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Treating Class II malocclusion in children. Vertical skeletal effects of high-pull or low-pull headgear during comprehensive orthodontic treatment and retention

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Structured Abstract

Objectives – To evaluate, in Class II malocclusion children, vertical skeletal changes occurring with high- and low-pull headgear during non-extraction comprehensive orthodontic treatment, and retention.

Setting and sample population – Two groups of thirty Class II malocclusion children (mean age 10.8 years) who had undergone non-extraction comprehensive orthodontic treatment with either high- or low-pull headgear and fixed appliances.

Material and Methods – Retrospective longitudinal study, where pre-treatment, post-treatment and at least 2 year post-retention lateral cephalometric radiographs were analyzed. Comparisons were made concerning changes during treatment and retention in high- or low-pull headgear-treated children. Correlation analyses were carried out investigating changes in vertical cephalometric parameters and pre-treatment vertical facial pattern or type of headgear used.

Results – During treatment, sagittal relationships improved in all children and remained stable during retention. Vertically, in both high- and low-pull headgear groups, the intermaxillary angle as well as the maxillary and mandibular plane angles did not show statistically significant changes during treatment or retention, and large variation was seen between patients. When pooling the whole patient sample, change in the vertical facial pattern was independent of the pre-treatment vertical facial pattern or type of headgear used.

Conclusion – When treating Class II malocclusion children non-extraction with high- or low-pull headgear and fixed appliances, changes in vertical skeletal relationships demonstrate wide variation, both during treatment and retention. Dentoalveolar changes brought about by these appliances may not be able to make a predictable difference in vertical skeletal patterns of growing patients.

Key words: angle Class II; cephalometry; extraoral traction appliances; malocclusion

Introduction

Extraoral forces applied to the maxillary dentition have been used for numerous years to help improve antero-posterior skeletal and dental mal-relationships. When treating growing children with Class II malocclusion, the direction of extraoral force is commonly believed to influence vertical skeletal relationships (1). Based on this assumption, it is argued that by controlling the vector of the force, with the use of headgear for example, the vertical skeletal relationship in the growing face can be altered predictably. Consequently, the initial vertical skeletal pattern of a patient normally dictates headgear choice.

Controlling the vertical dimension during orthodontic treatment is considered to be of major importance in hyperdivergent patients (2, 3). The high-pull headgear, attached to the first molars, was initially designed to avoid extrusion of the molars such as in open bite cases and patients with high mandibular plane angles (2, 4–6). High-pull headgear is thought to achieve this by its distal and intrusive force components, affording a better control of tooth movement (7, 8). However, can we rely on the use of high-pull headgear to improve the maxillomandibular vertical skeletal relationship?

In contrast, low-pull headgear is thought to cause an opening rotation of the mandible due to a downward vector of force. The clinical belief is that extrusion of the first maxillary molars is responsible for the opening rotation of the mandible (9–11). There is, however, considerable controversy regarding the action of this type of headgear appliance on the upper molars, maxillary plane, occlusal plane, and mandibular plane (12–17). Can we be sure that the use of low-pull headgear will predictably result in an opening rotation of the mandible? Van der Linden (18) stated that headgear serves to facilitate the correction of a Class II malocclusion with an improvement in the sagittal maxillomandibular relationship, but without any permanent effect on the amount and direction of facial growth.

Headgear appliances are rarely used in isolation, and are more often used preceding or in combination with full fixed appliance treatment, with or without extractions. In existing clinical studies looking at the effects of high-pull headgear, for example, authors have examined its effects in isolation (7, 19–22), or in a mixed group of patients where some also received full fixed appliances (13, 23), or where full fixed appliances were used along with extractions (3). Little is known about the vertical effects of high-pull headgear when used in a comprehensive fashion with full fixed appliances without extractions. Moreover, no data are available on the long-term changes that occur once the fixed appliances and headgear are discontinued. When evaluating the success of any comprehensive orthodontic treatment, long-term effects and an evaluation of treatment stability is paramount.

The objective of this study was to evaluate, in Class II malocclusion growing patients, vertical skeletal changes that occur with the use of high- or low-pull headgear in combination with full fixed appliances in non-extraction comprehensive orthodontics, during treatment and during retention. The null hypothesis was that there would be no vertical skeletal changes during the treatment or retention periods.

Materials and methods

Study design

Retrospective longitudinal study.

Patient sample

The sample consisted of two groups of thirty growing Class II malocclusion patients chosen consecutively, treated non-extraction with either high- or low-pull headgear and full fixed appliances. The sample size was calculated based on an alpha significance level of 0.05 and 80% power to detect a difference of 1 degree or millimeter between measurements. The power analysis showed that at least 25 patients were needed. The mean age for the total patient sample at the start of treatment was 10.8 (SD 1.8; min 7.9; max 14.0), with 15 females and 15 males in each group. The low-pull headgear group was matched according to age and sex to the high-pull headgear group.

Treatment records were searched to identify Class II malocclusion growing children who had been treated with a combination of high- or low-pull headgear and full fixed appliances. Inclusion criteria were as follows: patients in their late mixed dentition; at least half-cusp Class II molar relationship bilaterally; overjet ≥4 mm; ANB angle ≥4°; a treatment plan that included a combination of headgear and full fixed appliances; the presence of pre-treatment, post-treatment and at least 2 year post-retention lateral cephalograms. Exclusion criteria were as follows: the use of medium-pull or a combination-pull headgear; extraction cases; intra-oral presence of second molars when commencing headgear use; agenesis of permanent teeth other than third molars; cleft or craniofacial anomaly patients; the use of skeletal anchorage; orthognathic surgery cases; cases where it was documented in their records as having demonstrated poor cooperation with headgear use; cases who interrupted treatment prior to its completion. The patients were selected based on the sagittal relationships as opposed to the vertical relationships, based on the observation of van der Linden (18) that headgear ultimately assists in the correction of a sagittal malocclusion but does not have any permanent effect on the amount and direction of facial growth, which is determined instead by the intrinsic growth pattern of the particular patient.

Cephalometric assessment

The pre-treatment (T1), post-treatment (T2), and post-retention (T3) lateral cephalometric radiographs were traced by one examiner, the junior author, who had been calibrated with the senior author, and blinded to headgear type. Any enlargement of the cephalograms was accounted for. The following angular variables were measured: SNA, SNB, ANB, SN-maxillary plane, SN-mandibular plane, intermaxillary angle, gonial angle, upper incisors to SN plane, lower incisors to mandibular plane, and interincisor angle. The following linear variables were measured: overjet, overbite, upper and lower anterior facial heights. The variables are defined in Table 1.

The structural superimposition method (24) was used to superimpose the post-treatment and post-retention radiographs on the pre-treatment radiograph, transferring the pre-treatment SN plane onto each subsequent radiograph. Angular measurements using the SN plane were made on the pre-treatment SN plane, to avoid errors arising from vertical or sagittal changes with growth in the position of the sella or nasion points.

Statistical evaluation

The high- and low-pull headgear groups were compared as regard pre-treatment (T1) cephalometric characteristics, using independent sample t-tests. Additionally, changes during treatment (T2−T1), during the post-treatment period (T3−T2), as well as during the total treatment and post-treatment periods (T3−T1) were calculated for each of the headgear groups and paired sample t-tests were used to evaluate changes. Bonferroni corrections for multiple tests were applied using the formula α/n whereby $\alpha = 0.05$ and n = the number of cephalometric variables tested (thus n = 13). Statistical significance was accordingly set at $p < 0.004$.

Multiple linear regression analyses were carried out to investigate the relationships between initial (T1) vertical skeletal cephalometric characteristics and changes during treatment (T2−T1), post-treatment (T3−T2) or during the total treatment period (T3−T1), including type of headgear as a cofactor in the regression model. Vertical cephalometric characteristics investigated were SN-maxillary plane angle, SN-mandibular plane angle, intermaxillary angle, gonial angle, and upper to lower anterior facial height ratio.

Table 1. **Definitions of the angular and linear cephalometric variables measured**

Cephalometric variable	Definition
Angular variables	
SNA	The angle formed by the points sella, nasion, and A point
SNB	The angle formed by the points sella, nasion, and B point
ANB	The angle formed by the A point, nasion, and the B point
SN-maxillary plane	The angle between the sella–nasion plane and the maxillary plane (plane through the anterior nasal spine and the posterior nasal spine)
SN-mandibular plane	The angle between the sella–nasion plane and the mandibular plane (plane through menton and gonion)
Intermaxillary angle	The angle between the maxillary and mandibular planes
Gonial angle	The angle formed by the points condylion, gonion, and gnathion
Upper incisors to SN plane	The angle between the maxillary incisor (line through the root apex and middle of the cervico-enamel junction) and the sella-nasion plane
Lower incisors to mandibular plane	The angle between the mandibular incisor (line through the root apex and middle of the cervico-enamel junction) and the mandibular plane
Interincisor angle	The angle between the maxillary and mandibular incisors
Linear variables	
Overjet	The horizontal distance between the incisor edges of the maxillary and mandibular central incisors
Overbite	The vertical distance between the incisor edges of the maxillary and mandibular central incisors
Upper anterior facial height	The distance from nasion to the maxillary plane, based on a line through nasion and menton
Lower anterior facial height	The distance from menton to the maxillary plane, based on a line through nasion and menton

Error of the method

The error of the method for cephalometric measurements was calculated by performing duplicate tracings and measurements on 20 randomly selected cephalometric radiographs, with a 3-week interval between the measurements, using Dahlberg's formula (25). In using Dahlberg's formula ($\sqrt{\Sigma d^2/2n}$), Σd^2 denotes the sum of the squared differences between pairs of recordings, while n denotes the number of duplicate measurements. For linear measurements, the error did not exceed 0.5 mm, while for angular measurements this did not exceed 0.6° except for the gonial angle (0.8°) and the interincisal angle (0.9°).

Results

Patient characteristics

Regarding pre-treatment (T1) cephalometric characteristics, the high-pull headgear group presented with larger SN-mandibular plane, intermaxillary, and gonial angles, as well as a smaller upper to lower anterior facial height ratio, and a smaller interincisor angle, when compared to the low-pull headgear group (Table 2).

Treatment changes

The mean treatment period duration was 3.7 years (SD 1.9) and 3.9 years (SD 1.8) for the high- and low-pull headgear groups, respectively (Table 3). Sagittal treatment changes seen with the use of high-pull headgear and fixed appliances were a decrease in the SNA and ANB angles. Vertically, no significant changes were observed. Dentally, overjet and overbite decreased. Sagittal treatment changes with the use of low-pull headgear and fixed appliances consisted of a decrease in the SNA and ANB angles. Vertically, this group also showed no significant changes. Dentally, overjet and overbite decreased and mandibular incisors proclined.

Table 2. **Pre-treatment (T1) cephalometric characteristics of the high- and low-pull headgear groups**

	High-pull		Low-pull		Differences
	Mean	SD	Mean	SD	*p*-Value
Sagittal					
SNA (°)	80.8	3.5	81.4	4.0	ns
SNB (°)	74.6	2.9	76.4	3.2	ns
ANB (°)	6.2	1.9	5.0	1.9	ns
Vertical					
SN-Max (°)	6.9	2.7	7.6	3.4	ns
SN-Mand (°)	38.2	4.3	30.3	3.3	<0.001
Intermaxillary angle (°)	31.3	3.9	22.7	3.8	<0.001
Gonial angle (°)	123.6	5.7	117.0	4.7	<0.001
UFH/LFH (%)	80.3	7.0	87.8	7.1	<0.001
Dental					
1/-SN (°)	101.8	5.5	101.0	8.7	ns
/1-Mand (°)	96.5	5.1	97.4	6.4	ns
Interincisor Angle (°)	122.6	7.8	131.2	12.6	0.003
Overjet (mm)	5.8	1.9	5.3	2.1	ns
Overbite (mm)	3.5	1.9	4.6	2.2	ns

Significance of differences between the groups is presented, with a *p*-value of below 0.004 considered significant, and 0.004 or higher considered non-significant (ns), as per Bonferroni correction. Max = maxillary plane; Mand = mandibular plane; UFH = upper anterior facial height; LFH = lower anterior faciail height; 1/ = upper incisor; /1 = lower incisior.

Post-treatment changes

The mean post-treatment follow-up period duration was 3.1 years (SD 1.9) and 3.3 years (SD 1.7) for the high- and low-pull headgear groups, respectively (Table 3). No sagittal, vertical, or dental post-treatment changes were seen following the use of high-pull headgear and fixed appliances. Similarly, no sagittal or dental post-treatment changes were seen in the low-pull headgear group. Vertically, this group showed a closing of the gonial angle.

Total changes

Total treatment and post-treatment sagittal changes with the use of high-pull headgear and fixed appliances were a decrease in the SNA and ANB angles (Table 3). Vertically, this group showed a closing of the gonial angle. Dentally, overjet and overbite decreased. Similarly, total treatment and post-treatment sagittal changes with the use of low-pull headgear and fixed appliances were a decrease in the SNA and ANB angles. Vertically, this group showed an opening of the intermaxillary angle and closing of the gonial angle. Dentally, mandibular incisors proclined, and overjet and overbite decreased.

Regression analyses

No statistically significant multiple linear regression models were found for any of the investigated variables, when evaluating relationships between initial (T1) vertical skeletal cephalometric characteristics and treatment (T2−T1), post-treatment (T3−T2), or total treatment period (T3−T1) changes, with type of headgear included as a cofactor in the regression models. The model with the highest coefficient of determination (R^2), despite its lack of statistical significance, is presented in Table 4. Neither the initial vertical skeletal cephalometric characteristics of patients nor the type of headgear used was predictive in determining the treatment or post-treatment changes.

Table 3. **Treatment (T2−T1), post-treatment (T3−T2), and total (T3−T1) changes in the measured cephalometric variables, of the high- and low-pull headgear groups**

	High-pull									Low-pull								
	T2−T1			T3−T2			T3−T1			T2−T1			T3−T2			T3−T1		
	Mean	SD	*p*-Value	Mean	SD	*p*-Value	Mean	SD	*p*-Value	Mean	SD	*p*-Value	Mean	SD	*p*-Value	Mean	SD	*p*-Value
Sagittal																		
SNA (°)	−2.2	2.0	<0.001	0.4	2.1	ns	−1.8	2.5	0.001	−1.7	1.6	<0.001	0.1	1.7	ns	−1.6	1.8	<0.001
SNB (°)	−0.1	2.9	ns	0.6	2.7	ns	0.5	2.2	ns	0.2	1.8	ns	0.3	1.4	ns	0.5	1.8	ns
ANB (°)	−2.1	1.6	<0.001	−0.2	0.8	ns	−2.3	1.7	<0.001	−1.9	1.0	<0.001	−0.2	0.8	ns	−2.1	1.2	<0.001
Vertical																		
SN-Max (°)	0.0	2.2	ns	−0.8	2.1	ns	−0.8	2.6	ns	−0.3	3.1	ns	−0.7	2.3	ns	−1.0	3.5	ns
SN-Mand (°)	0.7	3.0	ns	0.2	2.9	ns	0.9	3.3	ns	0.6	3.1	ns	0.3	2.8	ns	0.9	4.5	ns
Intermaxillary angle (°)	0.7	3.2	ns	0.9	3.6	ns	1.6	3.8	ns	0.9	2.4	ns	1.0	2.1	ns	1.9	3.0	<0.001
Gonial angle (°)	−0.9	2.3	ns	−1.1	2.0	ns	−2.0	3.0	0.002	−0.4	2.7	ns	−2.2	3.1	0.001	−2.6	3.3	<0.001
UFH/LFH (%)	−0.6	3.3	ns	−0.6	3.7	ns	−1.2	3.4	ns	−0.2	4.1	ns	−0.3	2.3	ns	−0.5	4.1	ns
Dental																		
1/-SN (°)	−1.9	7.6	ns	0.6	5.0	ns	−1.3	7.1	ns	2.5	9.3	ns	−1.4	5.1	ns	1.1	10.2	ns
/1-Mand (°)	0.3	6.0	ns	1.4	3.3	ns	1.7	5.3	ns	3.1	5.2	0.003	1.8	4.3	ns	4.9	5.8	<0.001
Interincisor Angle (°)	2.3	10.2	ns	−0.1	7.7	ns	2.2	8.2	ns	−5.5	2.2	ns	1.1	9.5	ns	−4.4	15.5	ns
Overjet (mm)	−3.0	2.5	<0.001	0.4	0.8	ns	−2.6	2.2	<0.001	−2.9	2.5	<0.001	0.2	0.8	ns	−2.7	2.3	<0.001
Overbite (mm)	−1.7	1.9	<0.001	0.2	1.8	ns	−1.5	1.9	<0.001	−2.2	2.4	<0.001	0.5	1.1	ns	−1.7	2.3	<0.001

Significance is presented with a *p*-value of below 0.004 considered significant, and 0.004 or higher considered non-significant (ns), as per Bonferroni correction. Max = maxillary plane; Mand = mandibular plane; UFH = upper anterior facial height; LFH = lower anterior faciail height; 1/ = upper incisor; /1 = lower incisior.

Table 4. **Multiple linear regression analysis results showing the association between initial (T1) intermaxillary angle and total change (T3−T1) in intermaxillary angle, with type of headgear included as a cofactor in the regression model**

Multiple regression analysis model	$Y = b_0 + b_1$ (T1 intermaxillary angle) + b_2 (type of headgear)
Dependent variable (Y)	Total change (T3−T1) in intermaxillary angle (°)
Independent variable	Initial (T1) intermaxillary angle (°)
Independent variable cofactor	Type of headgear (0 = high-pull; 1 = low-pull)
Constant (b_0)	−2.420
Regression coefficient (b_1)	0.211
Regression coefficient (b_2)	0.443
Coefficient of determination (R^2) for model	0.100

Discussion

The present study illustrates that in Class II malocclusion growing children, when a high- or low-pull headgear is used in combination with full fixed appliances, no significant vertical changes occur during the treatment or retention periods regarding maxillary, mandibular, or intermaxillary angles. Many t-tests were performed in the present study, making it perhaps more probable that the null hypothesis would be rejected. Despite this, however, based on the results, the null hypothesis cannot be rejected.

A more scientifically rigorous study design would have included untreated Class II malocclusion control patients matched for age and sex as well as vertical skeletal cephalometric characteristics. The design of the present study, however, was retrospective and the inclusion of such a group from the same population was impossible to obtain. Moreover, the vertical growth pattern of a particular patient is impossible to predict based on cross-sectional cephalometric characteristics.

Changes in the vertical skeletal relationships during headgear therapy are known to demonstrate a wide variation, and mean changes in vertical skeletal measures as a result of treatment have been found to be negligible (12). This variation between individuals in response to treatment may imply that some patients show an opening and others a closing rotation of the mandible (15). The presence of large variation, evident when looking at the standard deviations, was also apparent in the present patient samples. When the standard deviation (and thus variation) is high, the mean becomes meaningless as a predictor for any individual subject (26).

Finite element analysis studies show that traditional beliefs concerning the effects of headgear hold true, in that high-pull headgear demonstrates better control of the vertical dimensions (27). However, clinically the situation is much more complex. Despite high-pull headgear causing vertical changes due to its intrusive vector of force, the combination of fixed appliances and growth may mask or negate some of the vertical changes occurring. Fixed orthodontic treatment is by nature extrusive, and leveling occurs almost totally by extrusion as long as continuous archwires are used (1). Some extrusion of the maxillary first molars can almost always be seen, with consequent effects on the vertical facial pattern. On the other hand, molar extrusion and an opening of the vertical facial pattern expected when using a low-pull headgear may be masked by the growth pattern of the patient as well as the effect of occlusal forces preventing an important amount of molar extrusion.

Initial facial form may not be a predictable indicator of vertical skeletal change occurring with or without extraoral force, and there may be no significant difference between the direction of extraoral force and changes in vertical skeletal relationships (9). Individual growth pattern is extremely variable, with some patients crossing over from an apparent vertical pattern to an average or horizontal growth pattern with age (28). Burke and Jacobson (13) found an absence of profound differences between mandibular plane angle changes, as well as changes in maxillary molar height, for high-angle patients treated with low- or high-pull headgear. Dentoalveolar changes brought about by orthodontic treatment may not be able to make a significant difference in a vertical skeletal discrepancy. As a matter of fact, Haralabakis and Sifakakis (17) in their patient sample with high or low mandibular plane angles demonstrate that vertical skeletal relationships in a growing face cannot be altered predictably by controlling the direction of extraoral force.

Long-term stability and post-treatment changes following headgear wear are of paramount importance to orthodontist and patient alike. Kim and Muhl (15) suggest that post-treatment mandibular rotation reflects more of an inherent growth pattern of an individual reasserted after treatment rather than a rebound or relapse effect. They found that rotation of the mandible during retention did not show significant correlations with either pre-treatment cephalometric measures or mandibular rotation during treatment. Melsen and Dalstra (16) also state that variation in vertical development is related more to each patient's growth pattern than to the force system applied. In this manner, individual patient response to treatment is highly variable and predictions for future growth behavior or changes must be made with caution. In the present study, no significant mean post-treatment changes were seen for maxillary plane, mandibular plane, or intermaxillary angles.

Haralabakis and Sifakakis (17) put forward that genetically controlled skeletal and muscular parameters seem to be predominant in determining vertical changes during growth and the reason that so many divergent treatment philosophies, techniques, and appliances are successful in resolving malocclusions is that they produce negligible skeletal change. Growth occurs with or without orthodontic appliances and perhaps the inherent vertical pattern cannot be altered significantly. What could possibly influence the post-treatment changes is whether or not a patient has completed growth at the time active treatment is completed.

The role of muscular forces on growth, facial form, and vertical facial pattern may also be important, via an interaction between masticatory muscle forces and craniofacial growth. It has been proposed that muscle thickness and bite force are inversely related to anterior facial height (29–31), and long-face individuals have less occlusal forces than those with normal vertical facial dimensions (32). Charalampidou et al. (33) also found a negative correlation between masseter muscle thickness and the intermaxillary angle. Masticatory muscles can be said to influence vertical dimensions of the face (34). In consequence, while appliances are thought to influence the vertical pattern, growth pattern is in all likelihood determined by other factors such as muscular characteristics and genetics, and thus, any changes during growth may occur independent of appliances.

In most cases of healthy children, the extrusive component of the low-pull headgear is counteracted by occlusal forces, regardless of facial morphology. Melsen and Dalstra (16) found that forces on molars did not lead to differences in molar eruption, stating that this is probably because of the interaction with occlusal forces. However, in individuals with hypotonic masticatory muscles, there may be good reason to avoid low-pull headgear as the extrusive component would not be able to be counteracted, resulting in molar extrusion and a change in the vertical facial pattern of the individual.

Conclusions

When treating Class II malocclusion children non-extraction with either high- or low-pull headgear and full fixed appliances, changes in vertical skeletal relationships demonstrate wide variation, both during treatment and retention. Dentoalveolar changes brought about by headgear with fixed appliances, based on the present study design, may not be able to make a predictable difference in vertical skeletal patterns of growing patients, indicating that other factors such as growth or functional factors may be more important than the use of headgear.

Clinical relevance

When treating growing children with Class II malocclusion where headgear is indicated, clinicians often choose the direction of pull of the headgear based on the child's vertical facial pattern. The direction of headgear pull is commonly thought to influence vertical skeletal relationships. This study looks at patients where a high-pull or low-pull headgear was used in conjunction with full fixed appliances, and where the choice of headgear was made based on vertical skeletal relationships. Results suggest that the vertical skeletal pattern of a growing child cannot be altered predictably with the type of headgear used.

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