Comparison of cephalometric changes in Class II growing patients with increased vertical dimension after high-pull and cervical headgear treatment

S. Sambataro[1], O. Rossi[2], S. Bocchieri[2], R. Fastuca[3], N. Oppermann[4], L. Levrini[5], M. Cicciù[1], A. Caprioglio[6]

[1]Department of Biomedical and Dental Sciences and Morphological and Functional Imaging, University of Messina, Messina, Italy
[2]Department of Medicine and Surgery, Section of Orthodontics, University of Insubria, Varese-Como, Italy
[3]Private Practice, Varese, Italy
[4]Department of Orthodontics, University of Illinois at Chicago, Chicago, USA
[5]Department of Human Sciences, Innovation and Territory, University of Insubria, Varese-Como, Italy
[6]Department of Biomedical, Surgical and Dental Sciences, University of Milan, Italy - Fondazione IRCCS Cà Granda, Ospedale Maggiore Policlinico, Milan, Italy

e-mail: salvo.bocchieri@gmail.com

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Abstract

Aim The aim of the present study was to evaluate the cephalometric changes in growing Class II patients with increased vertical dimension treated with cervical or high-pull headgear, by using an untreated control group with similar skeletal characteristics.

Materials and methods From the initial sample, 56 patients satisfied the inclusion and exclusion criteria; 20 patients were treated with cervical headgear (CHG), 15 with high-pull headgear (HHG), and 21 were not treated (CG). Cephalograms were available for each subject at baseline (T1) and after treatment/observation time (T2) for the three groups. A total of 17 measurements were taken on the lateral head films. Group comparison among CHG, HHG and CG was done using ANOVA test.

Results In the CHG group, 10 measurements presented significant T1-T2 modifications, while in the HHG only 5. The greatest reduction of Ba-N-A is observed in CHG when compared to HHG. The average reduction of convexity and overjet is greatest in CHG, followed by HHG and then CG. The greatest mean difference of U6 to L6 distance is observed in CHG.

Conclusions In Class II high-angle growing patients, cervical headgear seems to be preferred in the correction of maxillary protrusion, molar relationship and increased anterior facial height. Extrusion of the upper molar may favour forward repositioning of the mandible and clockwise rotation in Class II patients with increased vertical dimension.

KEYWORDS Class II malocclusion, Headgear, Increased vertical dimension.

Introduction

The headgear dates back to 1892 when William Kingsley advocated the use of a cranial support for the correction of maxillary protrusion and Class II molar relationship [Kloehn, 1953; Ricketts, 1979; Zervas et al., 2016]. The studies of Bjork on implants displayed that maxillary growth occurs from the cranial base in the downward and forward direction. The extraoral force is transmitted in a posterior and superior direction to the teeth and the maxilla and compresses the circummaxillary sutures, limiting or redirecting the maxillary growth by changing the pattern of bone apposition. Furthermore, the extraoral force also seems to influence the forward growth of the mandible [Poulton, 1967; Bjork and Skieller, 1972; Proffitt et al., 2000]. Ricketts clearly showed that naturally the maxilla grows downward parallel to itself 1 mm per year when Ba-Nasion at Nasion is used as superimposition reference. It has also been demonstrated that the Ba-N-A angle remains unchanged with growth. As a consequence, any change that occur to this value is due to the treatment [Ricketts, 1975; Ricketts 1981]. Different orthopaedic approaches were proposed concerning treatment plan and mechanics according to the individual skeletal pattern [Creekmore, 1967]. The control of vertical undesired effects has become of major importance in patients with high-angle growth tendencies [Strajnic et al., 2008]. Based on the ''wedge type effect'' principle, extraction or intrusion of posterior teeth might allow the mandible to hinge closed [Strajnic et al., 2008]. For this reason, an extrusive force on the upper molars might produce elongation of these teeth, resulting in undesirable effects in hyperdivergent patients, such as mandibular plane post-orientation and bite opening to accommodate teeth extrusion, with a consequent worsening of the facial profile [Poulton, 1967; Creekmore, 1967; Melsen, 1978; Merrifield and Cross, 1970]. This hypothesis is based on theoretical considerations [Creekmore, 1967; Williams et al., 2000] and practical findings [Williams et al., 2000; Barton, 1972; Gould, 1957; Wieslander, 1974]. For these adverse effects, high-pull headgear might be more indicated to prevent extrusion of the maxillary molars and mandible opening rotation in patients with increased vertical dimension [Poulton, 1967; Creekmore, 1967; Merrifield, 1970]. On the contrary, Kloehn [1953], Ricketts [1979] and Baumirind [1981] acknowledged the downward pull to improve Class II hyperdivergent patients, and the cervical traction is the most effective of the two types of headgears. The effects of cervical traction on the craniofacial complex has long been studied [Wieslander, 1974] and Class II hyperdivergent patients seems to benefit from the cervical headgear, showing significant mandible counter-clockwise rotation and maxilla clockwise rotation and distal displacement [Sambataro, 2017]. The cervical headgear seems to work synergistically with growth by levelling the occlusal plane, which becomes more horizontal after extrusion of maxillary molars [Zervas et al., 2016; Sambataro, 2020]. The occlusal plane seems to represent the key point of changes in mandibular position and of different dentoskeletal frames [Sambataro, 2020]. One possible reason of the different opinions between supporters of cervical or high-pull headgear is that several scientific publications either did not specify the skeletal patterns in patient samples [Barton, 1972; Wieslander, 1974; Godt et al., 2008; Sandusky, 1965] or they analysed headgear treatment in combination with multiband or other appliances [Creekmore, 1967; Sandusky, 1965]. The effects of headgear treatment might vary with the types of initial growth pattern [Godt et al., 2008]. Some authors observed the posterior rotation of the mandible and bite opening [Merrifield and Cross, 1970; Gould, 1957] in individual cases or in subjects with mainly horizontal growth patterns [Tweed, 1946], assuming that similar reactions also occurr in patients with increased vertical dimension [Gould, 1957]. Furthermore, only a temporary increase of FMA angle during the initial phase of treatment with low-pull headgear was reported in Class II patients [Sambataro, 2017; Sandusky, 1965]. Recently Zervas et al. [2016] reported a reduction of vertical dimension in growing Class II subjects treated with cervical headgear compared to a sample treated with high-pull headgear. However, a limitation of the study was the control group, generated from a computer growth prediction model.

The aim of the present study was to evaluate the cephalometric changes in growing Class II patients with increased vertical dimension treated with cervical or high-pull headgear, by using an untreated control group with similar skeletal characteristics.

Materials and methods

Signed informed consent for releasing diagnostic records for scientific purposes was obtained from the parents of the patients. The protocol was reviewed and approved by the Ethical Committee (Approval No. 826) and Institutional Review Board (No. 2013-1148) by the University of Illinois at Chicago (that contributed to the study) and the procedures followed adhered to the World Medical Organization Declaration of Helsinki.

Subjects

The initial sample consisted of Class II growing patients with increased vertical dimension, recruited from a private practice in Catania (Italy) and at the University of Illinois, Chicago (USA), and was then divided into 132 subjects treated with cervical headgear, 114 subjects with high-pull headgear and 120 subjects who received no treatment selected from a private practice and treated or followed by the same trained operator. Only those patients who satisfied the inclusion and exclusion criteria were selected for the final study sample. Inclusion criteria were: bilateral Class II (full cusp or end to end) molar relationship; increased vertical dimension (Facial Axis <90 degrees, Total Facial Height > 60 degrees); facial convexity ≥4 mm; prepubertal stage (CVMS I) as assessed on lateral cephalograms of the examined subjects according to the cervical vertebral maturation method [Baccetti et al, 2005]; early mixed dentition; no other orthodontic appliance (lip bumper, mandibular lingual arch or fixed or functional appliances before or during the observation time) or paediatric dentistry treatment provided. Exclusion criteria were loss of deciduous teeth during treatment, craniofacial syndromes or anomalies and missing records. From the initial sample of 132 patients, 20 patients (mean age 8.54 ± 1.15 years) treated with cervical headgear who satisfied inclusion and exclusion criteria were selected. From the initial sample of 58 patients, 15 patients (mean age 9.4 ± 2.5 years) treated with high-pull headgear who satisfied inclusion and exclusion criteria were selected. From the initial sample of 120 patients, 21 untreated patients (mean age 8.41 ± 1.15 years) who satisfied inclusion and exclusion criteria were selected as controls.

Treatment protocol

The samples of the cervical headgear group (CHG) and the control group (CG) have been selected from a private practice and treated and followed by the same trained operator. The high-pull headgear group (HHG) was randomly recruited at the University of Illinois having records before treatment (T1) and at the end of phase 1 (T2). The CHG received a Ricketts large type face bow with loops in outer arms and an elastic neck band. The appliance was worn by the patients for 10 hours per day (night only) with 500 g of total force. A bayonet bend was placed as a bumper and stop for the molars, in order to promote buccal expansion of the upper jaw. The connection between the inner arch and the outer arch was located 1.0 to 1.5 mm anteriorly to the front teeth, at the stomion. At the first appointment, the inner arch was delivered to patients with 150 g of total passive force in order to be easily placed by the child. Every 4 weeks and during the treatment period, the facebow was activated by the clinician: the bayonets mesial to U6 were bent of 1.5 degrees until they became parallel to each other obtaining distal rotation; the inner bow was also widened of about 2 mm to expand U6 as desired, changing the arch form; and the force applied was increased to 500 g for the whole period of treatment. After a couple of months, the connection was almost touching the upper incisors, as a result of the above-mentioned activations (molar distorotation), thus leading to improvement of the overjet. The subjects of the HHG were recommended to wear the headgear full time (10–18 hours per day) with 600 g of force. Preformed facebows were selected and modified to fit the arch form of the patient, and Omega loops served as stop and to allow the anterior portion to be 4–5 mm away from maxillary incisors. The outer bow and the inner bow must be parallel to each other and the anterior portion, when in place, should comfortably fit between the lips.

Cephalometric analysis

Cephalograms were available for each subject at baseline (T1) and after treatment/observation time (T2) for the three groups: CHG (T1: 8.5 ± 1.2; T2:10.4 ± 1.3), HHG (T1: 9.4 ± 2.5, T2: 10 ± 2) and CG (T1: 8.4 ± 1.2; T2: 9.9 ± 1.3). A total of 17 measurements (7 linear, 9 angular, 1 ratio) among skeletal and dental measurements, were performed on the lateral head films: maxillary position (Ba-N-A) (degrees), convexity (mm), facial axis (NaBa-PtGn) (degrees), facial angle (FH-NPo)(degrees), palatal plane inclination (ANS-PNS to FH) (degrees), Co-A (mm), Co-Gn (mm), Co-Go-Me (degrees), mandibular plane angle (FH-GoGn) (degrees), lower facial height (ANS-Xi-Pm) (degrees), total facial height (BaNa to XiPm) (degrees), N-ANS/ANS-Me (ratio), overjet (mm), overbite (mm), U6 (upper molar) to L6 (lower molar) distance (mm), U6 to palate plane distance (mm), and inclination of the U6 axis to palatal plane (ANS-PNS) (degrees).The linear and the angular measurements are shown in Figure 1. Descriptive statics were computed for all variables. Group comparison among CHG, HHG and CG has been done using ANOVA test.

Data analysis

Sample size was calculated considering as primary outcome the amount of first upper molar distalisation (U6 to PTV) on the data of previous literature [Zervas et al., 2016]: mean of U6 to PTV for treated patients was -1.2 mm, mean of U6 to PTV for control patients was 1.2 mm, higher standard deviation for U6 to PTV was 1.9 mm. To retrieve β=0.20 with α set at 0.05 a sample of at least 10 subjects per group was necessary. Inclusion of all consecutively treated patients should be considered for the retrospective design of the study; thus, a greater number of patients were involved in order to ensure at least 10 patients per group. The SPSS software, version 22.0 (SPSS® Inc., Chicago, Illinois, USA) was employed to perform the statistical analysis. First two-way analysis of variance (ANOVA) was used to determine if there were statistically significant differences among the 17 dentoskeletal parameters of the three groups (CHG, HHG and CG). Means and standard deviations (SDs) were calculated for each parameter in each sample group. Gender differences were investigated within the same group by using the Mann–Whitney U test, which showed no gender differences. Each group was then analysed as a whole without any gender stratification.

Method error

Method of moments variance estimator was used for quantifying method error. Fifteen randomly selected cephalograms were retraced by a third investigator (RF) after a two-month interval. No significant differences between two series of cephalometric analyses were found using paired t-test. The mean error and 95% confidence interval (CI) between the repeated records were calculated as follows: 0.7 mm (0.5–0.8 mm) for linear measurements and 0.8 degrees (0.6–0.9 degrees) for angular measurements; reliability coefficient (r) ranged from 94% to 98% and from 92% to 97%, respectively.

Results

Control Group

The parameters that highlighted statistically significant variations included a modest reduction in upper jaw position (Ba–N–A), an augmentation in midfacial length (Co–A), in mandibular length (Co–Gn), in N-ANS/ANS-Me ratio and in overbite (Table 1, Fig. 2).

Cervical Headgear Group (CHG)

In CHG, 10 of 17 measurements presented significant T1–T2 modifications (Table 2). The following variables: facial angle (FH-NPo), mandibular length (Co–Gn), ratio between anterior upper and lower facial height (N-ANS/ANS-Me), and extrusion of the upper first molar to the palatal plane (U6 to PP) were all augmented. Instead upper jaw protrusion (Ba–N–A), convexity, inclination of the palatal plane (PP inclination), distance of the upper first molar to the lower first molar (U6 to L6), the upper first molar axis to palatal plane (U6 axis to PP) and overjet (OVJ) were all reduced (Table 2, Fig. 3).

High-pull Hedgear Group (HHG)

The only skeletal values that showed statistically significant

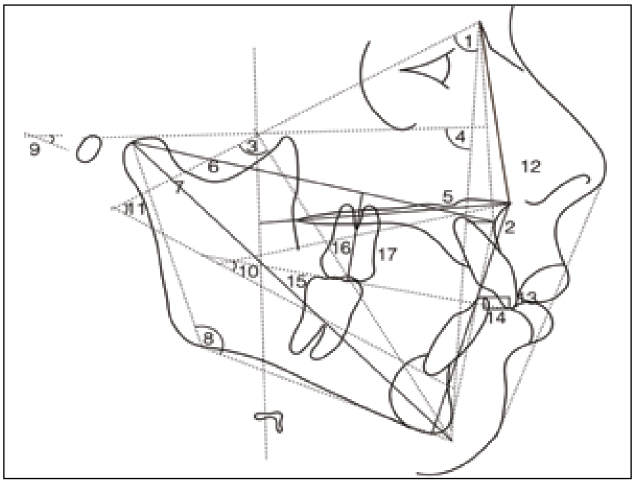

FIG. 1 Linear and angular cephalometric measurements. 1 Maxillary position (Ba–N–A) (degrees); 2 convexity (mm); 3 facial axis (NaBa–PtGn) (degrees); 4 facial angle (FH–NPo) (degrees); 5 palatal plane inclination (ANS–PNS to FH) (degrees); 6 Co–A (mm); 7 Co–Gn (mm); 8 Co–Go–Me (degrees); 9 mandibular plane angle (FH–GoGn) (degrees); 10 lower facial height (ANS–Xi–Pm) (degrees); 11 total facial height (BaNa to XiPm) (degrees); 12 N-ANS/ANS-Me (ratio); 13 overjet (mm); 14 overbite (mm); 15 U6 to L6 (mm); 16 U6 axis to palatal plane ANS–PNS (degrees); 17 U6 to palatal plane ANS-PNS (mm).

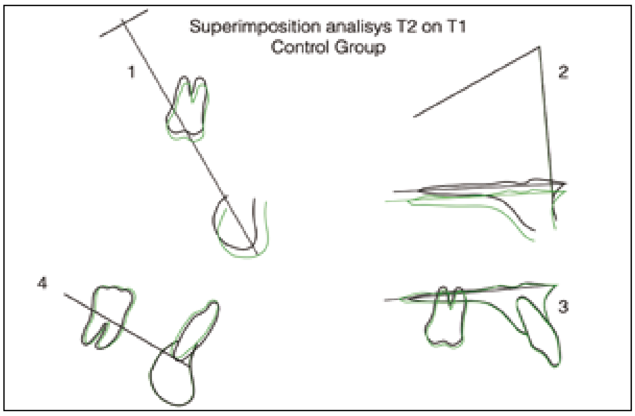

FIG. 2 Superimposition analysis of average tracing composite at T1 (black) vs T2 (green) of control group. 1: Ba-Na on Cc to appraise the vector of the face's growth: the facial axes are parallel to each other. 2: Ba-Na on Na to appraise the position of the upper jaw. Note that there is no variation of the Ba-Na-A angle. 3: ANS-PNS on ANS to appraise the upper teeth. The upper molar erupts 0,7 mm per year. 4: Xi-Pm on Pm to appraise the lower teeth. The lower molar erupts upward and forward 0,5 mm per year; the lower incisors erupt upward and backward 0,7 mm per year. Note that the arch depth tends to reduce during growth.

Control Group (n=21)					
	T1		T2		
	Mean	SD	Mean	SD	P
Age	8.4	1.2	9.9	1.3	0.00**
Skeletal measurements					
Maxillary position (Ba-N-A) (°)	65.1	2.8	64.3	3.0	0.02*
Convexity (mm)	6.4	1.5	6.2	1.6	0.38
Facial axis (NaBa-PtGn) (°)	88.1	3.0	87.7	3.3	0.14
Facial angle (FH-NPo) (°)	87.2	3.9	86.9	3.1	0.87
PP inclination (ANS-PNS to FH) (°)	-2.2	3.1	-1.6	4.1	0.72
Co-A (mm)	81.1	4.7	83.3	4.7	0.00**
Co-Gn (mm)	97.8	5.3	101.3	5.7	0.00**
Co-Go-Me (°)	130.0	5.3	129.0	5.0	0.13
Mandibular plane angle (FH-GoGn) (°)	27.8	5.0	26.9	5.4	0.10
Lower facial height (ANS-Xi-Pm) (°)	45.9	4.6	45.4	3.7	0.14
Total facial height (BaNa to XiPm) (°)	62.5	5.8	61.9	4.9	0.57
N-ANS/ANS-Me (ratio)	0.9	0.1	0.9	0.1	0.00**
Dental measurments					
Overjet (mm)	5.8	2.8	5.4	2.2	0.32
Overbite (mm)	1.6	2.5	2.8	2.4	0.02*
U6 to L6 (mm)	1.0	1.5	0.6	1.7	0.40
U6 axis to PP (°)	105.3	6.2	106.7	6.9	0.33
U6 to PP (mm)	16.8	1.6	17.5	2.2	0.25

* P<0.05 ** P<0.01

TABLE 1 Control Group mean differences comparison between T1 and T2. Data are shown as Mean and SD. Wilcoxon test results are shown for the comparison between the time points for the control group.

changes are the slightly reduced convexity and the increased Co-Gn distance. Regarding dental measurements, the overjet, the overbite and the U6 to L6 improved (Fig. 4, Table 3).

Among CHG, HHG and CG

The greatest reduction of Ba-N-A between T1 and T2 is observed in CHG when it is compared to HHG. The average reduction of convexity and overjet (OVJ) is greatest in CHG, followed by group HHG and then CG. ANOVA Test shows statistically significant differences between the three groups.

The greatest mean difference of U6 to L6 distance between T1 and T2 is observed in CHG. The ANOVA test shows statistically significant differences of CHG both with HHG and with CG, while there are no statistically significant differences between HHG and CG. Upper molar extrusion measured from U6 to PP is higher in CHG; the ANOVA test indicates statistically significant differences between CHG and CG and between CHG and HHG. Regarding U6 axis to PP, the ANOVA test shows statistically significant differences between CHG and CG.

The ANOVA shows significant differences of N-Ans/Ans-Me ratio between CHG and HHG, while there are no differences between each of the treated groups, CHG and HHG, with CG.

The average value of the facial axis increases from T1 to T2 more in HHG than in CHG. None of these T1-T2 changes within each group are statistically significant and the ANOVA does not show any significant difference among the three groups.

Regarding the facial angle, the ANOVA does not show significant differences between groups (Table 4).

Discussion

For years the effects of the headgear on skeletal growth have long been debated and orthodontists divided between supporters of cervical [Sambataro, 2017; Godt et al., 2008] and defenders of high-pull traction [Poulton, 1967; Creekmore, 1967; Melsen, 1978; Merrifield et al., 1970; Williams et al., 2000; Barton, 1972; Gould, 1957; Wieslander, 1974]. The purpose of the present study was to investigate dental and skeletal treatment outcomes with cervical (CHG) and with high-pull headgear (HHG) in growing patients with high-angle Class II malocclusion and compared the results to untreated control group (CG) of subjects with similar growth pattern and skeletal characteristics.

Cervical Pull Group (n=20)					
	T1		T2		
	Mean	SD	Mean	SD	P
Age	8.5	1.2	10.4	1.3	0.00**
Skeletal measurements					
Maxillary position (Ba-N-A) (°)	63.2	3.2	60.4	2.7	0.00**
Convexity (mm)	6.0	1.2	3.1	1.1	0.00**
Facial axis (NaBa-PtGn) (°)	87.4	4.6	87.5	4.0	0.65
Facial angle (FH-NPo) (°)	85.6	2.5	86.7	2.6	0.01*
PP inclination (ANS-PNS to FH) (°)	-3.5	2.5	-1.8	2.4	0.00**
Co-A (mm)	82.6	4.1	84.0	5.0	0.10
Co-Gn (mm)	100.2	4.7	105.4	5.8	0.00**
Co-Go-Me (°)	128.2	4.2	128.3	3.4	0.93
Mandibular plane angle (FH-GoGn) (°)	26.5	4.5	25.9	3.8	0.19
Lower facial height (ANS-Xi-Pm) (°)	46.0	4.7	46.1	4.5	0.69
Total facial height (BaNa to XiPm) (°)	61.7	4.9	62.2	4.1	0.24
N-ANS/ANS-Me (ratio)	0.9	0.1	1.0	0.1	0.02*
Dental measurements					
Overjet (mm)	6.5	2.4	3.2	1.9	0.00**
Overbite (mm)	1.0	2.4	1.8	1.5	0.07
U6 to L6 (mm)	2.0	1.8	-2.2	1.8	0.00**
U6 axis to PP (°)	106.4	3.5	101.4	5.8	0.00**
U6 to PP (mm)	17.5	2.1	20.2	1.9	0.00**

* P<0.05 ** P<0.01

TABLE 2 comparison of mean differences in Cervical Pull Group between T1 and T2. Data are shown as Mean and SD. Wilcoxon test results are shown for the comparison between the time points for the control group.

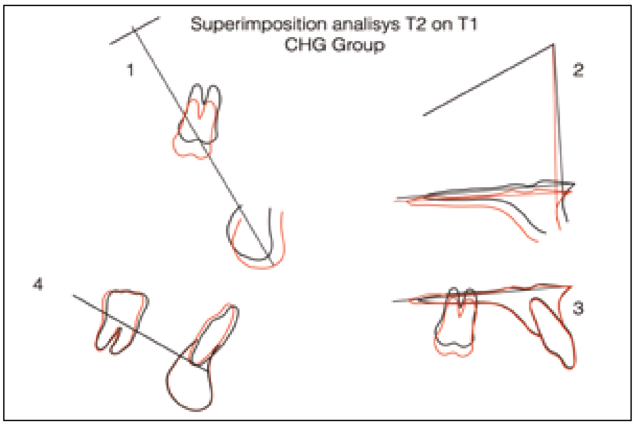

FIG. 3 Superimposition analysis of average tracing composite at T1 (black) vs T2 (red) of cervical headgear group.
1: Ba-Na on Cc to evaluate the growth direction of the chin. Notice how the therapy does not affect the vertical dimension. 2: Ba-Na on Na to evaluate the position of the maxilla. The maxilla moved backward and downward. 3: ANS-PNS on ANS to evaluate the upper teeth. Note the extrusion of the upper molar. 4: Xi-Pm on Pm to evaluate the lower teeth. The extrusion of the upper molar prevents eruption of the lower molar and this was compensated by the vertical growth of the ramus of the mandible.

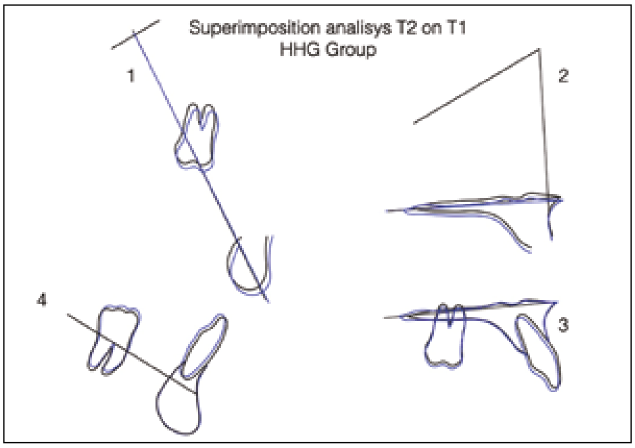

FIG. 4 Superimposition analysis of average tracing composite at T1 (black) vs T2 (blue) of high-pull headgear group.
1: Ba-Na on Cc to evaluate the growth direction of the chin. The mandible growth on the facial axis. 2: Ba-Na on Na to evaluate the position of the maxilla. The maxilla was not orthopaedically affected by the therapy. 3: ANS-PNS on ANS to evaluate the maxillary teeth. Note the control of the eruption of the upper molar. 4: Xi-Pm on Pm to evaluate the mandibulary teeth. None significant movement was induced by therapy.

High Pull Group (n=15)					
	T1		T2		
	Mean	SD	Mean	SD	P
Age					
Skeletal measurements					
Maxillary position (Ba-N-A) (°)	62.3	4.6	62.2	4.0	0.96
Convexity (mm)	5.7	2.1	4.5	2.3	0.01*
Facial axis (NaBa-PtGn) (°)	84.4	3.8	85.7	3.7	0.22
Facial angle (FH-NPo) (°)	83.5	2.3	84.5	3.3	0.14
PP inclination (ANS-PNS to FH) (°)	-1.7	2.2	-0.8	3.2	0.16
Co-A (mm)	77,0	6.2	78.8	6.6	0.12
Co-Gn (mm)	98.2	9.9	102.0	10.4	0.00**
Co-Go-Me (°)	124,9	4.5	126.1	4.4	0.13
Mandibular plane angle (FH-GoGn) (°)	31.5	3.1	31.4	4.2	0.91
Lower facial height (ANS-Xi-Pm) (°)	47.5	4.0	46.8	2.8	0.49
Total facial height (BaNa to XiPm) (°)	62.1	5.4	61.1	4.5	0.40
N-ANS/ANS-Me (ratio)	0.8	0.0	0.8	0.1	0.06
Dental measurements					
Overjet (mm)	6.9	2.1	5.4	2.1	0.00**
Overbite (mm)	-0.6	3.5	1.8	1.4	0.01*
U6 to L6 (mm)	1.3	2.3	-0.3	2.0	0.00**
U6 axis to PP (°)	69.7	5.1	72.4	5.8	0.08
U6 to PP (mm)	18.80	2.35	19.94	2.24	0.06

* P<0.05 ** P<0.01

TABLE 3 High-Pull Group mean differences comparison between T1 and T2. Data are shown as Mean and SD. Wilcoxon test results are shown for the comparison between the time points for the control group.

	Mean differences T2-T1			Sig.
	Cervical pull Group	High pull Group	Control Group	O ❑
Skeletal measurements				
Maxillary position (Ba-N-A) (°)	-2.7	-0.1	-0.8	O
Convexity (mm)	-2.9	-1.2	-0.2	O ❑
Facial axis (NaBa-PtGn) (°)	0.1	1.2	0.1	
Facial angle (FH-NPo) (°)	1.1	1.0	-0.4	
PP inclination (ANS-PNS to FH) (°)	1.7	0.9	0.7	
Co-A (mm)	1.5	1.8	2.1	
Co-Gn (mm)	5.2	3.8	2.6	
Co-Go-Me (°)	0.1	1.3	-1.0	
Mandibular plane angle (FH-GoGn) (°)	-0.6	-0.1	-0.3	
Lower facial height (ANS-Xi-Pm) (°)	0.1	-0.7	-0.8	
Total facial height (BaNa to XiPm) (°)	0.5	-1.0	-1.3	
N-ANS/ANS-Me (ratio)	0.1	0.0	0.6	O
Dental measurments				
Overjet (mm)	-3.4	-1.4	0.0	O ❑
Overbite (mm)	0.8	2.5	0.7	
U6 to L6 (mm)	-4.2	-1.6	-0.3	O❑
U6 axis to PP (°)	-5.1	2.7	1.4	❑
U6 to PP (mm)	2.7	1.14	0.7	O❑

O P<0.05 comparing cervical pull and high-pull groups;
P<0.05 comparing high pull and control groups;
❑ P<0.05 comparing cervical pull and control groups.

TABLE 4 Mean differences T2-T1 and comparison among groups. Data are shown as Mean of the differences between the two time points among the three groups understudy. ANOVA and Bonferroni test results are used for the comparison.

Initial values were comparable among groups and no gender differences were found, probably due to the young age of subjects who were all prepubertal (CS1 in CVM) as assessed on lateral cephalograms. From the results of the present study maxillary protrusion (Ba-N-A) decreased in all three groups after headgear treatment or period of observation and the greatest reduction is observed in the CHG, statistically different to HHG. Furthermore, the maxillomandibular skeletal relationship (convexity) and the overjet are statistically reduced from T1 to T2 in each group, more in the CHG, followed by the HHG. The cervical headgear improves the reduction of Class II skeletal parameters (maxillary position, convexity) which naturally occurs with growth. Cervical traction is also useful to obtain a greater modification of maxillary position and facial profile compared to high-pull headgear, probably due to the more horizontal line of action of the force: the more this line is closed to the centre of resistance of maxillary complex, the greater is the anterior-posterior correction [Poulton, 1967]. The analysis of facial angle (FH-NPo) represents relevant parameters of headgear efficiency in affecting the mandibular rotation [Zervas et al., 2016]. The increase of the facial angle in the CHG group is statistically significant, however ANOVA does not show significant differences between the groups. It might hypothesize that cervical headgear seems to cause a greater forward movement of pogonion and a significant mandibular ante-rotation, despite not statistically significant, when compared to the other study groups.

It is also important to underline that the CHG vertically affects the upper jaw displacing the palatal plane downward, inclining the palatal plane (ANS-PNS to FH) in a statistically significant way from T1 to T2, but not among the three groups.

Considering the vertical components, N-Ans and Ans-Me help to diagnose anterior upper and lower facial height problems, respectively. An increased N-Ans/Ans-Me ratio during growth may be desirable in subjects with tendency toward increased anterior facial height. N-Ans/Ans-Me ratio statistically increased in CHG and CG groups between time points. The ANOVA test shows significant differences between CHG and HHG but no differences between each headgear treatment group (CHG and HHG) with CG. This result might suggest a spontaneous reduction with growth of the anterior vertical dimension, and cervical headgear might be preferred to high-pull headgear in high-angle Class II patients. However, further investigation on the anterior facial height ratio might be necessary, considering also the posterior facial height in order to better investigate the changes in vertical dimension and skeletal pattern growth.

Overjet improvement is statistically significant among the three groups, but CHG treatment is more efficient than HHG indicating that the cervical headgear is effective in reduction of dental protrusion, hence it could prevent upper incisors traumas [Thiruvenkatachari et al., 2015].

The molar class relationship (U6-L6 distance) decreases in the three groups, being greatest in the CHG which was statistically significantly different with both HHG and CG. The T2-T1 reduction in the HHG was statistically significant but not in comparison with CG. These results suggest a slightly spontaneous improvement with growth of Class II molar relationship; however, the cervical headgear might guarantee a more rapid and predictable resolution of the molar class. Furthermore, from the results of the present study, the mesial inclination of the upper molars decreases from T1 to T2 only in the CHG (U6 axis to palatal plane) and increase in the HHG and CG. The cervical headgear produced an extrusion of U6 statistically significant among the groups and between T1 and T2. Extrusion of the upper molars inhibits eruption of the lower molars and maintain a flattened occlusal plane, according to Sato, Ricketts and Sambataro [Sambataro et al., 2017; Sambataro et al., 2020; Tanaka et al., 2008; Ricketts, 2003; Ricketts, 2002; Sambataro et al., 2020b] and may subsequently produce the forward movement of the mandible as displayed by the data of present study, in fact in CHG the facial angle increases from T1 to T2 indicating that the chin came forward.

This research involves a CG that matched the CHG and HHG at baseline in which no mandibular anterior rotation was noted, illustrating that the described effect for the CHG and HHG could be due to therapy. A possible explanation of this phenomenon should be that the extrusion of U6 prevented the eruption of B6, this allows a decompression of TMJ so that the condyle could grow upward and forward, displacing the chin downward and forward according to Ricketts [1952] and Bjork [1969]. This behaviour of the cervical headgear might encourage growth at the condyle, thus increasing mandibular ramus length and a forward repositioning of the mandible [Bjork and Skieller, 1972]. In agreement with the results of the present study, Burke and Jacobson [1992] postulated that an extrusion of the upper molars might be compensated to the relative positional stability of the mandibular molars and their relative extrusion or intrusion influences the occlusal plane orientation. Moreover, the cervical headgear may produce forces on the dentition that mimic natural growth and cause an increase in height at the maxillary molars much like what happens during natural forward rotation of maxilla [Sambataro, 2020]. Due to this consideration, the traditional prescription of intrusion of maxillary molars in dolichofacial patients, recommended by several authors [Creekmore, 1967; Schudy, 1964], seems to have no scientific support.

The major strength of the study is that the control group has similar dental and skeletal characteristics to the headgear treated groups though it has not been subjected to any treatment. The strict inclusion criteria that narrowed the participants to only those with increased vertical dimension and the choice of a real sample instead of computed growth prediction models reduce biases due to the possible different skeletal pattern and give a more accurate interpretation of treatment effects on natural growth [Zervas et al., 2016; Baumrind and Curry, 2015; Begnoni et al., 2020; Silvestrini-Biavati et al., 2020; Tentolouri et al., 2021]. However, the main limitation of this study remains that the report did not account for patients' compliance and it was unknown how long the headgear was worn per day.

Conclusion

From the present study, the following conclusions might be drawn. In Class II high-angle growing patients, cervical headgear seems to be preferred in the correction of maxillary protrusion, molar relationship, facial convexity and increased overjet and anterior facial height. In CHG, the extrusion of the upper molar is associated with a greater advancement of the chin and may favour forward repositioning of mandible and clockwise rotation in Class II patients with increased vertical dimension.

Further investigations on the vertical control of headgear on high-angle Class II patients are needed, perhaps evaluating other parameters such as the posterior facial height/anterior facial height (PFH/AFH) ratio or relationship between upper molar extrusion, mandibular rotation and ramus growth.

Data availability

The data that support the findings of this study are available from the corresponding author, upon reasonable request.

Conflicts of interest

The authors declare no conflict of interest.

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