Comparison of Hyrax and bonded expansion appliances

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The Hyrax or Biederman appliance is a common type of rapid maxillary expansion (RME) appliance.[1] It is tooth-borne and consists of a jackscrew and an all-metal framework that is soldered to bands on the first premolars and first molars. Several studies to date have shown that RME appliances contribute to an increase in the vertical dimension.[2-4] These studies reported a descent of the maxilla with opening of the bite.[2-4] In addition to the downward displacement of the maxilla, dental extrusion, lateral rotation of the maxillary segments, and cuspal interferences have also been attributed to this bite opening characteristic of RME.[5]

One of the foremost proponents of the concept of rapid maxillary expansion is Haas. He advocated the use of acrylic masses against the palate to exert heavy forces against the maxillary base during activation.[2] Haas contended that only with this design is optimal orthopedic movement possible. Haas also found an increase in the vertical dimension in his patients. He attributed this finding as secondary to lowering of the palatal vault due to the bracing action of the zygomatic buttresses.

In her 1985 study, Praskins[6] compared the Haas appliance with the Hyrax appliance using various dental and skeletal parameters. She found both tended to have similar effects on the dentofacial complex. Both appliances opened the bite, with the Haas appliance demonstrating slightly more vertical change than the Hyrax.

Other RME studies report asymmetrical expansion of the maxillary halves.[5,7] Alpern and Yurosko attributed this phenomenon to unilat-

Abstract

The majority of rapid maxillary expansion studies have reported the use of appliances with metal bands attached to the posterior teeth. Tooth extrusion, dental tipping, and an increase in the vertical dimension are often encountered, which may not coincide with treatment objectives. Bonded appliances using interocclusal acrylic may control the vertical dimension and expand the maxillary halves in a more bodily and symmetrical fashion. The purpose of this clinical trial was to determine, by radiographic analysis, the differences between a conventional banded expander (Hyrax) and a bonded acrylic expander. Fourteen patients who exhibited a need for expansion were enrolled in the study. The results suggest that the increase in the vertical dimension often seen with the more conventional Hyrax appliance may be minimized or negated with the bonded appliance. However, there appeared to be no significant difference between the amount of dental tipping or symmetrical expansion between the two appliances, as previously theorized.

Key Words

Rapid maxillary expansion • Vertical dimension • Dental tipping • Symmetrical expansion

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Figure 1A-B
A. Hyrax appliance design.
B. Bonded appliance design.

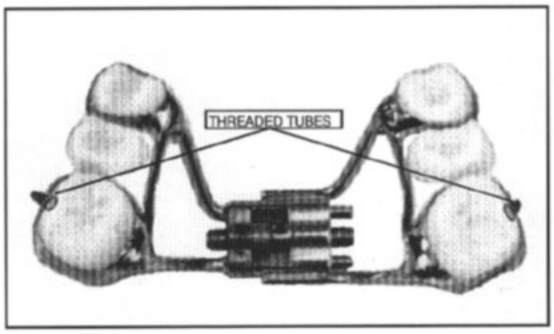

Figure 1A

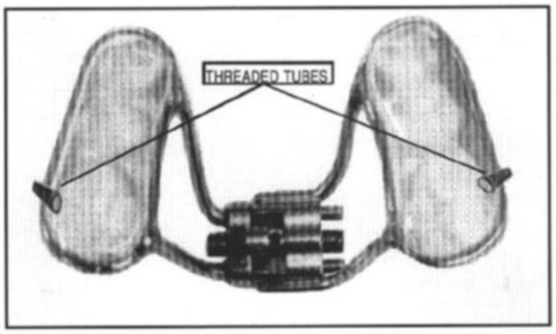

Figure 1B

eral interferences.[7] Recent studies suggest that bonded RME appliances using acrylic may not only control the vertical dimension, butmay expand the maxillary halves in a more bodily and symmetrical fashion as well.[7] Interocclusal acrylic was thought to prevent further vertical increase in some hyperdivergent patients by exerting an intrusive force to the maxillary and mandibular teeth.

Sarver and Johnston[8] compared a bonded appliance sample with Wertz's Hyrax population. Posttreatment lateral cephalograms revealed that the maxilla displayed a slight superior movement of the posterior aspect of the palatal plane relative to the banded appliance, indicating better control of the vertical dimension.[8]

In reviewing the literature, only recent studies have addressed some of the adverse effects of RME.[6-8] Rapid expansion appliances with acrylic occlusal coverage have been reported to counteract these side effects but have not been compared with the standard Hyrax in the same study.[8]

The aim of this investigation was to compare the two types of appliances through radiographic analysis and to determine differences between them regarding symmetrical expansion, the amount of tipping, and changes in the vertical dimension.

Materials and methods

The sample consisted of 14 patients, 7 boys and 7 girls, who presented with posterior crossbites. The subjects' ages ranged from 8.5 to 16.0 years. Appliances were randomly assigned.

The appliance assigned to group one was a conventional Hyrax expander consisting of a midpalatal jackscrew assembly with four rigid steel wires (.050) radiating outward from the palate. These were soldered to the bands of the abutment teeth, usually the first premolars and first molars (Figure 1A). The appliance was cemented with Ketac.

Group 2 used the same Hyrax framework, but the steel shafts were soldered to .036 wire loops bent circumferentially at the height of contour of the abutment teeth. The acrylic portion encased the lingual, occlusal, and buccal surfaces of the abutments on its respective side (Figure 1B). Appliances were bonded with Reliance bonding material. Selective equilibration of the occlusal surfaces of acrylic eliminated prematurities and maintained bilateral maxillomandibular contact as the maxillary arch expanded.

Threaded vertical tubes were either placed in the acrylic adjacent to the buccal surfaces of the maxillary first molars (bonded acrylic appliance) or soldered to the buccal surfaces of bands cemented on the maxillary first molars (Hyrax).

Patients were instructed to turn the screw once in the morning and once again at night.

The active phase of expansion was monitored weekly until the buccal segments were overcorrected by a half cusp. All appliance screws were fixated with light cured composite, then retained for a 3 month period before removal.

At the three measurement intervals (before insertion, at fixation, and 3 months retention) a threaded wire (.036) was inserted into the threaded tube prior to the posteroanterior cephalographs to facilitate measurement of the changes due to expansion (Figures 1A-B and 2).

Data collection

Three posteroanterior cephalographs were taken before insertion, at fixation, and after the 3 month retention period, respectively. Cephalograms were traced to determine changes between the insertion-fixation phase and the fixation-appliance removal phase. Two lateral cephalograms were taken to monitor anterior-posterior vertical changes. The first was taken before appliance insertion, and the second was taken after the 3-month retention phase.

Each patient was positioned in the same cephalostat in natural head position. All cephalographs were taken by the same operator at a distance of 13 cm from the film to the subject's midsagittal plane.

On the posteroanterior radiographs, an angu-

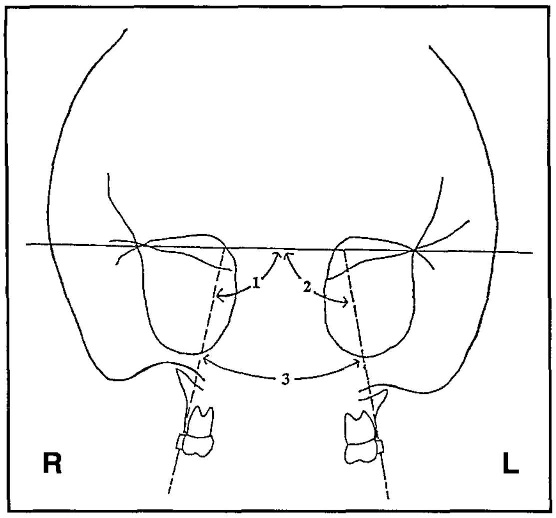

Figure 2

Angular measurements used in posteroanterior cephalometric analysis.
1. Upper right first molar-cranial reference line (UR6-CRL).
2. Upper left first molar-cranial reference line (UL6-CRL).
3. Total angular change.

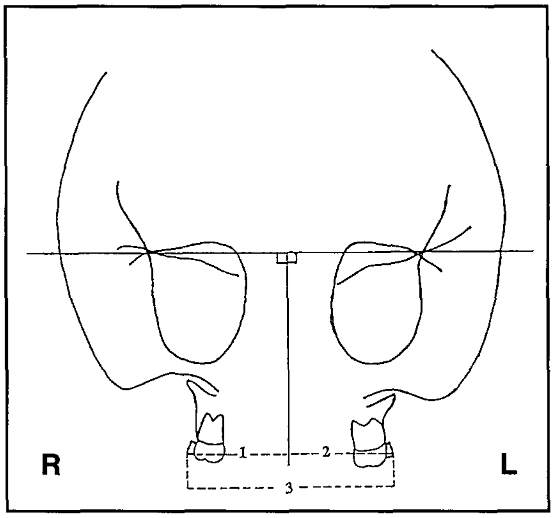

Figure 3

Linear measurements used in posteroanterior cephalometric analysis.
1. Upper right first molar-cranial reference line.
2. Upper left first molar-cranial reference line.
3. Total millimeter change.

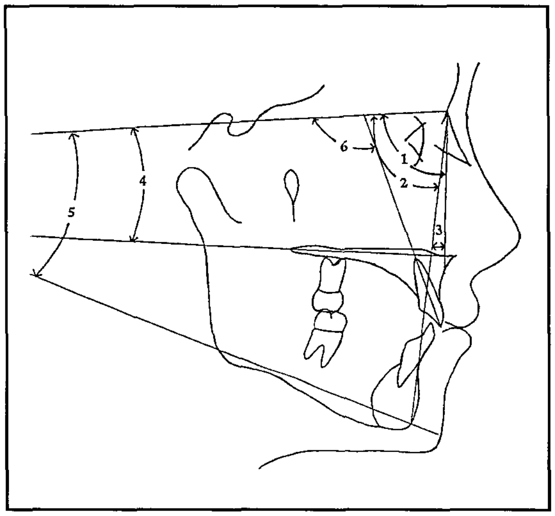

Figure 4

Angular measurements used in lateral cephalometric analysis measured in degrees.
1. Sella-nasion-point A (SNA).
2. Sella-nasion-point B (SNB).
3. Point A-nasion-point B (ANB).
4. Sella-nasion-palatal plane (SN-PP).
5. Sella-nasion-mandibular plane (SN-MP).
6. Sella-nasion-upper incisor (SN-U1).

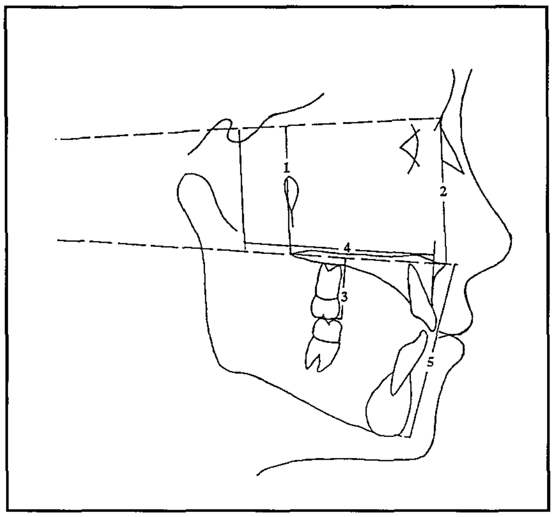

Figure 5

Linear measurements used in lateral cephalometric analysis measured in degrees.
1. Perpendicular distance from sella-nasion plane to posterior nasal spine (SN-PNS).
2. Perpendicular distance from sella-nasion plane to anterior nasal spine (SN-ANS).
3. Perpendicular distance from mesiobuccal cusp tip of upper first molar to palatal plane (U6-PP).
4. Horizontal distance from point A to a perpendicular from the S-N plane at sella (S-A pt.)
5. Distance from anterior nasal spine to menton (ANS-Me).

lar analysis was designed to document the amount of dental tipping. A cranial reference was drawn according to the method of Mossaz-Joelson and Mossaz, which connects the intersection of the greater wing of the sphenoid bone with the inner cortex of the orbit.[9] Molar reference lines were drawn bilaterally through the lateral portion of the threaded wires. The amount of tipping of the left and right molars relative to the cranial base line were measured as the difference between the pretreatment measurement, the angular measurements at the time of fixation, and the measurements after the 3-month retention phase (Figure 2).

To evaluate transverse linear changes, measurements were made with vernier calipers to the nearest tenth of a millimeter. Intermolar distances were recorded at the most lateral-inferior aspect of the buccal tubes. In an attempt to evaluate symmetrical expansion of the buccal segments, a reference line was drawn as the midpoint between the orbits perpendicular to the cranial reference line. Each molar was measured from its inferolateral aspect to this midline reference on subsequent radiographs (Figure 3).

Symmetry between the expanded segments was measured as the difference in mm of the total expansion between the left and right molars for each patient. A value of zero would indicate symmetric expansion of the right and left segments. Values above or below zero would indicate that greater expansion occurred on one side over the other. For example, if patient A experienced 6 mm of total expansion, and the left side expanded 4 mm while the right side expanded only 2 mm, a value of +2 mm would indicate asymmetrical expansion. Comparative measurements of both films were as follows:

Posteroanterior cephalograph

Angular measurements in degrees (Figure 2)

1. UR6-CRL (maxillary right first molar to the cranial reference line).

Table 1
Comparison of pretreatment cephalometric values.

	Hyrax			Bonded			
Value	Mean	Median	Range	Mean	Median	Range	P-value
SNA (deg.)	80.1	79.7	76.2 to 83.8	81.46	82.2	71.9 to 88.5	NS
SNB (deg.)	76.6	77.0	73.4 to 79.3	75.67	75.8	67.9 to 83.5	NS
ANB (deg.)	3.5	4.3	0.4 to 5.6	5.78	5.6	4.0 to 9.2	NS
SN-PP (deg.)	6.6	5.5	5.0 to 10.1	8.07	9.9	0.0 to 12.4	NS
SN-MP (deg.)	39.7	39.3	35.3 to 42.7	39.42	41.1	29.8 to 45.9	NS
SN-U1 (deg.)	104.3	102.2	99.7 to 110.8	101.26	98.6	91.2 to 112.7	NS
SN-PNS (mm.)	45.5	44.6	37.2 to 52.5	44.47	44.0	41.6 to 49.4	NS
SN-ANS (mm.)	52.1	51.5	43.9 to 61.0	51.84	51.8	46.3 to 58.5	NS
ANS-Me (mm.)	75.2	75.6	67.8 to 86.2	69.88	69.0	63.9 to 79.6	NS
U6-PP (mm.)	24.3	24.9	16.5 to 33.3	22.23	22.6	17.0 to 26.0	NS
S-A pt. (mm.)	60.3	60.5	51.8 to 69.5	61.89	61.8	50.1 to 73.4	NS

Two-tailed Wilcoxon rank-sum tests revealed no statistically significant difference between the pretreatment cephalometric values of the two groups.

2. UL6-CRL (maxillary left first molar to the cranial reference line).

Linear measurements in millimeters (Figure 3)

1. UR6-midline (maxillary right first molar to the constructed reference midline).
2. UL6-midline (maxillary left first molar to the constructed reference midline).
3. UR6-UL6 (maxillary right first molar to the maxillary left first molar).

Angular measurements in degrees (Figure 4)

1. Sella-nasion to point A (SNA).
2. Sella-nasion to point B (SNB).
3. Point A to nasion to point B (ANB).
4. Sella-nasion plane to palatal plane (SN-PP).
5. Sella-nasion plane to mandibular plane (SN-MP).
6. Sella-nasion plane to maxillary central incisor (SN-U1).

Linear measurements in millimeters (Figure 5)

1. Perpendicular distance from sella-nasion plane to posterior nasal spine (SN-PNS).
2. Perpendicular distance from sella-nasion plane to anterior nasal spine (SN-ANS).
3. Perpendicular distance from palatal plane to mesial cusp tip of maxillary first molar (U6-PP).
4. Horizontal distance of point A to a perpendicular from sella-nasion plane at sella (S-A pt).
5. Distance from the anterior nasal spine to menton (ANS-Me).

All measurements were taken twice and mean values were used for analyses. Measurement error was ascertained by correlating first and second observations for all data collected.

Two-tailed Wilcoxon rank-sum tests were used to compare the initial values of each variable measured between the two groups.

Two-tailed Wilcoxon rank-sum tests were also used to determine if there was a difference in the average change for each of these variables between the two groups. All tests were conducted at the 0.05 significance level.

Results

Clinical findings

There were no statistically significant differences between the treatment groups at baseline (see Table 1).

All of the patients demonstrated sutural opening, which was confirmed on the occlusal radiographs. A diastema between the central incisors was present in all of the subjects. No problems were reported by any of the patients in either group and all of them experienced routine expansion with minimal discomfort.

All data is presented in tabular form in Tables 2 to 5. These comprised the results of the angular and linear changes that were recorded from the pretreatment, fixation, and posttreatment cephalometric radiographs.

Radiographic findings

Lateral cephalograph (Table 2)

Noted values were as follows:

SN-PNS (mm): This measurement indicates the amount of movement of the posterior nasal spine in an inferior or superior direction. The bonded sample group (range -1.20 to +1.50 mm) dis-

Table 2
Lateral cephalograph measurements. Changes from pretreatment period to posttreatment period (refer to Figures 4 and 5)

Value	Hyrax Mean	Hyrax Median	Hyrax Range	Bonded Mean	Bonded Median	Bonded Range	P-value
SNA (deg.)	-0.53	-0.05	-3.85 to 0.90	-0.66	-0.40	-3.60 to 1.70	NS
SNB (deg.)	-1.16	-1.15	-3.90 to 0.20	-1.65	-1.80	-3.55 to 0.05	NS
ANB (deg.)	0.62	0.70	-0.80 to 1.75	0.98	0.15	-0.85 to 3.80	NS
SN-PP (deg.)	0.26	0.00	-1.25 to 2.05	1.25	0.70	0.20 to 2.80	NS
SN-MP (deg.)	2.21	2.30	0.75 to 3.40	1.55	1.00	0.45 to 4.15	NS
SN-PNS (mm.)	1.89	1.95	0.60 to 3.00	0.31	0.50	-1.20 to 1.50	0.02
SN-ANS (mm.)	1.47	1.10	-0.80 to 3.95	1.70	1.50	0.40 to 4.20	NS
SN-U1 (deg.)	-4.20	-3.30	-9.45 to 0.60	-2.98	-2.10	-5.80 to -0.55	NS
ANS-Me (mm.)	2.61	2.15	0.00 to 5.75	0.00	0.05	-1.70 to 2.00	0.02
U6-PP (mm.)	0.26	0.55	-2.65 to 2.50	-0.90	-1.10	-2.50 to 0.75	NS
S-A pt.(mm.)	1.47	1.30	-0.60 to 3.60	-0.80	0.15	-4.50 to 1.50	0.04

played less inferior displacement at PNS than the Hyrax group (range +.60 to +3.00 mm), which was significant at the 0.05 level.

ANS-Me (mm): This is a linear measurement which served as an indication of an increase or decrease in lower anterior face height (vertical dimension). The bonded sample group displayed less of an increase (range - 1.70 to 2.00 mm) than the Hyrax patients (range 0.00 to 5.75 mm). This was significant at the 0.05 level.

S-A pt. (mm): This linear measurement determined the anterior or posterior movement of the maxilla. The Hyrax appliance group showed greater anterior displacement of the maxilla (range -.60 to 3.60 mm) than the bonded sample group (range -4.50 to 1.50 mm), which was significant at the 0.05 level.

Posteroanterior cephalograph (Tables 3-5)

In the frontal plane, comparison between the two appliances revealed that there were no statistically significant differences between groups regarding tipping from the pretreatment period to the fixation period (Table 3). Total angular change for the Hyrax appliance ranged from 5.00 degrees to 18.10 degrees, while the bonded sample ranged from 3.10 degrees to 19.80 degrees.

Both groups displayed a tendency for relapse from fixation to appliance removal despite the 3-month retention period. The maxillary teeth tipped back toward their pretreatment values with no significant differences between the two appliances (Table 3).

The values of the changes in millimeters to assess the symmetry of expansion are presented in Tables 4 and 5. Table 4 reveals that there was no statistically significant difference in the amount of expansion between the two appliances. The total millimeter change for the Hyrax appliance ranged from 4.30 mm to 7.20 mm, while the bonded sample ranged from 3.20 mm to 7.70 mm. Table 5 suggests that both appliances resulted in unevenly expanded segments. No statistically significant differences were found between the two groups with asymmetrical expansion occurring more often than not.

Measurement error was extremely low, never exceeding the .02 level. All first and second observations of the primary investigator were highly correlated, ranging from .87 to .98 throughout.

Discussion

Studies to date have shown RME to be associated with various degrees of dental tipping.[4,5] However, even if there were no angular changes of the teeth within each maxillary segment, the teeth would still appear tipped due to the outward tilting of the alveolar processes.[4] Results from this study show that angular changes of the teeth occurred in both the Hyrax and bonded groups with no statistically significant differences between the two appliances. Expansion appliances that are tooth-borne can only be expected to tip the maxillary posterior teeth to varying degrees. Both appliances used in this

Table 3
Posteroanterior cephalometric measurements (angular measurements in degrees).

	Hyrax				Bonded				
Value	Mean	Median	Min	Max	Mean	Median	Min	Max	P-value
Total angular change	10.57	11.85	5.00	18.10	10.52	9.20	3.10	19.80	
UR6-CRL	-4.03	-4.25	-0.90	-8.45	-2.62	-2.05	2.70	-6.15	NS
UL6-CRL	-3.67	-4.25	-0.30	-6.20	-4.19	-4.60	-0.85	-8.00	NS

Total angular change = amount of total angular changes from pretreatment period to fixation period (refer to Figure 2)

UR6-CRL = angular change in upper right first molar to cranial reference line from fixation period to appliance removal (refer to Figure 2)

UL6-CRL = angular change in upper left first molar to cranial reference line from fixation period to appliance removal (refer to Figure 2)

Table 4
Posteroanterior cephalometric measurements (linear measurements in millimeters).

	Hyrax				Bonded				
Value	Mean	Median	Min	Max	Mean	Median	Min	Max	P-value
Total millimeter change	6.01	6.20	4.30	7.20	5.94	7.30	3.20	7.70	NS
UR6-midline	2.21	2.00	1.00	4.20	2.45	2.60	0.60	5.00	NS
UL6-midline	3.80	3.50	2.00	6.10	3.48	2.90	0.60	5.90	NS

Total millimeter change = amount of total millimeter changes from pretreatment period to fixation period (refer to Figure 3).

UR6-midline = millimeter change in upper right first molar to reference midline from pretreatment period to fixation period (refer to Figure 3).

UL6-midline = millimeter change in upper left first molar to reference midline from pretreatment period to fixation period (refer to Figure 3).

study distributed forces directly to the teeth, seemingly the farthest point from the fulcrum of rotation, which is said to be approximately at the frontomaxillary suture. Furthermore, asymmetrical tipping of the respective abutment teeth was observed more often than not. Most patients demonstrated a wide variation of angular change from one side to the other. Hicks evaluated slow expansion appliances in young children and also found that angular changes occurred that were asymmetrical from right to left in the frontal plane.[10] He attributed some of this tipping to the maxillary segments themselves. The amount of lateral rotation of the palatal shelves was not measured in this study since this bony change might have necessitated the use of implants.

Cuspal interferences have been thought to interfere with maxillary expansion. Many authors have observed expansion on one side while the other side remains in crossbite.[5,7] One basic tenet for the interocclusal acrylic design of the bonded appliance has been to relieve the interdigitation of the opposing teeth to allow for symmetrically expanded segments.[7] Our results suggest otherwise. There was no statistical difference between the two groups in expansion pattern. The manner in which expansion occurred was unpredictable and with asymmetry the rule rather than the exception (see Table 5). Both sample groups contained individuals who achieved twice the amount of expansion on one side than the other. This implies that elimination of the intercuspation may not be the foremost determinant in obtaining symmetrically expanded segments. Brossman et al. attributed this phenomenon to variation in the rigidity of skeletal articulations between maxillary segments, which may also account for the asymmetrical angular changes previously mentioned.[5]

During the 3-month retention period following fixation of the appliance, both groups displayed a tendency for the teeth to tip back toward their pretreatment values (Table 3). This tendency for the maxillary teeth and skeletal segments to return toward their original positions has been attributed to a number of probable factors: accumulated forces in the circummaxillary articulations,[5] occlusal forces, the surrounding buccal musculature,[11] and the stretched fibers of the palatal mucosa as theorized by Maguerza.[12] The angular changes demonstrated between these two time periods are meaningful, considering the appliances were fixated to maintain the new transverse dimension. Once the appliances are removed, the relapse tendency may increase despite the 3- to 4-month fixation period. To neutralize this force, palatal retainers, transpalatal bars, or fixed appliances with expanded wires should be considered. Due to this anticipated postexpansion relapse, overcorrection of the transverse problem is widely recommended to allow for the subsequent uprighting of the teeth, as recommended by Haas.[3]

Following expansion, the Hyrax appliance resulted in slight anterior movement of the maxilla, while the bonded appliance often showed posterior displacement of A point, which proved to be statistically significant. This measurement may have been influenced by the lingual tipping of the maxillary incisors. However, changes in angulation of the incisors were measured for both groups with no statistically significant differences. Sarver and Johnston[8] also reported similar findings of posterior maxillary displacement, but their bonded sample demonstrated significant posterior tipping of the incisors. Vertically, the Hyrax responded in a predictable fashion. The maxillary segments moved inferiorly, causing an opening of the bite with subsequent changes in the mandibular plane angle. This movement of the maxilla was demonstrated by changes in the measurements SN-PNS and SN-ANS in mm (Table 2). The bonded appliance showed less inferior movement of PNS, which was found to be statistically significant. In this sample, two subjects showed no displacement of PNS while one subject displayed a slight superior movement. This might be due to the interocclusal acrylic acting as an intrusive force to the basal bone of the maxilla by violating the freeway space and causing a passive stretch of the elevator musculature.[13] Although the relative intrusion of PNS found in some with the bonded appliance may be due to tracing error, it is certainly feasible that the posterior aspect of the maxilla was maintained despite the extrusive tendencies of rapid expansion.

There was relative stability in the lower face height of the bonded appliance group as measured from ANS to Me. Three of the patients with the bonded RME appliance showed slight decreases in anterior facial heights. This is probably a result of the lack of tooth extrusion with the bonded appliance due to the intrusive forces of the interocclusal acrylic. The Hyrax group showed a general increase after expansion, although Table 1 reveals that the Hyrax patients exhibited longer facial heights on average. Long-term studies are needed to assess the validity of this conclusion, as the results of this study are based on a 4-month period.

These findings may be a great benefit in the treatment of certain patients possessing specific characteristics, such as steep mandibular angles, openbite tendencies, and long faces, which typify a growth pattern. Such patients often exhibit constricted maxillae, which necessitate rapid maxillary expansion. The Class II patient with a vertical growth pattern may benefit from the intrusive components of the bonded appliance, potentially enhancing further mandibular growth and/or autorotation of the mandible.

The use of interocclusal acrylic in the bonded sample of the present study resulted in less inferior movement at PNS, which proved to be significant. The bonded group also showed less of an increase in the mandibular plane angle than the Hyrax group, which was not significant but which may have some clinical relevance.

The results of this study indicate an element of vertical control using a bonded expansion appli-

Table 5
Posteroanterior cephalogram. Difference between UR6 and UL6 to assess symmetry (in mm).

	Hyrax			Bonded			
Patient	UR6	UL6	Difference	UR6	UL6	Difference	P<.05
1	4.2	2.0	2.2	2.6	4.7	-2.1	NS
2	1.1	6.1	-5.0	2.7	2.0	0.7	NS
3	2.3	4.8	-2.5	2.6	0.6	2.0	NS
4	1.6	2.7	-1.1	5.0	2.6	2.4	NS
5	3.3	3.5	-0.2	1.8	5.9	-4.1	NS
6	2.0	3.3	-1.3	0.6	2.9	-2.3	NS
7	1.0	4.2	-3.2	1.9	5.7	-3.8	NS

Legend (refer to Figure 3)
UR6 => Upper right first molar measured to the reference midline
UL6 => Upper left first molar measured to the reference midline
Note asymmetrical expansion prevailed in both groups

ance to counteract the adverse effects seen with other expansion devices. Two of the subjects from the bonded sample displaying slight openbites at the start of treatment were observed to have positive overbites of greater than 2 mm after their appliances were removed. Lingual tipping with concomitant extrusion of both maxillary and mandibular incisors may have contributed to this bite closure.

Many clinicians prefer the Hyrax appliance for hygienic purposes. When using a Hyrax appliance, the conjunctive use of occlusal bite blocks and high-pull headgear should be considered when control of the vertical dimension is indicated.

In many instances, bite opening might benefit in the correction of certain malocclusions. Depending on the desired treatment objectives, the orthodontist must consider the design of each expansion device in choosing the appropriate appliance.

For example, in the treatment of a patient with openbite tendency and excessive vertical dimension, a bonded appliance with occlusal coverage would help to prevent extrusion of the maxilla or maxillary teeth. Conversely, a patient with a low mandibular plane angle, deep bite, and a lower anterior facial height would benefit from the bite-opening features of the Hyrax appliance.

Long-term studies are needed to determine any changes in the growth patterns between patients in both groups.

The results of this study suggest that neither appliance was successful in obtaining symmetrically expanded maxillary segments. Asymmetry was the rule, not the exception. Furthermore, both appliances tipped the teeth, with no statistically significant differences between the two.

Conclusions

1. The bonded RME appliance displayed less inferior movement of the posterior aspect of the palate as measured by SN-PNS in mm.
2. The bonded appliance showed less anterior displacement of the maxilla than the Hyrax appliance as measured by S-A pt. in mm.
3. The Hyrax appliance showed a greater increase in vertical facial height as measured by ANS-Me in mm.
4. Both appliances resulted in tipping of the posterior teeth, which was highly variable and asymmetric.

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