CLINICAL REPORT

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Effects of the headgear-activator Teuscher appliance in the treatment of class II division 1 malocclusion: a geometric morphometric study

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Structured Abstract
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Objectives – To test the hypothesis that there are no gender differences in the outcomes of patients with class II malocclusion treated with the headgear-activator Teuscher appliance (HATA).
Design – Retrospective, longitudinal
Setting and Sample Population – Puerto Rico and Scotland, UK. Thirty-one patients requiring correction of class II division 1 malocclusions.
Experimental Variable – Male and female patients treated using HATA.
Outcome Measures – Mean pre- and post-treatment parameters derived from cephalometry subjected to *t*-tests, and finite-element scaling analysis (FESA), which localizes and quantifies differences between mean pre- and post-treatment configurations.
Results – Post-treatment, cephalometry showed that for both males and females, angle SNA decreased, SNB increased, and lower facial heights increased significantly ($p < 0.01$). For the female post-treatment configuration, FESA revealed large size increases (≈20%) located in the inter-maxillary region, the ramus and mandibular body, and around the nasal and mental regions. Conversely, the lip region was diminished (≈20%). Similarly, male post-treatment showed size increases located in the inter-maxillary region that extended into the nasal region and the mandibular body (≈10–15%), and around the chin (15%). The lip region was diminished (≈5%).

Conclusion – In the attainment of a normal occlusion, both male and female patients treated for class II malocclusions using HATA exhibit antero-posterior restraint of the maxilla, improvements in the mandible maintaining facial height, and lip changes commensurate with improvements in the soft tissue profile.

Key words: activator; geometric_morphometrics; malocclusion; Teuscher

Introduction

The use of functional appliances to help correct class II malocclusion has become popular ever since the development of the activator by Andresen (1). The effects of activators on the maxillomandibular complex and the dentition have been investigated extensively. In one study (2), the authors concluded that the major effects of activator treatment were an increased amount of condylar growth and remodeling of the articular fossa. Thus, some investigators (3–5) found 1–2 mm increases in incremental growth of the mandible after the use of activators, but others (6,7) observed significant dento-alveolar changes, concluding that the magnitude of mandibular growth was not affected by activator treatment. These latter results were later confirmed (8), suggesting that a class I occlusion was achieved through distal tipping of the maxillary teeth and a mesial, vertical movement of the mandibular dentition when employing activator treatment. The combination of these effects was thought to result in the permanent anterior displacement of the mandible. Importantly, however, activator treatment was noticed to cause the maxilla and mandible to rotate in a downward and backward direction. This pattern of mandibular rotation is thought to be detrimental to the correction of class II malocclusion.

For the maxillary complex, it has been demonstrated (9,10) that activator treatment increased posterior maxillary vertical height, which resulted in a backward rotation of the mandible and pogonion. Indeed, in one study (5) the activator inhibited the horizontal anterior growth of the maxilla by 2 mm. This unwanted effect of the activator led to a modified use of the appliance. Ullrich Teuscher (11) advocated the use of high pull headgear with the activator to counteract the undesired maxillary side effect. Teuscher claimed some success using the headgear-activator Teuscher appliance (HATA). The effects of this modified activator technique included successful improvements in soft tissue facial profile, but there are only a few reports on the effects of this modification (12–14).

To date, there are very few scientific reports in the literature of the effects of the HATA. The aim of this current investigation is to evaluate the effects of HATA on the skeletal and soft tissue components of the maxillomandibular complex in the correction of class II malocclusion. The null hypothesis to be tested here is that there are no gender differences in the outcomes of patients with class II malocclusion treated using HATA. Furthermore, given the limitations of conventional cephalometry (15,16), a combination of traditional cephalometric analysis and geometric morphometrics will be employed in this study to investigate the effects of the HATA in the treatment of class II malocclusions.

Materials and methods

After obtaining consent, pre- and post-treatment (end of functional phase) lateral cephalographs of 31 children aged between 10 and 14 years with Angle's class II division 1 malocclusion were retrieved from an orthodontic department. The mean age of the 21 girls in this sample was 12 years 2 months (±1.3 years), while the 10 boys in the study had a mean age of 12 years 5 months (±0.9 years). All females and males in the sample had a large overjet (7–14 mm) with a distal occlusion related to a moderate to severe class II skeletal relationship, and were treated consecutively by the same orthodontist using HATA. Thus, the clinician's criteria for using HATA were moderate class II division 1 patients with an overjet of at least 7 mm but with average to increased vertical proportions. The mean overjet for the girls was 9 mm (±2.4), while the boys had a mean overjet of 10 mm (±2.5) prior to treatment. The average treatment time for the girls was 11 months (±3.4), and 12.5 months (±3.8) for the boys. The criteria for the completion of treatment was overjet reduction to 2 mm with the first permanent molars in an Angle's class I relationship. Exclusion criteria for sample selection were a history of previous orthodontic treatment, facial trauma requiring hospital attendance, and congenital maxillofacial deformity. The chronological age was assumed to match developmental age in this study, as carpal ages were unavailable. It was presumed that when all radiographs were taken, the central X-ray passed along the transmeatal axis while the teeth were in occlusion. The magnification of each film was standardized to 8%. For each lateral cephalograph, subject/chart identifiers were masked and *x*, *y* co-ordinates of 25 homologous, hard and soft tissue landmarks (Fig. 1) were digitized using appropriate software and a digitizing tablet (BST). These landmarks encompassed the lateral facial profile and permitted the construction of the hard–soft tissue configurations to be studied. The digitizing procedure was repeated twice on different occasions. For all *x*, *y* co-ordinates of the landmarks, the digitization error was found to be <1% on duplicate digitization ($p > 0.05$). Therefore, the

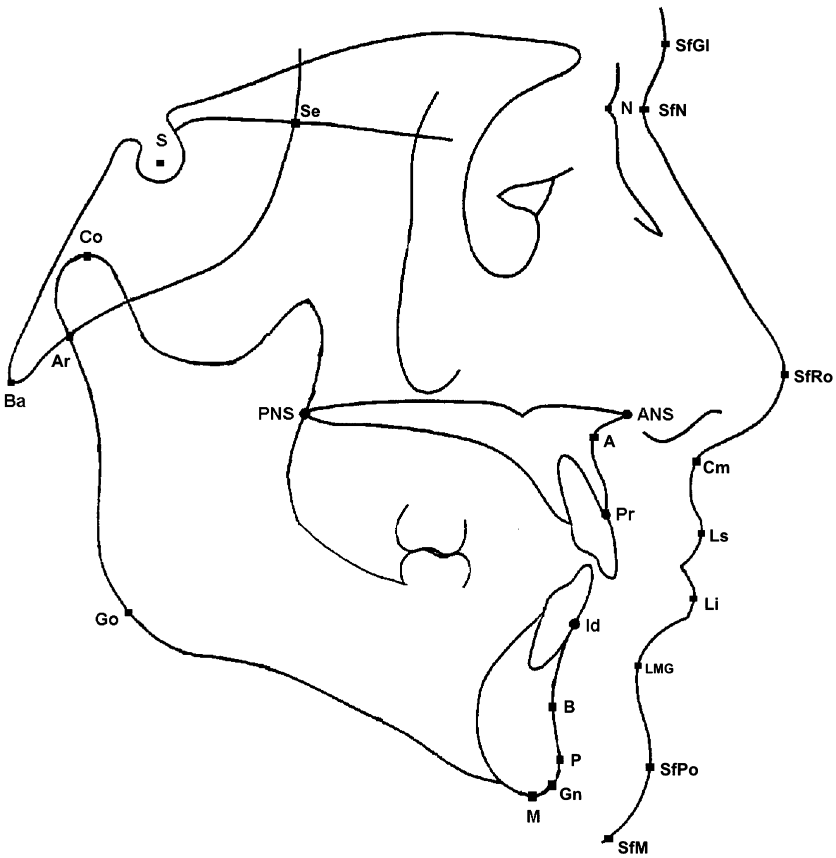

Fig. 1. Tracing of lateral cephalograph indicating the homologous, hard and soft tissue landmarks that were digitized, permitting the lateral facial profile to be studied. Subspinale (A): Point of maximum concavity inferior to the anterior nasal spine on maxillary alveolus; Sphenoidale (Se): Intersection of greater wing of sphenoid with anterior cranial base; Articulare (Ar): Posterior intersection of condylar head and posterior cranial base; Gnathion (Gn): Most anteroinferior point on mandibular symphysis; Nasion (N): The anterior aspect at the fronto-nasal suture; Sella (S): Midpoint in the hypophyseal fossa of the sphenoid bone; Basion (Ba): Most inferio-posterior point on the anterior margin of the foramen magnum; Condylion (Co): Point at the apex of the head of the mandibular condyle; Gonion (Go): Point at the infero-posterior aspect on the angle of the mandible; Menton (M): Most inferior point on the mandibular symphysis; Infradentale (Id): Most superior point of the alveolus on the labial aspect of the lower incisor; Prosthion (Pr): Most inferior point of the alveolus on the labial aspect of the upper incisor; Anterior Nasal Spine (ANS): Most anterior point of the hard palate; Supramentale (point B): Deepest point on mandibular symphysis above pogonion; Pogonion (P): Most anterior point on the mandibular symphysis; Posterior Nasal Spine (PNS): Posterior-most point on posterior nasal spine; Soft Glabella (SfGl): Most anterior point above Nasion on the forehead; Soft Nasion (SfN): Deepest point on the Nasion saddle; Soft Rhinion: Most anterior point on tip of nose on esthetic plane; Columella (Cm): Point where nose and upper lip meet; Labial Superioris (LS): Anterior-most point on the upper lip; Labiomental groove (LMG): Deepest point on concavity of labiomental groove below the lower lip; Labial Inferioris (LI): Anterior-most point on the lower lip; Soft Menton (SfM): Most inferior point on the chin on esthetic plane; Soft Pogonion (SfPo): Anterior-most point on the chin on esthetic plane.

landmarks were deemed to be identified reliably and further analyses warranted. Initially, a conventional cephalometric analysis was undertaken, and the mean pre- and post-treatment parameters were subjected to *t*-tests to determine statistically significant changes.

As a further investigation, a Procrustes method (16) was employed to determine the variance around each landmark and express it as a root-mean square. Therefore, both groups of female and male configurations were subjected to Procrustes superimposition and each configuration was represented as a mean and variance. The Procrustes routine was implemented on a personal computer, and an average geometry for each configuration was determined using a generalized orthogonal Procrustes analysis. Following this method, every subject's co-ordinates were translated, rotated and scaled iteratively until the least-squares fit of all configurations was no longer improved. Therefore, all configurations were co-registered, and as a result of this procedure, geometric configurations were scaled to an equivalent area, avoiding problems introduced by differences in size.

To determine whether the pre- and post-treatment hard–soft tissue configurations differed, each mean pre-treatment geometry was compared with the corresponding mean post-treatment geometry. In order to demonstrate areas of deformation, a finite element scaling analysis (FESA) was undertaken that incorporated a spline interpolation function. Based on this approach, form differences can be described graphically (17). The FESA software (MorphoStudio) was written in 'C++' and implemented on a personal computer. The mean, pre-treatment configuration was taken as the initial geometry, and this configuration was compared with the post-treatment mean. Deformation values were computed for at least 2000 points per subject for graphical display. A log-linear interpolation of the area-change values was used to generate a pseudo-color map. Thus, area-change measures were color-mapped into each pre-treatment configuration to provide graphical displays of geometrical change after treatment with HATA.

***Table 1*. Cephalometric analysis for patients treated with the Teuscher appliance**

	Pre-mean	Std.	Post-mean	Std.	*p*
Female					
SNA	82.47	4.40	80.84	4.25	<0.001
SNB	75.94	4.64	77.42	4.63	<0.001
ANB	6.52	1.64	3.42	1.26	<0.001
MM	27.68	5.38	26.31	5.29	<0.01
1MX	111.89	6.80	106.78	5.96	<0.001
1MN	95.52	7.13	98.00	6.61	<0.01
UFH	52.05	3.39	53.63	2.85	<0.01
LFH	64.47	5.58	67.10	4.45	<0.01
%	55.26	2.20	55.63	1.97	N.S.
Y-axis	66.31	5.31	67.68	4.86	<0.05
Male					
SNA	81.0	3.5	79.3	3.5	<0.01
SNB	74.6	2.5	76.4	2.4	<0.001
ANB	6.4	2.4	2.9	1.1	<0.001
MM	30.3	5.9	27.2	4.8	<0.01
1MX	110.6	9.3	105.9	6.6	<0.01
1MN	92.7	5.5	94.8	5.0	<0.01
UFH	54.0	2.2	55.6	3.1	=0.05
LFH	64.7	4.4	68.7	5.8	<0.01
%	54.4	1.8	55.0	1.8	N.S.
Y-axis	65.5	4.7	66.6	2.3	N.S.

SNA = Angle SNA (°)
SNB = Angle SNA (°)
ANB = Angle SNA (°)
MM = Maxillo-mandibular plane angle SNA (°)
1MX = Angle of upper incisor to maxillary plane (°)
1MN = Angle of lower incisor to Mandibular plane (°)
UFH = Upper face height: nasion perpendicular to maxillary plane (mm)
LFH = Lower face height: menton perpendicular to mandibular plane (mm)
% = Relative proportion of UFH to LFH
Y axis = Angle of facial growth: intersection of sella-gnathion line and Frankfort plane
Mandibular plane = Line from menton through gonion
Maxillary plane = Line through ANS and PNS
Frankfort plane = Line from porion to orbitale

Results

For females treated with HATA, Table 1 shows the outcomes of cephalometric analysis. Nearly all of the parameters measured showed statistically significant changes. Specifically, the angle SNA decreased while angle SNB increased, decreasing angle ANB. The mandibular plane angle and the *Y*-axis increased slightly. The upper incisor became more retroclined while the lower incisor became more proclined. The upper and lower facial heights also increased, but their relative proportion (%) remained unchanged. Similarly, Table 1 shows the outcomes of cephalometric analysis

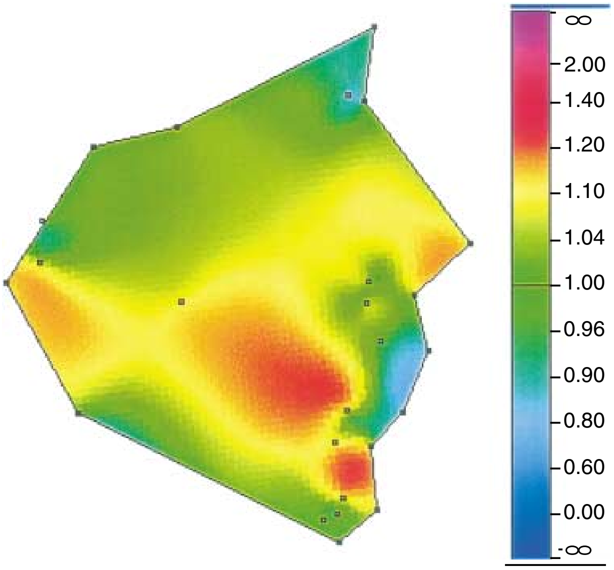

Fig. 2. Female configuration subjected to finite element analysis. Large size increases (≈20%) are located in the inter-maxillary region, the mandibular ramus and around the nose and the chin. Conversely, the lip region is diminished (≈20%).

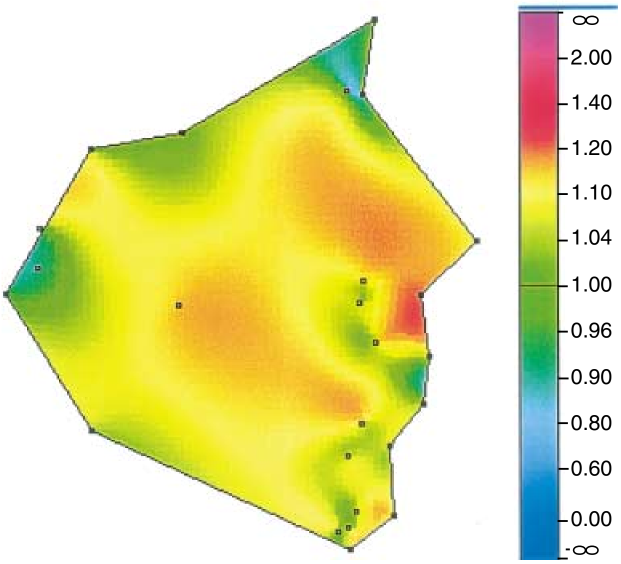

Fig. 3. Male configuration subjected to finite element analysis. Size increases (≈15%) are located in the inter-maxillary region, the nose and the soft tissues around the chin (by ≈10–15%, respectively). The lip region is slightly diminished (≈5%).

for males treated with HATA. Most of the parameters measured showed the same pattern of change as the females. However, while the lower facial height increased significantly, the upper facial height marginally failed to reach statistical significance, but their relative proportion (%) remained unchanged nevertheless. Similarly, the *Y*-axis remained unchanged in the boys.

Using FESA, Fig. 2 shows the female, post-treatment changes. There is a ≈20% increase in size within the inter-maxillary region of the configuration, suggesting that facial height had been increased. Similarly, the ramus of the mandible, the nasal soft tissues and the mental regions show an increase in size. In contrast, an increase in the midfacial region is not demonstrable, and the lip region shows a decrease in size (≈20%) in females treated with HATA.

Figure 3 shows the male, post-treatment configuration. The pattern of this configuration is not unlike that of Fig. 2. However, the 10–15% increase in size in the inter-maxillary region extends into the nasal region as well as the upper facial region of the configuration. In contrast, the mandibular ramus area, as well as the anterior/midfacial region, does not show large size increases. Nevertheless, an increase is seen in the mental region, which contrasts with the 5% decrease in size in the lip region of males treated with HATA.

Discussion

In this study, all subjects treated by the same orthodontist were consecutively enrolled; there was no selection based on success of treatment or availability of records or co-operation with the HATA. Thus, this study employs a longitudinal, retrospective, design and although retrospective investigations might be considered deficient when compared to prospective cohort investigations, the findings of this study compare favorably with previous randomized control trials (18–20).

A clear understanding of mechanisms of action of HATA is essential, as there is controversy on how functional appliances achieve their outcomes. Indeed, unequivocal demonstration of enhanced mandibular growth with functional treatments has yet to be illustrated. Therefore, this study employed a combination of cephalometry and a new geometric morphometric program (MorphoStudio) on configurations to test the null hypothesis that there are no gender differences in the outcomes of patients with class II malocclusion treated with the HATA. These comparisons aimed to identify the effects of HATA treatment, and provide evidence in the debate on how HATA achieves its clinical outcomes. Thus, although treatment compliance was noted clinically to be satisfactory, it was not possible to determine the full effect of compliance on overall treatment response. Nevertheless, a randomized control trial found that variation in treatment response could not be explained by cooperation alone (21).

Teuscher (11) was the first to combine the activator with high-pull headgear in the modified appliance for treatment of class II, division 1 malocclusion. The HATA treatment aims at correcting the malocclusion without diverting the anterior skeletal facial landmarks from their growth trajectories. In a comparative study (22), the efficiency of three activators (Andresen, Frankel and Teuscher) in the treatment of class II division 1 malocclusions in patients aged 8–14 years was studied. The Teuscher appliance combined with extraoral traction (HATA) was reported to produce good results by correction of the sagittal skeletal discrepancy. Thus, an inhibitory effect on the anteroposterior translation of maxillary development was achieved, as intended by Teuscher's modification. Similarly, another study (14) showed that the maxilla either remained unchanged in its relationship to the cranial base or became retrusive, suggesting that the correction of the skeletal component of class II malocclusion may take place by restriction of forward development of the maxilla. In a later study (23), the skeletal effect on the maxilla was retardation of its normal forward and downward displacement. More recently, a study (24) that investigated the effects of the modified Teuscher appliance on a group of 12-year-old, high-angle, class II patients, reported an inhibition of maxillary growth among the skeletal effects. In this current study, we also found evidence for maxillary retrusion using conventional cephalometry (Table 1). In addition, using size-scaled configurations, the effect of maxillary retrusion was noticeable in females (Fig. 2) but less so in males (Fig. 3). Overall, our results support the maxillary findings of earlier studies.

Although functional appliances have been used in orthodontics for many years, understanding of the anatomic basis of the orthodontic correction is still limited. In patients treated for class II Division 1 malocclusions with Twin-block appliances, condylar growth and osteogenesis in the dento-alveolar regions were associated with the correction of the underlying skeletal dysmorphology (25). However, activator treatment may cause the maxilla and mandible to rotate in a downward and backward direction, detrimental to the class I correction being attained. As the Teuscher appliance combines high-pull headgear with the activator, transfer of distally directed headgear forces from the maxilla to the mandible is prevented (11). Indeed, in one study (23) forward mandibular growth was reported in the majority of patients. Similarly, in another study (24) stimulation of mandibular growth was observed. In the present study, both conventional and geometric methodology demonstrated improvement in mandibular position and size (Figs. 2 and 3, respectively), supporting the concept of forward manipulation of the mandible. Thus, our morphometric findings reflect those of a cephalometric one (14), which noted that in patients treated with the Teuscher appliance, the mandible becomes more prognathic.

Soft tissue dynamics may influence the craniofacial growth of a child skeletally predisposed to a malocclusion (17,26). Conversely, children with malocclusions demonstrate deformations of the maxillomandibular soft tissue complex, which are amenable to orthodontic manipulations (27). Teuscher (11) postulated that, not only is the malocclusion corrected, but also significant improvement in facial profile is achieved by anterior development of the mandible. Indeed, size increases in the soft tissues of the nasal, upper facial and mental regions were demonstrated in the female configuration (Fig. 2). However, a similar increase in the lip region is not demonstrable, especially in females treated with HATA, supporting the contention of Teuscher. In patients treated with a surgical osteotomy, the soft tissue lower facial height was found to increase secondarily to the associated underlying skeletal change, improving the facial profile (28). In contrast, soft tissue profile improvements associated with the HATA treatment do not appear to follow the underlying skeletal changes. The current study somewhat supports cephalometric contentions (12), as a more prominent soft tissue mental region was noted in both female and male configurations (Figs. 2 and 3). For both sexes, the soft tissue nose became more prominent, as might be expected in growing children. Therefore, the final soft tissue profile may not reflect the underlying skeletal change; the final morphology of the lips may in fact be influenced by other factors such as dento-alveolar changes.

According to Teuscher (11), the maxillary dentition is restrained in a posterior direction, while the mandibular dentition is influenced in an antero-inferior direction by HATA. As it is generally accepted that in the treatment of class II malocclusion activators may tip the upper incisors (13), with the modified Teuscher activator we found it possible to control upper incisor inclination. In contrast to other studies in which dento-alveolar changes included retroclination of the maxillary incisors (23) the results of the current study indicate that mandibular incisors were well controlled. Thus, it is likely that occlusal correction occurs through a combination of skeletal and dento-alveolar changes, which have different impacts on the final lip position. More recently, upper incisor retrusion, and reduction of overjet and overbite have been reported (24). Indeed, the changes noted in the inter-maxillary regions of the configurations studied in this current two-dimensional investigation (Figs. 2 and 3) may equate to a decrease in overbite caused by molar extrusion in patients treated with the HATA. Nevertheless, the present study concurs with earlier studies (14) that dento-alveolar changes are characterized by wide individual variations, although the dental cephalometric changes reported here follow the expected pattern.

On average, when comparing the results of this study with normal growth data (29), the changes in antero-posterior and vertical direction are greater than those seen without the use of the functional appliance. Therefore, with the HATA, skeletal change is greater than that expected with normal growth alone. However, the extent to which these changes are maintained in these patients requires further observation and follow-up.

Conclusions

There is no gender difference in the outcome of patients with class II malocclusion treated with the HATA, which is associated with the following changes:

- Anterior restraint of the maxillary complex, affecting upper lip position.
- Antero-inferior manipulation of the mandibular complex, maintaining facial height.
- Improvements in lip position related to dento-alveolar changes of the upper and lower incisors.
- Overall improvements in facial profile require long-term observation and follow-up.

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