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Original article

Effects of cervical headgear and pendulum appliance on vertical dimension in growing subjects: a retrospective controlled clinical trial

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Summary

Objective: To analyze the effects on vertical dentoskeletal dimension produced by cervical headgear (CHG) or Pendulum (P) both followed by full fixed appliances in growing patients with Class II malocclusion.

Material and Methods: The CHG group (CHGG) consisted of 40 patients (25 females, 15 males) with a mean age of 11.5 years. The P group (PG) comprised 40 patients (21 females, 19 males) with a mean age of 11.6 years. Mean treatment duration with the CHG and P appliances were 1.5 years and 8.2 months, respectively. Lateral cephalograms were available before treatment (T1) and at the end of fixed therapy (T2) with a mean interval of 3.5 years. The effects of the 2 protocols were compared with a matched control group (CG) of 25 untreated Class II subjects (13 females, 12 males). The ANOVA with Tukey's *post hoc* tests was used to evaluate between-group differences at T1 and during the T1–T2 interval ($P < 0.05$).

Results: CHGG showed significantly greater decreases in both Sella-Nasion to A point angle and A-Nasion-B point anglel when compared with both PG (−1.2 and −0.9 degrees, respectively) and CG (−1.9 and −1.5 degrees, respectively). No significant between-group differences were recorded for any of the vertical skeletal measurements. Both CHGG and PG showed significantly greater improvement in molar relationships with respect to CG (+2.5 mm).

Conclusions: Both distalizing protocols were effective in the correction of Class II malocclusion without increasing the vertical dimension at the end of comprehensive treatment.

Introduction

Maxillary molar distalization is one of the most common strategies to correct Class II molar relationship and it is commonly indicated for patients with maxillary dentoalveolar protrusion or minor skeletal discrepancies (1, 2).

Cervical headgear (CHG) has been reported to be effective in maxillary molar distalization and for maxillary growth restriction, with dental movements that are achievable in all planes of space (3–5). However, studies on Class II treatment with CHG combined or not with fixed appliances have shown a postero-inferior redirection of maxillary growth, anterior downward tipping of the palatal plane, opening of the bite, an increase in anterior face height, and downward and backward rotation of the mandible (4, 6–8). Moreover, this method of Class II correction depends greatly on patient cooperation. To avoid unpredictable results because of varying patient compliance, Hilgers introduced the Pendulum (P) appliance in 1992 (9). It consisted of an anterior acrylic Nance button and

2 posterior titanium molybdenum Alloy (TMA) springs for molar distalization (9). Despite its efficacy for maxillary molar distalization, there are side-effects including increase in lower face height, clockwise mandibular rotation, and extrusion of first premolars (10–12). According to most studies (10–12) on the P appliance, significant increases in the vertical skeletal dimension must be expected.

However, the orthodontic literature is lacking about the comparison of dentoskeletal effects of these 2 therapeutic approaches for Class II correction especially on the outcomes on vertical skeletal dimension after comprehensive treatment with fixed appliances.

Mossaz *et al.* (5) compared 2 groups of 30 growing subjects treated with either CHG or P followed by full fixed appliances. They found a slight increase of the mandibular plane angle in the P group (PG) and a net extrusion of 1 mm of maxillary molars in both groups altering the direction of growth, at least temporarily, during treatment (5).

Angelieri *et al.* (13) analyzed 30 patients treated with CHG and preadjusted fixed orthodontic appliances and 22 patients who underwent P and fixed therapy with an initial mean age of 13.3 years. The cephalometric appraisal of the effects of CHG and P pointed out a clockwise rotation of the mandibular plane during distalization due to extrusion of maxillary molars in the CHG group and distal inclination of molar crowns after distalization in the PG. This inclination of the mandibular plane was corrected during fixed orthodontic treatment, as it returned to the initial values in the final stage of therapy probably due to the inherent growth pattern of each individual (13).

More recently, de Almeida-Pedrin *et al.* (14) evaluated the effects produced by either CHG or P at the end of comprehensive treatment with fixed appliances in growing subjects. They reported that the vertical growth pattern was not affected by the 2 therapies with an approximate increase in lower face height of 2 mm secondary to the extrusive mechanics during fixed orthodontic treatment (14).

To our knowledge, no study compared the outcomes of these 2 modalities of Class II correction with an untreated control group (CG) with similar initial dentoskeletal features. Only with a well-matched CG it is possible to verify if comprehensive orthodontic therapy influences the vertical dentoskeletal dimension in growing subjects.

The aim of the present retrospective controlled clinical study, therefore, was to analyze the effects on vertical dentoskeletal dimension of growing patients treated either with CHG or P followed by full fixed appliances when compared with a CG (CG) of untreated Class II subjects.

Materials and methods

Sample size determination revealed that for the analysis of variance (ANOVA) on 3 groups, with an effect size of 0.9 for the SN to mandibular plane angle (primary endpoint), an alpha level of 0.05, and a power of 0.8, a minimum of 25 subjects in each group was required (15) (SigmaStat 3.5, Systat Software, Point Richmond, California, USA).

A group of 80 patients with Class II division 1 malocclusion treated consecutively either with CHG or P were selected from the files of the University of Rome 'Tor Vergata'. This retrospective study was approved by the Ethical Committee at the University of Rome '"Tor Vergata' (Protocol number 56.14) and informed consent was obtained from the patients' parents. Two treatment alternatives for correction of Class II malocclusion (CHG or P followed by fixed appliances) were proposed to the patients' parents who decided for themselves. The inclusion criteria for the study sample were: late mixed or permanent dentition, Class II or edge to edge molar relationship, and crowding at the lower arch smaller than 5 mm.

The CHG group (CHGG) comprised 40 subjects (25 females, 15 males) treated consecutively between July 2008 and March 2013 with CHG and fixed appliances with an initial mean age of 11.5 ± 2.3 years. A conventional CHG (adapted to the tubes of the maxillary first molar bands) was used in this group. As recommended by Lima Filho *et al.* (16) the outer bows were bent 20 degrees upward to prevent molar distal tipping, and a force of ~450 g was applied (16). The patients were asked to wear the device 14 hours per day. The average treatment duration with CHG was 1.5 years. After the correction of the molar relationship, the CHG was used only at night for retention of molar distalization.

The PG included 40 subjects (21 females, 19 males) treated consecutively between September 2008 and June 2013 with the Pendulum appliance and fixed appliances with an initial mean age of 11.6 ± 3 years. In the PG, all patients received a P appliance as described by Angelieri *et al.* (13). The Nance button was anchored to the first and second premolars (or the first premolar and second deciduous molars) with removable wires. The 0.032-inch TMA wires were activated 45 degrees to produce a force of 200–250 g per side. On average, intraoral reactivation of the distalizing springs was performed twice during the procedure. As recommended by Byloff *et al.* (17), an uprighting bend was added to the end of TMA wire to prevent excessive molar tipping. When a super Class I molar relationship was obtained, the P was replaced by a Nance holding arch. The average treatment duration with P was 8.2 months. A second phase of preadjusted fixed appliance therapy (Boston prescription, 0.018 × 0.022 inch) began for all patients immediately after distalization. In both treatment protocols, the levelling and aligning phase was achieved with nickel–titanium archwires (0.014/0.016/0.016 × 0.022 inch). Heavier rectangular stainless steel archwires (0.016 × 0.022/0.017 × 0.025 inch posted) with Class II elastics were used when the anterior teeth were retracted.

For both treatment groups, lateral cephalograms were available before treatment (T1) and at the end of fixed therapy (T2) with a mean interval of 3.5 years between the 2 observation times.

The lateral cephalograms of a matched untreated CG with the same mean age, skeletal and occlusal characteristics, and observation interval were obtained from the AAOF Craniofacial Growth Legacy Collection (http://www.aaoflegacycollection.org, Bolton-Brush Growth Study and Michigan Growth Study). The CG included 25 subjects (13 females, 12 males) with a mean age of 11.4 ± 0.9 years (Table 1).

Since the success of therapy was not a factor for inclusion of treated patients in the study and because in the 2 treatment groups patients were treated consecutively by the same operator with a standardized protocol, an analysis of treatment-induced 'successful correction' of initial Class II relationships could be carried out in these 2 groups. Success (Class I occlusal relationships) or unsuccess (half-cusp Class II molar relationship) at T2 was assessed in the 2 treated groups.

Cephalometric analysis

All lateral cephalograms were hand traced at a single sitting. Cephalograms were traced and landmark identification was performed by one investigator (R.L.). A customized digitization regimen (Viewbox, version 3.0, dHAL Software, Kifissia, Greece) was created and used for the cephalometric evaluation. For each patient lateral cephalograms at T1 and T2 were digitized, and a custom cephalometric analysis was used. Eighteen variables (7 linear and 11 angular) were generated for each tracing. Lateral cephalograms of treated and CGs at T1 and T2 were standardized as to magnification factor (8 per cent).

Table 1. Demographics of the treated and untreated groups.

Variables	Headgear (1) (n = 40, 25 females, 15 males)				Pendulum (2) (n = 40, 21 females, 19 males)				Controls (3) (n = 25, 13 females, 12 males)							
	Mean	SD	Min	Max	Mean	SD	Min	Max	Mean	SD	Min	Max	P	1 versus 2	2 versus 3	1 versus 3
Age T1, years	11.5	2.3	8.2	15.4	11.6	3.0	8.4	15.4	11.4	0.9	10.0	12.5	0.934	NS	NS	NS
Age T2, years	14.9	2.4	11.7	18.8	15.1	3.2	11.8	18.9	14.5	1.2	13.0	17.1	0.401	NS	NS	NS

Descriptive statistics and statistical comparisons at T1 and T2 (ANOVA with Tukey's *post hoc* tests). T1 indicates before treatment; T2 at the completion of comprehensive fixed therapy after a mean interval of 3.2 years.
NS, not significant.
$^*P < 0.05$

The molar relationship was assessed on cephalometric tracing as described by McNamara *et al.* (18).

Statistical analysis

To evaluate the method error, 60 radiographs chosen at random were traced and digitized by the same investigator on 2 separate occasions at least 1 month apart. A paired *t-test* was used to compare the 2 measurements (systematic error). The magnitude of the random error was calculated by using the coefficient of reliability (19).

Descriptive statistics were calculated for all the measurements in each group. Exploratory statistics revealed that all variables were normally distributed (Kolmogorov–Smirnov test) with equality of variances (Levene's test). Between-group differences were tested by means of ANOVA with Tukey's *post hoc* tests at T1 and on the changes during the T1–T2 interval. The prevalence rates of successful and unsuccessful cases in the 2 treated groups were compared with the chi-square test with Yates' correction.

All statistical computations were performed by using a specific software (SigmaStat 3.5, Systat software, Point Richmond, California, USA).

Results

No systematic error was found between the repeated values. The coefficient of reliability varied from 0.761 (molar relationships) through 1.000 (Sella-Nasion to A point angle [SNA]). Descriptive statistics and significant between-group differences of the starting forms are given in Table 2. No significant between-group differences were found at T1 for any of the cephalometric variables. The only exceptions were the Sella-Nasion line (SN) to palatal plane angle that was significantly smaller in the CG than in both treatment groups ($P < 0.05$), and the inclination of the lower incisors to the mandibular plane that was 4.1 degrees larger in the CG when compared with the HGG ($P < 0.05$) (Table 2). No significant difference in the prevalence rates of successful cases at the end of comprehensive treatment (T2) was found between the 2 treated groups (95 per cent in the CHGG and 90 per cent in the PG, chi-square = 0.025, $P = 0.874$).

Descriptive statistics and statistical comparisons on the T2–T1 changes are given in Table 3.

As for the sagittal skeletal relationships, the HGG showed significantly greater decreases in both SNA and A-Nasion-B point angle (ANB) when compared with both PG (−1.2 and −0.9 degrees, respectively) and CG (−1.9 and −1.5 degrees, respectively). No significant between-group differences were recorded for any of the other sagittal skeletal variables or for the vertical skeletal measurements. Both the HGG and the PG showed significantly greater decreases in the overjet when compared to the CG (−1.7 and −1.1 mm, respectively). Both the HGG and the PG showed significantly greater increases in molar relationships with respect to the CG (+2.5 mm). No significant between-group differences were observed for the other dentoalveolar variables.

Discussion

In this retrospective controlled clinical study, the dentoskeletal effects on vertical dimension in growing subjects treated with CHG and P appliances followed by fixed therapy were compared with growth changes in a matched CG. Only few studies (5, 13, 14) have evaluated directly the dentoskeletal effects of these treatment protocols at the end of comprehensive orthodontic therapy and to our

Table 2. Descriptive statistics and statistical comparisons of starting forms (ANOVA with Tukey's *post hoc* tests).

Variables	Headgear (1) (n = 40)		Pendulum (2) (n = 40)		Controls (3) (n = 25)					
	Mean	SD	Mean	SD	Mean	SD	P	1 versus 2	2 versus 3	1 versus 3
Age	11.5	2.3	11.6	3.0	11.4	0.9	0.934	NS	NS	NS
Sagittal skeletal										
SNA (degrees)	80.1	3.7	80.6	3.2	80.3	3.0	0.843	NS	NS	NS
SNB (degrees)	75.7	3.0	76.9	3.5	75.9	2.2	0.202	NS	NS	NS
ANB (degrees)	4.4	2.4	3.7	2.3	4.4	1.7	0.272	NS	NS	NS
WITS (mm)	−0.4	2.8	−0.7	3.5	0.3	2.6	0.400	NS	NS	NS
Co–Gn (mm)	105.8	9.5	103.5	8.7	102.6	4.9	0.261	NS	NS	NS
Vertical skeletal										
SN to Funct. Occ. plane (degrees)	20.6	3.9	19.3	4.1	19.7	4.1	0.311	NS	NS	NS
SN to palatal plane (degrees)	9.9	3.8	10.0	3.6	7.7	3.2	0.025	NS	*	*
SN to mandibular plane (degrees)	35.2	5.2	32.6	6.8	32.1	4.2	0.052	NS	NS	NS
CoGoMe (degrees)	124.5	7.8	122.6	6.1	122.0	6.0	0.272	NS	NS	NS
Interdental										
Overjet (mm)	4.5	2.4	3.6	1.8	4.5	1.5	0.069	NS	NS	NS
Overbite (mm)	2.8	1.5	2.7	1.7	3.2	1.6	0.362	NS	NS	NS
Molar relationship (mm)	0.1	1.1	0.1	1.2	−0.6	0.9	0.051	NS	NS	NS
Upper inc. to palatal plane (degrees)	111.0	6.8	111.8	7.7	109.5	4.5	0.410	NS	NS	NS
Upper mol. to palatal plane (mm)	19.9	2.6	19.1	2.3	18.7	2.1	0.132	NS	NS	NS
Upper mol. to palatal plane (degrees)	101.1	7.0	100.0	5.3	102.3	4.2	0.277	NS	NS	NS
Lower inc. to mandibular plane (degrees)	93.6	5.3	94.7	6.9	97.7	5.3	0.027	NS	NS	*
Lower mol. to mandibular plane (mm)	86.9	7.1	87.9	7.0	86.3	4.8	0.601	NS	NS	NS
Lower mol. to mandibular plane (degrees)	29.6	3.6	28.1	3.0	28.0	2.3	0.051	NS	NS	NS

ANB, A-Nasion-B point anglel; NS, not significant; SNA, Sella-Nasion to A point angle; SNB, Sella-Nasion to B point angle.
*$P < 0.05$.

Table 3. Descriptive statistics and statistical comparisons on the T2–T1 changes (ANOVA with Tukey's *post hoc* tests).

Variables	Headgear (1) (n = 40)		Pendulum (2) (n = 40)		Controls (3) (n = 25)					
	Mean	SD	Mean	SD	Mean	SD	P	1 versus 2	2 versus 3	1 versus 3
Age	3.4	1.2	3.5	1.2	3.1	0.5	0.338	NS	NS	NS
Sagittal skeletal										
SNA (degrees)	−1.2	2.0	0.0	1.8	0.7	2.0	0.000	*	NS	***
SNB (degrees)	0.5	1.9	0.8	1.6	1.0	1.5	0.576	NS	NS	NS
ANB (degrees)	−1.8	1.7	−0.9	1.3	−0.3	1.5	0.000	*	NS	***
WITS (mm)	−0.5	3.3	−0.4	3.0	0.2	2.4	0.625	NS	NS	NS
Co–Gn (mm)	6.1	3.5	6.6	3.1	7.0	4.5	0.645	NS	NS	NS
Vertical skeletal										
SN to Funct. Occ. plane (degrees)	−2.2	3.5	−1.6	4.9	−1.6	3.8	0.783	NS	NS	NS
SN to palatal plane (degrees)	0.7	3.5	−0.1	2.9	0.0	2.1	0.390	NS	NS	NS
SN to mandibular plane (degrees)	−1.0	3.2	−0.6	2.7	−1.7	2.4	0.299	NS	NS	NS
CoGoMe (degrees)	−2.3	3.2	−0.5	3.7	−1.6	4.0	0.094	NS	NS	NS
Interdental										
Overjet (mm)	−2.1	2.3	−1.5	1.7	−0.4	1.0	0.001	NS	*	**
Overbite (mm)	−0.7	1.2	−0.5	1.6	0.0	1.1	0.151	NS	NS	NS
Molar relationship (mm)	2.9	1.5	2.9	1.6	0.4	1.3	0.000	NS	***	***
Upper inc. to palatal plane (degrees)	2.0	8.1	−0.2	7.4	−1.0	4.3	0.195	NS	NS	NS
Upper mol. to palatal plane (mm)	2.2	1.8	1.8	1.9	2.4	1.3	0.406	NS	NS	NS
Upper mol. to palatal plane (degrees)	−3.5	7.2	−1.8	4.4	−3.9	4.7	0.268	NS	NS	NS
Lower inc. to mandibular plane (degrees)	2.3	5.7	2.9	6.3	−0.3	4.6	0.084	NS	NS	NS
Lower molar to mandibular plane (mm)	−1.5	5.9	−1.2	5.4	−0.3	6.4	0.732	NS	NS	NS
Lower molar to mandibular plane (degrees)	2.4	2.1	2.9	2.2	2.3	1.7	0.363	NS	NS	NS

ANB, A-Nasion-B point anglel; NS, not significant; SNA, Sella-Nasion to A point angle; SNB, Sella-Nasion to B point angle.
*P < 0.05; **P < 0.01; ***P < 0.001.

knowledge, no previous investigation has compared the treatment changes of both devices with an untreated CG. Pinto Ramos *et al.* (20) evaluated the skeletal profile of Class II individuals treated with CHG and fixed appliance with a historical CG pointing out a tendency toward a forward displacement of the maxilla in untreated subjects and a significant reduction of the convexity of skeletal profile in the treated group (20).

A limitation of this study was the use of historical controls (21). The use of historical controls with untreated Class II malocclusions, though not ideal, was due mainly to the ethical issue of leaving subjects with Class II malocclusions without orthodontic treatment during the circumpubertal stages of development.

The results of the starting forms at T1 showed that all 3 groups had very similar values for the dentoskeletal characteristics (Table 2).

Due to the side-effects caused by the P appliance during distalization of the maxillary molars, including protrusion and labial tipping of the maxillary incisors, mesialization and mesial inclination of the maxillary premolars (1, 2, 10–12), it is also important to compare the effects of both distalizers after completion of fixed orthodontic treatment when the side-effects of the P have been corrected (13).

In this study, there was a statistically significant restriction of maxillary growth in the CHGG with respect to both PG and CG (SNA, −1.2 and −1.9 degrees, respectively). This result is in agreement with several previous investigations that analyzed the effects of the CHG on the maxillary complex (3, 8, 22–24). A significant improvement of the skeletal maxillomandibular relationship was observed in patients of the CHGG group with a greater difference when compared with the growth of untreated subjects (ANB, −1.5 degrees). The orthopaedic influence of the headgear is due to the high forces on the maxilla of about 450 g per side that allowed to control the maxillary forward displacement in growing patients (3, 8, 13, 22–24).

In agreement with the literature (5, 13, 14, 22–24), no mandibular effects were detected in the treatment groups. The slight increase in the Sella-Nasion to B point angle (SNB) and the increase of the total mandibular length (Co–Gn) in treated patients were similar to the values reported in untreated subjects.

In this study, similar changes between the 2 treatment groups and the CG were pointed out also with regard to the vertical components. In the literature several studies (4, 6–8, 10–12) reported at the end of distalization with both appliances a clockwise rotation of the mandibular plane and an increase in anterior face heights thus contraindicating the distalizing protocols in subjects with high-angle mandibular patter. Baumrind *et al.* (25) comparing the effects of CHG with an untreated CG observed higher values for anterior face height in treated subjects. Also Burkhardt *et al.* (26) pointed out an increase in the mandibular plane angle of 1.2 degrees at the end of treatment with P and fixed appliances. These transitory side-effects on the vertical dimension are related to the extrusion and to the distal crown tipping of maxillary molars due to the moments of forces directed far from the center of resistance of the first upper molars (4, 6–8, 10–12).

For this reason in our protocols the outer bows of the CHG were bent 20 degrees upward. As reported by Yoshida *et al.* (27), the line of action of force in relation to the molar is an important consideration in controlling the tipping and the extrusion effect of CHG. The longer the perpendicular distance from the center of resistance to the line of force, the more the molar will tip, while the more the outer bow is bent downward, the less extrusive force is exerted on the molar. Therefore, molar movements, can be controlled by altering the length of the outer bow or the angle between inner and outer bow with respect to the position of the anchorage (28). The headgear must be adjusted regularly during treatment and as suggested by Lima Filho *et al.* (16) the 20 degrees upward bending of the long outer bow is effective in controlling the distal tipping and the extrusion of the upper molars. Also in the PG an uprighting bend was added to the end of TMA wire as recommended by Byloff *et al.* (17). In this study, any possible rotation of the mandibular plane was avoided controlling the extrusion of upper molars and corrected during fixed orthodontic treatment with no significant between-group differences in the T2–T1 changes for any of the vertical skeletal variables. The similar changes in the 3 groups for the dentoskeletal variables confirmed that the vertical growth pattern was not affected by both treatment protocols with no repercussion on the resultant vertical dimension.

Both distalizers were equally effective in the correction of molar relationships with an improvement of 2.5 mm in both treatment groups with respect to CG. The only difference between the 2 distalizing protocols was the greater SNA angle reduction in the CHGG (−1.2 degrees) than in the PG (0.0 degrees), thus suggesting that in patients with Class II malocclusion associated with skeletal maxillary protrusion treatment with CHG should be preferred.

Conclusions

1. Both distalizing protocol resulted effective in achieving a Class I molar relationship without increasing the vertical dimension in growing subjects at the end of comprehensive treatment.
2. The CHGG produced a greater maxillary growth restriction than did the PG. The PG, however, is a valuable noncompliance alternative for Class II correction in patients with moderate skeletal discrepancy.

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