ORIGINAL ARTICLE

The role of cervical headgear and lower utility arch in the control of the vertical dimension

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Introduction: This study was carried out to evaluate the treatment changes in skeletal and dental parameters in growing patients. **Methods:** The sample consisted of 24 subjects with Class II Division 1 malocclusion. Half of the patients were treated with cervical headgear alone (group C, n = 12), and the other half received a combination of cervical headgear and lower utility arch (group CU, n = 12). The treatment groups were compared with a matched untreated control group (n = 12). The mean ages of the subjects at the beginning of the study were 8.85 ± 1.19 years in group C, 9.23 ± 0.76 years in group CU, and 8.62 ± 0.78 years in the control group. The cervical headgear was used with an expanded inner bow and a 15° to 20° upward bend of the longer outer bow, worn 12 to 14 hours a day, with a force of 450 to 500 g per side. The lower utility arch was designed as described in the bioprogressive technique. Treatment changes were assessed on lateral cephalometric radiographs. **Results:** The cervical headgear produced Class II correction through maxillary orthopedic and orthodontic changes. Anterior face height increased more in the treatment groups than in the control group. The treatment groups also displayed statistically significant increases in ramus height. Due to these effects, mandibular plane orientation stayed relatively unchanged. There was no opening rotation of the mandible in the treatment groups. The lower utility arch produced intrusion and lingual tipping of the mandibular incisors and distal tipping without extrusion of the mandibular molars. The treatment groups showed significant anterior descents of the palatal plane. Maxillary molar total extrusion produced by cervical headgear treatment was an average of no more than 1 mm as compared with the control group. The utility arch did not appear to influence mandibular rotational response. (Am J Orthod Dentofacial Orthop 2006;130:492-501)

The use of extraoral traction in the treatment of maxillary protrusion was first reported in the 1800s. Since then, many authors have reported on its use and effects in the treatment of Class II Division 1 malocclusions.[1-5]

Kloehn[1] noted the striking results with headgear treatment of Class II malocclusion in 1947. Kloehn[2,3] and Ricketts[5] later acknowledged that downward pull is needed to enhance the orthopedic effect, and ultimately cervical traction became a mainstay.

The effects of cervical traction on the craniofacial complex were studied in experimental[6,7] and clinical studies.[8-16] Orthopedic and orthodontic changes in the maxilla, the mandible, and the cranial base have created much discussion in orthodontic circles. Many authors reported significant changes in vertical parameters when patients were treated with cervical headgear. As a result, many orthodontists avoid using cervical headgear because of the possibility of undesirable changes in mandibular plane orientation (opening rotation of mandible) and maxillary molar extrusion.[5,9,17-19] Because of these adverse effects of cervical headgear, some orthodontists prefer to use high-pull headgear to prevent opening rotation of the mandible and extrusion of the maxillary molars in patients with high-angle growth tendencies.

Ricketts[5] and Bench et al[20-22] stated that a Ricketts-type cervical headgear and a lower utility arch together can prevent the opening rotation of mandible. This action is called the reverse response. They noted that the mandibular plane and the facial axis can be stabilized by such mechanics. Moreover, according to those authors, in patients with strong muscular patterns, the mandible can rotate in a counterclockwise direction, resulting in closure of the lower face height, the mandibular plane, and the facial axis.

If the statements of Ricketts[5] and Bench et al[20-22] are true, orthodontists can control and stabilize the opening rotation of the mandible by combining orthopedic cervical headgear and lower utility arch mechanics. Therefore, rather than high-pull headgear, these kinds of mechanics can be used more effectively in

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Table I. Age (y) and sex information for groups

	Control group		Group C		Group CU	
	Mean	*SD*	*Mean*	*SD*	*Mean*	*SD*
Girls	8.68	0.79	7.89	0.47	9.03	0.90
Boys	8.50	0.84	9.82	0.81	9.50	0.48
Total	8.62	0.78	8.85	1.19	9.23	0.76

Table II. Treatment and control durations (y)

	Mean	*SD*	*Minimum*	*Maximum*
Control group	1.42	0.11	1.25	1.66
Group C	1.43	0.13	1.25	1.66
Group CU	1.48	0.11	1.33	1.66

Class II Division 1 patients with high-angle vertical growth patterns during active growth.

The purpose of this study was to evaluate the control of the vertical dimension with cervical headgear and the combination of cervical headgear and lower utility arch in 2 groups of growing patients with Class II Division 1 malocclusions. Skeletal and dental effects of the treatments were evaluated on cephalometric radiographs.

Material and methods

The study material consisted of 72 lateral cephalometric films taken before and after treatment, and before and after the study period, from 36 patients. In group C (n = 12; 6 girls, 6 boys), the patients were treated with cervical headgear alone; in group CU (n = 12; 7 girls, 5 boys), the patients were treated with a combination of cervical headgear and lower utility arch. To eliminate the effects of growth and development on craniofacial structures, a control group (n = 12; 8 girls, 4 boys) selected with the same criteria as the 2 treatment groups was followed for the same time period. No other appliances were used during this period. Age and sex information is given in Table I. The average treatment times were 1.43 ± 0.13 years for group C and 1.48 ± 0.11 years for group CU, and the average follow-up time was 1.42 ± 0.11 years for the control group (Table II).

The criteria for patient selection were: (1) skeletal Class II Division 1 malocclusion with normal maxillary base or tendency of maxillary prognathism, (2) normal or hyperdivergent vertical growth pattern, (3) prepubertal growth spurt, (4) excessive overjet, and (5) acceptable tooth alignment in the mandibular arch.

All subjects received cervical headgear. The inner bows of the facebow were expanded 8 to 10 mm, and the outer bows were bent upward 15° to 20° to the inner bows (Fig 1). The force applied was 450 to 500 g per side. Figure 2 shows the force and moment diagram of the appliance. Patients were urged to wear the appliance 12 to 14 hours a day. The expansion of the inner bow, the upward bending of long outer bow, and the amount of traction force were checked and adjusted at every appointment.

Fig 1. Extra-oral profile of a treatment group patient.

The lower utility arch was used as described in the bioprogressive technique.[5] According to Ricketts,[5] the lower utility arch is prepared with 30° to 40° tip-backs and toe-in bends, and 30° to 40° buccal root torque on the distal ends. This appliance also required 5° to 10° labial root torque on the mandibular incisors, applied with an expanded arch form.

Cephalometric measurements

The data were obtained by the analysis of paired lateral cephalograms for the 36 subjects. Seventeen linear, 14 angular, and 2 proportional cephalometric parameters were measured on the pretreatment and posttreatment radiographs. Six reference planes defined by earlier research were used to assess the data[23-25] (Fig 3).

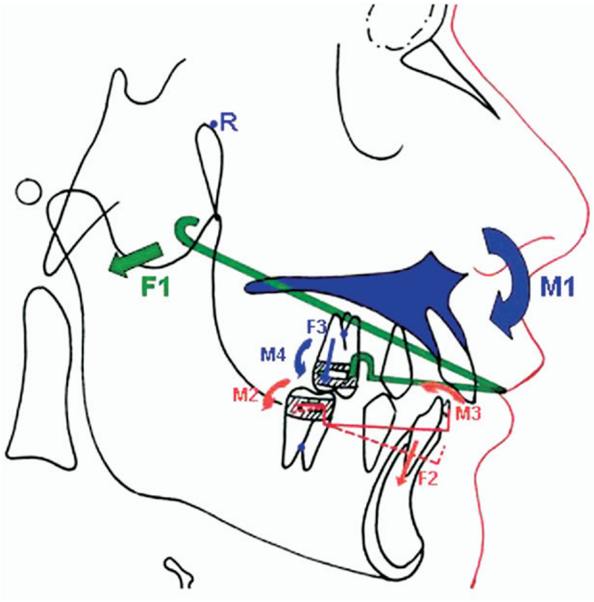

Fig 2. The mechanics. *F1*, Force applied by the cervical headgear (450-500 g); *F2*, intrusive force acting on the lower incisors applied by the utility arch (50-70 g); *F3*, extrusive force acting on the upper first molars applied by the cervical headgear; *M1*, clockwise moment acting on maxilla; *M2*, counterclockwise moment acting on lower molars; *M3*, counterclockwise moment acting on lower incisors; *M4*, counterclockwise moment acting on upper first molars; *R*, center of resistance of maxilla.

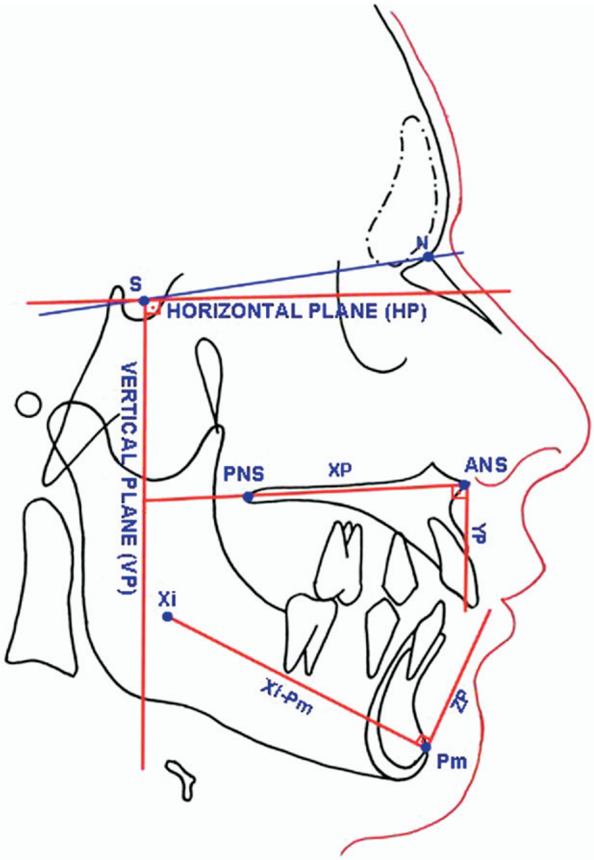

Fig 3. The reference plans used in the study.

The horizontal reference plane (HP) was drawn 7° below the sella-nasion (SN) line through point S. This plane is also called the corrected SN or constructed Frankfort horizontal plane. A vertical reference plane was constructed through sella, perpendicular to the constructed Frankfort horizontal plane.

To evaluate horizontal, vertical, and angular maxillary dental changes, the maxillary superimposition was made by using position 3 as described by Ricketts.[5] The X coordinate was the palatal plane (PP) registered at anterior nasal spine (ANS), and the Y coordinate was a line perpendicular to X from ANS.

Horizontal, vertical, and angular mandibular dental changes were evaluated by the mandibular superimposition made by using position 4 as described by Ricketts.[5] The X coordinate was the corpus axis (XiPm) registered at protuberence menti (Pm), and the Z coordinate was a line perpendicular to X (corpus axis) from the Pm.

Statistical analysis

Statistical calculations were performed with the GraphPad Prisma V.3 (San Diego, Calif) program for Windows. In addition to standard descriptive statistical calculations (means and standard deviations), the Wilcoxon test was used to detect intragroup changes (Tables III-V), the Kruskal-Wallis test was used for comparisons between groups (Table VI), and the Dunn multiple comparison test was used for subgroup comparisons (Table VII). The results were evaluated with a 95% confidence interval. The statistical significance level was established at $P < .05$.

To assess the magnitude of the method error for each parameter, lateral cephalometric radiograms of 20 randomly selected patients were traced and measured again by the same examiner (G.V.) after 20 days. Paired *t* tests and correlation analysis were used to evaluate the findings. The method error did not exceed 1 mm and 0.75° for the linear and angular measurements, respectively.

RESULTS

Twenty-one parameters in the control group, 22 in group C, and 21 in group CU showed statistically significant changes through time. Intragroup changes are described in Tables III-V. Intergroup comparison

Table III. Comparison of intragroup changes in control group with Wilcoxon *t* test

	Pretreatment		Posttreatment		Difference		
	Mean	SD	Mean	SD	Mean	SD	P
Skeletal measurements							
Ba-Na (°)	63.58	1.08	63.75	1.36	0.17	0.39	
SNA angle (°)	83.42	1.31	83.58	1.56	0.17	0.39	
SNB angle (°)	75.50	1.93	76.08	2.19	0.58	0.67	*
ANB angle (°)	7.92	1.16	7.5	1.51	−0.42	0.78	
SN-PP (°)	6.08	1.51	6.42	1.73	0.33	0.49	*
NPer-A (mm)	0.83	1.34	0.92	1.62	0.08	0.51	
A-HP (mm)	46.50	4.27	46.83	4.06	0.33	0.49	*
SGn-HP (°)	62.58	2.47	63.08	3.09	0.50	0.90	
Sn-GoMe (°)	34.92	3.94	35.33	4.19	0.42	0.67	
S-Ar-Go (°)	146.83	5.77	146.83	5.77	0.00	0.00	
Ar-Go-Me (°)	125.67	3.96	126.08	3.87	0.42	0.51	*
Σ (°)	396.50	3.68	396.92	3.75	0.42	0.51	*
NPer-Pog (mm)	−11.67	3.70	−11.75	3.98	−0.08	0.79	
ANS-Me (mm)	61.58	3.90	62.25	4.27	0.67	0.65	*
N-Me (mm)	109.08	5.37	110.17	5.77	1.08	0.79	†
ANS-Me/N-me (%)	56.37	10.06	56.50	1.20	0.13	0.36	
Ar-Go (mm)	40.83	4.37	41.25	4.60	0.42	0.51	*
S-Go (mm)	70.92	5.00	71.25	5.36	0.33	0.49	*
Ar-Go/S-Go (%)	57.46	3.63	57.77	3.64	0.31	0.46	*
Dental measurements							
Overjet (mm)	8.17	2.12	7.67	2.23	−0.50	0.52	*
Overbite (mm)	1.75	1.60	1.83	1.59	0.08	0.29	
U6-XP (mm)	20.83	1.85	21.92	1.78	1.08	0.51	†
U6-XP (°)	76.58	6.30	77.19	6.29	0.58	1.56	
U1-XP (mm)	28.25	1.82	29.42	2.15	1.17	0.83	†
U1-XP (°)	110.75	6.33	111.58	5.76	0.83	0.94	*
U6-YP (mm)	35.25	2.30	34.25	2.30	−1.00	0.60	†
U1-YP (mm)	0.92	2.15	−0.08	1.88	−1.00	0.74	†
L6-XiPm (mm)	14.42	1.73	14.83	1.34	0.41	0.67	
L6-XiPm (°)	82.92	3.23	85.00	3.44	2.08	0.79	†
L1-XiPm (mm)	25.92	2.75	26.83	2.86	0.91	0.79	†
L1-XiPm (°)	91.75	4.85	92.25	4.86	0.50	0.52	*
L6-ZP (mm)	33.08	2.54	31.83	2.69	−1.25	0.62	†
L1-ZP (mm)	7.83	2.44	7.50	2.50	−0.33	0.49	*

*P <.05; †P <.01.

Ba-Na, Angle between point basion and line nasion-A; *SN-PP,* angle between sella-nasion plane and palatal plane; *Nper-A,* perpendicular distance of point A from the perpendicular line drawn to the Frankfort horizontal from point nasion; *A-HP,* perpendicular distance of point A to the horizontal plane; *SGn-HP,* angle between horizontal plane and the line between points sella and gnathion; *Sn-GoMe,* angle between planes sella-nasion and gonion-mention; Σ, sum of the inner cranial angles; *Nper-Pog,* perpendicular distance of point pogonion from the perpendicular line drawn to the Frankfort horizontal from point nasion; *ANS-Me,* distance between points ANS and menton; *N-Me,* distance between pionts nasion and Menton; *ANS-Me/N-Me,* ratio of lower facial height to total facial height; *Ar-Go,* distance between points articulare and gonion; *S-Go,* distance between points sella and gonion; *Ar-Go/S-Go,* ratio of Ar-Go to S-Go; *U6-XP,* perpendicular distance of tip of mesial cusp of upper first molar to the X plane; *U1-XP,* perpendicular distance of incisal tip of upper incisor to the X plane; *U6-YP,* perpendicular distance of tip of mesial cusp of upper first molar to the Y plane; *L6-XiPm,* perpendicular distance of tip of mesial cusp of lower first molar to the XiPm plane; *L1-XiPm,* perpendicular distance of incisal tip of lower incisor to the XiPm plane; *L6-ZP,* perpendicular distance of tip of mesial cusp of lower first molar to the Z plane; *L1-ZP,* perpendicular distance of incisal tip of lower incisor to the Z plane.

describes statistically significant changes in 17 parameters (Table VI). Subgroup analyses showed which group was responsible for each related change (Table VII).

DISCUSSION

During growth, the maxilla is displaced downward and forward. The most frequent approach to growth modification has been extraoral force (headgear) to restrict or redirect the growth of maxilla.

The results of this study demonstrate that orthopedic cervical headgear used with an expanded inner bow and a 15° to 20° upward bend of the longer outer bow, 12 to 14 hours a day, with a force of 450 to 500 g per side, changed maxillary positions in both treatment groups with rotation in a clockwise direction.

Table IV. Comparison of intragroup changes in group C with Wilcoxon *t* test

	Pretreatment		*Posttreatment*		*Difference*		
	Mean	*SD*	*Mean*	*SD*	*Mean*	*SD*	P
Skeletal measurements							
Ba-Na (°)	64.17	2.37	61.50	1.68	−2.67	1.15	†
SNA angle (°)	83.17	2.44	80.25	1.60	−2.92	1.16	†
SNB angle (°)	76.42	1.93	77.00	1.76	0.58	1.00	
ANB angle (°)	6.75	1.11	3.25	1.00	−3.50	0.87	†
SN-PP (°)	5.75	1.42	8.83	1.53	3.08	0.79	†
NPer-A (mm)	0.17	2.82	−1.00	1.71	−1.17	2.86	
A-HP (mm)	47.42	2.71	51.33	2.90	3.92	1.00	†
SGn-HP (°)	61.25	2.09	61.92	2.54	0.67	0.65	*
Sn-GoMe (°)	34.17	3.43	34.75	3.77	0.58	1.00	
S-Ar-Go (°)	142.75	5.80	142.75	5.80	0.00	0.00	
Ar-Go-Me (°)	127.92	3.58	128.50	3.58	0.58	0.51	†
Σ (°)	396.75	3.22	397.33	3.50	0.58	0.51	†
NPer-Pog (mm)	−8.33	1.97	−7.17	2.48	1.17	1.70	*
ANS-Me (mm)	60.42	4.40	60.92	3.80	0.50	1.00	
N-Me (mm)	107.25	5.58	110.25	5.74	3.00	0.95	†
ANS-Me/N-me (%)	55.82	1.09	55.26	1.27	−0.56	0.57	*
Ar-Go (mm)	40.25	2.67	44.25	3.11	4.00	1.35	†
S-Go (mm)	69.50	3.83	72.75	4.00	3.25	1.22	†
Ar-Go/S-Go (%)	57.90	1.33	60.97	1.88	3.07	1.39	†
Dental measurements							
Overjet (mm)	7.75	2.05	3.00	1.04	−4.75	1.42	†
Overbite (mm)	2.58	1.78	2.75	1.29	0.17	0.72	
U6-XP (mm)	19.33	2.02	21.58	1.93	2.25	0.75	†
U6-XP (°)	76.33	7.58	86.08	11.12	9.75	6.74	†
U1-XP (mm)	26.33	2.42	26.58	2.02	0.25	0.75	
U1-XP (°)	112.25	4.75	113.92	6.76	1.67	4.91	
U6-YP (mm)	34.33	1.67	35.58	1.68	1.25	1.48	*
U1-YP (mm)	0.75	2.53	−0.17	2.76	−0.92	1.51	
L6-XiPm (mm)	11.67	2.64	12.00	3.10	0.33	1.15	
L6-XiPm (°)	82.42	5.48	81.83	4.53	−0.58	2.35	
L1-XiPm (mm)	24.58	2.27	25.50	2.15	0.92	0.90	*
L1-XiPm (°)	89.92	3.03	91.67	3.08	1.75	1.36	†
L6-ZP (mm)	34.75	1.86	33.83	1.99	−0.92	1.00	*
L1-ZP (mm)	9.50	1.31	8.67	1.15	−0.83	0.83	*

*P <.05; †P <.01.

Ba-Na, Angle between point basion and line nasion-A; *SN-PP,* angle between sella-nasion plane and palatal plane; *Nper-A,* perpendicular distance of point A from the perpendicular line drawn to the Frankfort horizontal from point nasion; *A-HP,* perpendicular distance of point A to the horizontal plane; *SGn-HP,* angle between horizontal plane and the line between points sella and gnathion; *Sn-GoMe,* angle between planes sella-nasion and gonion-mention; Σ, sum of the inner cranial angles; *Nper-Pog,* perpendicular distance of point pogonion from the perpendicular line drawn to the Frankfort horizontal from point nasion; *ANS-Me,* distance between points ANS and menton; *N-Me,* distance between pionts nasion and Menton; *ANS-Me/N-Me,* ratio of lower facial height to total facial height; *Ar-Go,* distance between points articulare and gonion; *S-Go,* distance between points sella and gonion; *Ar-Go/S-Go,* ratio of Ar-Go to S-Go; *U6-XP,* perpendicular distance of tip of mesial cusp of upper first molar to the X plane; *U1-XP,* perpendicular distance of incisal tip of upper incisor to the X plane; *U6-YP,* perpendicular distance of tip of mesial cusp of upper first molar to the Y plane; *L6-XiPm,* perpendicular distance of tip of mesial cusp of lower first molar to the XiPm plane; *L1-XiPm,* perpendicular distance of incisal tip of lower incisor to the XiPm plane; *L6-ZP,* perpendicular distance of tip of mesial cusp of lower first molar to the Z plane; *L1-ZP,* perpendicular distance of incisal tip of lower incisor to the Z plane.

In the vertical plane, SN-PP angle and A-HP distance increased significantly, and, in sagittal direction, Ba-NA angle and SNA angle decreased significantly in both treatment groups. When the subgroup comparison was evaluated, the increase in these parameters was found to be statistically and clinically significant in both treatment groups compared with the control group (Table VII). This means that the maxilla was affected in the same manner in both treatment groups, and certain general conclusions seem appropriate. First, Point A was significiantly displaced downward and backward in both treatment groups with orthopedic cervical headgear. The findings of this study confirm the observations of previous research.[1,5,9,18,26-31] Second, for

Table V. Comparison of intragroup changes in group CU with Wilcoxon *t* test

	Pretreatment		*Posttreatment*		*Difference*		
	Mean	*SD*	*Mean*	*SD*	*Mean*	*SD*	P
Skeletal measurements							
Ba-Na (°)	63.58	2.15	60.58	1.56	−3.00	0.95	†
SNA angle (°)	83.58	2.39	80.25	2.18	−3.33	0.78	†
SNB angle (°)	76.08	3.03	76.58	2.47	0.50	1.09	
ANB angle (°)	7.5	1.15	3.67	0.65	−3.83	0.95	†
SN-PP (°)	5.75	2.56	9.00	2.45	3.25	0.87	†
NPer-A (mm)	1.67	2.27	−0.33	1.92	−2.00	1.65	†
A-HP (mm)	46.50	3.94	49.08	3.37	2.58	2.97	*
SGn-HP (°)	61.58	2.02	62.17	1.99	0.58	0.79	*
Sn-GoMe (°)	34.33	3.80	34.83	3.59	0.50	0.67	
S-Ar-Go (°)	147.75	6.78	147.83	6.75	0.08	0.29	
Ar-Go-Me (°)	125.08	5.57	125.42	5.18	0.33	0.78	
Σ (°)	395.92	2.57	396.33	2.42	0.42	0.90	
NPer-Pog (mm)	−9.33	4.16	−8.75	3.89	0.58	1.44	
ANS-Me (mm)	61.08	2.15	62.33	1.78	1.25	1.14	†
N-Me (mm)	108.75	3.14	111.92	3.00	3.17	1.64	†
ANS-Me/N-me (%)	56.10	0.68	55.64	0.52	−0.46	0.61	*
Ar-Go (mm)	41.08	3.26	44.33	2.96	3.25	1.14	†
S-Go (mm)	70.67	3.94	74.42	3.63	3.75	1.29	†
Ar-Go/S-Go (%)	57.96	2.79	59.50	2.69	1.54	0.62	†
Dental measurements							
Overjet (mm)	8.50	1.68	4.50	1.31	−4.00	0.95	†
Overbite (mm)	2.83	1.40	3.00	1.04	0.17	0.83	
U6-XP (mm)	20.92	1.38	22.42	1.62	1.50	0.80	†
U6-XP (°)	75.00	5.41	84.25	5.51	9.25	4.00	†
U1-XP (mm)	28.25	1.76	28.92	2.15	0.67	1.37	
U1-XP (°)	113.17	5.27	113.33	7.35	0.17	5.44	
U6-YP (mm)	35.42	2.35	36.58	2.64	1.17	1.19	*
U1-YP (mm)	1.17	2.08	0.75	2.38	−0.42	2.71	
L6-XiPm (mm)	14.08	1.51	14.33	1.78	0.25	0.75	
L6-XiPm (°)	83.33	6.32	72.83	8.98	−10.50	4.01	†
L1-XiPm (mm)	26.25	1.54	24.25	1.54	−2.00	1.13	†
L1-XiPm (°)	90.42	5.68	88.17	4.55	−2.25	2.73	*
L6-ZP (mm)	34.15	2.30	34.75	2.26	0.50	0.80	
L1-ZP (mm)	9.33	2.90	9.92	2.54	0.58	0.79	*

*$P < .05$; †$P < .01$.

Ba-Na, Angle between point basion and line nasion-A; *SN-PP,* angle between sella-nasion plane and palatal plane; *Nper-A,* perpendicular distance of point A from the perpendicular line drawn to the Frankfort horizontal from point nasion; *A-HP,* perpendicular distance of point A to the horizontal plane; *SGn-HP,* angle between horizontal plane and the line between points sella and gnathion; *Sn-GoMe,* angle between planes sella-nasion and gonion-mention; Σ, sum of the inner cranial angles; *Nper-Pog,* perpendicular distance of point pogonion from the perpendicular line drawn to the Frankfort horizontal from point nasion; *ANS-Me,* distance between points ANS and menton; *N-Me,* distance between pionts nasion and Menton; *ANS-Me/N-Me,* ratio of lower facial height to total facial height; *Ar-Go,* distance between points articulare and gonion; *S-Go,* distance between points sella and gonion; *Ar-Go/S-Go,* ratio of Ar-Go to S-Go; *U6-XP,* perpendicular distance of tip of mesial cusp of upper first molar to the X plane; *U1-XP,* perpendicular distance of incisal tip of upper incisor to the X plane; *U6-YP,* perpendicular distance of tip of mesial cusp of upper first molar to the Y plane; *L6-XiPm,* perpendicular distance of tip of mesial cusp of lower first molar to the XiPm plane; *L1-XiPm,* perpendicular distance of incisal tip of lower incisor to the XiPm plane; *L6-ZP,* perpendicular distance of tip of mesial cusp of lower first molar to the Z plane; *L1-ZP,* perpendicular distance of incisal tip of lower incisor to the Z plane.

changes in the orientation of the PP, both treatment groups tended to change PP angulation (anterior descent of the PP), which, in the untreated control group, remained notably constant on average. In both treatment groups, the pattern of change in the direction of the growth of the maxilla was downward tipping of the anterior portion of PP as it descended. Several investigators noted this type of change.[4,5,18,26-30]

The most important overall finding in the mandible was the absence of profound differences in mandibular plane angle change in the patients treated with cervical headgear. Essentially no significant

Table VI. Comparison of intergroup changes with Kruskal-Wallis test

	Control group		*Group C*		*Group CU*		
	Mean	*SD*	*Mean*	*SD*	*Mean*	*SD*	P
Skeletal measurements							
Ba-Na (°)	0.17	0.39	−2.67	1.15	−3.00	0.95	‡
SNA angle (°)	0.17	0.39	−2.92	1.16	−3.33	0.78	‡
SNB angle (°)	0.58	0.67	0.58	1.00	0.50	1.09	
ANB angle (°)	−0.42	0.78	-3.50	0.87	−3.83	0.95	‡
SN-PP (°)	0.33	0.49	3.08	0.79	3.25	0.87	‡
NPer-A (mm)	0.08	0.51	−1.17	2.86	−2.00	1.65	†
A-HP (mm)	0.33	0.49	3.92	1.00	2.58	2.97	‡
SGn-HP (°)	0.50	0.90	0.67	0.65	0.58	0.79	
Sn-GoMe (°)	0.42	0.67	0.58	1.00	0.50	0.67	
S-Ar-Go (°)	0.00	0.00	0.00	0.00	0.08	0.29	
Ar-Go-Me (°)	0.42	0.51	0.58	0.51	0.33	0.78	
Σ (°)	0.42	0.51	0.58	0.51	0.42	0.90	
NPer-Pog (mm)	−0.08	0.79	1.17	1.70	0.58	1.44	
ANS-Me (mm)	0.67	0.65	0.50	1.00	1.25	1.14	
N-Me (mm)	1.08	0.79	3.00	0.95	3.17	1.64	‡
ANS-Me/N-me (%)	0.13	0.36	−0.56	0.57	−0.46	0.61	†
Ar-Go (mm)	0.42	0.51	4.00	1.35	3.25	1.14	‡
S-Go (mm)	0.33	0.49	3.25	1.22	3.75	1.29	‡
Ar-Go/S-Go (%)	0.31	0.46	3.07	1.39	1.54	0.62	‡
Dental measurements							
Overjet (mm)	−0.50	0.52	−4.75	1.42	−4.00	0.95	‡
Overbite (mm)	0.08	0.29	0.17	0.72	0.17	0.83	
U6-XP (mm)	1.08	0.51	2.25	0.75	1.50	0.80	†
U6-XP (°)	0.58	1.56	9.75	6.74	9.25	4.00	‡
U1-XP (mm)	1.17	0.83	0.25	0.75	0.67	1.37	
U1-XP (°)	0.83	0.94	1.67	4.91	0.17	5.44	
U6-YP (mm)	−1.00	0.60	1.25	1.48	1.17	1.19	‡
U1-YP (mm)	−1.00	0.74	−0.92	1.51	−0.42	2.71	
L6-XiPm (mm)	0.41	0.67	0.33	1.15	0.25	0.75	
L6-XiPm (°)	2.08	0.79	−0.58	2.35	−10.50	4.01	‡
L1-XiPm (mm)	0.91	0.79	0.92	0.90	−2.00	1.13	‡
L1-XiPm (°)	0.50	0.52	1.75	1.36	−2.25	2.73	‡
L6-ZP (mm)	−1.25	0.62	−0.92	1.00	0.50	0.80	‡
L1-ZP (mm)	−0.33	0.49	−0.83	0.83	0.58	0.79	‡

*$P < .05$; †$P < .01$; ‡$P < .001$.

Ba-Na, Angle between point basion and line nasion-A; *SN-PP,* angle between sella-nasion plane and palatal plane; *Nper-A,* perpendicular distance of point A from the perpendicular line drawn to the Frankfort horizontal from point nasion; *A-HP,* perpendicular distance of point A to the horizontal plane; *SGn-HP,* angle between horizontal plane and the line between points sella and gnathion; *Sn-GoMe,* angle between planes sella-nasion and gonion-mention; Σ, sum of the inner cranial angles; *Nper-Pog,* perpendicular distance of point pogonion from the perpendicular line drawn to the Frankfort horizontal from point nasion; *ANS-Me,* distance between points ANS and menton; *N-Me,* distance between pionts nasion and Menton; *ANS-Me/N-Me,* ratio of lower facial height to total facial height; *Ar-Go,* distance between points articulare and gonion; *S-Go,* distance between points sella and gonion; *Ar-Go/S-Go,* ratio of Ar-Go to S-Go; *U6-XP,* perpendicular distance of tip of mesial cusp of upper first molar to the X plane; *U1-XP,* perpendicular distance of incisal tip of upper incisor to the X plane; *U6-YP,* perpendicular distance of tip of mesial cusp of upper first molar to the Y plane; *L6-XiPm,* perpendicular distance of tip of mesial cusp of lower first molar to the XiPm plane; *L1-XiPm,* perpendicular distance of incisal tip of lower incisor to the XiPm plane; *L6-ZP,* perpendicular distance of tip of mesial cusp of lower first molar to the Z plane; *L1-ZP,* perpendicular distance of incisal tip of lower incisor to the Z plane.

rotational change in the mandibule was observed with cervical headgear in this study. This is in conflict with the observations of previous studies that reported that cervical headgear tends to increase the mandibular plane angle.[5,6,8,9,11,12,17-19,27,31-38]

The Ar-Go/S-Go ratio increased significantly as well. These data indicate an increase in the ramus height. On the other hand, the ANS-Me/N-Me ratio decreased significiantly. This was an unexpected finding because of the clockwise rotation of the maxilla.

Cervical headgear wear caused not only an increase in the anterior total face height but also a significiant increase in the ramus height as compared with the control group. Because total face height and ramus

Table VII. Subgroup comparison with Dunn multiple comparison test for parameters with significant differences in Table VI

	C/CU	*C/control*	*CU/control*
Skeletal measurements			
Ba-Na (°)		‡	‡
SNA (°)		‡	‡
ANB (°)		‡	‡
SN-PP (°)		‡	‡
NPer-A (mm)		*	†
A-HP (mm)		‡	*
N-Me (mm)		†	‡
ANS-Me/N-me (%)		†	*
Ar-Go (mm)		‡	‡
S-Go (mm)		‡	‡
Ar-Go/S-Go (%)		‡	*
Dental measurements			
Overjet (mm)		‡	‡
U6-XP (mm)		†	*
U6-XP (°)		‡	‡
U6-YP (mm)		‡	‡
L6-XiPm (°)	†		‡
L1-XiPm (mm)	‡		‡
L1-XiPm (°)	‡		*
L6-ZP (mm)	*		‡
L1-ZP (mm)	†		*

*$P < .05$; †$P < .01$; ‡$P < .001$.

Ba-Na, Angle between point basion and line nasion-A; *SN-PP,* angle between sella-nasion plane and palatal plane; *Nper-A,* perpendicular distance of point A from the perpendicular line drawn to the Frankfort horizontal from point nasion; *A-HP,* perpendicular distance of point A to the horizontal plane; *SGn-HP,* angle between horizontal plane and the line between points sella and gnathion; *Sn-GoMe,* angle between planes sella-nasion and gonion-mention; Σ, sum of the inner cranial angles; *Nper-Pog,* perpendicular distance of point pogonion from the perpendicular line drawn to the Frankfort horizontal from point nasion; *ANS-Me,* distance between points ANS and menton; *N-Me,* distance between pionts nasion and Menton; *ANS-Me/N-Me,* ratio of lower facial height to total facial height; *Ar-Go,* distance between points articulare and gonion; *S-Go,* distance between points sella and gonion; *Ar-Go/S-Go,* ratio of Ar-Go to S-Go; *U6-XP,* perpendicular distance of tip of mesial cusp of upper first molar to the X plane; *U1-XP,* perpendicular distance of incisal tip of upper incisor to the X plane; *U6-YP,* perpendicular distance of tip of mesial cusp of upper first molar to the Y plane; *L6-XiPm,* perpendicular distance of tip of mesial cusp of lower first molar to the XiPm plane; *L1-XiPm,* perpendicular distance of incisal tip of lower incisor to the XiPm plane; *L6-ZP,* perpendicular distance of tip of mesial cusp of lower first molar to the Z plane; *L1-ZP,* perpendicular distance of incisal tip of lower incisor to the Z plane.

height both increased, the mandibular plane orientation stayed relatively unchanged. These findings were similar to previous studies.[4,26,30,31,39-41]

When the skeletal parameters were evaluated, there were differences only between the 2 treatment groups and the control group. There was no statistical difference between the treatment groups (Table VII); this agrees with Cook et al.[4] On the other hand, Ricketts[5] and Bench et al[20-22] observed that cervical headgear and utility arch combination therapy caused different mandibular orthopedic responses in patients with severe maxillary protrusion in normofacial through brachyfacial patterns. According to these authors, the mandible rotates in the counterclockwise direction, resulting in closure of the lower face height. This action is called the reverse response of the lower utility arch.

The results of our study showed the extrusion of the maxillary molars in the treatment groups when compared with the control group, with no statistically significant difference between the treatment groups. The relative increase in molar extrusion was less than 1 mm, which can be considered clinically insignificant. Baumrind et al[40] also reported that the maxillary first molars were extruded by cervical headgear wear. According to them, cervical headgear treatment produced maxillary molar total extrusion on average of no more than 1 mm. Cook et al[4] and Hubbard et al[42] concluded that there was no significant extrusion in the maxillary molars when compared with their control groups after cervical headgear treatment.

The maxillary molar moved distally with mesial tipping in the treatment groups. In the control group, the maxillary first molar showed mesial displacement of 1.0 mm because of spontaneous mesial migration during the observation period. The difference between the treatment groups for the amount of distal movement was not statistically significant.

The results indicate that when the cervical headgear was worn with a 15° to 20° upward bend of the long outer bow directed above the center of resistance of the maxillary first molar (trifurcation), 12 to 14 hours a day, with a force of 450 to 500 g per side, significant distalization, mesial crown movement, and distal root tipping of molar occurred.

Many authors have mentioned the importance of placing the cervical headgear at particular angles relative to the molar's center of resistance.[5,43-46] When the outer bow of the cervical headgear was bent upward to pass over the center of resistance of the maxillary molar, the crown tipped mesially, and the root moved distally.[3,5,9,31,43-46] Many authors also showed that cervical headgear wear caused distal displacement of the maxillary first molar.[3-8,11,12,19,29,34,40,44,47,48]

In 1978, Melsen[9] compared 2 groups of patients who were treated with cervical headgear. In the first group, the extraoral bow was tilted downward, and, in the second group, the extraoral bow was tilted upward. Melsen showed that, in the group with the extraoral bow tilted upward, tooth movements in relation to the implants were considerably smaller, but no significant distal molar tipping took place.

When data for the mandibular teeth were evaluated, there was a difference between the CU group and the other 2 groups. The C group and the control group had similar changes in relation to the mandibular dental parameters. In the CU group, the mandibular first molar tipped distally with the effect of the lower utility arch, and no effective mesiodistal movement occurred. Many authors also reported distal tipping of the mandibular first molars produced by the lower utility arch.[4,5,20-22] In the control group, the mandibular molars tipped mesially with mesial movement. Similarly, in the C group, there was mesial movement with no tipping.

Another finding was the absence of vertical mandibular molar position change for the patients in the 3 groups. These findings showed that the lower utility arch was not effective in determining the vertical position of the mandibular molar. Similarly, Cook et al[4] reported that the lower utility arch did not significantly influence the vertical position of the mandibular molar and the mandibular rotational response.

In the CU group, the mandibular incisor tipped, moved lingually, and also showed intrusion. In the other 2 groups, however, the mandibular incisor moved, tipped labially, and also extruded.

Ricketts[5] and Bench et al[20-22] reported that the lower utility arch from the bioprogressive technique caused mandibular molar uprighting, and, as the mandibular molar uprights, the distalizing force is translated to the mandibular incisors through the utility arch. These teeth first intruded and then started to follow the mandibular molar distally. According to Ricketts,[5] the most efficient intrusion of the mandibular incisors is observed when the intrusive force is applied parallel to the long axis of the tooth. Therefore, a slight labial root torque (5°-10°) will free the apex of the mandibular incisors from the lingual planum, allowing their intrusion without labial flaring.

Our findings related to the mandibular incisors were similar to those of Ricketts.[5] In this study, to prevent the tipping of incisors during intrusion, the lower utility arch was prepared with 5° to 10° of labial root torque.

Cook et al[4] reported that the lower utility arch produced significiant intrusion and proclination of the mandibular incisor without significiant advancement. The difference might be due to the lack of the labial root torque on that lower utility arch design.

CONCLUSIONS

- Orthopedic cervical headgear wear produced Class II correction through maxillary orthopedic and orthodontic changes.
- The treatment groups showed significant reductions in maxillary protrusion and significant increases in the anterior descent of the PP.
- Increases in anterior face height had higher values in the treatment groups than in the control group. The treatment groups also had statistically significant rates of increase in ramus height. As a result, mandibular plane orientation was relatively unchanged.
- Cervical headgear treatment caused maxillary molar extrusion less than 1 mm compared with the eruption during growth and development. Opening rotation of the mandible was lacking in both treatment groups.
- The maxillary molars were moved distally and tipped mesially in both treatment groups.
- The lower utility arch produced mandibular incisor intrusion, retrusion, and lingual tipping. The mandibular molars tipped distally without extrusion. The lower utility arch did not appear to influence the mandibular rotational response.

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