Treatment of Class II open bite in the mixed dentition with a removable functional appliance and headgear

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Early diagnosis of patients exhibiting open bites that are complicated by skeletal Class II and vertical growth problems can facilitate subsequent treatment. Eight patients with Class II skeletal open bite were treated with the high-pull activator appliance and compared to reasonably matched controls to determine the effects of the appliance. The high-pull activator was found to reduce forward growth of the maxilla and increase mandibular alveolar height, transforming the Class II molar relationship into a Class I molar relationship. The overjet and open bite were decreased, and, in addition, the appliance reduced the amount of forward and downward movement of the maxillary molars, providing vertical control of the maxilla during Class II orthopedic correction. These results demonstrated that open bite complicated by a Class II vertical growth pattern can be treated during the mixed dentition with favorable results by a combination of a removable functional appliance and high-pull headgear.
(Quintessence Int *1992;23:323–333.*)

Introduction

Anterior open bite is defined as the absence of contact between the maxillary and mandibular incisors at centric relation.[1] In younger children, it can be caused by one factor or a combination of factors, including finger- and lip-sucking habits; enlarged tonsils or adenoids that interfere with proper tongue position, creating mouth breathing, a constricted maxilla, and a skeletal open bite growth pattern; mouth breathing associated with allergies and inadequate nasal breathing; abnormal tongue habits with tongue thrust and cheek biting; macroglossia; or abnormal tongue position.

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A dental open bite is one that is limited to the anterior region in an individual with good facial proportions.[2] Current orthodontic treatment often consists of fabrication of a habit appliance such as a tongue restrainer, evaluation for airway insufficiency, and placement of fixed orthodontic appliances if needed. However, it is rare that a patient who requests orthodontic care has an anterior open bite that is solely the result of a habit. Dental changes are frequently complicated by a Class II skeletal growth pattern with vertical and/or transverse complications.

The hallmarks of skeletal anterior open bite are increased anterior facial height, a steep mandibular plane, and excessive eruption of posterior teeth. Because the mandible is rotated downward and backward in this circumstance, the patient is likely to have a Class II jaw relationship in addition to the vertical problem.

One approach to the treatment of skeletal open bite is to control all subsequent growth so that the mandible will rotate in a counterclockwise direction, upward and forward. Successful early treatment of these problems in the mixed dentition can prevent the worsening of the facial profile. The elimination of anterior open bite can also improve tongue function and lip seal. Recent research has shown that tongue thrust swallow is more often an adaptation to the open bite than a cause of it.[3] Myofunctional therapy for tongue thrusting in skeletal Class II open bite patients is, for that reason, ineffectual and not recommended.

This paper discusses the use of high-pull headgear and functional appliances to maintain the vertical position of the maxilla and inhibit eruption of the maxillary posterior teeth during the mixed dentition period. Cephalometric analysis was used to evaluate the skeletal and dental adaptations to this treatment modality. Because the general dentist is often the first to diagnose anterior open bite in the child patient, the clinician's awareness of the differences between dental and skeletal open bite and the proper timing for intercepting these malocclusions will facilitate subsequent orthodontic treatment.

Rationale for appliance selection

Effect of functional appliances

Functional appliances, such as activators, have been used to treat Class II, division 1, patients who present with a retrognathic mandible. Functional appliances reportedly alter a Class II relationship through transmission of muscular force to the dentition and alveolus, thereby positioning the mandible anterior to its maloccluded position. Additionally, they are often designed to alter the amount and direction of tooth eruption, influencing the horizontal and vertical positions of the teeth. The use of simulated functional appliance therapy in animal models has been found to induce increased cellular activity in the mandibular condyle,[4–7] presumably leading to altered mandibular form and length. Harvold[8] and Harvold and Vargervick,[9] however, found no evidence of increased mandibular growth in patients treated with activator therapy, but rather reported, as a primary effect, a selective influence on the occlusal development of the dentition. In another study, it was reported that vertical maxillary growth was restrained during activator therapy by the hindered eruption of the maxillary posterior teeth.[10]

Effect of functional appliances in combination with high-pull headgear

High-pull headgear has been used with the aim of producing intrusion and posterior displacement of maxillary molars with backward maxillary rotation, producing a backward and upward displacement at the maxillary sutures.[11] The orthopedic concept of using a combination of activator and headgear appliances was introduced by Hasund.[12] Pfeiffer and Grobety[13] refined the combined orthopedic concept further to better cope with the demands of differential diagnosis. They chose the use of a cervical headgear to extrude maxillary molars and to apply orthopedic traction to the maxilla and an activator to induce orthopedic mandibular changes, restrain maxillary growth, and cause selective eruption of teeth. Levin[14] reported the skeletal changes in 30 patients treated with activator and cervical headgear. Patients treated with this combination of appliances were found to have their Class II molar occlusion corrected to Class I and a simultaneous reduction of overbite and overjet. Teuscher[15,16] was the first to attach the facebow directly to the activator and, with applied occipital traction, achieved better vertical and rotational control during orthopedic Class II treatment.

The simultaneous use of both activator and high-pull headgear appliances may result in a number of desirable treatment effects greater than those induced by each appliance separately. The effective changes are believed to be restraint of downward and forward maxillary growth, selective guidance of maxillary and mandibular dentoalveolar development, and some influence on mandibular growth and/or position.

The purpose of this study was to demonstrate the clinical and cephalometric findings of a sample of eight patients with Class II skeletal open bite who were treated with a high-pull activator (HPA) appliance.

Method and materials

Treated sample

The sample consisted of eight patients, two boys and six girls, with Class II skeletal open bite malocclusion who were treated with HPAs during the mixed dentition period. All subjects were treated by one of the authors at the Ohio State University, College of Dentistry. Before treatment, each patient had *(1)* a Class II, division 1, malocclusion with bilateral Class II molar relationship and excess overjet; *(2)* an anterior open bite, as measured by the overlapping of the maxillary to mandibular incisal edges; and *(3)* a skeletal open bite pattern, measured cephalometrically and considered to be a ratio of posterior facial height (sella-gonion) to anterior facial height (nasion-menton) of less than 62%. The mean age of the subjects was 10

Fig 1 Activator prior to placement. Note the lingual extensions and the acrylic resin ledge covering the occlusal surfaces of the molars and premolars. The Frankel lip shield has been incorporated in the appliance for this particular patient, who has mentalis hyperactivity.

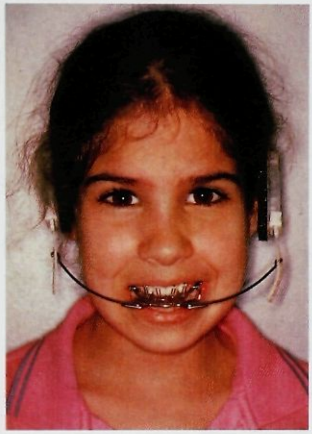

Fig 2 *(right)* Activator together with the high-pull headgear. Note the position of the torquing springs, which are adjusted to touch the crowns of the incisors as closely as possible to the gingival margin on the maxillary incisors.

years 3 months before treatment. The average treatment time was 1 year 2 months.

Control sample

A control sample, consisting of eight untreated Class II children with a skeletal open bite pattern as described in the treated sample, were obtained from the Ohio State University Growth Study for use as a comparison group. These subjects were matched in age and sex with the treated sample.

Objectives of treatment

The primary objectives of the treatment were to correct the Class II molar occlusion to a Class I occlusion and produce a concomitant reduction of the skeletal abnormality and open bite. Once these objectives were met, a second phase of treatment with fixed appliances was undertaken as indicated.

Appliances and treatment procedures

Each appliance was constructed according to the manner described by Teuscher[16] (Figs 1 and 2). The appliance consisted of an activator with an attached headgear. Anchorage in the maxillary arch was secured by the upper part of the appliance, which covered the occlusal surfaces of all posterior teeth. It was not desirable to cover the entire palate across and forward up to the incisors; instead a transpalatal bar (1.2 mm in diameter) was used, and the palate was kept free to provide as much room as possible for the tongue. To link the activator to the inner arch of the facebow, a 0.045-inch headgear tube was fastened in the acrylic resin between the maxillary and mandibular arches. The tube was placed sagittally between the primary first and second molars or premolars. The magnitude of the extraoral force was 400 g per side.

Because the activator headgear assembly transmits forces to the acrylic resin covering the occlusal and incisal portions of the teeth, with the result that the incisors tend to tip backward, a palatal root tipping force was used if the maxillary incisors were already in an ideal position. Torquing springs were fabricated with 0.5- or 0.6-mm, resilient, stainless steel wire. The lower part, with a horizontal leg on each side, was embedded in acrylic resin. The vertical part was kept away from the acrylic resin, and only the palatally curved tip touched the crown immediately coronal to the gingival margin.

The mandibular component of the appliance consisted of an incisal table for advancement of the mandible. In patients with mentalis hyperactivity, the addition of lower labial pads as proposed by Frankel has proven helpful in achieving reduction of adverse mentalis activity. The labial pads must be positioned deep in the vestibular fold, parallel to the alveolar process, and should be teardrop shaped.[17] The therapeutic po-

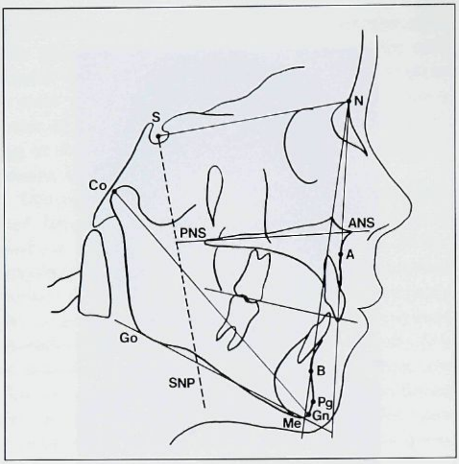

Fig 3 Cephalometric landmarks, constructed lines, and digitized points used: *(S)* sella; *(N)* nasion; *(Co)* condylion; *(PNS)* posterior nasal spine; *(ANS)* anterior nasal spine; *(A)* point A; *(Go)* gonion; *(B)* point B; *(SNP)* sella-nasion perpendicular; *(Pg)* pogonion; *(Gn)* gnathion; *(Me)* menton.

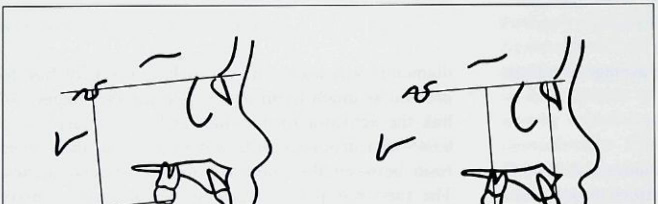

Fig 4 Determination of changes in *(A)* horizontal position of maxillary molar and central incisor; *(B)* vertical position of maxillary molar and central incisor; *(C)* horizontal position of mandibular molar and central incisor; *(D)* vertical position of mandibular molar and central incisor.

sitioning of the mandible was determined by the operator with a wax registration bite, which served to orient the casts for appliance construction. In most cases, the mandible was advanced until the incisors were in an edge-to-edge position. The maximal advancement did not exceed 5 mm.

Patients were instructed to wear the activator for only 2 hours, during the daytime, for the first 3 days. Patients were to increase the number of hours of activator wear until they could wear the appliance 24 hours a day and the headgear at night for 12 to 14 hours. During this first phase of treatment, evaluations were made every 3 to 5 weeks until treatment goals of overcorrected dental and skeletal relationships had been met, an average of 1 year 2 months after treatment had begun.

Cephalometric analysis

Lateral cephalograms were taken before and at the completion of this phase of treatment. All cephalograms were taken with the patients' teeth in occlusion and lips in a relaxed position to standardize soft tissue posture and morphology. Cephalometric landmarks were identified and lines were constructed as shown in Figs 3 and 4. Cephalograms were digitized with a Texas Instruments digitizer, and all analyses were performed on an IBM PC with Oliceph Orthodontic Software (OLI Inc).

The size of the combined method error (ME) in locating, superimposing, and measuring the changes in the different landmarks was calculated by the formula

$$ME = \sqrt{\Sigma d^2/2n}$$

where d is the difference between two registrations of a pair, in millimeters, and n is the number of double registrations. Before- and after-treatment cephalograms from ten randomly chosen subjects were traced and superimposed with measurements recorded on two different occasions. The combined ME did not exceed $\pm$ 0.8 mm for any of the variables investigated.

Statistical analysis

Comparisons of starting forms and serial changes in the control and high-pull activator groups were analyzed using a two-sample t test. The a priori level of statistical significance was set at .1.

Results

Equivalence of starting forms

Before serial changes observed in the treatment groups were compared with those in the controls for the same age range, the starting forms of the two groups were analyzed. There were no statistically significant differences ($P < .05$) between the treated and control groups in any maxillary or mandibular, horizontal or vertical measurements.

Cephalometric analysis of treatment effects

The changes in cephalometric values for the eight treated patients and eight control patients are shown in Table 1. For maxillary skeletal relationships, the annualized change in sella-nasion–point A in the treatment group was -1.90 ± 2.2 degrees, which was significantly different than the change in the control sample ($+0.23 \pm 1.46$ degrees). The relationship of point A to sella-nasion perpendicular showed a similar significant change (-0.21 ± 2.4 mm in the treatment group, compared with $+0.44 \pm 1.52$ mm in the control sample).

For the maxillary dentition, the change in horizontal position of the maxillary molar was determined by dropping a line perpendicular to sella-nasion to the mesial contact point of the maxillary first molar (see Fig 4). The maxillary molars in the treatment group moved 0.64 ± 2.11 mm backward, while those in the control group moved 0.90 ± 1.83 mm forward. Maxillary molars in the treatment group moved downward only 0.27 ± 2.61 mm; those in the control sample moved 1.05 ± 1.31 mm. With reference to sella-nasion, the maxillary incisors were moved significantly farther backward (4.25 ± 2.95 mm) than those in the control (0.50 ± 2.31 mm). The vertical position of the maxillary incisors remained relatively unchanged in both groups.

The positions of the mandibular molars and incisors were relatively unchanged with reference to sella-nasion. However, the mandibular incisors in the treatment group were moved farther inferiorly (3.13 ± 3.56 mm) than those in the control sample (0.12 ± 1.29 mm).

A greater increase in mandibular length was observed in the group treated with HPA (4.05 ± 2.74 mm) than in the control group (2.25 ± 2.91 mm). However, there were no differences between the control and treatment groups for the cephalometric measurements of sella-nasion-pogonion and sella-nasion–point B.

The vertical angular changes shown in Table 1 revealed a small but insignificant increase in skeletal anterior facial parameters.

Table 1 Change in measurements in control and HPA groups

	Control		Experimental			
	Mean	SD	Mean	SD	*t*	Sig
Maxillary skeletal						
SNA (°)	−0.23	1.46	−1.90	2.20	1.76	*
SNP–pt A (mm)	0.44	1.52	−0.21	2.40	0.64	*
Maxillary dental						
Max molar horizont (mm)	0.90	1.83	−0.64	2.11	1.56	*
Max molar vert (mm)	1.05	1.31	0.27	2.61	0.75	*
Max incisor horizont (mm)	0.50	2.31	−4.25	2.95	3.58	**
Max incisor vert (mm)	0.73	1.38	1.19	0.82	−0.81	NS
Mandibular dental						
Mand molar horizont (mm)	1.11	1.86	1.95	1.70	−0.94	NS
Mand molar vert (mm)	0.81	1.34	1.10	1.70	−0.38	NS
Mand incisor horizont (mm)	0.12	2.65	1.66	1.85	−1.35	NS
Mand incisor vert (mm)	0.12	1.29	3.13	3.56	−2.24	*
Mandibular skeletal						
Co-Gn (mm)	2.25	2.92	4.05	2.74	−1.98	*
SNB (°)	−0.26	1.53	0.28	0.99	−0.85	NS
SNB-Pg (mm)	0.23	3.27	0.58	2.33	−0.25	NS
SNP–pt B (mm)	0.05	2.88	0.98	1.59	−0.79	NS
Vertical relationship						
Mand plane angle (°)	0.03	2.10	1.83	2.11	−1.70	NS
Occlusal plane angle (°)	−1.58	4.10	1.00	2.67	−1.47	NS
Palatal plane angle (°)	−0.01	1.00	0.80	1.82	−1.11	NS
SN-ANS (mm)	1.44	1.55	2.41	0.85	−1.55	NS
SN-Me (mm)	2.50	1.98	4.61	2.65	−1.81	*

NS = not significant.
* $P < .1$.
** $P < .05$.

Clinical treatment effects

Clinically, a Class I molar occlusion was obtained approximately 1 year after the start of treatment. Simultaneously, open bite was considerably reduced, resulting in a concomitant improvement in lip balance. The clinical results of two patients treated with HPA are used to illustrate the treatment effects of the appliance.

Case 1

Figure 5 shows an 8-year-old girl who presented with a Class II, division 1, malocclusion, protrusive incisors, and a retrognathic mandible. Clinically, the patient exhibited bilateral Class II molar occlusion with 5 mm of excess overjet and anterior open bite (Figs 6 and 7). Cephalometric analysis showed a Class II jaw relationship with point A–nasion–point B angle of 10 degrees

Fig 6 Anterior intraoral view of the same patient reveals anterior open bite.

Fig 5 *(left)* An 8-year-old patient with a convex profile, an obtuse nasolabial angle, and a retrognathic mandible.

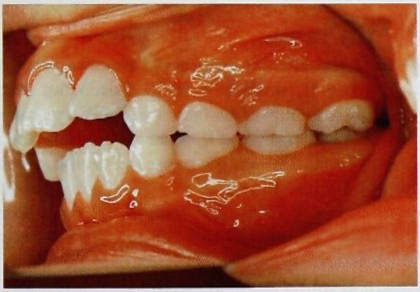

Fig 7 Lateral intraoral view of the same patient reveals Class II molar and canine relationships.

Fig 8 *(right)* Posttreatment view of the same patient.

(norm of 2°) and a Wits appraisal of + 6.5 mm (norm of 0 mm). The inclination of the maxillary incisors was 105 degrees (norm of 98 to 108 degrees). The mandibular plane angle of 29 degrees, y-axis of 60 degrees, and posterior-anterior facial height ratio of 61.5%, compared with the norms of 22 to 30 degrees, 59.4 degrees, and 63% to 68%, respectively, suggested that the patient had a vertical skeletal growth pattern.

Figure 8 shows the same patient after 14 months of HPA therapy. The posttreatment record revealed a correction of the Class II molar occlusion into a Class I relationship and a reduction in anterior open bite (Figs 9 and 10). Cephalometric analysis of the posttreatment radiograph revealed a point A–nasion–point B angle of 6 degrees, a Wits appraisal of + 3.0 mm, maxillary incisor inclination of 100 degrees, a mandibular plane angle of 30.5 degrees, and a y-axis of 61.5 degrees. Superimposition of the pretreatment and posttreatment cephalometric radiographs revealed the skeletal and dental effects of treatment: restraint in maxillary

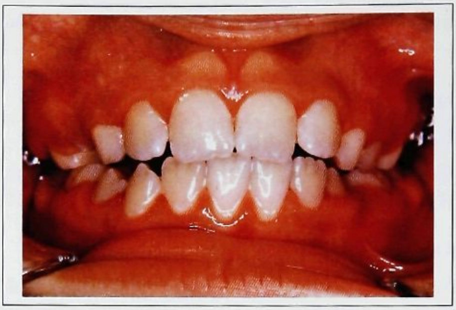

Fig 9 Posttreatment anterior intraoral view of the same patient reveals a reduction in anterior open bite.

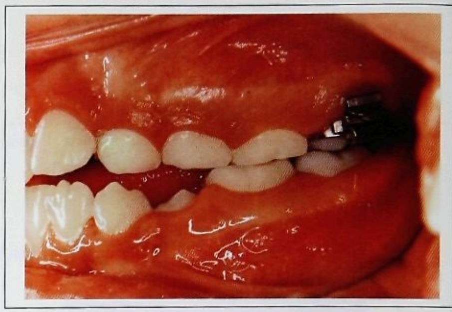

Fig 10 Posttreatment lateral intraoral view of the same patient reveals correction into a Class I molar relationship.

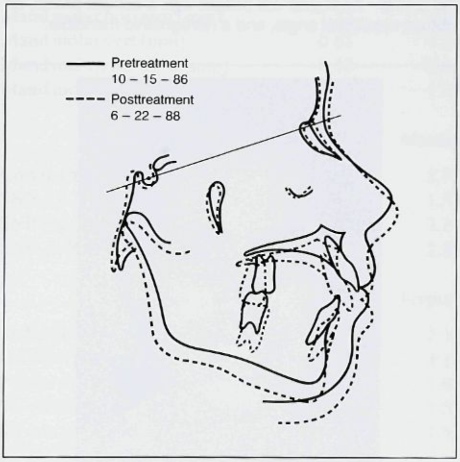

Fig 11 Pretreatment and posttreatment cephalometric tracings of the same patient reveal that the forward and downward movement of the maxillary molars and the lingual movement of the maxillary incisors have been restrained. The palatal, occlusal, and mandibular plane angles remain relatively unchanged.

growth and limited forward and downward movement of the maxillary molars (Fig 11). The mandible moved forward and downward with a 1.5-degree opening of the growth axis. The palatal, occlusal, and mandibular plane angles were also slightly increased.

A second phase of comprehensive orthodontic treatment was undertaken for this patient to provide detailed alignment as well as continued control of vertical growth of the maxilla and eruption of maxillary molars.

Case 2

Figures 12 and 13 show a 9-year-old boy who presented with a Class II, division 1, malocclusion, an excess overjet, and skeletal open bite. Clinically, the patient exhibited a bilateral Class II molar relationship and an overjet of 5 mm. The cephalometric radiograph revealed a point A–nasion–point B angle of 6 degrees and Wits appraisal of + 4.5 mm. The maxillary incisal inclination was 98 degrees. The mandibular plane angle was 29 degrees and the y-axis was 62 degrees.

Figure 14 shows the same patient after 12 months of HPA therapy. The Class II molar relationship was corrected to a Class I occlusion and overjet was reduced. Cephalometric analysis of posttreatment radiograph revealed a point A–nasion–point B angle of 4 degrees and Wits appraisal of + 1.5 mm. The maxillary incisal inclination was reduced to 90 degrees, and the mandibular plane angle and y-axis did not change with treatment. Cephalometric superimposition showed no movement of the maxilla, but forward movement of the mandible (Fig 15). In addition, a forward and downward movement of the maxillary molars was restrained. No tipping of the palatal or occlusal plane was observed. The mandibular plane angle remained relatively unchanged.

Discussion

The results demonstrated that HPA had both skeletal and dental effects on the growing craniofacial complex.

Fig 13 Lateral intraoral view of the same patient reveals a Class II molar relationship and excess overjet.

Fig 12 *(left)* A 9-year-old patient with a long lower facial height, an obuse nasolabial angle, and a retrognathic mandible.

Fig 14 Posttreatment lateral intraoral view of the same patient reveals the correction into a Class I molar relationship and the reduction in overjet.

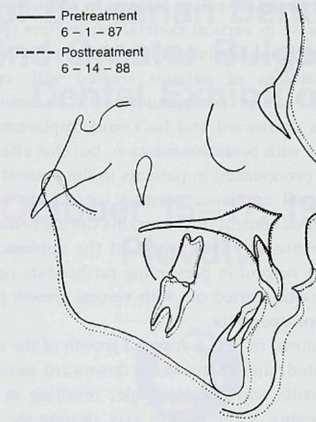

Fig 15 Pretreatment and posttreatment cephalometric tracings of the same patient reveal that the forward and downward movement of the maxillary molars and the lingual movement of the maxillary incisors have been restrained. The mandible has moved forward and downward, but there has been relatively little change in the mandibular plane angle.

Cephalometric measurements have shown that the effect of treatment was not uniformly distributed throughout the craniofacial region. The treatment affected some regions of the face more than others.

The HPA appliance can restrict maxillary skeletal growth. The decrease in forward movement of point A was also related to the posterior tipping of the maxillary incisors, because point A is a maxillary dentoalveolar landmark intimately associated with the maxillary incisor. The lingual movement of maxillary incisors by HPA was beneficial to patients who started out with protrusive maxillary incisors and/or open bite caused by forward positioning of the maxillary incisors.

One of the mechanisms of Class II correction, as proposed by Harvold and Vargervik,[9] is the inhibition of the downward and forward eruptive path of the maxillary posterior teeth, which allows the mandibular posterior teeth to erupt more vertically. In this study, HPA reduced the amount of forward and downward movement of the maxillary molars. In addition, only a small increase in vertical skeletal parameters (palatal, occlusal, and mandibular plane angles), was observed. Previous studies of patients treated with cervical headgear[11,18] or in combination with an activator[13] reported a downward and backward displacement of the maxilla with posterior rotation, but this effect was much less pronounced in patients in the present study. The high-pull appliance seemed to provide vertical and rotational control of the maxilla during orthopedic Class II treatment. This aspect of the appliance was particularly helpful in preventing further bite opening in patients who started out with vertical growth pattern and anterior open bite.

In the patient in case 1, forward growth of the maxilla was inhibited, and there was a downward movement of the maxilla and the mandible, resulting in a 1.5-degree opening of the growth axis, despite the use of high-pull headgear. However, in the second patient, no movement of the maxilla was observed, and there was no change in any of the vertical parameters. These observations suggest that response to this treatment modality may vary in different individuals. Furthermore, the treatment of skeletal open bite requires long-term growth modification of the maxilla, so that the mandible will continue to rotate in a counterclockwise direction, forward and upward.

In this study, HPA increased mandibular length during treatment as indicated by the measurement from the cephalometric landmarks condylion to gnathion. The influence of activators on the growth of mandibular length remains controversial. A significant increase in mandibular length by activators was not supported by studies by Bjork,[19] Harvold,[20] or Jakobsson,[21] whereas other investigators[22–24] have found a significant increase in growth of mandibular length by the use of monobloc type of appliance and other functional appliances.[4–6,10] The contribution made to Class II corrections by increased mandibular growth has to be interpreted with caution, because the landmark condylion cannot be accurately determined on a lateral cephalogram, and the sample size in this study was relatively small.

Some investigators have reported that activators promote forward growth of the mandible.[13–15,25–28] In the present study, sella-nasion–point B and sella-nasion-pogonion did not change significantly after treatment, for the group. However, forward movement of the mandible was demonstrated in case 2, and, in case 1, forward movement of the mandible may have been masked by the rotation and vertical change of the mandible.

Summary

The malocclusions of eight patients with Class II skeletal open bite were corrected by interceptive orthodontic treatment with the high-pull activator. The effects of the HPA on Class II growth included reduction of forward growth of the maxilla and an increase in mandibular alveolar height. This resulted in a transformation of the Class II molar relationship into a Class I molar relationship. The overjet and open bite were decreased by the reduced forward growth of the maxilla in combination with lingual tipping of the maxillary incisors.

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