Vertically the Y axis increased significantly more in the cervical group (1.6°) than in the high-pull group (0.4 °). The occlusal plane angle increased in the cervical group (1.2 °) and slightly decreased in the high-pull group (0.5°). The changes observed in the mandibular plane angle were not statistically different

between groups. The linear dimensions measured showed a statistically significant difference in the lower facial height where the cervical headgear group exhibited an increase of 5.6 mm and the high-pull headgear group showed a 3.9 mm increase.

Although some of the angular and linear changes produced by the two different protocols were significantly different, the clinical significance was questionable since the changes exhibited by the different headgear systems were small. Based on the results of this study either type of headgear system seemed to be acceptable for treatment of high mandibular plane angle cases.

INTRODUCTION:

The direction in which the mandible grows varies greatly in the general population (Bjork 1969; Bjork and Skieller 1983). A well-proportioned face is one in which there is a balance of both vertical and horizontal growth of the mandible. A less desirable growth pattern is when there is predominately vertical growth (dolichofacial growth pattern) causing an increase in facial height leading to compromised esthetics (Pearson 1978) (Figure 1). The usual characteristics of this type of growth pattern include a high mandibular plane angle, increased anterior facial height, open bite, lip strain, and a Class I or II molar relationship (Pearson 1978). In these individuals additional growth usually does not improve the sagittal position of the mandible, ultimately resulting in a long face with a minimized chin projection (Creekmore 1967; Nielsen 1991). For this reason it is important in orthodontic treatment to choose appliances that will maintain or more importantly minimize increases in the vertical dimensions of those patients with high mandibular plane angles.

Headgear is an extraoral appliance that is widely used for anchorage preparation and the correction of Class II skeletal and dental molar relationships. This method of treatment has been shown to work successfully in the distalization of upper first molars (Klein 1957; Poulton 1964; Wieslander 1974; Wieslander and Buck 1974; Fotis et al. 1984; Cook et al. 1994), and in reducing forward growth of the maxilla (Kloehn 1953; Klein 1957; Poulton 1964; Sandusky 1965; Jakobsson 1967; Watson 1972; Wieslander 1974; Cangialosi et al. 1988). Class II to Class I molar correction would subsequently occur by the growth differential between the maxilla and mandible. Most clinicians and researchers would agree that with good patient compliance, headgear is a viable treatment option for obtaining Class I molar and skeletal relationships in many growing Class II patients. What is not so clear are the vertical changes that occur with the use of different types of headgear.

Cervical-pull, high-pull, and combination-pull are all types of headgear that are currently in use. The inner bow of all three types of headgear inserts into the molar tubes on the buccal aspect of the maxillary first molar bands. Headgear differs in the direction of the force vectors that they produce which depends on what the outer bow is attached to. In cervical headgear the outer bow attaches to a strap that rests against the dorsal part of the neck. Usually the outer bow is tipped slightly vertically so that the force is distributed through the center of rotation of the molar in order to avoid creating a moment of force that would cause distal tipping of its crown. Due to the downward force exerted by the cervical aspect of the headgear, it is also believed to cause extrusion of the maxillary first molar (Proffit and Fields 2000; Graber et al. 2005). For this reason, it is believed that the best use of cervical headgear is in those patients with maxillary protrusion and reduced vertical dimension (short lower face height) (Brown 1978). The outer bow of high-pull headgear attaches to a headcap which lies on the occipital portion of the head. This headgear system delivers a vertically directed force which is believed to decrease the vertical displacement of the maxilla during growth (Proffit and Fields 2000; Graber et al. 2005). The outer bow of the combination headgear is attached to both a head cap and a cervical strap. In this way, the molar is thought to move distally as both extrusive and intrusive forces in the molar have been minimized (Proffit and Fields 2000; Graber et al. 2005).

Given these different headgear force systems, some researchers have concluded that during treatment different orthodontic and orthopedic changes will occur according to the type of headgear that is used (Ricketts 1960; Mays 1969; Barton 1972; Watson 1972; Brown 1978). Not all of these effects are universally desirable. One of the effects attributed to the use of cervical headgear is molar extrusion which is believed to cause increased vertical facial dimensions (Klein 1957; Wieslander 1974; Melsen 1978; Cangialosi et al. 1988). This effect is contraindicated when treating high mandibular angle cases especially since these individuals are already predisposed to increased posterior maxillary vertical dimensions as concluded by Issacson et al. In his 1977 study (Isaacson et al. 1977), he noted that the dimension between the palatal plane and the maxillary molars was significantly greater in high angle cases as compared to average and low angle cases. This indicated that posterior eruption was generally greater in high angle cases. Also headgear is chiefly used during active growth when it is most effective. During normal growth the nasomaxillary process drifts downward, in addition to molar eruption (Enlow and Hans 1996). Therefore, any orthodontic appliance that can possibly accentuate these processes should be avoided in high mandibular plane angle cases.

An increase in the mandibular plane angle is another effect that should be avoided when treating high mandibular plane angle cases and has also been linked to the use of cervical headgear (Klein 1957; Blueher 1959; Jakobsson 1967; Poulton 1967; Wieslander 1974; Melsen 1978; Knight 1988; Kim and Muhl 2001). An increase in this dimension is thought to make class II correction more difficult by hindering the forward movement of the mandible during growth (Proffit and Fields 2000). It is also believed to cause an increase in the anterior facial height additionally compromising the facial esthetics of those individuals with a pre-existing dolichofacial growth pattern (Jakobsson 1967). For these reasons, many clinicians advocate the use of high-pull headgear instead of cervical headgear in patients that have pronounced vertical growth patterns with the belief that the upward force exerted by high-pull headgear has an intrusive effect on the upper molars thereby minimizing both molar extrusion and clockwise rotation of the mandible (Ricketts 1960; Schudy 1963; Mays 1969; Armstrong 1971; Barton 1972; Watson 1972).

Our role as orthodontists is to give each individual the best treatment available and one which produces the best possible result. In order to do this we must consider not only the pre-existing malocclusion but also the craniofacial morphology of the individual. Are there detrimental vertical side effects that are caused by the use of cervical headgear? If so, when headgear is warranted in a patient with a high mandibular plane angle, cervical headgear may not be the best choice. Our vertically growing patients would be better served with the use of high-pull headgear which is designed to hinder vertical development. Perhaps there is no difference in the vertical effects when the different headgears are used. If the vertical effects are similar, then either high-pull or cervical headgear could be used for all patients regardless of their pretreatment facial pattern. The benefit of this would be that patients might be more accepting of the use of cervical headgear since it is more esthetically pleasing than high-pull headgear. Cervical headgear may be better tolerated by the patient as ear abrasion is not an issue as it can be with high-pull headgear. Also, headgear inventory would be reduced since one type of headgear could be used on all headgear patients.

Through the use of lateral cephalograms, the purpose of this study was to find if the treatment effects caused by cervical headgear were different than those caused by high-pull headgear when high mandibular plane angle cases were treated. The cephalograms studied were from two separate orthodontic practices. In one office, the orthodontist used cervical headgear for all Class II patients. In the other office, the orthodontist used high-pull headgear when treating high mandibular plane angle Class II patients. It is hoped that the information obtained from these cephalograms will allow us to make an informed decision in selecting treatment modalities for our growing high mandibular plane angle patients.

REVIEW OF LITERATURE

Vertical Changes

Many studies have investigated the vertical changes that occur when cervical headgear is used and have found an association between the use of cervical headgear and an increase in the mandibular plane angle and/or the Y axis. In 1957, Phillip L. Klein studied a sample of 24 Class II, division 1 patients to determine the effect of cervical traction on the maxilla and the upper first permanent molars. The sample consisted of 13 males and 11 females with an average age of 8 years 6 months. No control sample was used and a measurement of error was not mentioned. All the subjects were treated with cervical headgear and bite plates when necessary for an average time of 17 months. Beginning and progress cephalograms were superimposed using the manner described by Broadbent, registering point R and keeping the Bolton planes parallel. The average change in the Y axis as measured from the Bolton plane showed 1° of opening. When palatal planes were superimposed, the vertical position of the molar changed in 23 of the 24 cases showing vertical development with an average elongation of 2.3 mm. Klein suggested that there was a strong relationship between the vertical change in the upper molar and growth on the Y axis. The lack of an untreated control sample made it impossible to know what portion of the vertical change in molar position was due to growth and what was due to cervical headgear treatment.

The purpose of William A. Blueher's 1958 study was to determine the facial skeletal changes that occurred during treatment with full edgewise appliances and cervical traction. The cases were classified as Class II, division 1 or Class I with Class II tendencies. The sample of 34 cases included 17 boys and 17 girls. No control group was used and a method of error was not mentioned. Six of the boys and 6 of the girls had two phases of treatment. Phase 1 consisted of cervical headgear treatment only. Full edgewise appliances were added in phase 2. The average age of the 2 phase group was 10 years at the start of treatment and the combined treatment time was an average of 27 months. The 1 phase group consisted of 11 boys and 11 girls. The average pretreatment age for this group was 13 years and the mean treatment time was 18 months. Pretreatment and posttreatment cephalograms were traced and analyzed to observe changes. In 22 of the 34 cases, the angle NSGn (Y axis) opened an average of 1.86° in the males and 1.5° in the females. In 3 cases NSGn decreased, and in 9 cases it remained the same. He asserted that because of these findings, it was evident that treatment with cervical anchorage tended to open the bite. Sixteen of the 34 cases demonstrated an increase in MPA when measured to the Frankfort horizontal plane with the boys averaging 2.21° and the girls averaging 1.35°. No comparison to untreated controls was used to evaluate changes in the MPA that can occur during growth.

In 1967, Donald R. Poulton's clinical report presented cases treated with cervical headgear. In one of the cases, extrusion of the upper molar during cervical traction treatment resulted in the mandibular plane angle increasing by 3°. This increase was later compensated for by "excellent" condylar growth returning the mandibular plane angle to its pretreatment measurement. In another case, there was a 5° increase in the mandibular plane angle after cervical headgear treatment. Because there was no subsequent growth in this case, the increase was detrimental to the esthetics of this patient as the lower third of the face was elongated. There were no untreated control individuals for comparison.

Sven Olof Jakobsson's 1967 study evaluated the treatment effect on Class II, division 1 malocclusions when treated with either activator or headgear therapy. Fifty-seven subjects with a mean age of 8.5 years were divided into groups of three. In each of the groups of three, one subject was treated with Kloehn cervical headgear, one was treated with an activator, and one subject served as a control and remained untreated. Lateral head roentgenograms were taken pretreatment and 18 months later. The head films were superimposed on the spheno-ethmoid plane with the midline point of the two great wings of the sphenoid bone intersecting this plane. A reference line parallel to the SN plane and extending through the intersection point was then transferred to the two head films. Error of measurement was calculated using the formula $S = \sqrt{d^2/2n}$. Results showed that when the cervical headgear group was compared to the control group, the cervical group showed an upper facial height change that was 0.7 mm larger than that of the control and an increase of 0.8° in the mandibular plane angle.

In 1974, Lennart Weislander studied the effect of force on the basal maxillary structures and adjacent facial junctions. Twenty-eight cases treated with cervical headgear were matched and compared to 28 untreated Class II malocclusion subjects. Some of the cases had the upper incisors banded for a short period of time and/or a bite plate was used. Lateral head radiographs taken before treatment and 3 years later were used in the study. The radiographs were superimposed and the vertical and horizontal changes were measured on a grid system. A measurement error was calculated. Results showed that in the cervical traction group there was an extrusive tendency of maxillary molars with a mean difference between groups of 1.08 mm. This resulted in a slight clockwise rotation causing a steeper mandibular plane of approximately 1.58°. Menton therefore assumed a more inferior position.

In 1978, Birte Melsen designed a study using implants to note the effects of cervical headgear. In addition, she analyzed the influence of the tilt of the extraoral bow in the horizontal plane on treatment results. Twenty children in late mixed dentition with distal molar relationship were included in the study. The children were divided into two groups that were both treated with cervical headgear. In group I, the outer bow was tilted 20° upward in relation to the inner arch. In group II, the outer bow was tilted 20° downward in relation to the inner arch. No control group was used. Four implants were placed in maxillary bone of each patient, and five in the mandible. Lateral cephalograms were taken at the beginning of treatment, at 3 months, at 8 months (end of headgear treatment), and at the completion of growth. Error of method was checked by duplicate measurements on ten radiographs using the formula si= d/2n. In both groups the upper molar showed extrusion (2.3mm in Group I, 1.42mm in Group II) without a significant difference between the groups. A posterior rotation of the mandible ranging from 0° to 6° was found in relation to this extrusion to a similar degree in both groups.

Helen Knight's 1988 study investigated the effects of three methods of orthodontic appliance therapy on some commonly used cephalometric angular variables. The methods under question included the Andresen activator functional appliance, the Begg appliance, and cervical headgear. In addition, all had orthodontic treatment with full orthodontic appliances. This retrospective study included pretreatment, posttreatment, and postretention cephalograms of 30 patients per group. The control group included 7 male and 10 female skeletal Class I subjects. The error of method was calculated using the following formula $s=\sum d/2(n-1)$ as described by Dahlberg. An increase in the mandibular plane angle was observed in the headgear and Begg groups as observed by the changes between the pretreatment and posttreatment cephalograms. There was a 1.3° increase in mandibular plane angle in the cervical headgear group as compared to the control group which showed a decrease of 1.3°. These changes were no longer observed on the postretention cephalograms so it was concluded that the changes were temporary.

In 2001, Keum-Ryung Kim et al. conducted a retrospective cephalometric study to examine mandibular growth changes in 30 growing Class II patients (23 female, 7 male) treated with cervical headgear and full edgewise appliances. They compared those changes to the changes that occurred in 26 Class II untreated controls (16 female and 10 male). Lateral cephalometric radiographs were taken representing pretreatment, posttreatment, and postretention for each patient and chronologically comparable radiographs for the control subjects. Mandibular rotation was assessed with mandibular superimposition. Overall superimposition was carried out by the best fit at the cranial base and maxillary superimposition was also used all according to the method described by Bjork and Skieller (A. Bjork and V. Skieller 1984). Their method of error consisted of a t test that included measurements from 10 cephalograms that were retraced 2 weeks after the first tracing. During the treatment time the mandibular plane angle measured to FH increased 0.25° in the treated group as compared to the control group which showed a 1.6° closing rotation. Likewise the Y axis measured to FH increased 1.4° in the headgear group and decreased 0.3° in the control group. However the mean changes for lower anterior face height (LAFH), total anterior face height (TAFH), and posterior face height

(PFH) showed no difference between the groups. In addition the mean vertical change of the maxillary molar was comparable between groups with the cervical headgear group showing 7.5 mm and the control showing 6.8 mm of elongation.

Not all studies have found a relationship between the use of cervical headgear and an increase in the mandibular plane angle. In 1980, T.J. Fischer cephalometrically evaluated the effect of cervical facebow treatment on mandibular rotation. Forty Class II, division 1 subjects (20 males, 20 females) treated with cervical headgear were compared to an untreated group of 40 Class II, division 1 subjects (20 males, 20 females). The treatment group was treated with Kloehn cervical headgear and full edgewise appliances. It was mentioned that elastics were not used for any prolonged period of time but no specific times were given. A coordinate system was developed and the growth progress was plotted on the coordinate system by superimposing the serial cephalogram tracings on the sella-nasion line at sella, on the intersection point (not defined), on the registration point (not defined), and on the C.C point which from the figure included showed that it was an anterosuperior point on the pterygomaxillary fissure. The amount of growth was measured by comparing the pretreatment and posttreatment position of gnathion. Results showed that there was a significant difference among the four methods of superimposition. The sella-nasion and registration point methods showed that cervical headgear produced a downward and backward mandibular rotation. However, these same changes were not observed when using the intersection and the C.C. methods of superimposition. He concluded that the backward mandibular rotation of the mandible after the use of cervical headgear seemed to be related to the method of superimposition not to the method of treatment.

In a 1988, T. J. Cangialosi et al. conducted a study to determine the treatment effects of nonextraction edgewise therapy combined with cervical headgear on Class II, division 1 malocclusions. Data was collected from a sample of 43 Class II patients with a mean age of 11 years, 11 months and a mean treatment time of 2 years, 8 months. Class II elastics were used for a period of 2-3 months. No control group was used. An appraisal was done on pretreatment and posttreatment cephalograms and the initial and final measurements of points, lines, and angles based on accepted cephalometric analyses were compared. No error of measurement was mentioned except that each radiograph was traced separately by all of the authors and the mean of the individual measurements was recorded. There was a 2.77 mm extrusion of the upper first molar but a nonsignificant reduction in SN-MP angle of 0.25° was also noted. The Y axis increased 0.77°. The authors hypothesized that the increase in the Y axis may have occurred because of an error when plotting point Gn. The upper and lower face height increased 3.56 mm and 4.36 mm respectively. It was postulated that extrusion of maxillary and mandibular molars or the normal downward growth of the mandible could be the cause of the observed increase in the lower facial height.

In 1989, Paul R. Boecler et al. studied pretreatment and posttreatment cephalograms to determine if changes in several measures of vertical facial form might be influenced by varying vectors and amounts of extraoral force. Two-hundred children treated consecutively with full edgewise orthodontic appliances were divided into three pretreatment groups based on the type of extraoral force delivered. The three groups consisted of individuals treated with either cervical, combination, or no-headgear. Error of measurement was assessed by retracing and redigitizing 20 randomly selected radiographs. All of the groups showed a wide range of variation in treatment response but did not demonstrate significant differences. The extraoral forces improved horizontal maxillo-mandibular discrepancies but there was too much variation in response to predict vertical changes. This study also demonstrated that the change in the mandibular plane angle was no greater than 0.7° for any of the groups. Their data found no relationship between the initial form of the face and the net vertical change. The data did not support the theory that vertical skeletal relationships in the growing face can be controlled predictably by the direction of the extraoral force.

In 1994, Gregory Hubbard et al. studied the effects of cervical headgear in patients with Class II malocclusions with special reference to the dentition, maxillary complex, mandible, and the facial profile. The sample consisted of 85 Class II patients who received nonextraction and cervical headgear treatment. These were divided into several groups to determine if any differences existed based on gender, age, and FMA as determined by pretreatment and posttreatment cephalograms. Class II elastics were used in 38 patients for an average of 6.2 months. No control group was used but the changes observed in this study were compared to a publication of changes observed from growth of a normal sample. A measurement of error was calculated. They found that the amount of molar extrusion was not beyond that which would be expected during normal growth. The mandibular plane angle did not increase (0.62°) appreciably during treatment regardless of the pretreatment FMA. Very few significant differences were found between groups including groups based on gender and pretreatment FMA.

A 1994 retrospective study by A.H. Cook et al. investigated the control of vertical dimension in Class II correction using pretreatment and posttreatment lateral cephalograms. Their sample included 90 patients with Class II, division 1 malocclusion, 30 patients (14 male, 16 female) were treated with cervical headgear alone, 30 (21 male, 9 female) with cervical headgear and a lower utility arch but no other appliances, and 30 (15 male, 15 female) served as untreated controls. Measurement error was calculated with no significant findings. Results indicated that both the cervical group and the untreated control group exhibited similar amounts of extrusion of the maxillary molars. The extrusion noted in the cervical groups was 1.21 mm and that of the untreated control was 1.30 mm. The lower facial height as measured from ANS to Me showed a 0.81 mm increase in the cervical headgear group. Although the untreated control group showed a greater mean increase of 1.55 mm in lower face height, the difference between groups was not statistically significant. Total anterior face height also increased in all groups (4.64 mm in the cervical group, 3.13 mm in the control group) but the difference between the groups was not statistically significant. There was no opening rotation of the mandible even in subjects with dolichofacial patterns. All of the groups displayed a small and comparable decrease in the mandibular plane angle when measured to FH. There was no change noted in the Y axis for either the cervical headgear or the control group. According to this study, a certain amount of molar eruption is anticipated in a group of actively growing children. It is important to note that neither full appliances or elastics were used in any of these groups.

A focus of Mirja Kirjavainen et al.'s 2000 study was to determine whether the side effects of cervical headgear could be avoided. The side effects in question included extrusion of the molars and downward and backward rotation of the mandible. Forty children (20 female, 20 male) with a Class II, division 1 malocclusions were treated with orthopedic cervical headgear. A 10 mm expanded inner bow and a long outer bow bent 15° upwards was used. No control group was used but the results were compared to Finnish and US norms. An error of measurement was assessed using 5 randomly selected cases that were retraced. They found that there was minor extrusion of the molars showing a mean increase of 1.2 mm which was similar to normal eruption amounts in US norms. There was a small reduction in N-S-ML (mandibular plane) of 0.2° in boys and 0.4° in girls as a result of treatment. This was interpreted as proof that the mandible was following a normal growth pattern by rotating upward and forward.

Marcia R.E.A. Schiavon Gandini et al.'s 2001 retrospective study examined maxillary basal bone, dentoalveolar, and dental changes in Class II, division 1 patients treated to normal occlusion by using cervical headgear and edgewise appliances. A sample of 45 subjects treated with cervical headgear and edgewise appliances were compared with a group of 30 untreated control subjects. The subjects ranged in age from 7.5 to 13.5 years. The groups were matched based on age, gender, and malocclusion. The treatment group consisted of 87% mesocephalic or brachycephalic patterns, and 13% dolichocephalic facial patterns. A measurement of error was calculated using the Dahlberg formula. Lateral cephalograms were taken at the beginning and at the end of treatment and were superimposed to note changes. Results found that the vertical changes of the maxillary molar in the treatment group were small (1.86 mm/year increase) and not significantly different than what was observed in the untreated control sample (1.7 mm/year increase). No significant difference in the mandibular rotation pattern was noted (cervical group decreased 0.07°, control group increased 0.03°).

In their 2002 retrospective survey, Nick B. Haralabakis et al. compared the magnitude of posterior mandibular rotation during orthodontic treatment with edgewise appliance and cervical headgear in patients with a high or a low Frankfort mandibular plane angle (FMA). A sample of 29 low mandibular angle cases (FMA< 22°) and 31 high mandibular angle cases (FMA>28°) were included in the study. All subjects were treated nonextraction with cervical headgear and full orthodontic appliances. Class II elastics and bite plates were also used as needed. Pretreatment and posttreatment cephalograms were superimposed on internal structures of the mandible. The Dahlberg equation was used to estimate the error of measurement. They found no difference in changes in FMA between the two groups. The FMA of the high angle group decreased 0.1°, and the low angle group showed a decrease of 0.3°. The angle SN-GoGn increased 0.17° in the high angle group and decreased 0.69° in the low angle group resulting in a very small but significant difference of 0.86° between groups which they attributed to the counterclockwise rotation in the low angle cases. The Y-axis remained relatively constant in both groups with no significant difference. They asserted that the results gained from the high angle cases did not confirm the theory of headgear or growth induced mandibular rotation. While posterior facial height increased more in the low angle cases (7.18mm vs. 5.46mm), counterclockwise mandibular rotation was noted as a result of growth and treatment in both groups. They also noted that there was more counterclockwise rotation of the mandible in the low angle cases. Therefore, on average, growth and treatment resulted in improvements in the high angle patients but aggravated the problems in low angle patients with deep bites. They concluded that vertical skeletal relationships in the growing face could not be altered predictably by controlling the direction of the extraoral force.

In 2003, Roberto M. A. Lima Filho et al.'s study evaluated the posttreatment and long-term anteroposterior and vertical mandibular changes in a sample of 40 skeletal Class II, Division 1 patients (18 males, 22 females) treated with Kloehn cervical headgear. No control group was used. The treatment consisted of cervical headgear (mean treatment time 12 months) followed by cervical headgear and fixed appliances (mean treatment time 22 months). The inner bow of the headgear was expanded. A measurement error was calculated. Lateral cephalograms were taken at pretreatment (T1), posttreatment (T2), and approximately ten years after treatment (T3). Results showed that during treatment no significant change was found in the mandibular plane angle, (mean change between T1 and T2 was –0.50) but a significant decrease was detected at T3 (mean change –2.05°) as growth continued. The decrease observed in the posttreatment period was similar to that reported in untreated subjects of other studies.

In 2006, Gursu Ulger et al. studied the changes in vertical dimension produced by cervical headgear and lower utility arch treatment. All 36 subjects included in the study had a Class II, division 1 malocclusion. Twelve were treated with cervical headgear alone and 12 received a combination of cervical headgear and a lower utility arch. The inner bows of the headgear were expanded. The treatment groups were compared with 12 matched untreated Class II, division 1 control subjects. Treatment changes were assessed by comparing pretreatment and posttreatment lateral cephalometric radiographs.

A measurement of error was calculated using 20 randomly selected cephalograms and a paired t test. In the cervical headgear group, the upper facial height increased 3.08 mm. This was measured as a line from point A to HP which was a horizontal reference plane that was drawn 7° below SN through point S. This same dimension only increased 0.33mm in the control group. Likewise total face height (N-Me) also increased significantly more in the cervical group (3.0 mm) than in the control group (1.08 mm). None of the groups showed significant opening rotation of the mandible. All of the groups showed a slight increase in the mandibular plane angle (cervical group increased 0.58°, control group increased 0.42°) with no significant difference between groups. They explained this by postulating that similar increases in anterior facial height and ramus height in the cervical headgear group negated significant changes in the mandibular plane orientation. Maxillary molar extrusion produced by cervical headgear treatment was an average of no more than 1 mm as compared with the eruption seen with normal growth and development of the control group.

Clinicians often employ high-pull headgear to treat high mandibular plane angle cases with the belief that it inhibits maxillary vertical development. This is what F.F. Schudy suggested in his 1965 study whose purpose was to document growth changes that produce rotation of the mandible. He reviewed growth of the mandible and then suggested that high-pull headgear be used when treating high angle cases for the purpose of inhibiting the downward growth of the maxillary alveolar process and possibly the body of the mandible. He advised that when treating a patient where condylar growth was deficient and vertical growth excessive, one should try to inhibit the downward displacement or movement of the maxillary molars during growth. If it is determined that vertical growth is deficient resulting in a deep bite, one should try to stimulate the vertical growth of the alveolar process with Class II elastics and /or the conventional facebow headgear with cervical traction.

Based on clinical observation and experience, Maclay M. Armstrong demonstrated how the application and precise control of the magnitude, direction, and duration of extraoral force increased the efficiency and effectiveness in the treatment of malocclusions. His 1971 study reviewed the force vectors that cervical headgear produces and explained that the downward and distal pull of the cervical headgear resulted in distal tipping and extrusion of the first molar and resultant clockwise tipping of the maxilla. The direction of pull and the effects of high-pull headgear were reviewed as having a distal and an intrusive force. According to models and cephalograms obtained from cases he treated with combination headgear, he demonstrated how the control of different force vectors allowed for distal bodily movement of the molars without extrusion. He suggested that the direction of pull provided by the headcap is especially advantageous in treating a Class II case with a high mandibular plane angle where it is important not to extrude the upper posterior teeth and is advantageous to intrude them.

There are previous studies that have compared the effects of cervical and high-pull headgear to determine whether or not there are different vertical effects between the two headgear systems. In 1960, R.M. Rickett's study sought to answer the following questions: 1. What is the effect of various current corrective treatment procedures on facial structures? 2. Does similar orthodontic treatment affect all types of morphologic patterns in the same manner? His study included 5 sets of 50 subjects which included untreated Class I patients, untreated Class II patients, Class II patients treated with Kloehn cervical headgear, Class II patients treated with intraoral traction and/or intermaxillary elastics, and Class II patients treated with a combination of intraoral and extraoral traction. Measurements were taken from tracings of serial lateral cephalograms. Results indicated that improvement of the facial angle (FH-Npg) tended to be slightly inhibited with cervical headgear (the facial angle increased only 0.5°), compared to the high-pull headgear and conservative anchorage on the lower arch groups which showed an average increase of 1.3°. Cervical headgear and intermaxillary elastics tended to increase the face height faster as compared to the untreated controls. This was expressed as an increase in the the XY axis (angle formed between BaN-SGn) of 1.0°. The Class II control group showed a much smaller (0.26°) increase in the XY axis. In the cases treated with cervical traction the mandibular plane angle increased an average of 0.5° as compared to a 0.5° decrease observed in both control groups. No values were given for the high-pull subjects in this study but it was stated that its use improved the Y axis and XY axis which otherwise were expected to increase. In conclusion, Ricketts stated that cervical headgear erupted the molars and caused an opening of the Y axis and a resultant rotation of the mandible. High-pull headgear tended to intrude the molars thereby allowing the chin to grow straight forward without backward rotation.

In 1969, Richard A. Mays' cephalometric study compared the effects of the Kloehn cervical headgear and hook-up headgear when used in addition to edgewise appliance in the treatment of the Class II, division 1 malocclusions. The sample consisted of a hook-up headgear group of 18 orthodontic patients, a Kloehn cervical headgear group of 20 patients, and a control group of 10 untreated individuals. The

Kloehn cervical headgear group demonstrated significant opening of FMA. Lower facial height in the cervical headgear group increased twice the amount observed in the hook-up headgear group. The FMA of the hook-up headgear group was maintained as the maxillary molars were extruded only 1/3 the distance that was observed in the Kloehn cervical headgear group.

In 1972, John Barton compared the changes of 20 cases treated with high-pull headgear attached to the archwire mesial to the maxillary canines and 20 cases treated with cervical headgear attached to the first molars. All of the cases were treated with extraction of 4 premolars and full banded edgewise appliances. No control group was used. Pretreatment and posttreatment cephalograms were traced and measured. In the cervical headgear group N-Me (AFH) increased 7.18 mm and SN to the maxillary first molar increased 6.28 mm. In the high-pull group the increase in N-Me was 4.60 mm and SN to the maxillary molar was 2.8 mm. The difference in the mean increase between groups was significant. From these results, Barton concluded that the chin is forced downward 2.6 mm more as a result of treatment with cervical headgear. Cervical traction caused the mandible to rotate backward more than high-pull headgear (0.13° vs. –0.80°) but this difference was not statistically significant. His results supported what Weislander had previously reported: Cervical headgear extruded the maxillary molar but that it also extruded the condyle thereby causing the entire mandible to reposition vertically thereby keeping the MPA constant.

In 1972, Wayne Watson's study compared the effects of high-pull headgear to that of a previously computerized cervical headgear group. The sample consisted of group of 14 Class II, division 1(12 females, 2 males) subjects with a mean mandibular plane to SN value of 39.3°. All cases were treated nonextraction with full banded appliances. Lateral and frontal head films were taken at three different periods during treatment. These were compared to information already stored in a computer system of a sample of patients treated with cervical headgear. Results indicated that those treated with high-pull headgear had less opening of the facial axis (The intersection of the basion-nasion plane with CC point to gnathion plane). An average increase of 0.3°/year was noted in the high-pull group compared to those treated with cervical headgear which increased an average of 1.12°/year. The difference between the two groups was significant at the 10% level (p=0.10). Those treated with high-pull headgear showed a decrease in the lower facial height of 0.72°/year. The lower face height was an angular measurement that consisted of the angle formed by the ANS, Xi point, and Pogonion. It was noted that this dimension usually increases in this vertical type of growth pattern. No value was given for the increase in the cervical headgear group. The high-pull group showed a 0.44°/year decrease in the mandibular plane angle (Go-Gn/SN).

In 1978, Peter Brown compared the skeletal and dental changes incurred over one year of treatment with either cervical or high-pull headgear. He used intermittent application (12 hours a day) of lighter extraoral forces (less that 600 Gm. per side). Subjects were in the late mixed dentition or the early permanent dentition. Twenty cervical headgear patients and 17 high-pull patients were evaluated and compared to an untreated control group. Eight of the 17 high-pull subjects had an anterior auxiliary facebow in addition to the molar facebow worn for 1-3 months. All participants in the treatment groups were also being treated with full banded appliances. Males and females were studied together. Cephalograms were obtained prior to treatment and one year after the initiation of extraoral therapy. An error of measurement was calculated. Study results indicated that extrusion of the maxillary first molar as measured from the mesial cusp tip to the palatal plane was beyond the normal growth increment. This extrusion appeared to be related to the vertical component of the face-bow neck strap traction which produced an extrusion of 1.8 mm vs. 0.3 mm observed in the high-pull group and 0.6 mm in the control group. It was postulated that an increase in anterior face height (N-Me =4.6, Me⊥PP=3.5) and an increase in the mandibular plane angulation (0.8°) in the patients treated with cervical headgear were a result of the extrusion of the maxillary molars along with other factors. When comparing the cervical to the high-pull group, it was determined that the maxillary molars were significantly extruded in the cervical sample. The difference in change of the mandibular plane angle between the cervical and the high-pull group was not significant which they speculated might have been due to the short duration of the study.

Significant differences between cervical and high-pull headgear have not always been found. In 1978, Sheldon Baumrind et al. reported on the mandibular plane changes which occurred during clinical treatment with five different orthodontic methods for the delivery of force to the maxilla. Those methods included cervical traction (n=104), straight-pull headgear to J hooks (n-16), high-pull headgear to upper first molars (n=53), combination headgear (n=15), and intraoral removable appliances (n=61). A control group consisted of 54 untreated Class II subjects. The study concluded that each type of extraoral appliance studied appeared to produce a slight increase (<0.5°) in the mandibular plane angle measured as SN-GoGn and Downs MPA, but there were no statistically significant difference between the treated groups. The untreated group showed a small reduction (0.5°) in mandibular plane angle during a comparable time period. In another 1978 study using the same groups as previously mentioned, Baumrind et al. considered the differences that might exist when treating high angle cases. They found that the mean change in mandibular plane orientation was not different for the high angle cases when compared to the other cases in the study.

In a 1983 study, Sheldon Baumrind et al. compared the orthodontic and orthopedic effects of maxillary traction using several treatment methods. The samples included four treatment groups of Class II subjects: the control n=50, cervical headgear n=74, high-pull headgear n=53, and an intraoral group n=61. Lateral head films at two different time points were traced by four different judges and then digitized with a computer-linked electronic digitizer. The vertical level of the molar in the high-pull sample remained unchanged indicating that the high-pull headgear caused intrusion of the first maxillary molar as contrasted to both the control group and the cervical headgear group where extrusion of the maxillary first molar was observed. Cervical traction showed both orthopedic and orthodontic extrusion of the upper first molar but the extrusion observed was on average no more than 1 mm as compared to the control group.

In 1992, Michael Burke and Alex Jacobson studied the vertical changes in high angle Class II, division 1 patients treated with cervical or occipital-pull headgear (OPHG). The patients were all treated with headgear attached to the upper first molars. Thirty-two cases treated with OPHG and 21 cases treated with cervical headgear were included in the study. Some cases were treated as phase one of two phases of treatment while others were treated in one phase with headgear and full orthodontic appliances. Pretreatment, posttreatment, and follow up cephalograms were taken. Only the values of those measurements with statistically significant differences between groups were reported. There were no significant differences in mandibular plane angle changes between groups. It was reported that when treatment stopped, almost all mandibular plane angle measurements decreased. Maxillary molar extrusion was greater in the cervical headgear sample showing a 3.86 mm increase vs. 1.81 mm seen in the OPHG group. Facial height changes during the period of the active treatment were significantly greater in the cervical pull sample. However, when annualized none of theses changes remained significant.

Other studies have focused on the changes that occur with high-pull headgear as compared to untreated groups. In 1984, V. Fotis et al.'s study reported on the changes that occurred when high-pull headgear was added to the molar region of a maxillary splint. A sample of 28 Italian children (12 boys and 16 girls), most in the early mixed dentition with increased overjet and distal molar relationship, were included in the study. A full coverage maxillary splint worn at night and to some extent during the day was used with embedded molar tubes for the headgear insertion. Pretreatment and posttreatment cephalograms were taken. A publication of untreated Class II patients from an Australian child growth study was used as a control. An opening of the angle between the maxillary and mandibular planes was avoided as the results showed that the relationship between anterior and posterior facial height increased only an average of 0.2 mm. The mandibular plane angle measured to SN remained relatively constant only increasing minimally (0.4°). The distance from a point on maxillary first molar to SN was reduced 0.5 mm showing that the vertical development of the maxillary molar was restricted. It should be noted that only pretreatment values were given for the Australian control group. No information was given about changes observed in the control sample but the author stated that none of the changes observed in the headgear sample could be anticipated in an untreated group.

In 1992, Maurice Fiorouz et al. conducted a prospective cephalometric study to examine the skeletal and dental effects of high-pull headgear. Twelve Class II adolescent patients wore high-pull headgear about 12 hours a day for a 6 month period. A group of 12 untreated Class II adolescent patients of similar age range and similar skeletal and dental characteristics were chosen as controls. Lateral cephalometric films of the treated group were taken before treatment and after a 6 month period. Cephalograms of the individuals in the control group were taken before and after the observation period. Results exhibited that the molars were intruded 0.54 mm in the high-pull headgear group and extruded 0.42 mm in the control group. None of the cases in the treated group displayed any maxillary molar extrusion. The intrusion of the upper molar did not cause a statistically significant reduction in the lower facial height. Considering the MPA changes as measured to FH, there were no statistically significant differences between the groups. In both groups the mandibular plane remained relatively constant.

Horizontal movement of maxillary molars

Many studies have reported that the use of headgear moves maxillary molars distally. P.L. Klein's 1957 cervical headgear study superimposed cephalograms on the palatal plane and found an average of 1 mm distal movement of the upper first molar. Seventeen of 24 cases treated with cervical headgear showed distal bodily movement when measured in relation to the maxillary outline while seven showed no distal movement. None in the treated sample showed maxillary molar movement in the anterior direction. In the Class I and Class II control groups of R.M. Rickett's 1960 study, the molars drifted forward 3.5 mm and 2.0 mm respectively relative to the PTM line (posterior margin of the pterygomaxillary fissure perpendicular to the Frankfort plane). Those treated with cervical headgear exhibited a distal movement of 1.3mm. Jakobsson's 1967 study found that maxillary molars in the group treated with cervical headgear moved distally an average of 2.6 mm when compared to a control group. W. Watson's 1972 study found that distal movement of the maxillary molars occurred after high-pull headgear treatment. The amount of distal movement was comparable to that which was observed in the computerized cervical headgear group. Weislander's 1974 study included a sample of 28 patients treated with cervical headgear. The maxillary molars in the treatment group assumed a 5 mm more distal position than that of the Class II control group. He attributed 3 mm of this movement to tooth movement and 2 mm to changes in the base of the maxilla. In 1983, S. Baumrind et al.'s study found that the orthopedic distal displacement of the first molar was similar in the cervical group and high-pull group but the orthodontic distal displacement was greater in the high-pull group. They noted that in the high-pull group heavier forces were used for briefer treatment periods in contrast to the cervical headgear where lighter forces were used for longer treatment periods. M. Fiorouz et al.'s 1992 study noted that in their high-pull headgear group, the distal displacement of the molars that occurred was in the form of translation since both the molar crown and root moved distally 2.56 mm in contrast to the control group where the molar moved mesially an average of 0.23 mm. A.H. Cook et al.'s 1994 study indicated that the maxillary molars were significantly distalized (1.7 mm) in the cervical headgear groups in contrast to the control group whose maxillary molar moved forward an average of 0.41 mm. Gandini et al.'s 2001 study also confirmed that there was distal relocation of the maxillary molar when compared to an untreated control group. In their study, forward maxillary molar movement in the cervical headgear group was only 0.31 mm/year as compared to 1.27mm/year in the control group.

Although headgear creates a force in the posterior direction, two studies have not found that there is distalization of the maxillary molars after headgear use. The results from T.J. Cangialosi et al.'s 1988 study implicated that cervical headgear treatment caused a 1.06 mm movement of the maxillary molar in the mesial direction as determined by evaluating pretreatment and posttreatment palatal superimpositions. They explained this by saying that since this was a retrospective study, there was no control of patient cooperation, duration of wear, and force of the headgear which may not have inhibited forward growth of the maxilla. Likewise G. Hubbard et al.'s 1994 cervical headgear study found that maxillary molars moved in a mesial direction as measured from a vertical line from the palatal plane at Ptm and also from pterygomaxillary vertical plane. They explained that their results may be due to the full banded appliance therapy that followed cervical headgear wear.

Palatal plane changes

Many studies have concluded that cervical headgear causes an anterior downward tipping of the palatal plane. In P.L. Klein's (1957) cervical headgear study, the palatal plane showed a tendency to descend anteriorly an average of 1.75° when measured to SN. In W.A. Blueher's (1958) cervical-pull headgear study, the palatal plane angle was measured from a perpendicular projected to SN. Twenty five of the 34 cases showed an increase in palatal plane, six showed a decrease and three remained the same. The average increase in the palatal plane angle exhibited by the girls in his study was 1.76° and that of the boys was 1.95°. He commented that some in his group showed a decrease but this may be due to error of tracing since PNS can be difficult to locate because of the shadow produced by the erupting second molars. His study did not mention a calculation of measurement error. It was D.R. Poulton's (1967) clinical experience that led him to believe that tipping of the palatal plane was also an effect observed after treatment with cervical headgear. The palatal plane was tipped an average of 1.04°/year as measured from SN in W. Watson's (1972) high-pull sample. No information was given for the effect of cervical headgear on this measurement. Weislander's (1974) cervical headgear sample showed that ANS descended approximately 1 mm when compared with a Class II control group thereby causing a slight tipping of the palatal plane. Brown's (1978) results found that cervical headgear appeared to tip the maxilla down and backwards when compared to growth changes in the control group as indicated by an increase in SNPP of 1.3° in the cervical headgear group, and a decrease of 0.3° in the control group. He asserted that the downward tipping of the palatal plane was related to the vertical component of the face-bow neck strap traction. In their study, T.J. Cangiolosi et al. (1988) found that the palatal plane angle increased an average of 1.03° when measured to SN after the use of cervical headgear. He suggested that perhaps this happened because the distal force on the molar inhibited the vertical development of the posterior part of the palate meanwhile the anterior part continued to grow. G. Hubbard et al. (1994) found that there was an average increase of 1.6° in the palatal plane angle when measured to SN in his cervical headgear group. A.H. Cook et al.'s (1994) cervical traction only group showed a significantly greater anterior descent of the palatal plane when compared to the untreated group. The palatal plane when measured to SN showed a 1.59° increase while the untreated control showed only a 0.31° increase. Kirjavainen et al. (2000) found that there was an anterior decent of the palatal plane in their cervical headgear group as the N-S-PL angle increased an average of 1.4° in boys and 1.9° in girls. M.R.E.A.S. Gandini et al.'s (2001) cervical headgear study indicated that a small (0.25°/year) clockwise rotation of the palatal plane occurred in the cervical headgear group as compared to an increase of 0.09°/year for the control group. Kim et al.'s 2001 study found that treatment with cervical headgear resulted in a 2.2° increase in the palatal plane angle when measured in relation to FH while a control group showed a 0.7° decrease. In N.B. Haralabakis et al.'s (2002) study, both the high and low angle samples treated with cervical headgear exhibited statistically significant but clinically negligible increases in SN-PP with the high angle cases increasing 0.56° and the low angle cases increasing 0.93°. Most recently G. Ulger et al.'s 2006 study examined the changes in vertical dimension produced by cervical headgear treatment. The SN-PP angle increased 3.08° in the cervical headgear group compared to only a 0.33° in the untreated control group.

Some have found that cervical headgear caused a more pronounced anterior downward tipping than does high-pull headgear. R.M. Ricketts' (1960) study showed a downward tipping of the palatal plane of 1.6° in those treated with cervical headgear. This tipping was larger in the cervical traction group than those treated with anterior high-pull headgear but no value was given for the high-pull group. J. Barton (1972) found a significant difference in the amount of downward movement caused when cervical headgear was used as compared to high-pull headgear. According to his findings, the change observed in the cervical headgear group was a 1.33° increase in SNPP. In the high-pull headgear group he found a 0.38° decrease in SNPP. Results from S. Baumrind et al.'s 1983 study indicated that orthopedic downward displacement of ANS was significantly greater in the cervical group than in the high-pull group.

Others did not find that there were significant changes in the palatal plane angle among groups. When the changes between the cervical and the high-pull group in Brown's (1978) study were compared, both showed a downward movement of the palatal plane of 1.3° and 0.9° respectively. The difference between the groups was not statistically significant. H. Knight (1988), whose study included a cervical headgear group and an untreated Class I group, also did not find any significant differences when the maxillary plane was measured to SN. Both groups showed an increase in the maxillary plane of 1.3° and 0.9° respectively. P.R. Boecler et al.'s (1989) study recognized that a downward tipping of ANS occurred in both headgear groups (cervical and combination) and the non-headgear group of their study. The differences between these groups were not statistically significant which led to the conclusion that they did not find evidence for the expectation of downward tipping of ANS as a result of headgear treatment. In M. Firouz et al.'s (1992) high-pull group, ANS and PNS grew downward less than half of what was observed in the control group. There was no change in the palatal plane angulation and no significant difference between groups as the normal downward movement of ANS and PNS were reduced the same amount.

Occlusal plane changes

There is no unanimity of opinion about the effects of headgear on the occlusal plane. Some studies have found that the occlusal plane tips up anteriorly when cervical headgear is used. This is what was reported in P. Brown's (1978) study in which the occlusal plane angle (SN.OP) decreased after cervical headgear treatment by 2.9° as compared to his high-pull sample which showed no change. The changes in occlusal plane angle as measured to SN between the high-pull and cervical headgear groups in M. Burke et al.'s (1992) study were significantly different. The cervical group in their study exhibited a decrease of 3.28° compared to only a 0.87° decrease in the high-pull sample. In M.R.E.A.S. Gandini et al.'s (2001) study, they found a slight counterclockwise rotation of the occlusal plane in their cervical headgear sample. The mean change in occlusal plane angle (SN-OP) for the cervical headgear group was a decrease of 0.81°/year while the control showed a significantly lesser change decreasing only 0.46°/year.

Some studies have noted a steepening of the occlusal plane when high-pull headgear was used. According to Watson's (1972) study the posterior portion of the occlusal plane moved vertically 0.86 mm per year in the high-pull group which indicated that intrusion of the maxillary molars occurred. This intrusion was said to have helped tilt the occlusal plane upward. V. Fotis et al. (1984) noted a steepening of 2.6° in the occlusal plane as measured to SN and reasoned that the vertical development of the maxillary molar was restricted via the use of high-pull headgear which in contrast had no influence upon the vertical development of the mandibular alveolar region.

There are others who have found that the occlusal plane stays relatively constant after headgear use. In P.L. Klein's (1957) cervical headgear study, the occlusal plane as measured from the mandibular plane, with the symphysis registered, showed very little change decreasing an average of only 0.5°. One half of the cases did not change at all. Based on D.R. Poulton's (1967) clinical observation, he believed that high-pull headgear had an intrusive action on the upper incisors which aided in maintaining the stability of the occlusal plane. In T.J. Cangiolosi et al. (1988) cervical headgear study, their results indicated that the decrease of 0.42° in the occlusal plane angle when measured to SN was not significant. The occlusal plane stayed constant after headgear treatment according to G. Hubbard et al.'s (1994) cervical headgear study when measured in relation to SN.

Changes in SNA

Several studies have produced evidence to support the premise that headgear corrects Class II molar relationships orthopedically by restricting the forward growth of the maxilla. Some studies have shown this as a reduction in SNA after headgear treatment. In P.L.Klein's (1957) cervical headgear study, SNA was reduced an average of 1.3°. Of W.A. Blueher's (1958) 34 subjects, he found that there was a reduction in SNA in 29 of the subjects with an average reduction of 1.86° in the boys and 1.96°in the girls. In four subjects SNA was maintained. An increase in SNA was found in only one subject. He reasoned that this result demonstrated that forward growth of the maxilla was restricted in full edgewise appliance with cervical traction treatment. R.M. Ricketts (1960) found that SNA was reduced significantly in the groups treated with headgear with an average reduction of 2.7°. He did not differentiate between the types of headgears used. Both control samples in his study showed an increase of 0.6°. Likewise in R.A. May's (1969) cervical and high-pull study, both experimental groups showed a significant decrease in the SNA angle. In B. Melsen's (1978) cervical traction implant study, the prognathism of the maxilla was reduced in Group I where the outer bow was tilted upwards 20° in relation to the occlusal plane. In Group II, where the outer bow was tilted downwards, it remained unchanged in some and reduced in others. This was reflected by the changes in S-N-Ss (Ss –Subspinale) and by changes in position of the maxillary implants in relation to the anterior cranial base. T.J. Cangiolosi et al.'s (1988) cervical traction study also showed a mean reduction in SNA of 1.13°. H. Knight (1988) found a reduction of 1.3° in SNA in her cervical headgear group when compared to the Class I control group which showed an increase of 0.9°. This reduction was stable as observed by her posttreatment records that were taken on the cervical headgear group. Cook et al. (1994) found that their cervical headgear group showed a mean SNA reduction of 1.88° while the control group increased 0.48°. M. Kirjavainen et al. (2000) reviewed records following cervical headgear treatment and found a mean SNA decrease of 1.7° in boys and 2.1° in girls. A reduction in SNA was also a finding in Ulger et al.'s 2006 study. After cervical headgear treatment, SNA was reduced 2.92° as compared to an increase of 0.17° seen in the untreated control group.

Two studies have not found that the maxilla is restricted from growing forward as a result of headgear treatment. Even though G. Hubbard et al.(1994) found that there was a reduction in SNA in his cervical pull sample, the linear distances (ANS-PNS, Ar-ANS,and Ar-Apoint) increased during treatment which led them to believe that the maxilla continued to grow forward as in normal untreated individuals. In M.R.E.A.S.

Gandini et al.'s (2001) study, maxillary basal bone changes (excluding dentoalveolar changes) did not differ significantly between the treated and the untreated groups. According to this study, there was not enough evidence to prove that cervical headgear caused growth modification of the maxillary bone.

Changes in SNB

Reports on the changes that occur in SNB as a result of headgear treatment are variable. In Blueher's (1958) study, 11 of the 34 the subjects showed a decrease in SNB (boys decreased 0.87°, girls decreased 0.85°), 6 stayed the same, and 17 showed an increase in SNB, (boys increased1.27°, girls increased 1.5°). In his study, Barton (1972) found the SNB angle decreased 0.35° in the cervical headgear group while the high-pull group showed an increased of 0.50°. A study by Knight et al. (1988) showed a reduction of 0.3° in SNB in their cervical headgear group, compared to an increase of 1.2° in the control group.

Other studies have reported an increase in SNB after headgear treatment. Cangiolosi et al. (1988) found a mean increase in SNB of 0.49° in his cervical headgear study. Kirjavainen et al. (2000) suggested that the mandible grew forward in her cervical headgear group since they saw an increase in SNB of 0.8° in boys and 0.7° in girls. Lima Filho et al. (2003) found that in their cervical headgear study there was a mean increase in SNB 0f 0.94° from T1 to T2. This angle continued to increase as growth continued (mean increase T2 to T3 was 0.93°). In Ulger et al.'s (2006) study, both the control group and the cervical headgear group showed a mean increase of 0.58°.

MATERIALS AND METHODS

Case Selection

The sample selection was based on pretreatment criteria from pretreatment records. The high-pull sample was gathered from the treated orthodontic records of Dr. Bruce Fiske, and the cervical headgear subjects from the practice of Dr. David Cruikshank. Inclusion criteria for this study included:

(1) Patients that had been diagnosed with a Class II, division 1 malocclusion.

(2) Mandibular plane angle greater than 36° (SN – GoMe).

(3) Nonextraction treatment with cervical or high-pull headgear and full orthodontic appliances.

(4) No congenitally missing teeth anterior to the third molars.

Those subjects whose record indicated that cooperation was inadequate were excluded from the study. Pretreatment (T1) and posttreatment (T2) cephalometric radiographs were obtained for each of the subjects. No untreated control group was used for comparison. Progress cephalometric radiographs were not available for all patients so progress radiographs were not included in this study.

Subjects

The groups consisted of 28 high-pull headgear subjects (21 females, 7 males) and 34 cervical headgear subjects (18 females, 16 males). The mean age of the cervical headgear patients was 11.9 years with a range of 9.5-14.3 years. The mean age of the high-pull headgear patients was 12.7 years with a range of 9.8-16.0 years. Due to the small sample size, females and males were studied together. Table I shows the number of subjects, the mean age at the start of treatment, the headgear duration, and the treatment duration for each group. All of the cases were treated in one phase with full .022x.028 in. straight-wire orthodontic appliances. Most patients in the high-pull sample were treated with a quadhelix palatal expander for a short period of time at the beginning of treatment. Class II elastics were used as needed in both groups.

Methods

The following biographical data was collected for each subject in each of the two groups:

Gender
Age at T1
Total treatment time
Headgear treatment time
Length of time elastics were worn

All cephalometric radiographs were scanned using an Epson Perfection 4990 Photo Scanner. One researcher digitized and traced all of the radiographs using cephalometric software (QuickCeph Studio, 2007). When right and left images did not superimpose, a midpoint between right and left points was used.

Twenty eight points were digitized as per the requirements of analysis with QuickCeph Studio (Figure 2):

0- Sella	Center of sella turcica
1- Porion	Most superior point of external auditory meatus
2- Basion	Most inferior point of occipital bone
3- Hinge Axis	Center of rotation of the condyle
4- Pterygoid	Eleven o'clock position of the pterygoid fissure
5- Nasion	"V" notch of frontal and nasal bones
6- Orbitale	Most inferior point of orbital contour
7- ANS	Tip of anterior nasal spine
8- PNS	Tip of posterior nasal spine
9- A-point	Deepest point between ANS and the upper incisal alveolus
10- B-Point	Deepest point between pogonion and lower incisal alveolus
11- PM	Point where curvature changes between B-point and pogonion

12- Pogonion	Most anterior point of the symphysis
13- Menton	Most inferior point on the symphyseal outline
14- Corpus Left	Left point on a tangent of the inferior border of the corpus
15- Ramus Down	Lower point of a tangent of the posterior border of the ramus
16- Articulare	Intersection of inferior cranial base surface & posterior surface of condyle
17- R3	Most inferior point of the sigmoid notch of the ramus
18- R1	Deepest point of the curvature on the anterior border of the ramus
19- mx 1 crown	Tip of the crown of the upper incisor
20- mx 1 root	Tip of the root of the upper incisor
21- md 1 crown	Tip of the crown of the lower incisor
22- md 1 root	Tip of the root of the lower incisor
23- Occlusal Plane	Midpoint between upper and lower first bicuspids
24- mx 6 distal	Distal contact point of maxillary first molar
25- mx 6 root	Distal buccal root of maxillary first molar
26- md 6 distal	Distal contact point of mandibular first molar
27- md 6 root	Distal buccal root of mandibular first molar

The following measurements were made:

SNA:	Angle formed between sella, nasion, and A point
SNB:	Angle formed between sella, nasion, and B point
ANB:	Angle formed between A point, nasion, and B point
Articulare angle:	Angle formed between sella, articulare, and constructed gonion
Saddle angle:	Angle formed between nasion, sella, and articulare
Gonial angle:	Angle formed between articulare, gonion, and menton
Mandibular plane angle (MPA):	Angle formed from the line sella to nasion and gonion to menton
Y axis:	Angle formed between nasion, sella, and gnathion
Palatal plane angle (SN-PP):	Angle formed from line sella to nasion and ANS to PNS
Occlusal plane angle (SN-OP):	Angle formed from line sella to nasion and a line through the occlusion from mesiobuccal cusp of the maxillary first molar to the midpoint of the overlap of the upper and lower 1's where there is positive overbite, or the midpoint between the incisal edges of the upper and lower 1's when there is no positive overbite
Mx 6 to PTV:	Distance in mm between the distal of Mx 6 to PT point Pterygoid perpendicular to sella
Posterior face height (PFH):	Distance in mm between sella to gonion
Anterior face height (AFH):	Distance in mm between nasion to menton
Lower anterior face height (LFH):	Distance in mm between ANS to menton
Ramus Height:	Distance in mm between articulare and gonion

Figure 3 shows the the reference planes for some of the angles measured.

The radiographs used in this study were taken on two different cephalometric machines, one of which was no longer available. In order to account for enlargement and make certain that both machines enlarged a comparable amount, a radio-opaque marker of known dimension was placed on the right and left temporal areas of a skull and a lateral cephalogram of the skull was taken on the machine that was still in use. The enlargement for that machine was calculated by using the right side marker on the skull and comparing it to the image of it on the lateral cephalogram. The enlargement was calculated at 9%. A subjects' study cast was then examined from that same practice. The mesial-distal dimension of the mandibular right first permanent molar was measured and compared to the image of the mandibular right first molar on the corresponding patients' lateral cephalogram. The enlargement in this instance was also calculated at 9%. Since these two methods of accounting for enlargement gave comparable results, we were confident that using the first molar dimension on a cast and comparing it to the corresponding patients' radiograph was a legitimate way of accounting for enlargement in the practice where the radiograph machine was no longer available. Four more casts were selected from the first practice and 5 casts were selected from the second practice. The mesial-distal dimension of the mandibular right first molars were measured and compared to the mesial-distal dimension of the mandibular right first molar on their corresponding lateral cephalogram. The average of both sets was calculated. The average enlargement for the five subjects from each practice was measured at 9% for the cervical headgear group (practice 2) and 8.5 % for the high-pull headgear group (practice 1). It was concluded that the enlargement of the structures on the cephalometric radiographs from both practices were comparable.

Statistical Analysis

Means and standard deviations for age, duration of headgear, duration of treatment, elastic wear, and all cephalometric measurements at T1 for the cervical and the high-pull headgear groups were calculated. Additionally mean differences and standard deviations were calculated for the changes of T2-T1 for each group. The data was analyzed with statistical software GraphPad InStat 3. An alpha value of less that 0.05 was considered statistically significant. Starting cephalometric measurements were compared with independent sample t tests. Mean differences between the cervical and high-pull headgear groups at the time interval T1-T2 were compared by using independent sample t tests as well.

Error of Method

Reproducibility of landmark location was checked by choosing 10 randomly selected cases. These were retraced and digitized two weeks after the first tracing. The error of method was determined by the Dahlberg statistic (Dahlberg 1948) using the formula

$$s = \sqrt{\sum d^2/2n}$$

where d is the difference between the first and second measurements and n is the number of determinations (in this case 10). The precision for the variables varied with a range of 0.3-1.3 (Table III).

RESULTS

Table I shows the sample description. The samples in this study were gathered from the practices of two orthodontists. No control group was employed since the focus of this study was to observe the changes that occurred when expert clinicians treated high mandibular plane angle cases with modalities of their own choosing. Although males and females were studied together, there was a distribution difference between groups. Whereas the cervical headgear sample was somewhat evenly distributed (18 females, 16 males), the high-pull sample consisted of three times as many females as males (21 females, 7 males). The mean length of time that the headgear was worn and the mean treatment duration was longer for the high-pull headgear group but these differences between the groups were not statistically significant. The mean age of the high-pull group (12.7 years) at the start of treatment was nearly one year older than that of the cervical headgear group (11.9 years). Class II elastics were worn in most cases for both groups (Table II). The cervical headgear group wore them an average of 2.2 months longer than did those in the high-pull sample. This difference was statistically significant ($p \leq 0.05$).

Pretreatment mean values of all the parameters evaluated are presented in Table IV. Comparison of the pretreatment values between groups showed differences in SNA, SNB, articulare angle, gonial angle, and saddle angles. All of these differences were small but were statistically significant ($p \leq 0.05$). However the difference in the pretreatment ANB angle was not significant (4.4° compared to 4.3°).

The angular and linear vertical changes in the two samples at the completion of orthodontic treatment are recorded in Table V. Negative numbers represent a decrease in value from T1 to T2 and positive numbers represent an increase. The cephalograms for each group were taken on different machines. The enlargement factor was calculated at close to 9% for both cephalometric machines. As seen in Table V, there were significant differences in the occlusal plane angle (SN-OP), Y axis, and the lower facial height between groups. The occlusal plane angle increased (tipped down anteriorly) in the cervical headgear group (1.2°) and decreased slightly (tipped up anteriorly) in the high-pull headgear group (0.5°). The Y axis increased in both the cervical (1.6°) and the high-pull headgear group (0.4°). The difference in the change between the two groups was 1.2°. The lower facial height increased significantly more in the cervical headgear group (5.6 mm) than in the high-pull group (3.9 mm). The mandibular plane angle increased 1.0° in the cervical headgear group and decreased slightly (0.1°) in the high-pull headgear group. This 1.1° difference between the groups was not statistically significant ($p=0.06$). The Measurement errors were calculated according to Dahlberg's formula (Dahlberg 1948) and are recorded in Table III.

DISCUSSION:

Limitations of the study

In retrospective studies, it is difficult to find a sample large enough to obtain valid results. It is even more difficult, if not impossible, to find records from one practice where the same facial pattern and malocclusion are treated using two different modalities. For this reason, we used the records from two different orthodontic practices. However in doing so, we introduced several differences between the groups. They included treatment protocols for the use of headgear such as differences in the amount of force, length and angulation of the outer bows, how the headgear was adjusted at routine visits, the length of time that the patients were instructed to wear the headgear, and the effectiveness of the motivational methods used to gain patient cooperation. Another intergroup difference was the amount of time that Class II elastics were worn. The cervical headgear group wore them an average of 2.2 months longer than did those in the high-pull sample which was statistically significant ($p \leq 0.05$). Also, a majority of the high-pull sample (22 of 28) wore a quad-helix for a short period of time at the start of treatment, whereas no one in the cervical group wore any type of palatal expander. The age of menarche and/or hand wrist films for all of the individuals in these groups were not available. Therefore, all individuals both female and male were studied together.

Treatment similarities between groups included that both samples underwent full orthodontic treatment in one phase. Both groups were treated using straight-wire appliances with an orthodontic bracket slot size that measured .022 x .028 in. Also, both practitioners routinely finished their cases on .019 x .025 in. stainless steel archwires. Although it would have been beneficial to have a more uniform sample, the main goal of this study was to look for major differences in treatment results between the use of cervical and high-pull headgear during full orthodontic treatment. The type of headgear used for high mandibular plane angle cases was the one major difference in the treatment approach between these two practitioners.

Angular changes

The most interesting finding in this study was that the change observed in the mandibular plane angle was not significantly different between the two groups. Several studies (Klein 1957; Blueher 1959; Jakobsson 1967; Poulton 1967; Wieslander 1974; Melsen 1978; Knight 1988; Kim and Muhl 2001) found an increase in the mandibular plane angle and/or the Y axis after the use of cervical headgear. These findings have been disputed by other studies (Fischer 1980; Cangialosi et al. 1988; Boecler et al. 1989; Cook et al. 1994; Hubbard et al. 1994; Kirjavainen et al. 2000; Schiavon Gandini et al. 2001; Lima Filho et al. 2003; Haralabakis and Sifakakis 2004; Ulger et al. 2006) which did not find a significant increase in the mandibular plane angle after cervical headgear treatment. In the present study there was variability between individuals in response to treatment. Overall, there was an average decrease of 0.1° exhibited by the high-pull group. However, 13 of the 28 subjects (46%) in the high-pull headgear group showed an increase in the mandibular plane angle that ranged from 0.5° to 3.0°. In the cervical sample 21 of the 34 subjects (62%) showed an increase in the mandibular plane angle with a range of 0.5° to 6.5°. The mean increase in the mandibular plane angle exhibited by the cervical group was 1.0°. The results suggested that treatment with cervical headgear did not notably increase the mandibular plane angle.

The Y axis of the cervical group increased an average of 1.6° while the high-pull headgear group showed an increase of only 0.4°. The difference between groups was statistically significant ($p \leq 0.05$). This result indicated that the downward vector produced by the cervical headgear may have caused an opening rotation of the mandible. On the other hand, since high-pull headgear has an intrusive force, the vertical development in that group may have been minimized as indicated by the small decrease in MPA and minimal increase in the Y axis. From this particular result, it seems reasonable to use high-pull headgear when treating high mandibular plane angle cases. The high-pull headgear patients were on average no worse at the end of treatment than the cervical headgear patients. One must consider how much of an increase in anterior face height can be produced by one or two degrees of opening in the mandibular plane angle and/or the Y axis. Kim and Muhl (2001) noted no increase in facial height even in the presence of an increase in mandibular plane angle. On the other hand, Cangiolosi et al. (1988) found an increase in anterior facial height in the presence of a decrease in the mandibular plane angle.

A possible reason for the slight increase in the mandibular plane angle and Y axis that was observed in the cervical headgear group was the use of Class II elastics. The cervical headgear group wore class II elastics an average of five months which was roughly two months longer than those in the high-pull group. Class II elastics are believed to cause extrusion of the mandibular molar and a subsequent downward and backward rotation of the mandible (Proffit and Fields 2000).

We must consider the effects of the palatal expander on treatment. Wertz and Dreskin (Wertz and Dreskin 1977) found that by the end of suture opening, banded palatal expanders displaced the maxilla inferiorly an average of 1 mm thereby increasing the vertical length of the maxilla. In their sample they also found that the mandibular plane angle increased an average of 2°. A majority of the high-pull group (78%) used in our study wore a quadhelix at the beginning of treatment yet, both the mandibular plane angle and the Y axis remained relatively constant. This suggests that the vertical development caused by palatal expanders may have been counteracted by the use of high-pull headgear. It is possible that we did not see a larger decrease in the mandibular plane angle and the Y axis because of the use of expanders in this group.

Since high-pull headgear is designed to produce an upward vector at the maxillary molar, it is expected that the occlusal plane will either increase (tip down anteriorly) or stay constant in cases treated with high-pull headgear as found in several studies (Watson 1972; Brown 1978; Fotis et al. 1984). Similarly in the present study the occlusal plane angle of the high-pull sample remained relatively constant as it only decreased an average of 0.5°. Unlike other studies (Poulton 1967; Brown 1978; Burke and Jacobson 1992; Schiavon Gandini et al. 2001) that suggested that the downward force exerted by cervical headgear decreased the occlusal plane (tipped up anteriorly), the cervical sample in the present study showed an increase of 1.2°. A possible explanation for this increase is that this group wore Class II elastics for a greater amount of time than did the high-pull group. Class II elastics are believed to tip the occlusal plane downward anteriorly (Proffit and Fields 2000). It should also be noted that the measurement error for this parameter was one of the greatest (1.3°) in this study. This measurement error was greater than the average change observed (1.3° vs. 1.2°) therefore it is possible that the observed change may have been due to error in locating the occlusal plane and not a change that was produced by orthodontic treatment.

When cervical and high-pull headgear groups were compared, some studies found that there was an increase in the palatal plane angle for both groups with the cervical headgear group showing a significantly greater increase (Ricketts 1960; Barton 1972). Other studies (Brown 1978; Baumrind et al. 1983) reported that there was not an intergroup difference in palatal plane angle changes. Similarly there was a small increase in the palatal plane angle in both the cervical (0.6°) and the high-pull (0.3°) group but the changes were not statistically different between groups. This finding suggests that treatment with either cervical or high-pull headgear does not have the adverse effect of significantly tipping the palate down anteriorly. It may also be that remodeling of the nasal floor masks the effects of the therapy, as suggested by Knight (1988).

Results in the present study showed a small decrease in SNB of 0.4° in the cervical headgear group. This is similar to the changes observed in Barton's (1972) and Knight's (1988) cervical headgear groups. Other studies (Cangialosi et al. 1988; Kirjavainen et al. 2000; Lima Filho et al. 2003; Ulger et al. 2006) have found an increase in SNB when subjects were treated with cervical headgear. Barton's study (1972) of cervical headgear compared to high-pull headgear agrees with the theory that high-pull headgear allows the mandible to assume a more anterior position while cervical headgear inhibits this movement (his high-pull group exhibited an increase in SNB and his cervical headgear group a decrease). In the present study, the SNB angle of the high-pull group remained relatively constant as it only increased an average of 0.1° which does not support Barton's observations. Why did the cervical headgear group of this study show a slight decrease in SNB? One possible explanation is that since the cervical headgear group exhibited a slight clockwise rotation of the mandible, seen as an increase in MPA and Y axis, this placed B point in a slightly more posterior position. The changes in SNB of both the cervical and high-pull headgear groups were small and the difference between the groups was not significant. This suggests that SNB remained relatively constant in both groups and was not adversely affected by either type of headgear.

No matter the mechanism, one thing that most clinicians agree with is that headgear is effective at reducing SNA (Blueher 1959; Brown 1978; Cangialosi et al. 1988; Cook et al. 1994; Kirjavainen et al. 2000; Ulger et al. 2006). Similarly in the present study, there was a reduction in SNA in both groups. The cervical headgear group exhibited an average reduction of 1.5° and the high-pull headgear group's SNA value decreased an average of 0.7°. This difference between the two groups was not statistically significant. Since changes in SNA were larger than those observed in SNB for both groups in this study, it is suggested that the reduction in ANB (cervical 1.0°, high-pull 0.8°), also seen in both groups of this study, was mainly due to distalization of A point.

Linear changes

The changes observed in posterior face height and ramus height were comparable with no significant difference between groups. In the cervical sample, the posterior face height increased an average of 5.1 mm and the high-pull sample showed an increase of 4.7 mm. Similarly the ramus height increased 2.6 mm in the cervical group and 3.3 mm in the high-pull group. This suggests that extraoral traction either does not affect these dimensions and that the changes observed may be due to normal growth or that the effect that cervical and high-pull headgear have on these dimensions is comparable.

In agreement with several studies (Mays 1969; Barton 1972; Watson 1972; Brown 1978; Baumrind and Korn 1981; Baumrind et al. 1981), the lower facial height of the cervical headgear group increased significantly more than did that of the high-pull headgear group (5.6 mm vs. 3.9 mm). It has been postulated (Wieslander 1974; Brown 1978; Cangialosi et al. 1988) that an increase in lower facial height can be expected as a result of maxillary molar extrusion when cervical headgear is used. The vertical change of the maxillary molar was not measured in our groups so it is not possible to confirm or deny a relationship between molar extrusion and increased facial height. This possible relationship should be investigated by a follow-up study using the same lateral cephalograms used in the present study. The horizontal change Mx6-Ptv (mm) was significantly different between groups. The mean change for the cervical headgear group was -0.5 mm and for the high-pull group was 1.8 mm. Since the measurement error of this dimensional change was high (1.2mm), little confidence is placed on this statistical difference. Further study of the horizontal effect on the maxillary molar of cervical versus high-pull headgear is also recommended. Although there was a larger increase in lower face height observed in the cervical group of our study, this increase was not greater than that found in both the cervical headgear and the control group of Kim and Muhl's (2001) study. This indicates that the cervical headgear group did not show a greater increase in lower facial height than that which is expected with normal growth. Furthermore, the lower facial height difference between our cervical and high-pull groups (1.7mm) though statistically significant may be considered clinically negligible.

SUMMARY

Because of the variables that could not be controlled, caution must be taken in interpreting the results of this study. In the high mandibular plane angle cases that were treated with either cervical or high-pull headgear, the following trends were observed:

1. The mandibular plane angle of the cervical headgear group increased an average of 1.0° while that of the high-pull group showed a slight decrease of 0.1°. The difference in changes between groups was not statistically significant.

2. The change in the Y axis angle measured to SN was significantly different between groups as the cervical headgear showed a larger mean increase (1.6°) than did the high-pull group (0.4°).

3. The occlusal plane angle increased (tipped down anteriorly) in the cervical headgear group (1.2°) and decreased slightly (tipped up anteriorly) in the high-pull headgear group (-0.5°). The difference between the groups was statistically significant.

4. Palatal plane angle changes between groups were not significantly different and remained relatively constant.

5. Both cervical pull and high-pull headgear were effective at reducing SNA without a significant difference between groups. This decrease in SNA aided in the decrease of the ANB.

6. SNB stayed relatively constant in both the high-pull and cervical pull headgear groups.

7. The ramus height and posterior face height of both groups increased by comparable amounts.

8. There was a significantly larger increase in the lower face height of the cervical group (5.9 mm) than the high-pull headgear group (3.9 mm).

CONCLUSIONS

1. Neither headgear system appears to produce significantly different sagittal effects in high mandibular plane angle cases.

2. The mean increases in MPA, Y axis, and lower facial height observed in the cervical headgear group were small and of questionable clinical significance.

3. At the very least high-pull headgear maintains the MPA and Y axis.

4. Either type of headgear system seemed to be acceptable for treatment of high mandibular plane angle cases.

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TABLES

Table I. Sample Description

		Age T1 (years)		HG Duration (mo.)		Tx Duration (mo.)	
Group	Sample (N)	Mean	SD	Mean	SD	Mean	SD
Cervical pull	34 (18 Female, 16 Male)	11.9*	1.2	7.9	2.99	26.9	4.5
High-pull	28 (21 Female, 7 Male)	12.7*	1.5	10.3	8.2	28.4	6.5

*Difference between groups statistically significant $p \leq 0.05$

Table II. Elastic Wear

	Cervical pull headgear		High-pull headgear		
	Mean	SD	Mean	SD	p
Elastic wear mo.	5.0	2.3	2.8	3.3	*

* Difference between groups statistically significant $p \leq 0.05$

Table III. Method of Error $\sqrt{\sum d^2/2n}$

SNA	0.6
SNB	0.3
ANB	0.5
Atrticulare Angle	0.9
Gonial Angle	1.3
Saddle Angle	0.8
MPA	0.5
Y Axis	0.5
SN-PP	0.4
SN-OP	1.3
Mx6- PTV	1.2
PFH	0.9
AFH	0.6
LFH	0.4
Ramus Height	0.9

Table IV. Comparison of pretreatment means

	Cervical pull N=34		High-pull N=28		
Measures	Mean	SD	Mean	SD	p
SNA(°)	77.6	2.1	79.2	2.9	*
SNB(°)	73.2	2.6	75.0	2.4	*
ANB(°)	4.4	1.8	4.3	1.9	NS
Articulare angle(°)	142.1	8.5	146.5	6.9	*
Gonial angle(°)	134.7	6.2	131.4	6.2	*
Saddle angle(°)	125.0	5.0	122.3	4.9	*
MPA(°)	41.7	3.0	40.3	3.0	NS
Y axis(°)	72.1	3.1	70.9	2.4	NS
SN-PP(°)	4.5	3.3	5.8	3.1	NS
SN-OP(°)	21.8	3.0	20.0	3.2	NS
Mx6 –Ptv(mm)	12.8	3.4	12.4	2.7	NS
PFH(mm)	71.2	5.3	71.6	5.8	NS
AFH(mm)	120.0	6.2	119.8	8.1	NS
LFH(mm)	66.9	4.5	68	5.1	NS
Ramus height(mm)	41.3	4.8	40.2	4.7	NS

*Statistically significant $p \leq 0.05$

Table V. Comparison of mean changes during treatment

	Cervical pull N=34			High-pull N=28				
Measures	mean	SD	Range	mean	SD	Range	Difference	p
SNA (°)	-1.5	2.4	-6.5 to 4.5	-0.7	2.4	-4.5 to 7.0	0.8	NS
SNB(°)	-0.4	1.9	-4.0 to 5.0	0.1	1.6	-3.0 to 4.0	0.5	NS
ANB(°)	-1.0	1.7	-4.0 to 5.0	-0.8	2.2	-4.0 to 2.3	0.2	NS
Articulare angle(°)	3.3	5.7	-8.0 to 17.0	1.5	3.7	-8.5 to 8.5	1.8	NS
Gonial angle(°)	-2.1	5.0	-19.0 to 6.0	-0.9	2.9	-7.0 to 8.0	1.2	NS
Saddle angle(°)	-0.02	2.5	-7.0 to 7.0	-0.6	2.9	-7.0 to 7.0	0.4	NS
MPA(°)	1.0	2.5	-6.5 to 6.5	-0.1	1.9	-5.5 to 3.0	1.1	NS
Y axis(°)	1.6	2.3	-4.5 to 9.0	0.4	1.5	-4.0 to 3.0	1.2	*
SN-PP(°)	0.6	1.9	-3.0 to 4.5	0.3	2.4	-8.0 to 4.5	0.3	NS
SN-OP(°)	1.2	2.7	-3.5 to 7.0	-0.5	2.6	-8.0 to 3.5	1.7	*
Mx6 –Ptv (mm)	-0.5	2.6	-7.0 to 5.0	1.8	2.4	-3.5 to 6.0	2.3	*
PFH (mm)	5.1	3.9	-6.5 to 11.5	4.7	2.8	0 to 12.0	0.4	NS
AFH (mm)	8.3	5.2	-4.5 to 18.5	6.2	3.5	-1.5 to 14.0	2.1	NS
LFH (mm)	5.6	3.3	-3.0 to 11.5	3.9	2.4	-0.5 to 9.5	1.7	*
Ramus height (mm)	2.6	4.3	-9.0 to 11.5	3.3	2.3	-1.0 to 8.5	0.7	NS

*Statistically significant $p \leq 0.05$

FIGURES

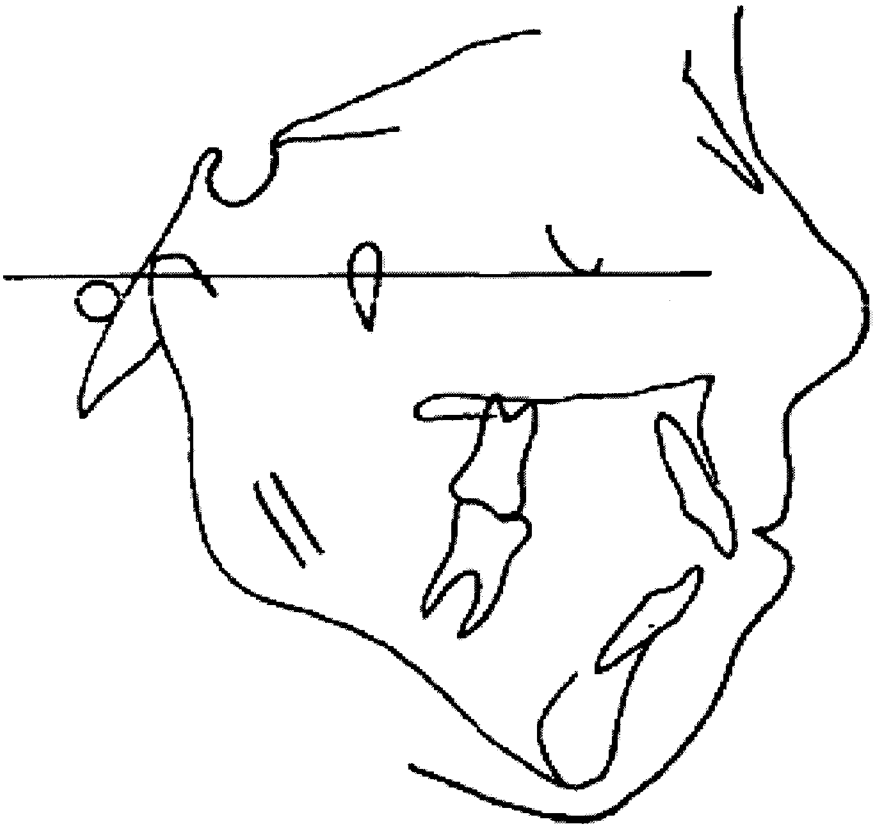

Figure 1. Usual characteristics of a dolichofacial growth pattern include a high mandibular plane angle, increased anterior facial height, open bite, lip strain, and a Class I or II molar relationship. (Pearson 1978)

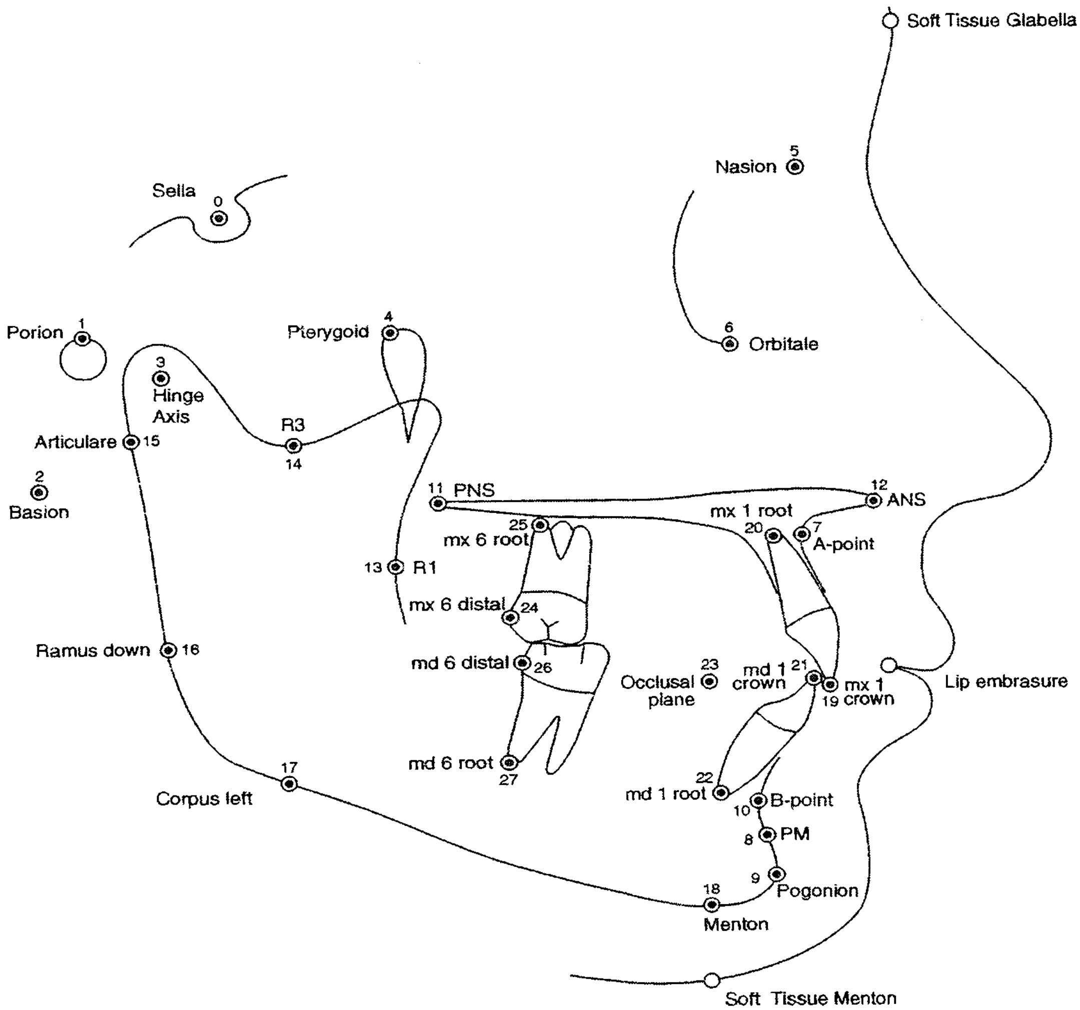

Figure 2. Cephalometric points digitized on the lateral headfilms (figure from Quick Ceph 2000 Users Manual)

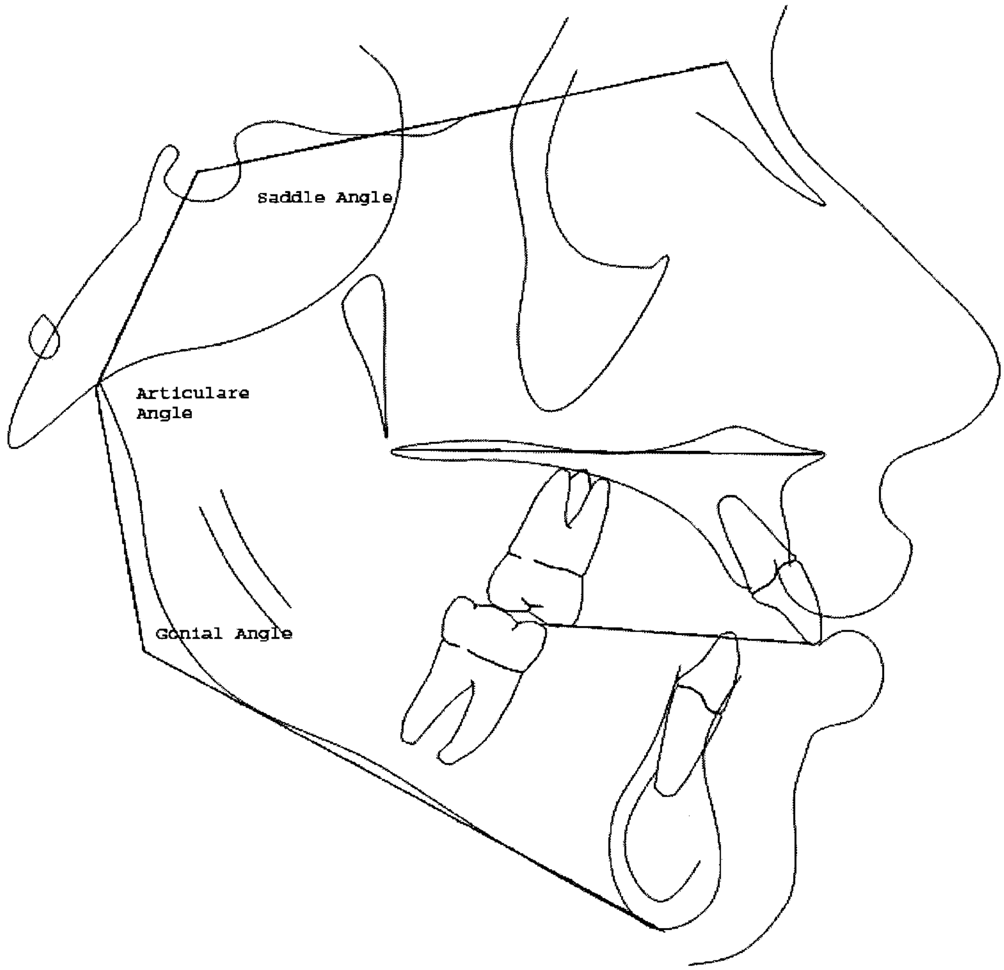

Figure 3. Reference planes for the angular measurements

Cervical headgear group (T1)

Pt #	SNA T1	Art T1	Saddle T1	Gonion T1	MPA T1	RamusH T1	PFH T1	AFH T1	LFH T1	SNB T1	ANB T1	QCOcc T1	Mx6-PTV T1	Y axis T1	SN-PP T1	SN-OP T1
101	76	134.5	127	142	43.5	37	67	118	63.5	70.5	5	24	12	72	10	23
102	78	136	129	139.5	44.5	40.5	69.5	117.5	65.5	70	8	26.5	11.5	76	7	25.5
110	75	138.5	124.5	141.5	45	35	61.5	111.5	63	72.5	2.5	26.5	14.5	71.5	8	24.5
111	77.5	150.5	124.5	130	44.5	34	61.5	113	63	71.5	6	30	6	73	11.5	23.5
119	77	139.5	122	142	43	41.5	74.5	119.5	68	73.5	4	27.5	11	74	6	21
128	80	156.5	115.5	131	43	45.5	80	130	72	75.5	4.5	22.5	7.5	73.5	10	21
136	78.5	142	122.5	140.5	45	46.5	75	124.5	74.5	73	5.5	24	16	74	6.5	22
138	78.5	140	128.5	129	38	50	80	123.5	69	72	6.5	25.5	12.5	74	7	23.5
144	76	142.5	130	133.5	45.5	34.5	66.5	118	67.5	72.5	3.5	28	7	76	4.5	23
152	82	147	119	135	41	39	67.5	116	67	77	5	25.5	11.5	68.5	5	18
161	75	131	130	140	41	50.5	82	129.5	75	73	2	22.5	11	73.5	7	22.5
162	75	138.5	128.5	132.5	40	47	74.5	122	64.5	73	2	25	12.5	72.5	11.5	22
164	74.5	137	133.5	133	43.5	45.5	73	126	71	69.5	5	22	16	75	9.5	21.5
166	78.5	141.5	129	130.5	41	38	68	115	61	70.5	8	31	12.5	74	13	29
177	74	149	124	135	48	38.5	70.5	125.5	72.5	69.5	4.5	27	6.5	77	8	24.5
179	81	164.5	111	126.5	42	38	74	128	75	75.5	5	21	12	71	0	19.5
181	79	139.5	125.5	139	43.5	38.5	68.5	120.5	64.5	73.5	5.5	28	18.5	72	11.5	24
184	78	141	130	130.5	41	43	75.5	124	71	71.5	6.5	21	11.5	75	9.5	21
187	81	133.5	126	139	38.5	39	68	112	58.5	76	4.5	23	16.5	69	8.5	21
200	80.5	141	119.5	139	39.5	41	68.5	113.5	63.5	79	1.5	15.5	9.5	67	3	14.5
204	78.5	145	124.5	127	36.5	39.5	68	111.5	62	74.5	4	24.5	14.5	68.5	6.5	20
205	77.5	127	132.5	142	41.5	50	76	123.5	66	72.5	5	23.5	18	73	12.5	23
216	76.5	136.5	123.5	137.5	37.5	43	69	113	64	75	1.5	20	18.5	67	3	14
221	74.5	144	120.5	141.5	46	38	70.5	124.5	69	71.5	3	21	7.5	73	8	23
227	76	145	132.5	129	46.5	40.5	72.5	129.5	73	69	7	28.5	13.5	77.5	10	26.5
243	78	140	121	139.5	40.5	38.5	68	118	65	73.5	4.5	22.5	16.5	68	9	23
250	76.5	148	121.5	135	44.5	39.5	64.5	114	66	73	3.5	18	13	72	3.5	19.5
256	74.5	156.5	123.5	121	40.5	37	70.5	119	66	70.5	4	28.5	13.5	74.5	9	25
272	78.5	141	128.5	129	38.5	51	82	130	71	72	6.5	23	12	73	7.5	20.5
274	80	141	123.5	132.5	37.5	45.5	76.5	125.5	70.5	79	1	19	15.5	68	0.5	18
278	80.5	133	121	145.5	39	41	70	114.5	60.5	78	2.5	24	11	66.5	10	22.5
285	77.5	161	121	120	41.5	33	66	116	66	73	4.5	21.5	15	72	2	20.5
289	79	128	129.5	138.5	36	43	66	108	58.5	75.5	3.5	21.5	17	66	7.5	19.5
291	77.5	140.5	128.5	131.5	40.5	43	74.5	124	68	72.5	4.5	23	14.5	73	8	20.5
Pt #	SNA T1	Art T1	Saddle T1	Gonion T1	MPA T1	RamusH T1	PFH T1	AFH T1	LFH T1	SNB T1	ANB T1	QCOcc T1	Mx6-PTV T1	Y axis T1	SN-PP T1	SN-OP T1

Cervical headgear group (T2)

Pt #	SNA T2	Art T2	Saddle T2	Gonion T2	MPA T2	RamusH T2	PFH T2	AFH T2	LFH T2	SNB T2	ANB T2	QCOcc T2	Mx6-PTV T2	Y axis T2	SN-PP T2	SN-OP T2
101	71	140	128.5	135	43.5	40.5	73	132	68.5	68.5	2.5	25.5	9	73	12	25.5
102	80.5	135.5	126	137	38	43	76	120	68.5	75	5.5	20	10.5	71.5	6.5	22
110	74.5	144	126.5	137.5	48.5	35.5	64.5	121	69	69.5	5	25	13	75.5	8.5	24
111	73.5	165.5	124	119.5	49	30	63.5	124.5	68.5	69	4.5	29	4	77.5	16	28
119	73	148.5	125	135	48.5	42	76.5	132.5	77	70.5	2.5	28.5	8	78.5	9.5	28
128	78	155.5	116	134	45.5	36.5	86.5	144	81.5	74	4	23.5	5	76	7	23.5
136	77.5	146.5	124	135	45.5	51	83.5	138.5	84.5	72.5	4.5	24.5	15.5	76.5	8	23
138	75	145.5	129	127	41	55	89.5	142	80	69.5	5.5	34	11.5	77.5	8	30
144	76	142.5	132	134	48.5	38	70	126	71	72	4.5	27	7.5	78.5	8.5	26.5
152	79	154.5	117	130	41.5	40.5	71.5	124.5	72	76	3	22.5	8	70	6.5	23
161	72	141.5	126	135.5	43	56.5	90	142.5	84	73.5	-1	21.5	16	75	8.5	21
162	79	130.5	131.5	137.5	39.5	48.5	79	126.5	68	75	4	20.5	12	72	9.5	21
164	74	138	133.5	133.5	45	47	76	131.5	77	69.5	5	25.5	18.5	77	8.5	25
166	75	146.5	131	128	45.5	40.5	71.5	126.5	70	67.5	7.5	33	14	78	14.5	32
177	74	157.5	124.5	126	48	37.5	72	133	78.5	70	4	28.5	-0.5	77	8	26.5
179	76.5	169.5	110	129	48.5	44.5	81.5	142.5	86.5	72	4.5	23	11.5	76.5	1.5	22
181	77	150	124.5	130	44.5	37.5	71.5	128.5	69.5	72.5	4.5	27	20	74	11.5	27.5
184	77	141	131.5	131.5	44	48	80.5	134	77.5	70.5	6.5	25.5	9	77	11	24.5
187	82	137	124	138	38.5	41	76	124	66.5	76	6	23.5	15	69.5	8	23
200	79	138	120	141.5	39	42.5	69	112.5	63.5	78.5	0.5	15.5	11	67	2	15.5
204	77.5	139	124	133	36	48.5	78.5	122	68	77	1	17	17.5	68	8.5	17
205	79	130	129.5	143.5	43.5	55.5	84	133.5	75.5	74	5	23.5	17	73.6	11.5	23.5
216	75.5	136	122	140.5	38.5	53	80.5	125	71.5	75	0.5	10.5	20	68.5	2	14
221	71.5	139	123	141	43	44.5	80.5	133	74.5	72.5	-1	22	10.5	73.5	7	21.5
227	76	154	124.5	128.5	46.5	46	77	134	77.5	70	6	24	12	77	9.5	25.5
243	71.5	157	124.5	120.5	42	43	77	127.5	70	69.5	2	22	11.5	77	12	22.5
250	79	153	116.5	137.5	47	37	63.5	116	68.5	73.5	5.5	22.5	11.5	72	3.5	24
256	73.5	151	124.5	124.5	39.5	48.5	81	127.5	70	70	3.5	22	10.5	76	11.5	22
272	74.5	142.5	129	128.5	40	51.5	84	135.5	74.5	71	3.5	22.5	15	74.5	8	21.5
274	81	145.5	123.5	129.5	38.5	38	70	121	67.5	79.5	1	22	15	68	2	18.5
278	81	136.5	120	141	37.5	42	74	118	63	79	2	20.5	14	67	9.5	20.5
285	73.5	158.5	122	119.5	40	38	69.5	117	65.5	73	0.5	23	13	72.5	5	22.5
289	75.5	131	127	138	36.5	47	75.5	120	67	76	-0.5	19	19.5	67.5	5.5	18.5
291	77	142	128.5	128.5	39.5	46.5	76	123.5	70	74	3	20.5	14	72.5	5	18
Pt #	SNA T2	Art T2	Saddle T2	Gonion T2	MPA T2	RamusH T2	PFH T2	AFH T2	LFH T2	SNB T2	ANB T2	QCOcc T2	Mx6-PTV T2	Y axis T2	SN-PP T2	SN-OP T2

Cervical headgear group (T1-T2)

Pt #	SNA D	Art D	Saddle D	Gonion D	MPA D	Ramus D	PFH D	AFH D	LFH D	SNB D	ANB D	QCOcc D	MxPtv D	Yaxis D	SN-PP D	SN-OP D
101	5	-5.5	-1.5	7	0	-3.5	-6	-14	-5	2	2.5	-1.5	3	-1	-2	-2.5
102	-2.5	0.5	3	2.5	6.5	-2.5	-6.5	-2.5	-3	-5	2.5	6.5	1	4.5	0.5	3.5
110	0.5	-5.5	-2	4	-3.5	-0.5	-3	-9.5	-6	3	-2.5	1.5	1.5	-4	-0.5	0.5
111	4	-15	0.5	10.5	-4.5	4	-2	-11.5	-5.5	2.5	1.5	1	2	-4.5	-4.5	-4.5
119	4	-9	-3	7	-5.5	-0.5	-2	-13	-9	3	1.5	-1	3	-4.5	-3.5	-7
128	2	1	-0.5	-3	-2.5	9	-6.5	-14	-9.5	1.5	0.5	-1	2.5	-2.5	3	-2.5
136	1	-4.5	-1.5	5.5	-0.5	-4.5	-8.5	-14	-10	0.5	1	-0.5	0.5	-2.5	-1.5	-1
138	3.5	-5.5	-0.5	2	-3	-5	-9.5	-18.5	-11	2.5	1	-8.5	1	-3.5	-1	-6.5
144	0	0	-2	-0.5	-3	-3.5	-3.5	-8	-3.5	0.5	-1	1	-0.5	-2.5	-4	-3.5
152	3	-7.5	2	5	-0.5	-1.5	-4	-8.5	-5	1	2	3	3.5	-1.5	-1.5	-5
161	3	-10.5	4	4.5	-2	-6	-8	-13	-9	-0.5	3	1	-5	-1.5	-1.5	1.5
162	-4	8	-3	-5	0.5	-1.5	-4.5	-4.5	-3.5	-2	-2	4.5	0.5	0.5	2	1
164	0.5	-1	0	-0.5	-1.5	-1.5	-3	-5.5	-6	0	0	-3.5	-2.5	-2	1	-3.5
166	3.5	-5	-2	2.5	-4.5	-2.5	-3.5	-11.5	-9	3	0.5	-2	-1.5	-4	-1.5	-3
177	0	-8.5	-0.5	9	0	1	-1.5	-7.5	-6	-0.5	0.5	-1.5	7	0	0	-2
179	4.5	-5	1	-2.5	-6.5	-6.5	-7.5	-14.5	-11.5	3.5	0.5	-2	0.5	-5.5	-1.5	-2.5
181	2	-10.5	1	9	-1	1	-3	-8	-5	1	1	1	-1.5	-2	0	-3.5
184	1	0	-1.5	-1	-3	-5	-5	-10	-6.5	1	0	-4.5	2.5	-2	-1.5	-3.5
187	-1	-3.5	2	1	0	-2	-8	-12	-8	0	-1.5	-0.5	1.5	-0.5	0.5	-2
200	1.5	3	-0.5	-2.5	0.5	-1.5	-0.5	1	0	0.5	1	0	-1.5	0	1	-1
204	1	6	0.5	-6	0.5	-9	-10.5	-10.5	-6	-2.5	3	7.5	-3	0.5	-2	3
205	-1.5	-3	3	-1.5	-2	-5.5	-8	-10	-9.5	-1.5	0	0	1	-0.6	1	-0.5
216	1	0.5	1.5	-3	-1	-10	-11.5	-12	-7.5	0	1	9.5	-1.5	-1.5	1	0
221	3	5	-2.5	0.5	3	-6.5	-10	-8.5	-5.5	-1	4	-1	-3	-0.5	1	1.5
227	0	-9	8	0.5	0	-5.5	-4.5	-4.5	-4.5	-1	1	4.5	1.5	0.5	0.5	1
243	6.5	-17	-3.5	19	-1.5	-4.5	-9	-9.5	-5	4	2.5	0.5	5	-9	-3	0.5
250	-2.5	-5	5	-2.5	-2.5	2.5	1	-2	-2.5	-0.5	-2	-4.5	1.5	0	0	-4.5
256	1	5.5	-1	-3.5	1	-11.5	-10.5	-8.5	-4	0.5	0.5	6.5	3	-1.5	-2.5	3
272	4	-1.5	-0.5	0.5	-1.5	-0.5	-2	-5.5	-3.5	1	3	0.5	-3	-1.5	-0.5	-1
274	-1	-4.5	0	3	-1	7.5	6.5	4.5	3	-0.5	0	-3	0.5	0	-1.5	-0.5
278	-0.5	-3.5	1	4.5	1.5	-1	-4	-3.5	-2.5	-1	0.5	3.5	-3	-0.5	0.5	2
285	4	2.5	-1	0.5	1.5	-5	-3.5	-1	0.5	0	4	-1.5	2	-0.5	-3	-2
289	3.5	-3	2.5	0.5	-0.5	-4	-9.5	-12	-8.5	-0.5	4	2.5	-2.5	-1.5	2	1
291	0.5	-1.5	0	3	1	-3.5	-1.5	0.5	-2	-1.5	1.5	2.5	0.5	0.5	3	2.5
Pt #	SNA D	Art D	Saddle D	Gonion D	MPA D	Ramus D	PFH D	AFH D	LFH D	SNB D	ANB D	QCOcc D	MxPtv D	Yaxis D	SN-PP D	SN-OP D

High-pull headgear group (T1)

Pt #	SNA T1	Art T1	Saddle T1	Gonion T1	MPA T1	RamusH T1	PFH T1	AFH T1	LFH T1	SNB T1	ANB T1	QCOcc T1	Mx6-PTV T1	Y Axis T1	SN-PP T1	SN-OP T1
107	77.5	141	127.5	130	39	44	76.5	127.5	71	74.5	3	20	13	70.5	6.5	16
124	81	152	120	125	37.5	35	67.5	110.5	64	76.5	4	19	11	69	3	16
131	78.5	159	119.5	118.5	37.5	39.5	71.5	116.5	61.5	72	6.5	26.5	11	72	12	23.5
145	74.5	147.5	128	122.5	38	43	81.5	130.5	75	72.5	2	28.5	12	74	6	19.5
148	85	146	116	137.5	39.5	33.5	61.5	105	61	78	7	22	15	67	4	17.5
154	82.5	150.5	115.5	130	36	39.5	71.5	114	67	80	3	19.5	17	66.5	2	17
163	82.5	144	125.5	132	42	34	65	113	64	74	9	23.5	13.5	72.5	7.5	21.5
175	81	134.5	126	141.5	42	43	68	113.5	67	75.5	5.5	23	15	70	1	18
178	79.5	155	115.5	131.5	42	44.5	83.5	140.5	79	73	6.5	23	10	72	9.5	16.5
183	77	146.5	120.5	137.5	45	42	69	121	69	74.5	2.5	22	14.5	71.5	6	19
188	80	142.5	124.5	133	40	46	78	123.5	73	75	5	21	7.5	73	7.5	20
191	79	154	122	122	38	38.5	71.5	119.5	66	74.5	4.5	26	16.5	70	5.5	22
197	78	133	127	138	38	44	70	112.5	63	74	4	19.5	11	68	8.5	17.5
202	76.5	157	119	123.5	39.5	34	70	125.5	72.5	78	-1.5	16	12.5	68	2.5	16
203	80.5	135.5	129	134.5	39	46	79.5	125.5	73.5	75	5.5	19.5	14	73	5	20
210	73.5	148.5	124.5	129	42	41	75.5	128	67	71	2.5	27	17	74	11.5	26.5
218	82.5	143	125.5	130	38	50.5	80.5	123.5	73	76	6	21.5	13	72	5	16.5
222	77.5	146.5	119	135.5	41.5	34.5	62	106	56.5	72.5	5	26.5	13	70.5	12	23
223	80	143.5	122	134.5	40.5	43.5	75	124.5	72	76	4.5	18	6.5	70.5	6.5	17.5
231	80.5	144.5	122.5	136	43	36	68	119.5	66.5	75.5	5	26	11.5	71.5	6.5	21
239	78.5	136	131	133	40	43	74.5	123.5	69.5	74.5	3.5	25	14.5	72	13	20.5
242	82.5	150.5	115	132.5	38	37.5	70.5	116	65.5	77.5	5	25	12	68	6	23
245	76.5	153	122	128.5	43.5	38.5	69.5	126	73	73	4	27	12	72	9.5	23.5
255	77	147	124	126	37.5	45	76	120.5	67	74.5	2.5	22.5	11	71.5	6	19
258	84.5	150.5	117	131.5	39	40	68	112	65	80.5	4	23.5	14.5	67.5	10.5	22.5
262	75	144	119.5	147	50.5	36	64	116.5	69	72	3	27.5	8	75	7	26
267	76.5	140.5	131.5	132	43.5	42.5	74.5	128	72.5	72	4.5	29.5	8	75.5	7.5	25
275	80.5	156.5	115	126	37.5	31	66.5	110.5	61	77	4	17	13	68	4	16
Pt #	SNA T1	Art T1	Saddle T1	Gonion T1	MPA T1	RamusH T1	PFH T1	AFH T1	LFH T1	SNB T1	ANB T1	QCOcc T1	Mx6-PTV T1	Y Axis T1	SN-PP T1	SN-OP T1

High-pull headgear group (T2)

Pt #	SNA T2	Art T2	Saddle T2	Gonion T2	MPA T2	RamusH T2	PFH T2	AFH T2	LFH T2	SNB T2	ANB T2	QCOcc T2	Mx6-PTV T2	Y axis T2	SN-PP T2	SN-OP T2
107	75.5	140	127	132	39	43.5	77	128	72	74.5	0.5	19.5	12	70.5	6	15.5
124	80.5	152	120	127	39	37	71.5	118.5	69	75.5	5	20	13	71	4	18.5
131	75.5	157.5	121.5	120.5	39.5	41.5	75.5	123.5	66	71.5	4.5	28	13	73.5	12.5	24.5
145	75.5	150.5	125.5	122	38	46.5	88.5	139.5	79.5	73	2.5	22	12	74	5.5	18
148	82.5	145.5	118.5	134	38	38	69.5	114	67.5	77.5	5	17	18	68	3	15
154	82.5	158.5	116	123	37.5	42	75.5	122	71.5	78.5	4	22	17.5	69	3.5	18.5
163	81	148	123	132	42.5	39.5	71	121	69	74	7	21.5	15.5	72.5	9.5	23.5
175	83	137.5	123.5	139.5	40.5	45.5	71.5	117	68	78.5	5	20	16	68.5	4	18
178	78	158	112	130	40.5	49	85.5	139	79.5	74.5	3.5	17.5	10	70.5	7.5	16
183	75.5	155	116.5	135	46	43	73	128.5	73	75	1	17.5	11	72	6.5	16
188	80	144.5	121.5	134	40	48.5	85	131.5	77	76.5	3	21	11.5	73.5	7	18.5
191	74.5	155.5	125.5	118	39	42	76	128.5	69.5	71.5	3	29	19.5	73	10	25.5
197	76	135	125.5	137.5	37.5	48.5	76	119	65.5	74	2	21	17	69.5	9	18.5
202	81	148.5	119	131.5	39	40.5	75	127	73.5	77.5	3.5	18.5	18	68	4	16.5
203	78.5	140	125.5	133	38.5	46.5	83.5	129	74	75	3	20	14.5	73	8	21
210	72.5	149.5	124.5	128	42.5	47	83	137.5	74	72	0.5	24.5	14	75	12.5	22.5
218	80.5	145	126	129	40	52.5	83	129	74.5	75.5	4.5	21	13.5	74	8.5	20
222	84.5	151.5	114	133	38.5	35.5	67	109	61.5	75.5	8.5	20.5	14.5	68.5	8	20
223	79.5	145	120.5	135	40.5	46	78	129	75.5	77.5	2	23	9.5	69.5	6	19.5
231	79.5	145.5	121.5	139	45.5	41.5	75.5	133.5	76	76	3.5	21.5	13.5	72.5	7	20.5
239	78.5	137	124	133	34.5	48.5	85	130.5	79	78.5	0	13	13.5	68	5	12.5
242	80	146	122	131.5	39.5	42	72	122	68.5	76	4	22	16	69	7.5	21
245	77	148	125	127.5	40	47	81.5	135	77.5	73	4	23.5	12.5	72	10.5	20
255	75.5	149.5	125	123	38	50	81.5	127	72.5	75	0.5	21	12.5	73	5.5	18.5
258	86	157.5	115.5	127.5	40	42	70	116	67	78.5	7.5	25	18.5	69.5	11.5	23
262	76	147	120	141	48.5	35	65	121	71.5	71.5	5	25.5	11	74	4.5	23
267	74.5	141	133	132.5	46.5	47.5	80	140.5	78	70.5	4	26.5	13.5	77	9.5	27
275	76	156	117	125	37.5	31	66.5	111.5	62	76	0	16.5	16.6	68.5	3.5	15.5
Pt #	SNA T2	Art T2	Saddle T2	Gonion T2	MPA T2	RamusH T2	PFH T2	AFH T2	LFH T2	SNB T2	ANB T2	QCOcc T2	Mx6-PTV T2	Y axis T2	SN-PP T2	SN-OP T2

High-pull headgear group (T1-T2)

Pt #	SNA D	Art D	Saddle D	Gonion D	MPA D	Ramus D	PFH D	AFH D	LFH D	SNB D	ANB D	QC Occ D	MxPtv D	Yaxis D	SN-PP D	SN-OP D
107	2	1	0.5	-2	0	0.5	-0.5	-0.5	-1	0	2.5	0.5	1	0	0.5	0.5
124	0.5	0	0	-2	-1.5	-2	-4	-8	-5	1	-1	-1	-2	-2	-1	-2.5
131	3	1.5	-2	-2	-2	-2	-4	-7	-4.5	0.5	2	-1.5	-2	-1.5	-0.5	-1
145	-1	-3	2.5	0.5	0	-3.5	-7	-9	-4.5	-0.5	-0.5	6.5	0	0	0.5	1.5
148	2.5	0.5	-2.5	3.5	1.5	-4.5	-8	-9	-6.5	0.5	2	5	-3	-1	1	2.5
154	0	-8	-0.5	7	-1.5	-2.5	-4	-8	-4.5	1.5	-1	-2.5	-0.5	-2.5	-1.5	-1.5
163	1.5	-4	2.5	0	-0.5	-5.5	-6	-8	-5	0	2	2	-2	0	-2	-2
175	-2	-3	2.5	2	1.5	-2.5	-3.5	-3.5	-1	-3	0.5	3	-1	1.5	-3	0
178	1.5	-3	3.5	1.5	1.5	-4.5	-2	1.5	-0.5	-1.5	3	5.5	0	1.5	2	0.5
183	1.5	-8.5	4	2.5	-1	-1	-4	-7.5	-4	-0.5	1.5	4.5	3.5	-0.5	-0.5	3
188	0	-2	3	-1	0	-2.5	-7	-8	-4	-1.5	2	0	-4	-0.5	0.5	1.5
191	4.5	-1.5	-3.5	4	-1	-3.5	-4.5	-9	-3.5	3	1.5	-3	-3	-3	-4.5	-3.5
197	2	-2	1.5	0.5	0.5	-4.5	-6	-6.5	-2.5	0	2	-1.5	-6	-1.5	-0.5	-1
202	-4.5	8.5	0	-8	0.5	-6.5	-5	-1.5	-1	0.5	-5	-2.5	-5.5	0	-1.5	-0.5
203	2	-4.5	3.5	1.5	0.5	-0.5	-4	-3.5	-0.5	0	2.5	-0.5	-0.5	0	-3	-1
210	1	-1	0	1	-0.5	-6	-7.5	-9.5	-7	-1	2	2.5	3	-1	-1	4
218	2	-2	-0.5	1	-2	-2	-2.5	-5.5	-1.5	0.5	1.5	0.5	-0.5	-2	-3.5	-3.5
222	-7	-5	5	2.5	3	-1	-5	-3	-5	-3	-3.5	6	-1.5	2	4	3
223	0.5	-1.5	1.5	-0.5	0	-2.5	-3	-4.5	-3.5	-1.5	2.5	-5	-3	1	0.5	-2
231	1	-1	1	-3	-2.5	-5.5	-7.5	-14	-9.5	-0.5	1.5	4.5	-2	-1	-0.5	0.5
239	0	-1	7	0	5.5	-5.5	-10.5	-7	-9.5	-4	3.5	12	1	4	8	8
242	2.5	4.5	-7	1	-1.5	-4.5	-1.5	-6	-3	1.5	1	3	-4	-1	-1.5	2
245	-0.5	5	-3	1	3.5	-8.5	-12	-9	-4.5	0	0	3.5	-0.5	0	-1	3.5
255	1.5	-2.5	-1	3	-0.5	-5	-5.5	-6.5	-5.5	-0.5	2	1.5	-1.5	-1.5	0.5	0.5
258	-1.5	-7	1.5	4	-1	-2	-2	-4	-2	2	-3.5	-1.5	-4	-2	-1	-0.5
262	-1	-3	-0.5	6	2	1	-1	-4.5	-2.5	0.5	-2	2	-3	1	2.5	3
267	2	-0.5	-1.5	-0.5	-3	-5	-5.5	-12.5	-5.5	1.5	0.5	3	-5.5	-1.5	-2	-2
275	4.5	0.5	-2	1	0	0	0	-1	-1	1	4	0.5	-3.6	-0.5	0.5	0.5
Pt #	SNA D	Art D	Saddle D	Gonion D	MPA D	Ramus D	PFH D	AFH D	LFH D	SNB D	ANB D	QC Occ D	MxPtv D	Yaxis D	SN-PP D	SN-OP D