A cephalometric evaluation of nonextraction cervical headgear treatment in Class II malocclusions

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The cervical facebow appliance has been in use for over a half century and many studies have reported on its treatment effects.[1-29] Several claims have been made in the literature on the effects of this appliance on the dentition, the maxillary complex, the mandible, the cranial base, and the face. Some have been favorable in context while a majority have been adverse.

Silas Kloehn was a major proponent of this treatment during the transitional dentition. Kloehn[1] originally began treating patients in the transitional dentition with the occipital headgear attached by elastics to an outer bow that was stopped against the maxillary permanent first molars. He reported later on a modification of the appliance where he used only the cervical portion of the occipital headgear. The facebow could then be attached to an occipital or a cervical strap, and the degree of molar angulation managed by adjusting the outer bow relative to the inner bow and/or the occlusal plane of the patient.

A major effect of the cervical face bow appliance is the distal movement of maxillary molars.[1,3-11] However, Mills[12] and Cangiolasi[13] have stated that there is mesial movement of the permanent first molars. The rationale for

Abstract

The effects of orthodontic treatment with the use of the cervical pull facebow headgear in patients with Class II malocclusions were evaluated with special reference to the dentition, the maxillary complex, the mandible, and the facial profile. The records of 85 patients, with a mean age of 11.3±1.7 years, were selected from a sample of 125 patient records requested from the office of John S. Kloehn in Appleton, Wisconsin. Dr. Kloehn has used traditional cervical pull facebow therapy in his practice. Over 100 linear and angular cephalometric measurements were made from the pretreatment and posttreatment records. These measurements were used to evaluate growth and/or treatment changes. The treatment sample was divided by size of the pretreatment FMA, sex, and the age range in which treatment was started, i.e., prepubertal, circumpubertal, and postpubertal. Overall, the results showed that the changes were very close to what would occur as a result of normal growth in Class I individuals. The maxillary permanent first molars continued to progress forward, the maxilla continued to grow forward, and the cranial base showed very little change, if any. The mandibular plane angle did not increase appreciably with treatment, regardless of the size of the pretreatment mandibular plane angle. Very few significant differences were found between sexes, pretreatment age groups, or between groups based on pretreatment Frankfort mandibular plane angle.

Keywords

Class II division 1 malocclusion • Nonextraction • Kloehn cervical pull • Treatment changes • Facebow headgear

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this finding was the variability in patient compliance and possibly different methods of superimposition. Additionally, several authors reported extrusion of the maxillary molars.[6,14-22]

Klein[6] and King[14] reported that the inclination of the occlusal plane remained relatively unchanged, while others found it increased relative to the cranial base.[13,16,18] Brown[22] and Boatwright[26] found that the angle of the occlusal plane to the cranial base decreased with cervical facebow treatment.

Some of the studies cited in the literature showed that the position of the pterygomaxillary fissure changed with cervical pull facebow therapy.[10-12,16,17,25,27] Wieslander[12] and Wieslander and Buck[25] also found that the sphenoid plane exhibited clockwise rotation with treatment. In contrast to these observations, Bernardi[4] and Moore[23] stated that the pterygomaxillary fissure remained stable throughout treatment.

There is unanimity of findings on the effect of the cervical facebow appliance at point A. All the measurements connected with point A have indicated that it is repositioned posteriorly relative to the remainder of the face.[4,6,10,13,14,16,18,25,26,28]

The palatal plane has been reported to tip anteriorly with an uneven descent of the maxilla, causing the anterior nasal spine to be positioned downward more than the posterior nasal spine.[6,7,10,13,16,18,19,22,25,26,28] However, others[1,20,29] have reported no change in the angulation of the palatal plane with cervical facebow therapy.

Many investigators[12,15,17-19,21,22,25] have stated that the mandible is hinged back and the mandibular plane angle opens with this appliance. There are others[10,20,26] who state that the mandibular plane will close with cervical headgear treatment. There are still others[1,13,14,16,29,48] who have found that the mandibular plane was not altered with treatment. Bleuher[28] found that 16 of the 34 patients showed an increased FMA, 13 decreased and 5 stayed the same.

The anteroposterior relationship or sagittal relationship of the mandible has been correlated to the adverse vertical opening associated with treatment. Hanes,[15] Poulton,[45] Mays,[17] and Merrifield and Cross[18] reported that there was a downward and backward rotation of the mandible, B point and pogonion moved downward and backward and there was an increase in the mandibular plane angle. Kloehn[1] and Ringenberg and Butts[10] found no change in angle SNB, but others have found either posterior[15,17,18,45] or anterior movement[4,13,16,26] of point B.

Only a few authors have dealt with the effect of cervical pull facebow headgear on the facial profile. Moore,[23] Bleuher,[28] and Sandusky[16] reported that the changes were consistent with forward growth of the mandible and that the facial profile improved. Mays[17] found that vertical increase was twice as great with the cervical facebow. Ringenberg and Butts[10] discounted the excessive increase in vertical height.

A review of the literature showed an overwhelming negative impact on the direction of maxillary growth from use of the Kleohn cervical pull facebow headgear. Controversies surrounding the posterior rotation of the palatal plane and excessive extrusion of the maxillary molars hinging the mandible down and back have not been satisfactorily resolved. The sample and the methodology of each investigation are different. The forces on the cervical pull headgear and the time required to be worn were also variable and not in accordance with the regimen originally suggested by Kloehn[2]. It was decided, therefore, to revisit this subject and to study the effects of Kloehn headgear therapy on a sample of patients treated according to Kloehn.[2]

Materials and methods

Pretreatment and posttreatment orthodontic records of 125 patients of Caucasian descent were obtained from the office of Dr. John S. Kloehn in Appleton, Wisconsin. The final sample of 85 patients—38 male and 47 female—was based on the following criteria:

1. Good quality radiographs with clear landmark visualization and good head posture with minimal or no sagittal or transverse tilting.
2. Class II permanent first molar relationship in the transitional or permanent dentition.
3. Nonextraction therapy.
4. Good cooperation, based on treatment notes.

The mean age of the sample at the time of the pretreatment radiograph was 11.3 years ± 1.7 with a range of 8.2 to 15.6 years. The mean age for males was 11.3 years ± 1.7 with a range of 8.4 to 15.5 years; the mean age for females was 11.2 years ± 1.8 with a range of 8.2 to 15.6 years. Forty-seven (22 female and 25 male) of the 85 patients were in the transitional dentition at the time of first records. There was a time lag of about 10 months between the initial treatment records and the institution of orthodontic therapy. Treatment changes were assessed on the basis of the initial cepahlometric radiographs. The average age of the patients used in this sample when the Kloehn cervical pull facebow appliance was initiated was 12.1 years ± 1.6 with a range of 9.2 to 15.9 years.

Method of treatment with Kloehn's cervical pull headgear

The outer bow of the facebow was long to better control the axial inclination of the maxillary molars. A force of 1.5 to 1.7 pounds was delivered by an elastic rubber band on each side for a total of 3 to 3.5 pounds.

The appliance was initially adjusted so there was as little discomfort as possible to the patient by leaving the outer bow straight along the plane of the patient's occlusion. The inner bow was expanded 4 to 5 mm to allow for distalizing the molar to remain in the trough of medullary bone.

After about 6 weeks the outer bow was bent down, (Figure 1A), and the inner bow received a compensatory adjustment to elevate it into the upper lip. The patient was recalled in 6 weeks. The prescribed wearing time was 14 hours each night, 7 nights a week. If compliance was good, the patient was seen on shorter intervals. During the first 6 to 12 weeks, the first molar crown was expected to tip distally with spaces evident between the permanent first molars and second premolars, as well as the second and first premolars. After the crowns of the first molars had shown distal tipping, the outer bow was adjusted well above the plane of the occlusion to impart distal root tip, (Figure 1B). Over the next 6 to 8 weeks, the molars were expected to upright and the outer bow was adjusted to impart a distal crown tip once again. The procedure was alternately continued with distal crown tipping followed by uprighting of the molar by distal root tip.

The goal of this treatment was to overcorrect the sagittal molar position to such an extent that the mesiobuccal cusp of the maxillary permanent first molar occluded opposite the distobuccal groove of the mandibular permanent first molar with the second premolar in a full Class I relationship. Once a full Class I molar relationship had been achieved, treatment was usually completed with full banded maxillary and mandibular edgewise appliances. Dr. Kloehn used a conventional 0.022", 0° torque 0° angulation edgewise appliance. He started with round stainless steel archwires, usually 0.016", for initial alignment and progressed up to a 0.021" x 0.025" stainless steel archwire to finish. The headgear wear may or may not have been continued in order to maintain the overcorrected sagittal molar relationship. If the headgear was continued, lighter elastics, with a force of 0.5 pound each, were used—considerably less force than that used for initial molar correction.

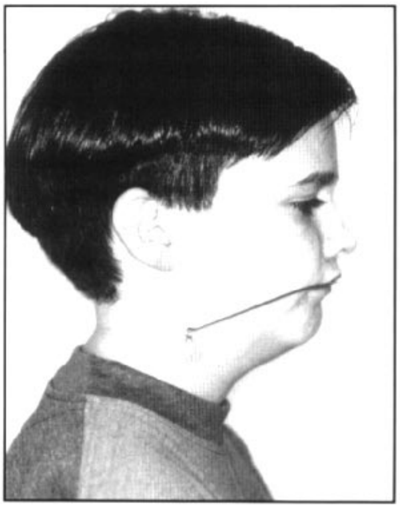

Figure 1A

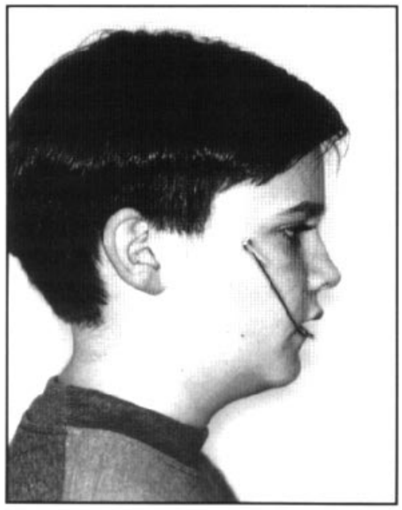

Figure 1B

Figure 1A-B
Lateral facial photographs showing the position of the outer bow at the initial phase of treatment, at the first active adjustment, and at the second active adjustment. The sequence is continued until overcorrection of the sagittal molar relationship occurs.

The sample

The selected sample of 85 patients was divided into several categories to see if any differences existed based on gender, age at the time therapy began, or the size of pretreatment Frankfort mandibular plane angle.

The categories based on age were arbitrarily divided into prepubertal, circumpubertal, and postpubertal groups according to chronological age. The age ranges were: prepubertal females below 11 years and males below 13 years; circumpubertal females 11 to 13 years and males 13 to 15 years; and postpubertal females above 13 years and males above 15 years.

The division according to Frankfort mandibular plane angle was designated on the basis of the average angle being 25°.[30] One standard deviation above the mean and one standard deviation below the mean (±4°) were designated as HIGH and LOW cases. Six patients exhibited a Class II division 2 malocclusion. Their records were removed from the above treatment sample and categorized as a separate group. All the patients that exhibited a Class II division 2 malocclusion were a part of the LOW sample, because they all had an FMA value less than 21°.

Thirty-eight of the 85 patients wore Class II elastics at one point in treatment. Class II elas-

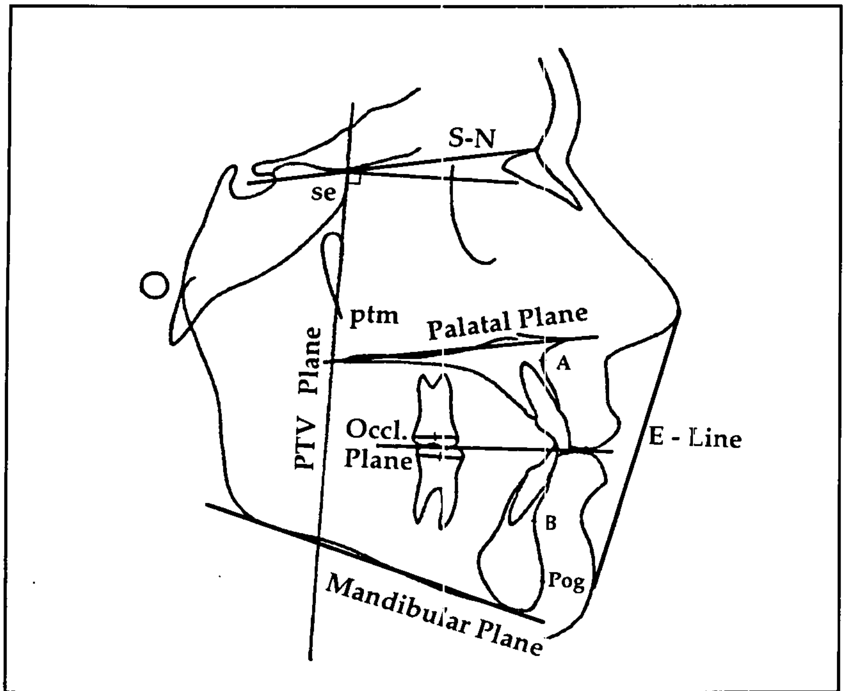

Figure 2
Cephalometric planes used.

tics were used to correct unilateral sagittal discrepancies and/or midlines and the average wear was 6 months. The longest was 14 months and the shortest was 1 month.

Method

All the cephalometric radiographs were traced and 57 points were digitized. If right and left images were not superimposed, a midpoint between the sides was used. The dental points were taken from the dentition of the patient's right side only. The definition and location of the points used in this study were in accordance with Riolo et al.,[36] Kapila,[51] and Nanda.[52]

For the purpose of this study, a molar centroid was constructed for each molar in the maxillary and mandibular arch by joining the mesial and distal height of contour and bisecting the distance. Linear measurements were taken directly from the molar centroid, whereas angular measurements to show tipping movements were taken off a line perpendicular to the mesial/distal height of contour at the molar centroid, (Figure 2).

The functional occlusal plane was drawn according to a modification of the method described by Demisch.[31] The mesial and distal heights of contour of the permanent first molars were found to be more reliable landmarks than other landmarks used to locate the posterior point of the occlusal plane, such as the mesiobuccal cusp tip, etc. The anatomic occlusal plane was formed by a line passing anteriorly through a point bisecting the overlap of the maxillary and mandibular central incisors.

There were three other planes of reference, i.e. the sella-nasion plane (SN), the palatal plane (PP), and the pterygomaxillary vertical plane (PTV). PTV has been shown to be a stable and reliable landmark during the growth period.[32,33,34] PTV is drawn through SE along the posterior surface of the maxillary tuberosity through the most inferior and posterior points of the pterygomaxillary fissure (Ptm).

The dentition

The cephalometric planes used in this study are shown in Figure 2. Angular variables were measured to SN and to PP. Linear variables were measured to PP, to PTV, and, in the case of the mandibular teeth, to the mandibular plane.

The maxillary complex

Changes in the location of Ptm were analyzed by the linear measurements taken from a perpendicular line drawn from SN at S to Ptm and the linear distance from SE to Ptm.

Changes in PP were assessed by the linear distance of a perpendicular line from the midpoint of the distance ANS-PNS to SN and by the internal angle SN-PP. Sagittal changes in the maxilla were assessed by changes in SNA and also by changes in the linear dimensions Ar-ANS and Ar-A point.

The mandible

Changes in mandibular position were measured relative to cranial base by the angles GoGn-SN, SNB, SN-MP, and Frankfort Horizontal to mandibular plane (FMA). Linear measurements were used to describe different components of the mandible separately. Ar-Go provided length of the mandibular ramus, while Ar-Pog and Go-Pog were used to assess length of the mandibular corpus. The angle Ar-Go-Gn measured changes in the gonial angle.

The face

The patient's facial profile was assessed by the facial angle (FH-NPog), angle of convexity (N-A-Pog), and the ratio of lower face to total face height (ANS-Me:N-Me). Posterior vertical face height was measured from Ar-Go and S-Go. The soft tissue analysis included several angular and linear measurements. There were 13 soft tissue measurements, three of which were angular and 10 linear, all referenced to PTV.

Error of method

The error of digitization was found to be less than 1° for angular and less than 0.5 mm for the linear measurements. Three linear measurements showed an error greater than 0.5 mm; they were: S-Go (0.6 mm), Ar-Go (0.6 mm), and Go-Pog (0.7 mm).

Results

Table 1 gives the mean pretreatment and posttreatment measurements for males and females, the three age groups, and groups based on pretreatment Frankfort mandibular plane angle. Excluding male and female information, only the changes in size are presented here. The posttreatment changes that were significant at $p<0.05$ are indicated by shading.

Treatment changes of several measurements between the male and female groups were significant. These changes were considered to be no different from the gender-specific growth changes seen in this age period.[36]

In other subgroups of the sample, based on age at initiation of treatment and the size of their pretreatment FMA, no significant changes were noticed for most of the measurements. The exceptions were linear lengths gonion to pogonion and soft tissue thickness at point B. The two measurements that were found to be significant on the basis of pretreatment FMA were the thickness of the upper and lower lips. In the Class II division 2 cases, the upper lip became thinner by a mean of 1.8 mm and in the LOW Class II division 1 sample the upper lip increased in thickness by a mean of 2.2 mm. The thickness of the lower lip decreased significantly in patients with Class II division 2 and LOW Class II division 1 malocclusions.

Discussion

This study offered a unique opportunity to investigate posttreatment changes in Class II patients who had received nonextraction, cervical pull headgear treatment strictly according to the methodology enunciated by Dr. Silas Kloehn. Previous studies had a number of variables, e.g., the magnitude, direction, and duration of the force, the physiologic age, cooperation, and biologic responsiveness of the patient. Therefore, it was difficult to assess their exact influence, singly or in combination, on the overall treatment. As a result, the effect of cervical traction and the biologic principles underlying its actions remained somewhat obscure.[35] The major premise that should be remembered is that studies using extraoral appliances are subject to patient cooperation and the accuracy of reported results is dependent upon the patient.

The literature provides controversial evidence with respect to changes resulting from use of cervical pull facebow headgear. The most serious consideration has been its effect in extruding the maxillary first molars, downward anterior tipping of the palatal plane, and steepening of the mandibular plane. Obviously these are detrimental effects if they really are true. The reports in the literature have been based on different samples with a variety of treatment regimens. Most of these did not follow the principles put forth by Kloehn, who was the principal promoter of this appliance therapy. The amount of force used by Kloehn was much greater, the length of time the appliance was worn was restricted to 14 hours daily, and the long outer bow of the facebow was adjusted down and up over the occlusal plane to seek first tipping and then uprighting of the maxillary molars.

In retrospective clinical studies, it is difficult to find a large enough sample to obtain reliable and valid results. This study had the singular advantage of having a fairly uniform sample of male and female patients from the same office treated by the same clinician. The investigators had access to treatment records to assess the level of cooperation and the dates when records were taken.

Thirty-seven patients had used Class II elastics and were included in the sample because there were no statistically significant differences between those patients who used the elastics and those who did not. Those patients who used Class II elastics wore them for an average of 6.2±2.6 months. The only statistically significant finding was a change in the inclination of the mandibular incisors between the two groups. The group that used Class II elastics started treatment with more upright incisors (mean IMPA 95.5°±6.0°) than those who did not use elastics (mean IMPA 96.8°±5.3°). The mean difference in change during treatment was 8.0° in the elastic group and 5.0° in those who did not use elastics. When the means of the two samples were considered posttreatment, it was observed that the mandibular incisors tipped forward in both groups, but more in the elastic group (mean IMPA 103.5°±6.2°) than the no elastic group (mean IMPA 101.8°±5.3°). However, the differences in the changes were not considered clinically significant.

In the absence of normative data for growing untreated Class II division 1 subjects, the changes observed in the present investigation were compared to those of a normal sample.[36]

Table 1
Mean changes and standard deviations from pretreatment to posttreatment according to sex, age group and pretreatment size of FMA. All the measurements were compared for statistical significance; pairs found significant at least at p<0.05 are shaded and designated with a similar symbol.

	Male			Female		
MEASUREMENT	Pretreat (N=38)	Posttreat (N=38)	Change (N=38)	Pretreat (N=47)	Posttreat (N=47)	Change (N=47)
Ages (years)						
Males	11.33±1.7					
Females				11.21±1.8		
Linear Dental - mm						
Vertical						
Max 6 to SE off PTV	61.59±2.9	69.78±4.4	8.19±3.1 *	61.13±3.3	67.07±5.0	5.94±3.3 *
Max 6 to PP	17.24±2.8	21.24±3.7	4.00±1.8	16.23±1.3	19.56±2.1	3.33±1.7
Max 6 to MP	26.46±1.6	30.10±2.5	3.64±1.7 *	26.32±1.9	28.37±2.9	2.05±1.9 *
Sagittal						
Max 6 to PTV	20.22±3.8	22.70±5.6	2.48±3.7 *	20.62±3.5	21.74±5.2	1.12±3.3 *
Max 6 to PP	16.88±3.1	19.20±4.8	2.32±3.3 *	17.93±2.8	18.98±4.1	1.05±2.7 *
Max 6 to MP	24.21±2.6@	22.89±3.9	-1.32±2.5	22.88±2.0@	21.79±3.0	-1.09±2.0
Angular Dental - deg.						
Max 6 to SN	64.20±7.1	66.89±10.8	2.69±7.3	65.54±7.0	67.45±10.3	1.91±6.5
Max 6 to PP	64.20±7.5	68.48±11.2	4.28±7.4	72.38±6.4	75.86±9.5	3.43±6.2
Max 6 to MP	101.21±5.1	106.06±7.8	4.85±5.4	102.17±5.3	106.34±8.0	4.17±5.4
Angular Skeletal - deg.						
SN-PP	6.53±1.4	8.13±2.2	1.60±1.5	6.84±1.9	8.41±2.7	1.57±1.7
SNA	80.81±1.8	78.53±2.5	-2.28±1.3	81.00±1.6	78.99±2.3	-2.01±1.4
S-SE-Ptm	74.77±2.2	73.26±3.5	-1.51±2.6	73.44±2.7	71.69±3.9	-1.75±2.5
SN-MP	32.95±1.2	32.80±2.0	-0.15±1.4	33.53±2.4	34.15±3.4	0.62±2.1
FMA	22.20±1.1	21.98±1.9	-0.22±1.6	22.17±2.5	22.75±3.6	0.58±2.2
GoGn-SN	33.01±1.2	33.20±2.0	0.19±1.7 *	33.19±2.4	34.27±3.5	1.08±2.2 *
Y-Axis (SN-SGn)	68.06±1.8	69.04±2.3	0.98±1.1	67.84±1.5	68.85±2.2	1.01±1.5
Y-Axis (FH-SGn)	57.31±1.9	58.21±2.6	0.90±1.3	56.48±1.8	57.46±2.6	0.98±1.6
SNB	75.34±1.0	75.81±1.6	0.47±1.1	75.52±1.0	75.78±1.6	0.26±1.2
Ar-Go-Gn	125.89±1.4	125.29±2.2	-0.60±1.7	126.70±2.2	126.21±3.2	-0.49±2.0
Ba-SN	130.50±1.2	129.69±2.0	-0.81±1.7	128.85±2.1	128.80±3.0	-0.05±1.9
SN-FH	10.75±0.4	10.83±0.7	0.08±0.7	11.36±0.9	11.40±1.2	0.04±0.7
SN-Ar	123.33±1.1	123.50±2.0	0.17±1.9	124.74±2.0	124.48±2.9	-0.26±1.8
Linear Skeletal - mm						
ANS-PNS	54.97±2.4	58.48±3.6	3.51±2.3 *	54.07±2.4	55.66±3.4	1.59±2.2 *
Ar-ANS	91.55±2.2	96.65±3.6	5.10±2.8 *	90.11±3.0	92.33±4.3	2.22±2.7 *
Ar-A point	87.18±2.1	90.51±3.2	3.33±2.1 *	86.47±2.5	87.51±3.7	1.04±2.3 *
Mid. PP to SN	48.29±1.9	52.65±2.9	4.36±1.9 *	47.60±2.0	50.02±3.0	2.42±1.8 *
Ptm-SN	15.77±1.9	15.56±2.5	-0.21±1.1 *	15.10±1.4	15.20±2.0	0.10±1.2 *
Ar-Go	40.97±4.1	47.11±6.4	6.14±4.4 *	40.82±3.2	44.28±4.8	3.46±3.1 *
Ar-Pog	101.84±3.2	112.13±5.0	10.29±3.7 *	100.88±4.2	107.11±6.1	6.23±4.0 *
Go-Pog	74.02±2.3	80.10±3.6	6.08±2.7 *	72.94±3.0	76.87±4.4	3.93±2.8 *
Pog-NB	2.35±1.8	3.37±1.4	1.02±0.9 *	2.20±1.5	2.58±2.1	0.38±1.1 *
S-N	72.52±1.6	76.39±2.4	3.87±1.7 *	71.44±2.0	73.57±2.9	2.13±1.9 *
S-Ba	47.24±2.8	50.48±4.0	3.24±2.6 *	46.26±2.3	47.48±3.4	1.22±2.1 *
Ar-N	96.41±2.3	102.89±3.3	6.48±2.9 *	94.76±3.0	97.93±4.3	3.17±2.7 *
Facial Measurements						
Angular - deg.						
N-A-Pog	8.96±2.5	2.47±3.3	-6.49±2.7 *	9.07±3.0	4.03±4.6	-5.04±3.2 *
FH-NPog	87.32±1.0	88.21±1.7	0.89±1.3	88.07±1.7	88.49±2.4	0.42±1.5
Nasolabial Angle	111.07±7.1	111.95±11.0	0.88±7.9	110.60±10.5	113.01±14.9	2.41±8.9
Mentolab. Angle	100.35±18.2	115.28±27.5	14.93±18.6	106.45±22.4	122.07±32.8	15.62±20.8
Z-Angle	67.60±4.5	72.32±6.3	4.72±4.5	70.02±5.6	74.56±7.9	4.54±4.5
Skeletal Linear - mm						
Total (N-Me)	115.02±4.4	127.69±6.6	12.67±4.3 *	112.95±4.2	121.50±6.2	8.55±4.1 *
Upper (N-ANS)	51.60±2.8	57.06±4.0	5.46±2.3 *	51.04±2.4	54.38±3.5	3.34±2.2 *
Lower (ANS-Me)	66.06±2.4	72.78±3.7	6.72±2.6 *	64.37±2.7	69.17±3.9	4.80±2.5 *
LF:TF	57.38±2.2	57.38±2.3	0.00±1.1	56.95±1.3	56.95±1.9	0.00±1.1
SGo	72.30±3.0	81.66±4.7	9.36±3.4 *	70.46±4.0	75.66±5.9	5.20±3.8 *
Nose Length	77.35±3.4	86.09±5.1	8.74±3.4 *	76.71±4.2	81.21±6.1	4.50±4.0 *
Thickness at A	14.77±2.0@	17.45±2.9	2.68±1.9 *	13.88±2.1@	14.94±3.1	1.06±1.9 *
Thickness of UL	11.60±2.3	14.94±3.5	3.34±2.6 *	11.12±3.0	12.45±4.4	1.33±2.8 *
Thickness of LL	15.34±1.2@	14.82±2.1	-0.52±1.8 *	14.33±2.0@	12.88±2.8	-1.45±1.8 *
Thickness at B	11.17±1.5	13.06±2.3	1.89±1.4	10.62±1.3	12.37±1.8	1.75±1.1
Thickness at Pog	11.80±1.2	12.78±1.8	0.98±1.1	11.27±1.4	12.42±1.9	1.15±1.2
UL to E-Line	0.84±2.0	-3.10±2.9	-3.94±1.9	-0.05±1.9	-3.66±2.7	-3.61±1.7
LL to E-Line	0.85±2.7	-0.91±3.8	-1.76±2.2	0.08±2.2	-1.17±3.1	-1.25±2.0
Height of UL	21.79±2.1	23.24±3.1	1.45±2.0 *	21.05±2.2	21.39±3.1	0.34±2.0 *
Height of LL	15.98±1.5	19.57±2.6	3.59±2.2	15.70±1.9	19.15±2.8	3.45±1.7

Table 1, continued
Columns are continuous laterally

	Age Group			FMA Groups		
Prepub (N=40)	Circumpub (N=31)	Postpub (N=14)	LOW II-2 (N=6)	LOW II-1 (N=28)	AVG II-1 (N=41)	HIGH II-1 (N=10)
			11.13±1.6	11.40±1.7	11.04±1.9	11.93±1.2
11.3±1.7	13.7±0.5	14.5±2.1	12.33±2.2	11.50±1.4	10.98±1.8	12.00±1.6
10.2±0.6	11.9±0.5	14.2±1.0	10.53±1.1	11.25±1.9	11.10±2.0	11.88±1.1
8.02±3.1	6.09±3.0	5.76±4.1	5.29±4.6	5.95±5.5	7.67±4.0	7.78±5.3
3.92±1.9	3.44±1.4	3.24±2.0	3.25±1.9	2.88±2.3	4.09±2.7	4.10±2.0
3.36±1.8	2.13±1.9	2.48±1.8	1.64±1.3	2.85±2.6	2.88±2.3	2.73±2.8
2.59±3.6	1.02±2.5	0.83±2.9	-0.20±4.0	1.61±3.3	2.07±3.7	1.79±2.5
2.50±3.4	0.98±2.4	0.52±2.8	-0.03±4.1	1.43±2.6	1.98±3.0	1.66±2.9
-1.39±2.4	-1.21±2.0	-0.62±2.0	-0.86±0.9	-1.46±2.5	-1.14±2.6	-0.88±2.6
2.65±8.1	2.46±5.2	0.67±6.1	-0.75±3.7	1.18±4.8	3.19±6.9	3.25±4.4
4.24±8.0	4.34±5.1	1.57±6.2	0.42±5.4	2.51±4.9	4.96±7.2	5.01±4.8
5.51±5.1	3.95±5.6	2.67±6.0	0.62±7.5	4.55±5.7	5.26±4.6	3.34±4.3
1.59±1.5	1.87±1.8	0.91±1.8	1.18±2.0	1.33±2.9	1.77±3.6	1.77±3.4
-2.15±1.5	-2.30±1.3	-1.68±1.1	-1.15±2.4	-2.10±3.4	-2.14±2.7	-2.71±3.0
-1.69±3.0	-1.73±2.1	-1.33±2.8	0.58±6.5	-1.33±4.8	-1.80±4.2	-3.23±5.1
0.12±1.9	0.58±1.7	0.05±2.1	-0.33±4.7	0.14±3.8	0.42±3.4	0.41±2.7
0.16±2.0	0.36±1.9	0.09±2.2	-0.21±5.8	0.09±3.2	0.52±2.1	-0.35±1.1
0.60±2.1	0.75±1.6	0.77±2.5	-0.14±4.3	0.59±3.6	0.79±3.3	0.95±2.6
0.94±1.2	1.11±1.3	0.92±1.4	0.32±2.9	1.05±2.3	0.99±3.0	1.26±3.2
0.98±1.4	0.89±1.5	0.96±1.5	0.45±3.3	1.00±2.7	1.09±2.4	0.49±2.5
0.61±1.1	0.08±1.2	0.23±1.1	0.78±2.5	0.30±2.9	0.40±2.5	0.03±3.3
-0.57±1.9	-6.00±1.8	-0.31±2.1	0.24±5.4	-0.28±5.7	-0.89±3.9	-0.29±4.3
-1.13±1.7	0.42±1.9	-0.07±2.0	-0.89±6.8	-0.32±4.7	-0.62±5.1	0.64±5.1
-0.04±0.8	0.22±0.7	-0.04±0.6	-0.12±2.6	0.06±2.7	-0.09±2.4	0.77±2.8
-0.38±1.6	0.42±2.1	-0.31±1.8	0.05±7.5	0.08±4.8	-0.28±4.9	0.33±5.3
2.90±2.4	1.98±2.0	2.19±2.3	1.33±4.0	2.66±3.3	2.57±3.0	2.05±4.5
4.15±2.7	2.94±2.8	2.95±2.9	2.63±7.6	3.93±3.8	3.51±4.2	2.89±3.9
2.57±2.3	1.68±2.1	1.47±2.5	2.04±6.9	2.16±3.6	2.15±3.9	1.43±2.3
4.04±1.9	2.74±1.9	2.38±1.9	2.07±3.6	3.25±2.9	3.52±2.8	3.21±2.7
0.05±1.3	-0.23±0.9	0.14±1.3	0.53±3.0	0.00±1.8	-0.10±2.2	-0.22±1.6
5.27±3.1	4.14±2.8	4.07±2.9	4.96±4.8	4.69±4.0	4.49±3.0	5.12±6.4
9.60±4.0	6.89±3.8	6.15±3.8	6.87±6.0	7.63±4.9	8.51±5.5	8.03±6.4
5.99±2.9#	4.08±2.7#	3.54±2.5#	3.22±4.6	4.49±3.8	5.62±4.6	4.05±1.8
0.95±0.9	0.42±1.2	0.42±0.8	0.63±1.9	0.61±1.7	0.77±1.8	0.44±2.2
3.43±1.8	2.47±1.7	2.36±2.0	2.25±4.6	2.84±2.8	3.06±2.4	2.87±2.7
2.93±2.5	1.53±2.0	1.12±2.2	1.25±2.2	1.85±3.5	2.53±2.8	1.72±6.7
5.48±2.9	4.11±2.7	3.47±3.1	3.46±6.2	4.66±4.3	4.89±3.9	4.36±3.7
-6.58±3.1	-5.19±3.3	-4.27±2.3	-4.70±3.7	-5.60±4.8	-5.90±4.5	-5.68±4.6
0.90±1.3	0.42±1.5	0.30±1.2	0.79±2.5	0.56±2.2	0.58±2.5	0.94±2.3
1.77±9.5	1.57±7.9	1.92±6.4	-5.65±6.0	3.88±9.0	1.61±10.8	0.53±6.9
16.40±20.2	15.47±18.2	11.83±23.7	9.65±21.3	15.91±22.9	18.40±22.7	4.38±28.1
5.23±4.7	3.61±4.2	5.10±4.7	4.52±4.7	4.14±7.2	4.67±6.1	5.77±4.8
11.87±4.1	9.20±4.1	8.81±4.8	7.27±5.0	9.76±5.9	11.27±5.9	10.45±6.1
5.03±2.2	3.91±2.4	2.99±2.2	2.78±3.2	4.09±2.9	4.62±3.3	4.35±2.7
6.30±2.5	4.89±2.2	5.55±3.3	4.01±3.5	5.41±4.2	6.14±4.7	5.36±3.9
0.00±1.1	0.00±0.8	0.00±1.0	0.00±1.8	0.00±1.8	0.00±2.4	-0.01±1.1
8.29±3.8	5.99±3.7	5.90±3.8	6.15±6.7	7.03±6.5	7.23±4.7	6.98±4.5
7.64±3.6	5.38±3.8	5.07±4.1	3.98±7.0	6.40±3.9	6.82±3.6	6.08±3.4
2.33±1.8	1.54±2.0	0.77±1.8	0.37±2.9	2.02±1.5	1.91±1.9	1.45±2.0
3.08±2.5	1.52±3.1	1.36±2.6	-1.77±1.8 $	2.20±2.2 $	2.50±2.6	3.57±3.2
-0.70±1.8	-1.16±1.8	-1.71±1.7	-2.93±2.3 $	-1.05±2.3 $	-0.79±2.1	-0.90±2.5
2.16±1.2#	1.76±1.5#	0.94±0.9#	1.35±1.5	1.94±1.3	2.06±1.7	0.72±2.5
1.16±1.1	1.05±1.3	0.89±0.8	0.39±2.9	1.23±2.2	1.20±1.9	0.52±1.8
-3.90±1.9	-3.42±1.6	-4.10±1.9	-2.66±1.8	-3.60±2.9	-3.91±2.0	-4.27±1.1
-1.47±2.3	-1.22±1.6	-2.07±1.9	-0.46±2.1	-1.35±3.5	-1.75±2.3	-1.31±3.1
1.19±2.0	0.61±1.9	0.33±2.0	-0.15±1.6	0.91±2.3	1.01±1.9	0.54±2.4
4.10±2.3	3.12±1.6	2.70±1.6	1.70±1.4	3.27±1.8	3.64±2.3	4.72±3.2

Due to the difference in cephalometric magnification in this study (9%) with that in the normal sample (12.7%), a correction factor was applied to the mean values for comparison.

Several dental, skeletal, and soft tissue measurements showed statistically significant sex differences. These differences were to be anticipated on the basis of sex differences in growth changes inherent during the treatment period. None of the changes could be attributed solely to orthodontic therapy.

The dates of menarche or pubertal growth maximum were not available for this sample. To find out if there were any effects of starting treatment early or late, the male and female groups were arbitrarily divided on the basis of puberty occurring around the age of 13 to 15 years in males and 11 to 13 years in females. Thus, the sample could be divided into three subgroups, namely, prepubertal, circumpubertal, and postpubertal. The changes noticed during treatment were statistically significant for two measurements—soft tissue thickness at B point and the length of the mandible (Go to Pog). These changes were considered a reflection of the differential growth prior to, during and after puberty. Moore[23] and Weislander[11] both stated that the effects of the cervical facebow appliance could be greater with earlier treatment. Our findings do not support this claim. There was a general trend throughout the treatment sample that greater linear changes occurred in the prepubertal group compared to the others, but this would be expected due to normal growth.

The dentition

The amount of molar extrusion in this sample was not beyond what would be expected during the normal period of growth when compared to untreated controls.[36] Several researchers have noted extrusion of the maxillary permanent molars above and beyond the normal growth expectations.[7,12,16,18-22] Some have even found the magnitude of extrusion to be two[19] to three[17] times greater than other forms of headgear appliances. Sandusky[16] stated that the effects of the headgear could be partially negated with edgewise treatment and we feel that this may be the result of less dramatic changes seen in the posttreatment records of this study. Progress records taken at the time the permanent first molar relationship had been overcorrected (just prior to full banded edgewise therapy) would have helped verify the extent of reversal of the headgear treatment changes.

The maxillary permanent first molars migrated mesially as measured from a vertical line from palatal plane at Ptm and also from pterygomaxillary vertical plane, a finding corroborated by other authors.[12,13] Several[1,2,4-11] have reported that the maxillary permanent first molar was distalized with the cervical facebow headgear. Again, our results may be due to the full banded appliance therapy that followed the use of cervical headgear.

The ratio of the amount of maxillary molar extrusion from the palatal plane divided by the amount of mandibular molar extrusion from the mandibular plane equaled 1.3 for the sample as a whole, 1.1 for the males and, 1.7 for the females, while the Class II division 2 were 2.1, the LOW FMA Class II division 1 at 1.0, the AVG FMA Class II division 1 at 1.4, and the HIGH FMA Class II division 1 at 1.5. Schudy[37] stated that the downward movement of the maxillary molars within the facial complex was the most important growth factor in reducing the amount of overbite, particularly that growth which occurred below the palatal plane. It was the most important factor in establishing facial height. When looking at the amount of vertical eruption of the maxillary permanent first molars from the anterior cranial base compared to the vertical eruption of the mandibular teeth, the Class II division 2 group exhibited the greatest amount of vertical increase of the maxillary first molars over that of the mandibular molars by 3.2 mm to 1.0 mm. The LOW FMA Class II division 1 group showed the smallest ratio in maxillary to mandibular permanent first molar eruption, at 2.1 mm to 1.0 mm. According to Riolo et al.[36] the comparable ratio of average eruption of maxillary to mandibular molars is 4.1 mm to 3.8 mm for males and 2.0 mm to 2.3 mm for females.

King,[14] Klein,[6] and Cangiolasi[13] found that the anatomic occlusal plane remained relatively constant when patients were treated with the cervical pull facebow headgear. However, Sandusky[16] and Merrifield and Cross[18] reported opening of the anatomic occlusal plane angle with the cranial base. In our study the anatomic occlusal plane also remained constant throughout the period of treatment and did not change significantly. Normal untreated controls have shown that the anatomic occlusal plane closed with age, but this study did not show closure.[36,51] This lack of change in the anatomic occlusal plane could be a direct result of the downward anterior tipping of the palatal plane with treatment. We noted that the anterior part of the palatal plane tipped downward by an average of 1.6°.

The functional occlusal plane closed significantly with treatment by changing from a pretreatment value of 21.1° to a posttreatment value of 19.1° This follows the findings of Boatwright[26] and Brown[22] who also noted closure of the functional occlusal plane during treatment with this appliance. Riolo et al.[36] and Frank[51] showed a closure of the functional occlusal plane as a normal growth process.

The occlusion

In an examination of the changes in linear measurements relating to teeth in the maxilla and mandible, it was found that the molar Class II relationship improved 4 mm, while the overbite improved from a mean of 4.9 mm to 0.7 mm, and the overjet improved from 7.5 mm to 1.8 mm. No significant differences were found in the correction of molar relation, overbite and overjet based on gender, age and the size of the pretreatment Frankfort mandibular plane angle.

The maxillary first molars migrated mesially an average of 1.6 mm. They were restricted by about 2 mm when compared to the Class I normals.[36] However, whether cases with Class II will, on average, experience mesial movement of maxillary molars to the extent that it is found in untreated Class II cases is left to speculation. A review of the mesial migration of the maxillary and mandibular first molars in this study indicated that since both moved mesially about the same extent, the correction of Class II relation could not have been due to orthodontic adjustment in the position of the teeth. It would be reasonable to assume that the change in Class II relation was brought about by increased sagittal growth of the mandible. This would not be in agreement with others[12,16,25] who have stated that the maxillary complex as a whole continued to grow forward. They stated that the changes in the malocclusion resulted from restricted anterior movement of the maxillary molars.

The maxillary complex

The linear measurement of Ptm from a perpendicular line dropped from SN at S showed there was no significant change (decreased 0.04 mm) from pretreatment to posttreatment in the sample as a whole. This was contrary to the findings reported by Ringenberg and Butts[10] that the linear distance decreased with treatment and that the pterygomaxillary fissure was, therefore, rotated down and back. Our findings support the findings of earlier reports[32-34] that the location of Ptm, SE and the pterygomaxillary vertical plane are stable references.

On average, SNA decreased 2.1° for the entire sample which is in agreement with previous studies. Eighty of the 85 patients evaluated showed a decrease in SNA, while those that did exhibit an increase showed a change of less than one degree. Analysis of the records showed that with a lower pretreatment FMA, the decrease in angle SNA was smaller. The reports on Class I normals did not indicate any appreciable change in angle SNA for a comparable age period.[36] It is difficult to explain the decrease in SNA. The minor difference in the change in SNA may be due to the differential vertical and horizontal effects of growth. However, the linear distances ANS-PNS, Ar-ANS, Ar-A point, and the measurement from the center of the palatal plane to sella-nasion plane increased during treatment. The increments in these measurements were almost identical to the changes reported for a normal untreated Class I sample.[36] Our findings do not support the observations of several authors that the normal forward and downward growth of the maxilla is impeded by means of extraoral traction.[2,6,10,14,23,27,35,38-42]

The angle formed by the palatal plane (ANS-PNS) and the anterior cranial base (SN) showed an average increase of 1.6° in the findings of this study. In normal untreated Class I samples[36,43,44] this angle has been reported to increase only slightly with age (0.4°); but the change is not clinically significant.

In general, our findings reaffirmed the anterior downward tip of the palatal plane which other authors found to be of approximately the same magnitude.[6,7,10,13,16,18,19,22,25,26,28]

The mandible

Most of the angular and linear changes in the mandible could be explained by growth alone. The notable aspect of mandibular posttreatment changes was that no significant change in the mandibular plane angle was recorded in the sample as a whole or in any of the subsamples. Many authors[10,15,17,27,28,25,35] have commented on the steepening of the mandibular plane as a result of cervical pull headgear treatment caused by maxillary molar extrusion and hinging open (posterior rotation) of the mandible. This will have a resultant excessive increase of lower anterior face height. As far as the mandibular plane was concerned, not even the patients with a high FMA showed any increase. Nanda[46] and Riolo et al.[36] have shown that in Class I cases, the mandibular plane is reduced several degrees during this age period. Since there was no change in this angle, one may surmise that the usual reduction of this angle was circumvented and that may be due to the extent to which this angle may have changed with treatment. The Y-axis increased in the sample 1.0°±0.84°. This change was similar to that reported by Klein,[6] Fischer,[52] and Cangiolasi.[13] In growing Class I cases, it has been shown that there is a normal reduction of this angle.[36] Even though the Y-axis showed an increase, the angles SNB and SNPog increased an average of 0.35° and 0.57°, respectively.

The face

Our study did not show any change in the ratio of lower to total anterior face height, indicating that no untoward increase in lower face height occurred. This finding is not in accordance with the findings of previous investigators.[10,12,17,19-21] According to other studies[54,55] on soft tissue changes, our findings do not show any notable differences. Generally speaking, the soft tissue drape increases in thickness relative to age, while the profile of the upper and lower lip continues to retract from the esthetic plane.

This investigation has two shortcomings. One is that the changes with treatment could not be compared to the untreated Class II division 1 cases as no data were available in the literature or from clinical records. The second is related to the fact that no cephalometric radiograph was available at the termination of the first phase of treatment with the cervical pull headgear so the results had to be compared using only the pre- and posttreatment records.

The results of our study did not show significant changes in the dentofacial complex due to treatment with the cervical pull facebow headgear. The lack of overt changes in our sample in contrast to those reported by other authors may very well be due to the effect that the orthodontic treatment subsequent to use of the headgear nearly nullified most of the effects of the cervical pull headgear. It is to be accepted that techniques of treatment and sequence of procedures vary among the clinicians. The important clinical finding that may be projected on the basis of this study is that the negative affects of cervical pull headgear may not be anticipated in each and every patient. Much depends on the manner in which the clinician chooses to apply their treatment mechanics.

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