Dental and skeletal contributions to occlusal correction in patients treated with the high-pull headgear–activator combination

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The purpose of this study was to examine dental and skeletal changes in patients treated with the high-pull headgear–activator combination. A group of 40 consecutively treated subjects with a Class II molar relationship and a minimum of 5 mm overjet was used for this study. The results showed that Class II correction often was achieved by distal repositioning of the maxillary teeth (mean, 0.07 mm) and mesial repositioning of the mandibular teeth (mean, 3.3 mm) with a wide range of variation. Correlation of maxillary molar repositioning with total interarch occlusal change showed a positive relationship; however, a weak correlation suggested that other variables were contributing factors, in addition to distal upper molar positioning. The change in mandibular molar position compared with the movement of pogonion strongly suggests that forward growth of the mandible is important to the correction of the Class II malocclusion. When total molar repositioning in the upper jaw was correlated with total molar repositioning in the lower jaw, a strong inverse correlation was found, indicating that upper molar movement parallels lower molar movement. (AM J ORTHOD DENTOFAC ORTHOP 1990;97:495-504.)

The use of combined activator–high-pull headgear appliance has been recommended as a means of reducing vertical and sagittal maxillary displacement, achieving autorotation, and increasing forward displacement of the mandible.18-20 26

Cephalometric analysis of the high-pull headgear–activator combination has focused mainly on individual case reports18 and the average treatment effects of this appliance in comparison with untreated controls.26

The purpose of this study is to examine the dental and skeletal contributions to the correction of Class II malocclusion in patients treated with the high-pull headgear–activator combination as advocated by Teuscher18 and Stöckli and Teuscher.26

MATERIALS AND METHODS

The materials used for this study consisted of the orthodontic records of 40 consecutively treated patients (17 girls and 23 boys) who initially demonstrated some degree of Class II malocclusion, at least 5 mm of overjet, and wore only a high-pull headgear–activator combination for their treatment. Because of incomplete records, 6 of the 40 patients were not included in all parts of the study. All the patients were of Swedish descent and were treated in the Public Orthodontic Clinic in Halmstad, Sweden.

The distribution of age and sex is shown in Table...
Fig. 1. Illustration of force direction between center of resistance of maxilla (CRm) and center of resistance of upper dentition (CRd).

I. Orthodontic treatment was initiated at a mean age of 10.5 years for both groups, the girls and the boys. A comparison of the ages at the beginning and end of treatment showed no statistically significant sex-related differences. The mean duration of treatment was 1.5 ± 0.6 years for the girls and 1.8 ± 0.5 years for the boys.

All patients were instructed to wear the activator—headgear only during sleeping hours. Compliance with these instructions was clinically evaluated by applying manual pressure to the maxilla; this resulted in some clinically detectable degree of mobility. Also, the appliance was examined at each visit for evidence of usage (e.g., soiled neckstrap and the formation of plaque and calculus on the acrylic). No other attempts were made to assess patient cooperation. The criterion for discontinuing treatment in all cases was clinical reduction of the initial overbite and overjet.

Appliance design

The appliances used in this study were constructed as described by Stöckli and Teuscher. Each appliance consisted of an activator anchored to the maxillary arch by an occipital headgear. The inner arch of the face-bow was fitted into specially constructed headgear tubes that were processed into the acrylic of the activator and located anteroposteriorly between the first and second deciduous molars. The outer bow of the face-bow was bent upward in an effort to produce a force vector on the maxilla located between the centers of resistance of the maxilla and of the upper dentition. The headgear was adjusted to provide about 300 gm of force to the maxilla and the upper dentition (Fig. 1).

Torquing springs, made from 0.6 mm round wire, were embedded in the acrylic incisally and adjusted to touch the crowns as close as possible to the gingival margin on the maxillary incisors of 32 patients. The torquing springs were activated with a force no greater than 30 gm per tooth (Fig. 2). In 8 patients who demonstrated proclined maxillary incisors a 0.7 mm round Hawley wire was used to upright the incisors with a tipping force instead of the torquing springs. All the maxillary teeth as well as the mandibular incisors were covered with at least 2 mm of acrylic. The posterior or mandibular teeth were initially covered with acrylic, but in deep-bite cases this acrylic was removed one or two visits later, after the patient became accustomed to the appliance, to permit eruption of these teeth.

The appliance was constructed with a protrusive mandibular bite not exceeding 6 mm. The vertical dimension of the construction bite was opened to a maximum of 4 mm, making possible placement of the headgear tubes.

Cephalometric analysis

Lateral cephalometric radiographs and study models were obtained at the beginning and end of treatment. Cephalometric measurements were obtained independently by 3 independent observers. Displacement of the maxilla, mandible, incisors, and molars relative to the anterior cranial base were measured to the nearest 0.5 mm or 0.5°.

On each initial tracing, reference lines—a masion sella line (NSL) and a nasion sella perpendicular at sella (NSP)—were constructed. Subsequent films were made by direct superimposition on stable structures in the anterior cranial base and the reference lines from the initial tracing carried forward.

During the treatment period the changes in occlusion were determined with the use of occlusograms to locate the most accurate molar position on the headfilms. For the occlusogram technique, the most labially prominent incisor in the mandible and the maxilla of each patient was used to locate the molars anteroposteriorly on the lateral headfilm. A Polaroid system that
produced a 1:1 magnification factor between the study models and their photographs was developed. On each Polaroid photograph, a midline was constructed and the mesial surfaces of the left and right first molars were connected with a straight line. A line tangent to the labial surface of the most prominent incisor was drawn at right angles to the midline. The distance between the incisor tangent and the molar line was increased by 10% to adjust for headfilm magnification. This midline distance from the incisor to the molar was then used sagittally to locate the molar on each headfilm tracing. The positional changes between the maxilla and maxillary incisors and the mandible and mandibular incisors, relative to each other and to the cranial base, were determined as shown in Figs. 3a, 3b, and 4.

The pretreatment facial and dental structure of the boys and girls was compared according to sagittal and vertical parameters. In the sagittal direction, none of the mean angular or linear measurements were significantly different. In the vertical direction, the linear measurements showed the boys had significantly longer mean anterior facial heights. On the basis of the pretreatment similarity between the two groups, with respect to both age distribution and facial structure, the groups were combined for pretreatment and posttreatment comparisons.

RESULTS

The high-pull headgear–activator appliance is designed to correct a Class II interarch relationship. In this study this relationship was termed zero when the mesial surfaces of the upper and lower first permanent molars were flush at the original occlusal plane (Fig. 5). As upper molars moved mesially or lower molars moved distally toward a more severe Class II molar relationship, the change was recorded as a negative number. Similarly, as upper molars moved distally or lower molars moved mesially toward a Class I molar relationship, the change was recorded as a positive number. All changes recorded are referenced to NSL.

The distribution of the total interarch changes achieved in these 34 patients is shown in Fig. 6. The change ranged from +7.5 mm of Class II correction in one patient to a −2.0 mm change actually recorded for another patient (i.e., an increase of 2 mm of Class II correction during treatment). The mean total Class

Table 1. Treatment by age (years) and sex

<table>
<thead>
<tr>
<th></th>
<th>Girls (N = 17)</th>
<th>Boys (N = 23)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>SD</td>
</tr>
<tr>
<td>Beginning of treatment</td>
<td>10.5</td>
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<tr>
<td>End of treatment</td>
<td>12.0</td>
<td>1.3</td>
</tr>
<tr>
<td>Treatment time</td>
<td>1.5</td>
<td>0.6</td>
</tr>
</tbody>
</table>

Fig. 2. Intraoral view of appliance with torquing springs. Note location of headgear tubes.
II correction was 3.29 ± 2.16 mm. The large standard deviation resulted from a spectrum of responses making mean values relatively nondescriptive of individual responses to the appliance action. It is interesting, however, to factor out the contributions of the maxilla and its dentition to the mandible and its dentition with respect to the total individual interarch occlusal change.
Anteroposterior maxillary molar repositioning

The change in the maxillary molar position was measured according to occlusograms. The change recorded in the anteroposterior (AP) direction represents the sum of maxillary molar movement at the periodontium plus AP relocation of the maxilla at maxillary sutural articulations.

The total changes in maxillary molar position relative to SNL are shown in Fig. 7. The mean change was +0.07 ± 2.92 mm of distal relocation of the maxillary molar. The range was +7.5 to −5 mm of molar relocation. When compared with the maxillary values, the interarch occlusal change was strongly associated with forward mandibular growth (Figs. 8 and 9). This suggests that forward mandibular growth was important for the desired molar interarch correction of Class II malocclusions with this treatment modality and in this sample of children.

An attempt was also made to separate the orthopedic effects of the appliance on mandibular growth as opposed to tooth movement changes by measuring changes at pogonion. The mean anterior relocation of pogonion (2.81 ± 1.70 mm) parallels (Fig. 10) the total relocation of the lower molar as shown in Fig. 11.

In this regard when total molar repositioning in the upper jaw was correlated with total molar repositioning in the lower jaw, a strong inverse correlation was present ($R^2 = 0.507$). This is a measuring system function where forward mandibular molar relocation results in a positive number but forward maxillary molar relocation is a negative number (Fig. 12).
Other skeletal/dental effects

The criteria for stopping treatment of these patients with the Zurich activator were clinical correction of the overbite and overjet. A full Class II correction was not always achieved since this could not be present without adequate torque control of incisor long axes and associated overbite and overjet.

Sagittal angular changes during treatment are shown in Table II. The direction of the mean maxillary change (s-n-ss) was backward rather than forward as expected. The maxillary incisors (NL-ILs, SNL-ILs) were typically retracted toward a more upright position.

The mean mandibular growth (s-n-pg, s-n-sm) was in an anterior direction. Contrary to many reports of mandibular incisor advancement with functional appliance therapy, the mean movement of the mandibular incisors (ML-ILi) was toward a more upright position.

The reduction of forward maxillary growth accompanied by forward mandibular growth resulted in a mean reduction of the retrognathic skeletal profile (ss-n-pg, ss-n-sm). While the mean skeletal and dental sagittal characteristics of these patients improved during Class II correction there is a wide range of results among individual patients.

The vertical angular changes shown in Table II reveal small and mostly insignificant changes in skeletal anterior facial parameters. The dental interincisal angle (ILs-ILi) shows a large and significant increase that can
be attributed to the uprighting of the maxillary incisors.

The vertical linear changes in Table II show significant increases in skeletal facial height as measured to the NSL and a reduction in the dental overbite.

**DISCUSSION**

The average pretreatment facial morphology of this Class II sample was characterized by a normal sagittal maxillary position and retrognathic mandibular position. The sagittal jaw relationship was significantly greater than in the mean values for a Scandinavian sample, which is in agreement with the findings reported by McNamara. The vertical jaw relationship was, in general, normal in comparison with the mean values reported by Björk and with greater individual variation.

The total interarch molar change is shown in Fig. 6. This change has been described as the result of appliance therapy retarding the normal forward migration of the maxilla and maxillary teeth while mandibular growth carries the mandibular molars downward and forward. This attractive hypothesis undoubtedly is important in the process but probably does not describe all of the multiple interacting factors involved.

The appliance used in this study is designed to correct Class II malocclusions by distal repositioning of the maxillary teeth or mesial repositioning of the mandibular teeth. Maxillary teeth can be distally repositioned by tooth movement at the periodontium or distal orthopedic movement of the maxillary complex carrying the teeth with it. Similarly, mandibular teeth can be mesially repositioned by tooth movement at the peri-
Table II. Pre-post treatment differences

<table>
<thead>
<tr>
<th>Measurement</th>
<th>Mean</th>
<th>SD</th>
<th>Minimum</th>
<th>Maximum</th>
<th>Differences</th>
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<td><strong>Sagittal angular</strong></td>
<td></td>
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<tr>
<td>Maxillary position s-n-ss</td>
<td>−0.6</td>
<td>1.1</td>
<td>−3.0</td>
<td>1.5</td>
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<td>Mandibular position s-n-pg</td>
<td>0.7</td>
<td>1.0</td>
<td>−1.5</td>
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</tr>
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<td>Mandibular apical base position s-n-Pt. B</td>
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<td>0.9</td>
<td>−2.0</td>
<td>2.5</td>
<td>***</td>
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<tr>
<td>Sagittal jaw relation ss-n-pg</td>
<td>−1.3</td>
<td>1.2</td>
<td>−5.0</td>
<td>1.0</td>
<td>***</td>
</tr>
<tr>
<td>Sagittal apical base relation A-N-B</td>
<td>−1.2</td>
<td>1.1</td>
<td>−3.5</td>
<td>1.5</td>
<td>***</td>
</tr>
<tr>
<td>Maxillary incisor inclination NL-ILs</td>
<td>−6.6</td>
<td>5.3</td>
<td>−20.0</td>
<td>3.0</td>
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<tr>
<td>Maxillary incisor inclination cranial base NSL-ILs</td>
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<td>5.2</td>
<td>−21.5</td>
<td>2.5</td>
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<td>Mandibular incisor inclination ML-ILi</td>
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<td>4.5</td>
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<td>Overjet</td>
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<td>1.9</td>
<td>−10.5</td>
<td>−2.0</td>
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<tr>
<td><strong>Vertical angular</strong></td>
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<tr>
<td>Maxillary inclination NSL-NL</td>
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<td>1.2</td>
<td>−1.5</td>
<td>3.0</td>
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<td>Mandibular inclination NSL-ML</td>
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<td>1.7</td>
<td>−4.0</td>
<td>3.0</td>
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<tr>
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<td>5.0</td>
<td>NS</td>
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<tr>
<td>Interincisor angle ILs-ILi</td>
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<td>26.0</td>
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<td><strong>Vertical linear (mm)</strong></td>
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<td>Maxillary position SNP-ss</td>
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<td>8.0</td>
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<td>1.7</td>
<td>−1.0</td>
<td>8.0</td>
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<td>Mandibular incisor position NSL-ii</td>
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<td>2.5</td>
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<td>Maxillary molar position NSL-U6C</td>
<td>2.8</td>
<td>2.5</td>
<td>0.0</td>
<td>10.0</td>
<td>***</td>
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<tr>
<td>Mandibular molar position NSL-L6C</td>
<td>3.6</td>
<td>2.6</td>
<td>0.0</td>
<td>10.0</td>
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<td>Overbite</td>
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<td>1.4</td>
<td>−3.0</td>
<td>3.5</td>
<td>***</td>
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</table>

*p < 0.05; **p < 0.01; ***p < 0.001

odontium or forward growth of the mandible carrying the teeth with it. About half of the maxillae were reported to have moved in a negative or posterior direction. Normal maxillary growth was reported not only to be downward at an angle of 42° to the cranial base but also to be varied by 0 to 90° anteriorly relative to NSL.29 Thus it seems likely that the appliance had an orthopedic effect
on some maxillae by altering the growth to totally vertical or distal directions. This type of effect was previously reported for headgear in conjunction with implants.20

During treatment, maxillary prognathism in this study was often unchanged with a vertical parallel lowering of the maxilla. Downward and backward displacement of the maxilla with posterior rotation, which was reported in previous studies of patients treated with cervical headgear31,32 or of patients treated with cervical headgear in combination with the conventional activator,33 was found to be considerably less pronounced in this study. The maxillary occlusal plane often remained unchanged during treatment in contrast to reports on activator or cervical headgear treatment.34

Total maxillary molar change, whether by distal movement of the maxilla or of the maxillary teeth, is only a part of the basis for total interocclusal correction of some maxillae by altering the growth to totally vertical or distal directions. This type of effect was previously reported for headgear in conjunction with implants. The maxillary occlusal plane often remained unchanged during treatment in contrast to reports on activator or cervical headgear treatment.34

Total maxillary molar change, whether by distal movement of the maxilla or of the maxillary teeth, is only a part of the basis for total interocclusal corrections. This limited role of the upper jaw appears to comprise in large part by arrest of anterior or actual distal movement of the maxilla. This factor requires better definition, but it suggests the orthopedic potential of the appliance for maxillary changes.

An important statistical point is shown graphically in Fig. 7 where total maxillary molar movement data are reported to be almost evenly distributed over a range of positive and negative values. Pooling these data and reporting mean changes would present a very unrepresentative picture of the effect of the appliance and the individual patient responses, which ranged from +7.5 mm to -5.0 mm. This demonstrates how individual responses can be far more descriptive than mean values, even when one is describing a population with a universe of responses. Thirty percent of the sample demonstrated +2.0 mm or more of distal repositioning of the maxillary molar. Similarly, 25% of the sample showed -2.0 mm or more mesial repositioning of the molar. These changes cannot be factored out from normal growth by the methods and materials reported here. It is important to note that those patients with the greatest total occlusal change did not always have the greatest total maxillary molar change. Similarly, those patients with the least total occlusal change did not have the least total maxillary movement. This suggests that maxillary molar movement is only one of the factors responsible for total interocclusal change.

In the mandible, molar teeth were repositioned mesially in all except two patients (Fig. 10). It is probable that the normal forward mandibular rotation associated with vertical condylar growth contributed to this effect.24

Mandibular prognathism was often found to increase during treatment (Fig. 11). The mandibular plane inclination showed no statistically significant change during treatment. This observation is in agreement with activator studies25 but in contrast to studies of cervical headgear that reported a significant increase in inclination of the mandibular plane.31 The vertical change in pogonion position was often found to be three times greater than the horizontal change with similar individual variations in both planes. This suggests that the improvement in occlusion was related mainly to changes in the vertical plane. The stability of the mandibular plane in combination with greater vertical lowering of the mandible indicates that the amount of mandibular condylar growth equaled the vertical displacement of pogonion. The vertical angular changes shown in Table II reveal small and mostly insignificant changes in skeletal anterior facial parameters. However, the absence of statistically significant change does not guarantee that the appliance in individual cases can cause an increase in face height. In a study of forty patients, Teuscher29 observed only two patients in whom the y axis opened during treatment. In this study it was found that in nine patients the mandibular inclination, as expressed by the mandibular plane, increased during treatment. In five of the nine patients, this could be associated with the lack of torquing springs in the appliance, leading to pronounced retroclination of the upper incisors.

The vertical linear changes in Table II show significant increases in skeletal facial height as measured to NSL. Again, this is normal for the age group and does not directly address the question of the mode of action of the appliance.

Mandibular growth normally results in forward movement of the molars and pogonion.27,34 No data reported here suggest that the mandible grew any differently than it would have grown had the appliance not been in place.

It was also interesting to relate the total molar change in both jaws. This relationship was \((R^2 = 0.507)\) (Fig. 12) and is, of course, an inverse relationship. Thus it appears the data support the findings that the appliance can affect total forward positioning of the maxillary molar by acting on both the sutures and the periodontal regions. Further, the appliance permits mandibular growth although there are no data to show that the appliance alters mandibular growth from its natural course of development. Most likely such data would be most apparent on vertical alveolar development and subsequent jaw rotations. No evidence of effects of the appliance on lower molar movement is seen. However, freeing the occlusal surface of the appliance is most likely to develop the dental height of the lower molars, which in turn may affect the balance
between anterior and posterior face height changes. Increased vertical dental height of the lower arch has been described as contributory to Class II corrections. Others have noted that increased alveolar height in either jaw, unmatched by vertical condylar growth, produces backward jaw rotation and a potential worsening of the Class II relationship.

While it is tempting to explain variations in the response to the appliance on the basis of either inconsistent patient compliance or growth-related biologic differences, the absence of any data on these matters makes any such statement only speculative.

REFERENCES


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