Change in the vertical dimension of Class II Division 1 patients after use of cervical or high-pull headgear

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Introduction: The goals of this study were to compare the effects that cervical and high-pull headgear have on the vertical dimensions in Class II Division 1 patients during phase 1 treatment and to compare these effects with untreated predicted growth for the sample population. **Methods:** Pretreatment and posttreatment cephalometric radiographs of children who had undergone Class II Division 1 correction with cervical (n = 22) or high-pull headgear (n = 19) were analyzed for the measurements that describe the changes in the vertical component of growth and mandibular position. The groups were matched for age (mean, 9 ± 2.5 years), treatment time (mean, 14 months), malocclusion, and similar skeletal features. The groups were compared with each other and also with an untreated growth model. **Results:** Treatment with cervical headgear resulted in smaller increases in measurements that describe the vertical dimension than with high-pull headgear. Cervical headgear showed more favorable changes in mandibular growth that were statistically significant when compared with the untreated growth models. **Conclusions:** In this study, the cervical headgear showed more control over the vertical dimension and produced more favorable changes in mandibular position by normalizing the occlusal plane. Compared with the untreated growth model, cervical headgear worked synergistically with growth to produce more optimal changes in mandibular position. (Am J Orthod Dentofacial Orthop 2016;150:771-81)

The use of headgear dates back to 1892 when William Kingsley advocated the use of extraoral anchorage to obtain a Class I molar relationship.[1] It was not until the 1950s that the cervical headgear of Kloehn[2] came into common use. In 1957, Ricketts[3,4] showed downward and forward rotation of the occlusal plane, whereas the palatal plane and the maxillary complex rotated in a clockwise direction. In his follow-up article on cervical headgear, Ricketts[5] stated that cervical headgear controls the extrusion of the maxillary molars. The soft tissue change was also favorable, with the upper lip moving back with the maxillary complex and therefore preventing excess gingival display in the anterior. Contrary to what was shown by Kloehn[2] and Ricketts,[3-5] some clinicians doubt the efficacy of cervical headgear. The force that the cervical headgear places on the dentition can result in extrusion of the maxillary molars. Others have stated that extrusion of the maxillary molars leads to downward and backward rotation of the mandible to accommodate the maxillary teeth, resulting in worsening of the facial profile. Opponents of cervical headgear have also claimed to see severe relapse of Class II patients, second molar impactions, ectopic eruption of second molars, overextrusion of maxillary

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incisors, and torque issues in both maxillary and mandibular incisors, which have been called the "Kloehn reaction."[6]

Root[7] and Watson[8], using high-pull headgear combined with the J-hook for controlling vertical dimensions successfully demonstrated vertical control of molars with 600 to 1000 g of force of the headgear worn 18 to 22 hours a day. The high-pull headgear was set up with a short outer bow with the line of action going through the center of resistance of the maxillary first molar.

The implant study of Bjork and Skieller[9] showed that growth of the maxilla is in downward and forward directions, and also displays forward rotation resulting in an increased vertical height at the posterior molars. This increase in height at the maxillary molars causes interference with the mandibular molars and forward positioning of the mandible. Together, these actions result in flattening of the occlusal plane.[10] It has even been suggested that the increase in the vertical dimension in the posterior dentition and the forward repositioning of the mandible result in a stimulus for the condyle to grow to allow the mandible to function in a more functional position.[11] When there are changes in the structure and therefore the function of the oral system, the growth of the condyle and the mandible is affected. This has been shown in studies where occlusal function was altered in monkeys by placing a piece of plastic between the premolars. This altered occlusal function created an artificial axis point and changed the growth of the mandible.[12] Evidence in humans that the occlusal relationship alters growth and development was shown in a study by Fushima et al,[10] who compared 50 cephalometric radiographs of women with a Class II Division 1 malocclusion with radiographs of a similar group of women who had Class I occlusion. They found a correlation between the cant of the posterior occlusal plane and the inclination of the maxillary molars. The steeper the posterior occlusal plane, the more distally inclined were the molars. Further evidence can be found in a 2008 study by Tanaka and Sato.[13] They gathered cephalometric radiographs from 102 untreated subjects at 3 times. These subjects were split into groups based on their malocclusion classification of Class I, Class II, or Class III. They also split the conventional occlusal plane into anterior and posterior segments just as the previously mentioned study did. They found that in all 3 groups the occlusal plane tended to become more horizontal with growth. No significant difference between the groups was seen when the angle of the anterior occlusal plane or the conventional occlusal plane to Frankfort horizontal was measured. They did find significant differences when the posterior occlusal plane was measured from the Frankfort horizontal. Subjects with Class II malocclusions had steeper posterior occlusal planes than did their Class I and Class III counterparts. This shows that the cant of the posterior occlusal plane is closely related to the development of a Class II, Class I, or Class III malocclusion.[13] Some authors have suggested in treatment of Class II malocclusions that it is best to use techniques that work with development to encourage correct mandibular adaptation and growth. Because of the correlation between high-angle Class II malocclusions and a steep posterior occlusal plane and a short vertical height at the maxillary second molar, the ideal treatment would be to level the occlusal plane and extrude the maxillary molars.[14]

The goal of this study was to compare the effects of occlusal plane control caused by cervical and high-pull headgear on the vertical dimensions (face typology and mandibular growth direction) in Class II Division 1 patients with hyperdivergent face typology. There were 3 hypotheses tested: (1) there is no statistically significant mean difference in vertical dimension changes between cervical headgear and high-pull headgear during phase 1 treatment of growing skeletal Class II subjects, (2) there is no statistically significant mean difference in vertical dimension changes after phase 1 treatment with cervical headgear compared with normal growth measurements, and (3) there is no statistically significant mean difference in vertical dimension changes after phase 1 treatment with high-pull headgear compared with normal growth measurements.

MATERIAL AND METHODS

This study was approved by the Institutional Review Board (number 2013-1148) at the University of Illinois at Chicago. We randomly recruited 80 patients from 2 distinct orthodontic practices having records before treatment (T1) and at the end of phase 1 (T2). One practice used only cervical headgear and the other used high-pull headgear. After our exclusion criteria were applied, the sample for this study included 41 white subjects with a Class II Division 1 malocclusion who received treatment with cervical ($n = 22$) or high-pull ($n = 19$) headgear and no other appliances. The subjects had a facial convexity of 4 mm or more, a facial axis of 90° or less, and a Ricketts total facial height of 57° or more. Subjects were excluded if they had any other occlusion, missing records, or craniofacial anomalies. The 19 subjects who received treatment with high-pull headgear were on average 9.4 ± 2.5 years of age. They were instructed to wear the appliance full time (at least 10-18 hours daily) with 550 to 600 g of force per side with the outer bow parallel to the inner bow and the end positioned anterior to the first molar.[8,15,16] The 22 subjects who received treatment with cervical headgear were 8.6 + 2.5 years at the start of treatment and were instructed to wear their headgear 8 to 10 hours per day with 450 g of force per side with the outer bow angled up 30° from the inner bow. The end of the outer bow was positioned posterior to the first molar.[4,5] The average headgear wear in both groups was 1 year (10 ± 2 month) as phase 1 treatment.

T1 and T2 radiographs of the subjects who had undergone Class II Division 1 correction with cervical or high-pull headgear were scanned and uploaded into Dolphin software (version 11.0; Dolphin Imaging and Management Solutions, Chatsworth, Calif) and calibrated using the ruler in the radiograph. The transfer structures method by means of fiducials and anatomic best-fit structures was used to ensure the most accurate tracing possible and minimize landmark identification errors. Once all structures were transferred successfully, each radiograph was oriented so that the Frankfort horizontal line was perpendicular to the true vertical. This was done for all subjects at T1 and T2. Fifteen cephalometric variables were analyzed as part of the study.

Statistical analysis

The principal investigator (E.D.Z.) was tested for intrareliability by tracing 10 cephalometric radiographs as described previously. The investigator then traced the same 10 radiographs 2 weeks later. All 15 variables were tested for reliability. Interreliability was determined by comparing variables from the 10 radiographs traced by the investigator to the same variables from radiographs traced by a faculty member (B.K.) of the Department of Orthodontics at the University of Illinois at Chicago. Intraclass correlations were estimated to determine the intrarater and interrater reliabilities of each variable in the study method. The data analysis is reported using the Student paired-samples *t* test and the independent *t* test. Because the Shapiro-Wilk normality test results indicated that the raw data for a few variables were not distributed on a normal curve, corresponding nonparametric tests were run for those variables as well. Similar results were found with parametric and nonparametric tests, so the parametric data analyses were reported for all variables. Statistical significance was set at 0.05.

Data analysis was done with SPSS Statistics for Windows (version 22; IBM, Armonk, NY).

RESULTS

Descriptive statistics were computed for all variables. The Shapiro-Wilk test showed that most variables had a normal distribution. At T1, all 15 variables were tested using the independent-samples *t* test. The only variable that showed a significant difference between the 2 treatment groups was ramus height (Ar-Go), with the high-pull headgear group having a 3.18-mm higher mean ($P = 0.021$). One variable, facial angle (FH-NPo), displayed a borderline statistically significant mean difference at $P = 0.055$. The high-pull group had on average a 1.55° higher facial angle. For the most part, the independent *t* tests showed similarity between the cervical headgear group and the high-pull headgear group at T1 (Table I).

The paired-samples *t* test was used to compare the mean difference between T1 and T2 for each variable in each treatment group. In the cervical headgear group, 11 of 15 variables showed significant mean differences. Facial axis, facial angle, posterior facial height, posterior ramus, palatal plane inclination, distance from the maxillary first molar to the sella-nasion line distance from the maxillary first molar to pterygoid vertical (PTV), and extrusion of the maxillary first molar to the palatal plane all increased (Fig 1). At the same time, convexity, inclination of the occlusal plane, and Frankfort-mandibular plane angle decreased (Table II). In the high-pull headgear group, the variables that showed statistically significant changes included the decrease in palatal plane inclination, the increase in posterior facial height, the extrusion of the maxillary first molar to the palatal plane, and the extrusion of the mandibular first molar to the mandibular plane (Fig 2; Table III).

To assess the effect of growth on the variables after phase 1 treatment, the variables of both groups at T2 were compared with the values generated from the growth predictions of Ricketts, programmed into the Dolphin software (Fig 3, Table IV). For the cervical group, the variables with statistically significant changes from T1 to T2 that could be attributed to normal growth and not to the cervical headgear included the increases in facial axis, ramus height, and distance from the maxillary first molar to PTV (Fig 4; Table V). The variables with statistically significant changes from T1 to T2 and at the same time that displayed greater changes than would be expected from normal growth included the increase in facial angle and the decrease in the angle of the occlusal plane to the Frankfort horizontal and the mandibular plane angle. Interestingly, the statistically significant decrease in convexity from T1 to T2 was less than would have been expected if it was the result of the subjects' normal growth. The 2 variables that did not show statistical differences from T1 to T2 and were not statistically different from normal growth at T2 were maxillary depth and mandibular arc. Similar comparisons were made for the group treated with high-pull headgear, and only the increase in the distance from the maxillary first molar to PTV was significantly less than would have been expected with normal growth (Fig 5).

Table I. Independent-samples *t* test between the cervical and high-pull headgear groups before treatment

	Group					
	Cervical, n = 22		High pull, n = 19			
Variable	Mean	SD	Mean	SD	Mean difference	P value
Maxillary depth (FH-NA) (°)	92.16	3.45	93.09	2.48	−0.93	0.334
Convexity (A-NPo) (mm)	6.90	2.88	6.40	2.08	0.50	0.530
Facial axis (NaBa-PtGn) (°)	83.94	3.17	84.77	2.85	−0.83	0.385
Facial angle (FH-NPo) (°)	84.93	2.62	86.48	2.36	−1.55	0.055*
Facial height (NaBa-XiPm) (°)	63.55	4.08	63.87	3.29	−0.33	0.78
Mandibular arc (°)	28.50	4.68	27.58	5.14	0.92	0.553
Occlusal plane (OP-FH) (°)	10.22	2.42	9.03	3.66	1.19	0.221
FMA (MP-FH) (°)	29.49	3.69	28.51	3.01	0.98	0.361
U6 to SN (°)	64.69	4.60	67.11	3.29	−2.42	0.063
Ramus height (Ar-Go) (mm)	36.51	4.31	39.69	4.17	−3.18	0.021†
Palatal plane inclination ANS-PNS to FH) (°)	2.76	2.81	3.73	3.98	−0.97	0.369
Posterior facial height (Go-CF) (mm)	54.05	5.23	56.44	4.68	−2.39	0.134
U6 to PTV (mm)	12.62	3.22	13.03	3.26	−0.40	0.693
U6 to PP (mm)	17.80	1.80	18.80	2.35	−1.00	0.132
L6 to MP (mm)	31.98	2.42	31.60	3.15	0.38	0.668

PTV, Pterygoid vertical; *PP*, palatal plane; *MP*, mandibular plane.
*Borderline significance; †statistically significant at $P < 0.05$.

DISCUSSION

There is a lack of consistent evidence that describes the differences between the effects of cervical and high-pull headgear on the dental and skeletal growth of a child. This is especially true for a child with the tendency toward increased anterior facial height and possible clockwise rotation. The purposes of this study were to determine and compare the outcomes of treatment between cervical and high-pull headgear in growing children with vertical growth tendencies to better understand how each type of headgear works in controlling the vertical dimension. We also attempted to make comparisons with predicted normal growth as the control group.

The results of this study demonstrate that facial profiles in the cervical group improved by decreasing facial convexity and the angle of the mandibular plane to the Frankfort horizontal plane, and simultaneously increasing the facial axis and its angle. The result of these changes is protrusion of the chin. These results indicate that in our sample the cervical headgear produced a favorable change in the direction of facial growth from vertical to more horizontal.

During the study, the facial angle increased by 1.82°, indicating that the chin came forward. The expected amount of change over the 3-year growth period from ages 9 to 12 years is 1°.[3,5] This indicates that in this study the treatment with cervical headgear resulted in a significant increase of the facial angle compared with the controls.

This was more than would be expected from growth alone. Our results indicate that the cervical headgear aids in flattening the occlusal plane, which is a critical component to normal growth and development of the face.[9] This flattening of the occlusal plane was significantly more than expected from normal growth. The finding agrees with normal changes in mandibular plane growth, which is expected to decrease by 1° per every 3 years.[3,5] This finding is also supported by other authors who reported flattening of the occlusal plane while increasing the angle of the palatal plane to the Frankfort horizontal.[4,16,17] The flattening of the occlusal plane has been reported to be stable over time.[15]

The distance of the maxillary first molar to the palatal plane increased by 1.14 mm during treatment (maxillary first molar extruded). Although the proponents of high-pull headgear use claim that it holds the position of the maxillary molar, this was not the case in our study.[18] Also, the distance of the mandibular first molar to the mandibular plane increased by 1.14 mm from T1 to T2, supporting the findings of Burke and Jacobson,[17] who observed extrusion of the mandibular first molars in their high-pull sample but not in the cervical sample. Posterior facial height increased but not significantly and based on the growth prediction of Ricketts,[3,5] this change in posterior facial height was consistent with normal growth.

The palatal plane decreased in steepness by 1.29°. One explanation for this flattening of the palatal

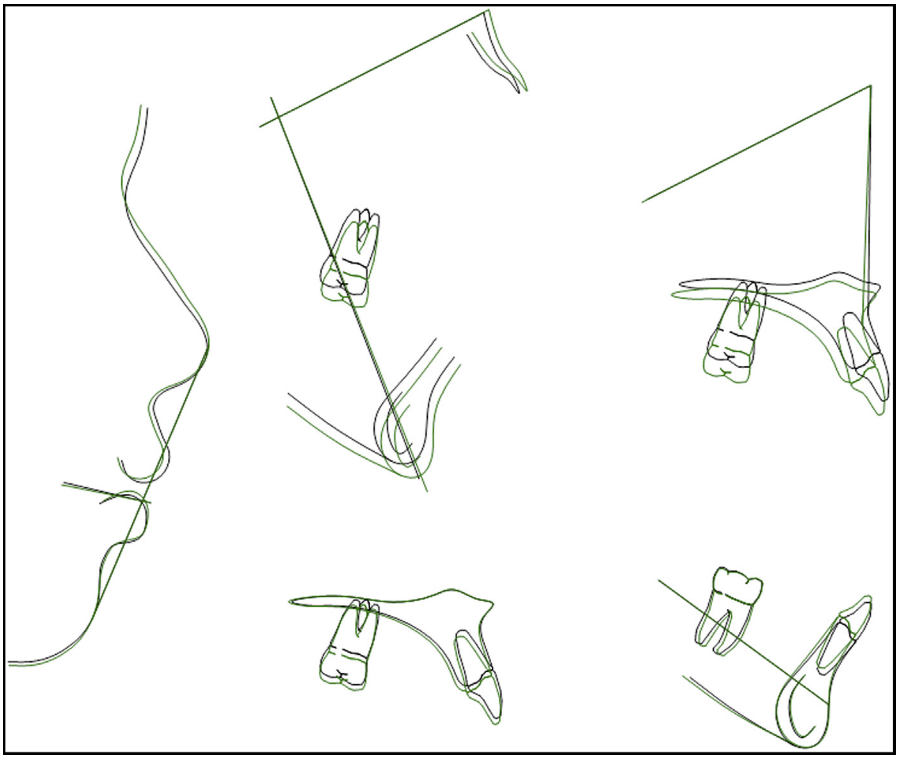

Fig 1. Average tracing composite at T1 (*black*) vs T2 (*green*) with cervical headgear.

Table II. Paired-samples *t* test of cervical headgear variables before and after phase 1 treatment

			95% CI			
Variable	*Mea difference*	*SD*	*Lower*	*Upper*	*df*	P *value*
Maxillary depth (FH-NA) (°)	−0.32	2.10	−1.25	0.61	21	0.485
Convexity (A-NPo) (mm)	−1.84	1.94	−2.70	−0.98	21	0.000*
Facial axis (NaBa-PtGn) (°)	1.04	1.74	0.26	1.81	21	0.011*
Facial angle (FH-NPo) (°)	1.82	1.70	1.06	2.57	21	0.000*
Facial height (°)	−0.52	1.79	−1.31	0.27	21	0.184
Mandibular arc (°)	0.70	3.73	−0.96	2.35	21	0.391
Occlusal plane (OP-FH) (°)	−2.18	2.47	−3.27	−1.09	21	0.000*
FMA (MP-FH) (°)	−1.13	1.69	−1.88	−0.38	21	0.005*
U6 to SN (°)	3.20	4.66	1.14	5.27	21	0.004*
Ramus height (Ar-Go) (mm)	2.53	2.68	1.34	3.72	21	0.000*
Palatal plane inclination (ANS-PNS to FH) (°)	0.94	1.90	0.09	1.78	21	0.031*
Posterior facial height (Go-CF) (mm)	2.20	2.70	1.00	3.39	21	0.001*
U6 to PTV (mm)	1.64	2.82	0.39	2.89	21	0.013*
U6 to PP (mm)	1.73	1.32	1.15	2.32	21	0.000*
L6 to MP (mm)	−0.65	2.25	−1.65	0.35	21	0.190

PTV, Pterygoid vertical; *PP*, palatal plane; *MP*, mandibular plane.
*Statistically significant at $P < 0.05$.

plane is that high-pull headgear causes the maxillary complex to rotate counterclockwise around a center of rotation in the anterior portion of the maxilla, whereas cervical headgear causes the maxilla to rotate clockwise around a center of rotation in the posterior portion of the maxilla. This is supported by Gautam et al,[19] who used the finite element model of the stresses applied to dry skulls. The other 11 variables showed no significant differences between T1 and T2.

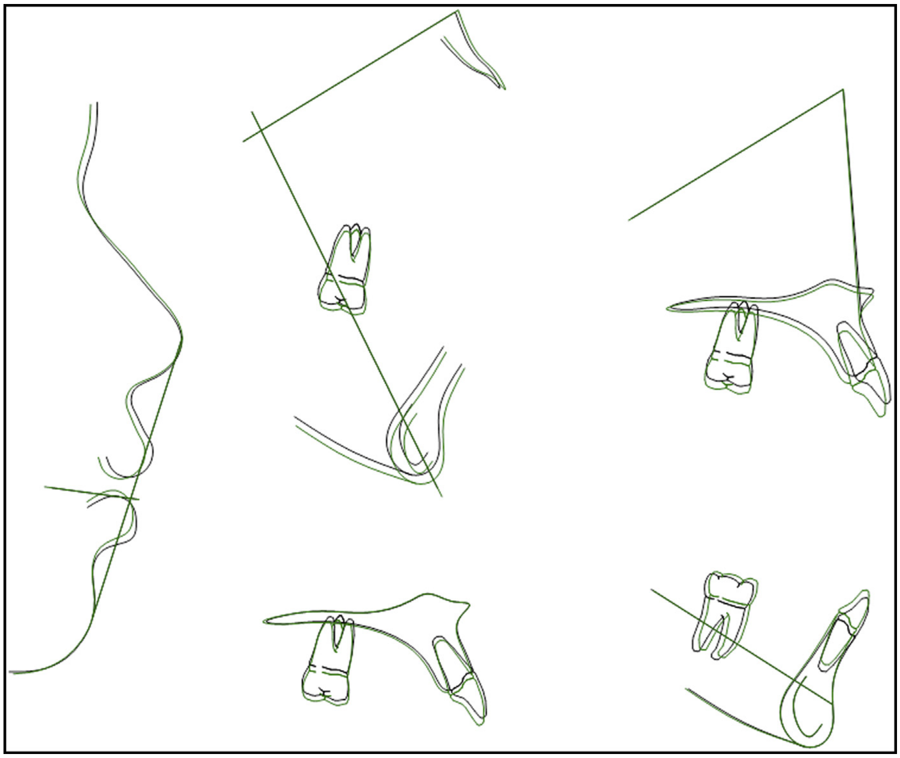

Fig 2. Average tracing composite at T1 (*black*) vs T2 (*green*) with high-pull headgear.

Table III. Paired-samples *t* test between high-pull variables before and after phase 1 treatment

Variable	Mean difference	SD	95% CI Lower	95% CI Upper	df	P value
Maxillary depth (FH-NA) (°)	−0.54	1.54	−1.28	0.21	18	0.147
Convexity (A-NPo) (mm)	−0.51	1.41	−1.19	0.18	18	0.136
Facial axis (NaBa-PtGn) (°)	0.00	1.14	−0.55	0.55	18	1.000
Facial angle (FH-NPo) (°)	0.21	1.10	−0.32	0.74	18	0.426
Facial height (mm)	−0.23	1.35	−0.88	0.42	18	0.465
Mandibular arc (°)	0.85	2.78	−0.49	2.19	18	0.198
Occlusal plane (OP-FH) (°)	0.28	2.28	−0.81	1.38	18	0.593
FMA (MP-FH) (°)	−0.08	1.89	−1.00	0.82	18	0.838
U6 to SN (°)	1.33	3.30	−0.26	2.92	18	0.096
Ramus height (Ar-Go) (mm)	0.95	2.81	−0.40	2.31	18	0.156
Palatal plane inclination ANS-PNS to FH) (°)	−1.30	1.71	−2.12	−0.47	18	0.004*
Posterior facial height (Go-CF) (mm)	1.74	2.00	0.77	2.70	18	0.001*
U6 to PTV (mm)	0.37	1.93	−0.55	1.30	18	0.409
U6 to PP (mm)	1.14	1.01	0.64	1.65	18	0.000*
L6 to MP (mm)	1.14	1.50	0.42	1.86	18	0.004*

PTV, Pterygoid vertical; *PP*, palatal plane; *MP*, mandibular plane.
*Statistically significant at $P < 0.05$.

Some parameters did not change significantly from normal growth. Even though the distance between the maxillary 6 teeth and the palatal plane increased, indicating that cervical headgear extruded the maxillary molars, it was expected that extrusion of the maxillary first molars may have caused a clockwise rotation of the mandible.[20] However, in our subjects, extrusion of the molars did not adversely affect the vertical position

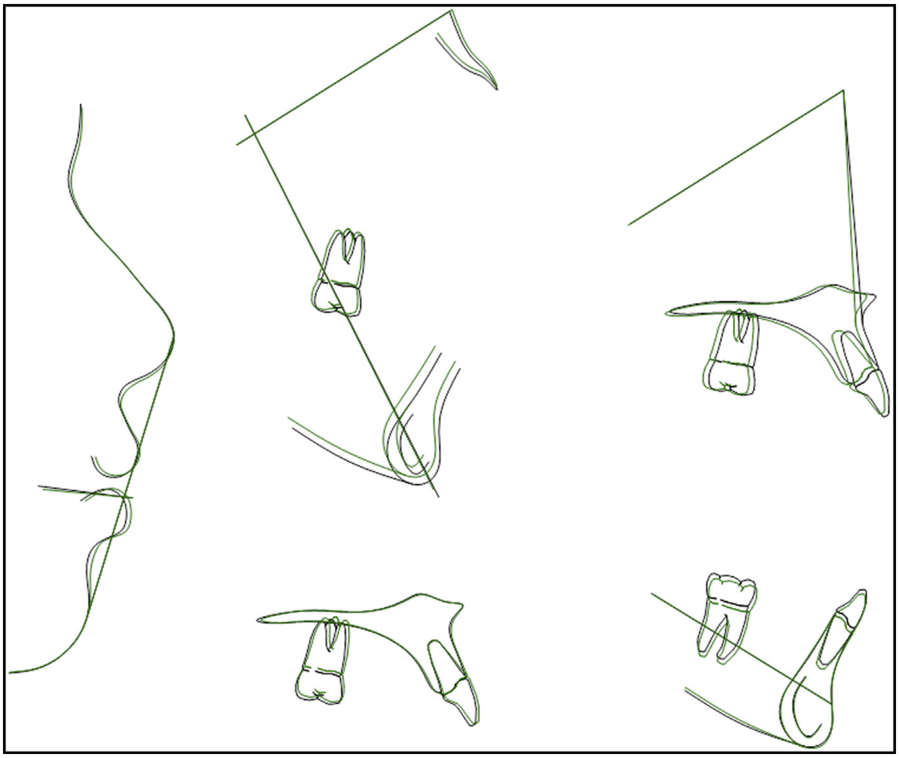

Fig 3. Average tracing composite at T2 between cervical (*green*) and high-pull (*black*) headgear.

Table IV. Independent *t* test between the treatment groups at T2 and the untreated predicted growth

Group	Variable	Mean difference	SD	95% CI Lower	95% CI Upper	df	P value
Cervical	Convexity	−1.83	2.61	−2.99	−0.67	21	0.004*
	Facial angle	1.53	2.31	0.50	2.55	21	0.005*
	Occlusal plane	0.66	2.03	−3.66	−1.86	21	0.000*
	FMA	−1.88	3.60	−3.48	−0.29	21	0.023*
High-pull	U6 to PTV	−2.46	4.39	−4.58	−0.34	18	0.025*

*Statistically significant at $P < 0.05$.

of the mandible; on the contrary, it produced forward movement (Fig 4). This clinical outcome agrees with the study of Burke and Jacobson,[17] who postulated that extrusion of the maxillary molars was compensated by the relative positional stability of the mandibular molars. A similar observation was noted in our study, where the distance of the mesiobuccal cusps of the mandibular first molars to the mandibular plane did not change significantly. As previously published, extrusion of the maxillary 6 teeth along with the musculature helped to hold the mandibular first molars in position.[17,21]

Both the changes in total facial height from T1 to T2 and the values at T2 were not significantly different from those from the Dolphin Imaging growth prediction. This is a significant finding; previous studies have recommended that cervical headgear should not be used in vertical growers because of its tendency to increase anterior facial height. However, these results do not support this recommendation, since the use of cervical headgear did not increase facial height.

In the comparison of posttreatment changes between cervical and high-pull headgear, 6 of 15 variables showed statistical significance when the mean changes from T1 to T2 were compared. They included convexity, facial axis, facial angle, occlusal plane inclination, palatal plane inclination, and vertical distance of the mandibular first molars to the mandibular plane.

Facial convexity is 1 parameter that indicates a Class II skeletal relationship with a retrusive mandible. When

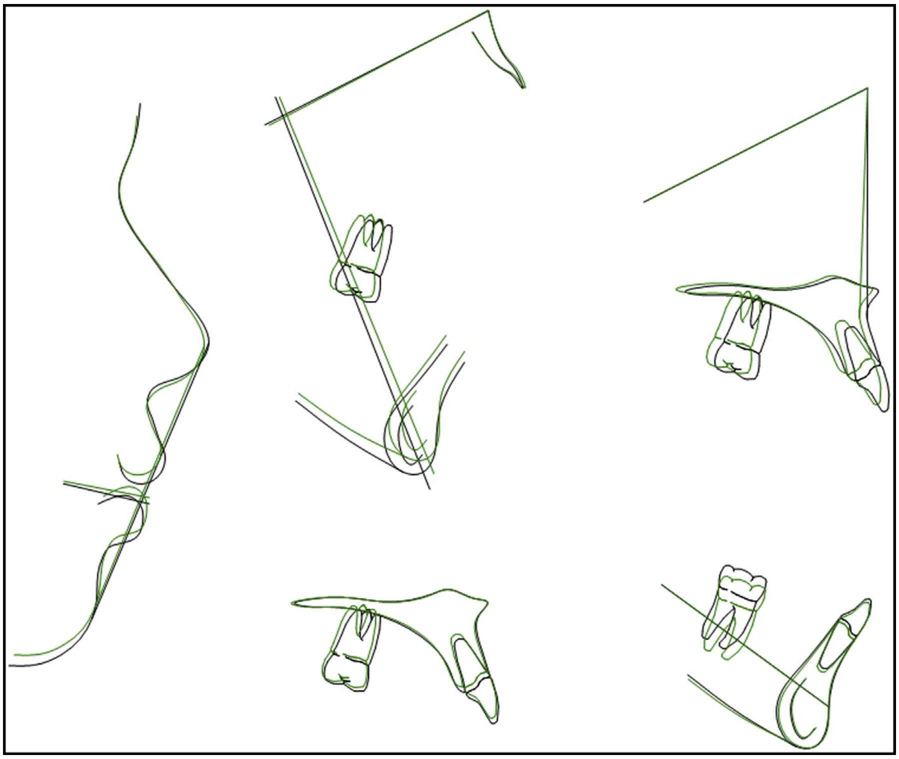

Fig 4. Average tracing composite at T2 (*green*) vs the visual treatment objective (*black*) in the cervical headgear group.

Table V. Changes from T1 to T2 in the cervical group compared with changes from T1 to T2 in the high-pull group

	Group							
	Cervical, n = 22		High-pull, n = 19			95% CI		
Variable	Mean	SD	Mean	SD	Mean difference	Lower	Upper	P value
D Maxillary depth (FH-NA) (°)	−0.32	2.10	−0.54	1.54	0.22	−0.96	1.40	0.710
D Convexity (A-NPo) (mm)	−1.84	1.94	−0.51	1.41	−1.34	−2.42	−0.25	0.017*
D Facial axis (NaBa-PtGn) (°)	1.04	1.74	0.00	1.14	1.04	0.089	1.98	0.033*
D Facial angle (FH-NPo) (°)	1.82	1.70	0.21	1.10	1.61	0.69	2.53	0.001*
D Facial height (NaBa-XiPm) (°)	−0.52	1.79	−0.23	1.35	−0.29	−1.30	0.72	0.565
D Mandibular arc (°)	0.70	3.73	0.85	2.78	−0.16	−2.26	1.95	0.881
D Occlusal plane (OP-FH) (°)	−2.18	2.47	0.28	2.28	−2.47	−3.97	−0.96	0.002*
D FMA (MP-FH) (°)	−1.13	1.69	−0.09	1.89	−1.04	−2.17	0.92	0.074
D U6 to SN (°)	3.20	4.66	1.33	3.30	1.87	−0.72	4.47	0.152
D Ramus height (Ar-Go) (mm)	2.53	2.68	0.95	2.81	1.58	−0.15	3.31	0.073
D Palatal plane inclination ANS-PNS to FH) (°)	0.94	1.90	−1.30	1.71	2.23	1.08	3.38	0.000*
D Posterior facial height (Go-CF) (mm)	2.20	2.70	1.74	2.00	0.46	−1.06	1.98	0.546
D U6 to PTV (mm)	1.64	2.82	0.37	1.93	1.26	−0.29	2.81	0.107
D U6 to PP (mm)	1.73	1.32	1.14	1.04	0.59	−0.17	1.35	0.125
D L6 to MP (mm)	−0.65	2.25	1.14	1.50	−1.79	−3.02	−0.60	0.005*

D, Difference.
*Statistically significant at $P < 0.05$.

the 2 headgear managements were compared, the reduction in convexity was greater for the cervical group.

The facial axis indicates the growth direction of the chin. A smaller-than-normal facial axis indicates a vertical grower, and a larger-than-normal facial axis indicates a horizontal grower. Without intervention, the facial axis of patients diagnosed with Class II Division 1 malocclusion was not expected to change much with

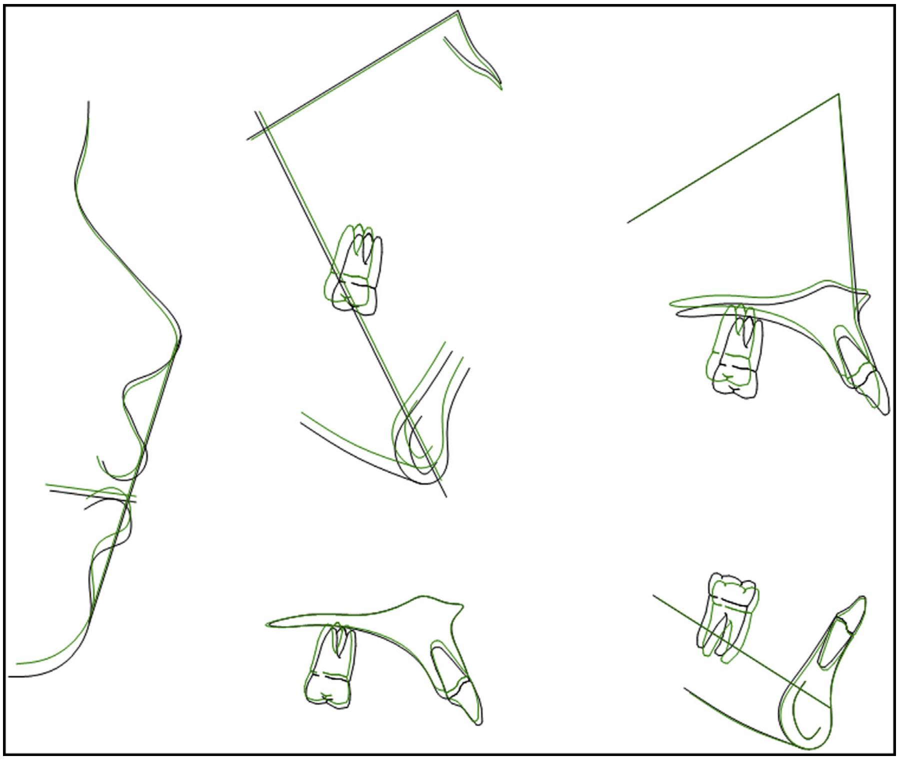

Fig 5. Average tracing composite at T2 (*green*) vs the visual treatment objective (*black*) in the high-pull headgear group.

growth. This was consistent with the outcome in the high-pull group, whereas the facial axis increased in the group treated with cervical headgear. These results indicate that cervical headgear facilitates the reduction in vertical growth in the vertical growers.

Changes in the facial angles from T1 to T2 were significantly different between the 2 groups. Cervical headgear produced a much greater forward movement of pogonion when compared with high-pull headgear.

The main significant changes were found in the occlusal plane. Cervical headgear flattened the occlusal plane. This is especially helpful in a growing child, since Class II malocclusions are strongly related to the steepness of the posterior occlusal plane.[10,11] By flattening the occlusal plane and providing a fulcrum at the first molar,[12] the cervical headgear acts to encourage growth at the condyle.[22]

We found that cervical headgear produced flattening of the occlusal plane as well as clockwise movement of the palatal plane (T1, 2.75°, to T2, 3.69°), whereas the opposite happened in the high-pull headgear group (T1, 3.73° to T2, 2.43°). This is consistent with findings from other studies.[4,18,19] Kuhn[23] illustrated and explained the biomechanical effects of the various types of headgear as well as the relationship of each type of facebow (long and short) and the direction of pull in relation to the center of resistance of the maxilla and the first molars. He also explained most of the effects that we found, particularly those that were related to the leveling of the occlusal plane.

Finally, the last variable that displayed a significant difference from T1 to T2 between the groups was the distance between the mandibular first molars and the mandibular plane. The mandibular plane angle decreased by an average of 1.13° over the 2 years of treatment. In untreated normal growth, the mandibular plane is expected to decrease at a rate of 1 degree every 3 years.[3,24,26] The findings in this study suggested more closing of mandibular plane then the untreated normal growth in the cervical headgear group, which mainly attributed to its indirect effect to the mandibular first molars. Cervical headgear intruded, whereas high-pull headgear allowed the mandibular first molars to extrude by almost 1.5 mm. The results may explain why the high-pull headgear was unable to produce favorable changes in the Frankfort-mandibular plane angle, facial axis, and facial angle compared with cervical headgear. Unlike in the cervical headgear group, the extrusion of the mandibular molars seems to prevent any favorable mandibular changes in the high-pull headgear group

(Fig 3). One possible explanation for the difference in action of the 2 types of headgear is their direction of pull through the center of resistance of the maxilla. The center of resistance of the maxilla is located approximately at the pterygomaxillary fissure when cervical headgear is used, whereas during wear of high-pull headgear, it is located farther anteriorly at the premaxilla, but this article failed to mention the type of the outer bow used.[19]

The success that many practitioners have had with cervical headgear may be due to its ability to produce forces on the dentition that mimic natural growth. The appliance can cause an increase in height at the maxillary molar much like what happens during forward rotation of maxilla. This increase in height produces interference and subsequent movement of the mandible forward to maintain the occlusal contacts.[9] The long outer bow headgear, as proposed by Ricketts[4] and Kloehn,[2] has been shown to exert a distal and upward force on the maxilla. One theory of headgear biomechanics has been that these forces would inhibit extrusion of the maxillary first molars because of the line of force of action that is most of the time located at the center of resistance of the maxillary complex and therefore allows full expression of condylar growth.[27] Any clockwise rotation of the mandible is avoided[20]; this is imperative in children exhibiting a medium to high mandibular plane angle.[28] On the contrary, even though the direction of force of the high-pull headgear is predominantly vertical, in this study we found that for most subjects, the line of force was applied below the center of resistance of the maxillary complex, thus producing counterclockwise rotation of the palatal plane with a minimal horizontal component to distalize the maxilla when compared with the cervical headgear.[23,29] High-pull headgear also tends to produce a slower correction of the Class II malocclusion and does little to prevent vertical facial growth. On the other hand, cervical headgear is much more effective in correcting Class II malocclusions. Most of the negative effects of its use can be avoided by decreasing the extraoral force and prescribing nighttime wear only. This approach gives the occlusion and musculature time to rebound and recover.[21]

The major strengths of this study include its strict inclusion criteria that narrowed the participants to only those with a vertical growth pattern, and its analysis of the facial angle and facial axis as the additional parameters of headgear efficiency, which were rarely analyzed in previous studies.

The main limitation of this study was that it did not account for the patients' compliance. It was unknown what the true duration of the headgear wear was each night. During the treatment, both headgears had effects on the craniofacial growth of the subjects; however, each headgear affected growth differently. These results suggest that the cervical headgear has more control over skeletal vertical measurements than does the high-pull headgear in treating a Class II malocclusion with hyperdivergent facial type. The other major limitation of this study was its untreated control group. The group was generated using a computer growth prediction model (visual treatment objective), which also has its own limitations despite its reliability as reported previously.[24-26] A future study with matched samples from the American Association of Orthodontists Foundation Legacy longitudinal data collection may provide a more accurate control group and subsequently the interpretation of treatment effects on normal growth.[30]

CONCLUSIONS

In this study, the cervical headgear showed more control over the vertical dimension and produced more favorable changes (closer to normal growth) in mandibular position by normalizing the occlusal plane particularly in response to controlling the maxillary and mandibular molars.

When compared with the untreated growth model, the cervical headgear worked synergistically with growth to produce more optimal changes in mandibular position than did the high-pull headgear.

This study demonstrated the following.

1. There is a statistically significant mean difference in vertical dimension changes between cervical headgear and high-pull headgear during phase 1 treatment of growing skeletal Class II subjects (reduction of vertical dimensions in the cervical headgear group) except for the variable ramus height.
2. There is a statistically significant mean difference in vertical dimension changes after phase 1 treatment with cervical headgear when compared with normal growth measurements for convexity, facial angle, occlusal plane, and Frankfort-mandibular plane angle (improvement of those variables closer to the normal group).
3. There is no statistically significant mean difference in any variable measuring vertical changes after phase 1 treatment with high-pull headgear when compared with normal growth measurements.

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