Effects of bonded rapid palatal expansion on the transverse dimensions of the maxilla: A cone-beam computed tomography study

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Introduction: The purpose of this study was to examine the maxillary response on the transverse dimensions to rapid palatal expansion (RPE) by using cone-beam computed tomography (CBCT). Methods: Twenty-four children (average age, 9.9 years) who had RPE treatment with a bonded expander were included. Pretreatment orthodontic records (T1) and immediately after expansion (T2) CBCT images were taken for all patients. For each patient, the width of the nasal cavity at the level of the maxillary first permanent molar and second deciduous molar (or second permanent premolar), the width of the maxillary basal bone, and the width of the midpalatal suture at the level of the second deciduous molar (or the second permanent premolar), the first deciduous molar (or first permanent premolar), and the deciduous canine (or permanent canine) at T1 and T2 were measured. In addition, the amount of tipping for both the maxillary right and left first permanent molars was measured. Results: From T1 to T2, mean increases in nasal width, related to the mean jackscrew opening (8.19 mm), occurred at the levels of the first permanent molars of 33.23% (2.73 mm, P < 0.05) and the second deciduous molars of 37.32% (3.06 mm, P < 0.05). Significant increases in basal bone of the maxilla were found at all levels (P < 0.05), with mean increases of 40.65% (3.33 mm), 44.08% (3.49 mm), 46.73% (3.83 mm), and 46.83% (3.62 mm) of the mean jackscrew opening at the levels of the first permanent molars, and the second deciduous molars, first deciduous molars, and deciduous canines, respectively. Significant openings in the midpalatal sutures was found at all levels (P < 0.05), with mean increases of 52.82% (4.33 mm), 53.23% (4.36 mm), 54.35% (4.46 mm), and 52.77% (4.33 mm) of the jackscrew opening at the levels of the first permanent molars, and the second deciduous molars, first deciduous molars, and deciduous canines, respectively. The right first molar tipped buccally an average of 6.2° (P < 0.05), and the left first molar tipped buccally 5.6° (P < 0.05). Conclusions: After RPE, significant increases in the transverse dimensions of the nasal cavity, the maxillary basal bone, and the midpalatal suture opening occurred, with the greatest increase in the midpalatal suture followed by basal bone and nasal cavity. The midpalatal suture opened in a parallel fashion. Moreover, significant buccal tipping occurred on both maxillary first molars. (Am J Orthod Dentofacial Orthop 2010;137:S79-85)

Rapid palatal expansion (RPE) has been widely used by many orthodontists to increase the maxillary transverse dimension in young patients. Throughout the years, many types of palatal expanders and their effects on facial structures have been studied. Historically, these studies have been conducted by using traditional lateral and posteroanterior (PA) cephalograms, occlusal films, and dental casts. More recently, computed tomography (CT) scanning has been used by investigators to study the effects of RPE on facial structures.

Haas,1 and Memikoglu and Iseri2 demonstrated increases in the width of the nasal cavity after RPE by using PA cephalograms. Podesser et al3 found an increase in nasal cavity width at the level of the maxillary first molars using CT scanning. Garib et al4 reported an increase in the width of the nasal floor after RPE using CT scanning and found it to be one-third of the amount of the jackscrew opening of the expander. Using cone-beam CT (CBCT), Garrett et al5 found a nasal width increase of 37.2% of the mean hyrax appliance expansion.

Haas6 suggested that the midpalatal suture opens after RPE in a parallel manner anteroposteriorly and triangularly infero-superiorly, with the apex in the nasal
cavity. However, Wertz and Dreskin reported that after RPE the midpalatal suture opening was not parallel, with the widest opening at the anterior nasal spine (ANS) and diminishing posteriorly. Using CT scanning, Habersack et al found a parallel opening of the midpalatal suture in a young patient after RPE, whereas an older patient had a pyramidal opening of the suture with jigsaw-like rupture lines indicating greater suture interdigitation. Silva Filho et al found that the posterior nasal spine (PNS) opened to a lesser extent than did the ANS in children in the deciduous and mixed dentition stages on CT images after RPE. Podesser et al evaluated the effects of RPE in 9 children using CT imaging. They reported that the average expansion measured at the molar crowns was 3.6 mm, whereas the actual midpalatal suture opening was as low as 1.6 mm. Using CBCT, Garrett et al found more skeletal expansion of the maxilla in the first premolar region and less in the first molar region: 55% and 38% of the hyrax appliance expansion, respectively.

Chung and Font examined 20 adolescents expanded with Haas-type expanders. They found that 9.7% of intermolar expansion and 4.3% of intermolar expansion were due to buccal crown tipping, but the degree of tipping was not determined because of the inability to measure the axial inclination from PA cephalograms. Haas suggested that more bodily movement and less dental tipping were produced when acrylic palatal coverage was added to support the appliance. Garib et al examined the dentoskeletal effects of tooth tissue-borne and tooth-borne expanders, and concluded that RPE led to buccal movement of the maxillary posterior teeth by tipping and bodily translation in both groups. However, the tooth tissue-borne expander produced greater changes in the axial inclination of the supporting teeth, especially the first premolars compared with the tooth-borne expander. Kilic et al reported that both hyrax (tooth borne) and acrylic bonded (tooth tissue-borne) palatal expanders produced significant buccal tipping of supporting teeth, but the amount of tipping was less in the tooth tissue-borne appliance.

The purpose of this study was to use CBCT to examine the effects of RPE on the widths of the nasal cavity, maxillary basal bone, and midpalatal suture, and the inclination of maxillary first molars with a bonded Haas-type expander.

### MATERIAL AND METHODS

Twenty-four healthy children (mean age, 9.9 years; range, 7.8-12.8 years; 14 boys, 10 girls) who required RPE treatment, from a private orthodontic practice, were included for the study. The skeletal age of each patient was determined from a hand-wrist radiograph, according to the standards of Greulich and Pyle. The mean skeletal age of the patients was 10.3 years (range, 7.5-13 years).

A pretreatment CBCT image (T1) was taken as part of the initial orthodontic records of all patients. The scans were obtained with an I-CAT machine (Imaging Sciences International, Hatfield, Pa). For each patient, a bonded Haas-type maxillary expander was cemented in place. The design of the expander was full occlusal and palatal acrylic coverage. The occlusal coverage included the deciduous canine (or the permanent canine if in the arch) through to the first molar (Fig 1). The appliances were all made by the same orthodontic laboratory. Before cementation, 2 small holes were drilled on either side of the expander in both anterior and posterior regions. Once the expander was cemented in place, the distance between the 2 holes was measured with a digital caliper. Expansion was carried out as 2 turns per day (0.2 mm per turn) until the required expansion was complete.

An immediate postexpansion CBCT image (T2) was taken of each patient on the day the appliance was tied off when adequate expansion was achieved. To decrease the amount of radiation, the posttreatment scan had a smaller window, which decreased the imaging time from 20 to 10 seconds and halved the amount of radiation. A digital caliper was used to measure the distance between the 2 acrylic halves after expansion. The amount of activation of the jackscrew was measured by averaging the difference in distance between the T1 and T2 images in the anterior and posterior areas. The mean interval between the T1 and T2 was 66 days (range, 21-152 days), but the mean active expansion period (from beginning of expansion to T2) was 30 days (range, 21-42 days). None of the patients
received any brackets or wires in the maxillary arch until the CBCT images were taken at T2.

All CBCT images were oriented and standardized by using Dolphin Imaging (version 10.5, Dolphin Imaging & Management Solutions, Chatsworth, Calif). Each head was oriented in 3 planes of space for frontal, right lateral, and left lateral views. The head was oriented in the frontal view with the floor of the orbits parallel to the floor. The right lateral view allowed placement of the head so that the Frankfort horizontal line (upper rim of external auditory meatus, porion, to the inferior border of the orbital rim, orbitale) was parallel to the floor. Both the right and left posterior borders of the ramus and the angle of the mandible were superimposed to the best possible fit. The left lateral view was also examined to ensure that the Frankfort horizontal was parallel to the floor, and the borders of the ramus and the angle of the mandible were superimposed as best fit.

The first set of data was calculated from the patient’s 3D skull view. Quantitative evaluation of the parameters was based on the identification and registration of a series of points. Points 1 and 2 were reference points that represented the levels of basal bone of the maxilla. These landmarks were plotted from the frontal view of the skull on both sides. These landmarks were defined as the most superior aspect of the concavity of the maxillary bone as it joined the zygomatic process (Fig 2).

From point 1, a horizontal reference line parallel to the floor was drawn. Points 3, 4, 5, and 6 were marked on the right lateral view of the 3D skull on the horizontal reference line and above the center of the clinical crown of the maxillary first molar, second deciduous molar (or second premolar if in the arch), first deciduous molar (or first premolar if in the arch), and canine, respectively (Fig 3).

Once points 1 through 10 were plotted on the 3D skull, the axial section was brought into view to ensure that all points were plotted on the alveolar bone. The maxillary base width and the width of the suture opening were calculated from the axial view.

The measurement of the width of the maxillary base at the level of the maxillary first molars, second deciduous molars, first deciduous molars, and canines were measured as the distances between points 3 and 7, 4 and 8, 5 and 9, and 6 and 10, respectively (Fig 3).

On the T2 images, once the maxillary base width had been recorded, the axial slice with points 1 through 10 plotted was used to measure the width of the suture opening.
Quantitative evaluation of the parameters was based on the identification and registration of a series of points, as suggested by Podesser et al.10 Points 1 and 2 were the lateral limits of the nasal cavity: point 1 was the lateral point on the lateral wall of the right nasal cavity with a line perpendicular to the floor. Point 2 was constructed on the lateral wall of the left nasal cavity from point 1 by using a line perpendicular to the floor. Points 3 and 4 represented the apices of the palatal roots of the right and left first molars, respectively. Points 5 and 6 represented the tips of the mesiobuccal cusps of the maxillary right and left first molars, respectively.

The image was adjusted at slice thickness distance 1.0 mm until the entire suture opening could be seen. Points 11 and 12 were marked at the horizontal level of point 3, which marked the maxillary right first molar. Point 11 was placed on the right border of the suture, and point 12 was placed on the left border of the suture. Point 13 was placed on the right border of the suture following the horizontal line of point 4 (right second deciduous molar), and point 14 was placed on the left border of the suture in the same horizontal plane. Point 15 was placed on the right border of the suture following the horizontal line of point 5 (right first deciduous molar), and point 16 was placed on the left border of the suture in the same horizontal plane. The distances between points 11 and 12, 13 and 14, 15 and 16, and 17 and 18 were calculated, representing the distances between the suture opening at the level of the maxillary first permanent molar, second deciduous molar, first deciduous molar, and canine, respectively (Fig 4).

The second set of data for the coronal sections was collected and analyzed according to the guidelines of Podesser et al.10 For the molar slice, the most anterior slice showing the entire palatal root of the maxillary first molar was chosen. The second deciduous molar (or second premolar if present), and the first deciduous molar (or first premolar if present) were chosen as the most anterior slice on which the crown and root could be seen in their entire length, regardless of whether the tooth was the deciduous one or its permanent successor.

1. On the first molar: (1) nasal cavity width, the distance between points 1 and 2; (2) right molar inclination, points 5 to 3 to the floor; (3) left molar inclination, points 6 to 4 to the floor; and (4) intermolar angle, the angle of intersection of lines from points 5 to 3 and points 6 to 4.
2. On the second deciduous molar (or second premolar): nasal cavity width, the distance between points 1 and 2.
3. On the first deciduous molar (or first premolar): nasal cavity width, the distance between points 1 and 2.
Table I. Changes in nasal cavity, basal bone of the maxilla, and midpalatal suture after bonded RPE

<table>
<thead>
<tr>
<th></th>
<th>Mean difference,</th>
<th></th>
<th>Mean/mean screw</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n</td>
<td>T1-T2 (mm)</td>
<td>SD (mm)</td>
<td>Range (mm)</td>
</tr>
<tr>
<td>Nasal cavity</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>First molar</td>
<td>24</td>
<td>2.73</td>
<td>0.92</td>
<td>0.75–4.35</td>
</tr>
<tr>
<td>Second deciduous molar</td>
<td>24</td>
<td>3.06</td>
<td>0.88</td>
<td>1–4.65</td>
</tr>
<tr>
<td>Basal bone of maxilla</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>First deciduous molar</td>
<td>24</td>
<td>3.33</td>
<td>1.32</td>
<td>0.5–5.45</td>
</tr>
<tr>
<td>Second deciduous molar</td>
<td>24</td>
<td>3.49</td>
<td>2.02</td>
<td>0.03–6.1</td>
</tr>
<tr>
<td>First deciduous molar</td>
<td>24</td>
<td>3.83</td>
<td>1.46</td>
<td>0.2–5.45</td>
</tr>
<tr>
<td>Canine</td>
<td>24</td>
<td>3.62</td>
<td>2</td>
<td>0.7–8</td>
</tr>
<tr>
<td>Midpalatal suture</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>First molar</td>
<td>24</td>
<td>4.33</td>
<td>1.19</td>
<td>1.9–7.25</td>
</tr>
<tr>
<td>Second deciduous molar</td>
<td>24</td>
<td>4.36</td>
<td>1.27</td>
<td>1.9–8.2</td>
</tr>
<tr>
<td>First deciduous molar</td>
<td>24</td>
<td>4.46</td>
<td>1.11</td>
<td>2.15–7.3</td>
</tr>
<tr>
<td>Canine</td>
<td>24</td>
<td>4.33</td>
<td>1.06</td>
<td>2.7–6.2</td>
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</table>

Statistical analysis

Descriptive statistics including means, standard deviations, and ranges were calculated for the measurements at T1 and T2. The Student paired t test was used to evaluate whether the changes from T1 to T2 were significantly different. To test intraexaminer reproducibility, all images were remeasured by the same examiner (K.F.C.) a minimum of 2 weeks later and compared with the original measurements. The paired t test and the Pearson correlation coefficients were run to determine whether the measurements at the 2 times showed significant differences. To test interexaminer reproducibility, 12 patients were selected at random and measured by an orthodontic resident. The Student paired t test and the Pearson correlation coefficients were run to determine whether the measurements by the 2 examiners showed significant differences. Significance for all statistical tests was predetermined at P <0.05.

RESULTS

The intraexaminer reproducibility test showed that only 2 (nasal cavity width at the second deciduous molar and intermaxillary angulation) of the 24 measurements had significant differences (P <0.05). However, in each case, the Pearson correlation coefficient varied between 0.99 and 0.97, indicating high reproducibility among measurements, and the magnitudes of the difference were only 0.26 mm and 0.33°, respectively.

The interexaminer reproducibility test showed that 5 (basal bone width of the maxillary first molar at T1, right molar angulation at T1, left molar angulations at T1 and T2, intermolar angulation at T2, and midpalatal suture opening at the first deciduous molar [or first premolar] at T2) of the 24 measurements had statistically significant differences (P <0.05). In each case, the Pearson correlation coefficient varied between 0.98 and 0.99, indicating high reproducibility among measurements. The differences were 0.84 mm, 0.78 mm, 1.33°, 1.08°, 0.38°, and 0.03 mm, respectively.

Table I shows the increase in the width of the nasal cavity at the level of the maxillary first molar and second deciduous molar (or second premolar) after RPE. The mean increases were 2.73 mm at the maxillary first molar and 3.06 mm at the maxillary second deciduous molar. Because the actual mean expansion from the bonded expander was 8.19 mm, the nasal width expansions of 2.73 mm at the first molar and 3.06 mm at the second deciduous molar were 33.23% and 37.32%, respectively.

The increases in the width of the basal bone of the maxilla at all levels as a result of RPE are given in Table I. The mean increases in basal bone width at the levels of the maxillary first molar, second deciduous molar, first deciduous molar, and canine were 40.65% (3.33 mm), 44.08% (3.49 mm), 46.73% (3.83 mm), and 46.83% (3.62 mm) of the amount of jackscrew opening (8.19 mm), respectively.

Table I also shows the increases in width of the midpalatal suture at all levels as a result of RPE. The mean increases at the levels of the maxillary first molar, second deciduous molar, first deciduous molar, and canine were 52.82% (4.33 mm), 53.23% (4.36 mm), 54.35% (4.46 mm), and 52.77% (4.33 mm) of the amount of jackscrew opening (8.19 mm), respectively. There was no significant difference for suture opening at each level (P >0.05). This demonstrated the parallel effect of the suture opening across all levels.

A statistically significant increase (11.82° ± 3.07°) was seen in the intermolar angle after expansion, with 6.22° ± 2.5° of buccal tipping on the right first molar and 5.60° ± 2.6° of buccal tipping on the left first molar (Table II).

DISCUSSION

The objective of this study was to evaluate the effects of bonded RPE on nasal width, maxillary basal bone, midpalatal suture opening, and first molar tipping with CBCT. The mean time from the T1 to the T2 CT images was 66 days (range, 21–152 days), but the mean
active expansion period (from beginning of expansion to T2) was only 30 days (range, 21–42 days). The reason for the long interval between T1 and T2 was that some patients did not start treatment until 3 or 4 months after the T1 images (initial records) were taken. Thus, some skeletal changes from T1 to T2 in this study could be attributed to growth during this waiting period, although the amount was estimated to be small.16-18

Our data clearly showed significant increases in nasal cavity width at the levels of the maxillary first molars (mean, 2.73 mm; 33.23% of jackscrew expansion) and the second deciduous molars (mean, 3.06 mm; 37.32% of jackscrew expansion) after RPE. We did not measure the width of the nasal cavity at the level of the first deciduous molar and canine because of distortion of the coronal image, since the section was taken more anteriorly. Our results agreed with those of Garib et al.,4 who reported that the transverse increase at the level of the nasal floor corresponded to one-third of the amount of jackscrew expansion after RPE. We measured the lateral limits of the nasal cavity, which was at a higher level than the nasal floor as described by Garib et al.4 This finding might support the theory that maxillary expansion increases air flow and improves nasal breathing.1,6,11,12,19 However, additional research is warranted in terms of how the volume of the nasal airway is affected by RPE.

We found that, as a result of RPE, the midpalatal suture opened in a parallel fashion. This was different from the results of Wertz and Dreskin,7 who used occlusal films and described the opening to be the widest at ANS and diminished posteriorly after RPE in subjects aged 8 to 29 years. This was also different from the CT study by Silva Filho et al.,8 who reported that the opening of the midpalatal suture in the area of the PNS occurred to a lesser extent than at ANS after RPE with a Haas-type expander in subjects from 5.2 to 10.5 years of age. Our results compare with those of Habersack et al.,9 who used CT imaging to demonstrate complete parallel opening of the midpalatal suture in a child in the mixed dentition (skeletal age, 10 years) after RPE with an acrylic splint expansion appliance. Perhaps the parallel nature of the midpalatal suture opening seen at the levels of canine through the maxillary first molar in this study was due to a combination of the rigid acrylic bonded expander and the younger skeletal age (mean, 10.3 years) of our patients. In our study, we measured the suture opening at the level of the teeth, whereas in previous studies, such as that of Wertz and Dreskin,7 the measurements were at ANS and PNS.

Because of the previous limitations in technology, the amount of basal bone change after RPE was never clearly understood at the levels of the maxillary first molar, second deciduous molar (second premolar if present), first deciduous molar (first premolar if present), and canine. Traditionally, the width of the maxillary basal bone was measured on a PA cephalogram. The radiographic landmark of jugule was plotted on PA cephalograms and defined as the intersection of the outline of the tuberosity of the maxilla and the zygomatic buttress of both sides.4 The distance between right and left jugales was used to estimate the transverse dimension of the maxilla. However, jugale can be hard to identify because of the superimposition of many structures on a PA cephalogram. There was also no way to measure the width of the basal bone of the maxilla at any other level because of the 2-dimensional limitations of traditional PA cephalograms. CBCT allowed us to clearly visualize and quantify the changes throughout the basal bone of the maxilla from palatal expansion. Our data showed that all levels of the maxillary basal bone examined were significantly increased (P <0.05) after RPE.

Our data also showed a significant buccal crown tipping effect on the first molars from RPE. Clinically, this information is important, since it could help clinicians to determine the appropriate amount of overexpansion from RPE. The mean amounts of buccal tipping were 6.22° ± 2.5° for the right molar and 5.60° ± 2.6° for the left molar; these amounts are similar to those found by Ciambotti et al.10 of 6.08° ± 6.25° of buccal crown tipping of the maxillary molars after RPE using a toothborne appliance on children and measured on dental models. Oliveira et al.10 examined the various effects of a tissue-borne appliance (Haas) and a tooth-borne appliance (hyrax) on children. The Haas group had more orthopedic movement and less dentoalveolar tipping than did the hyrax group. Recently, Kilic et al.13 compared the dentoalveolar inclination of patients treated with either a hyrax expander (mean skeletal age, 13.9 years) or an acrylic bonded expander similar to the type used in our study (mean skeletal age, 13.6 years) using study

### Table II. Tipping effects on maxillary first molars after bonded RPE

<table>
<thead>
<tr>
<th></th>
<th>Mean difference, T1-T2</th>
<th>SD (°)</th>
<th>Range (°)</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Right molar angulation</td>
<td>6.22°</td>
<td>2.5</td>
<td>2.2–11.7</td>
<td>&lt;0.00001</td>
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<tr>
<td>Left molar angulation</td>
<td>5.6°</td>
<td>2.6</td>
<td>0.95–10.65</td>
<td>&lt;0.00001</td>
</tr>
<tr>
<td>Intermolar angle</td>
<td>11.82°</td>
<td>3.07</td>
<td>3.4–17.05</td>
<td>&lt;0.00001</td>
</tr>
</tbody>
</table>
models. They determined that both types of expander produced significant tipping, but the dentoalveolar inclination was greater in the maxillary group. They reported tipping amounts with means of 7.01° for the right molar and 6.79° for the left molar with a mean jackscrew opening of 7.31 mm in the acrylic bonded group. These results were slightly higher than our findings.

We found that, after RPE, at the level of the first molar, the mean nasal cavity width increase was 2.73 mm, the mean basal bone width increase was 3.33 mm, and the mean suture opening was 4.33 mm. This demonstrated that the expansion had a triangular pattern, with the greatest increase in the suture, followed by basal bone width and the nasal cavity width. Previous studies reported similar patterns in the expansion of skeletal structures after RPE.  

CONCLUSIONS

The effects of bonded RPE (mean jackscrew opening, 8.19 mm) on the transverse dimensions of the maxilla in children, examined by CBCT, are as follows.

1. There were significant nasal width increases (P < 0.05) at the levels of the maxillary first molar and second deciduous molar (second premolar if present) with means of 33.23% (2.73 mm) and 37.32% (3.06 mm) of the jackscrew opening, respectively.

2. There were significant increases in the width of the basal bone (P < 0.05) at the levels of the first molar, second deciduous molar (second premolar if present), first deciduous molar (first premolar if present), and canine with means of 40.65% (3.33 mm), 44.08% (3.49 mm), 46.73% (3.83 mm), and 46.83% (3.62 mm) of the jackscrew opening, respectively.

3. There were significant midpalatal suture openings (P < 0.05) at the levels of the first molar, second deciduous molar (second premolar if present), first deciduous molar (first premolar if present), and canine with means of 52.82% (4.33 mm), 53.23% (4.36 mm), 54.35% (4.46 mm), and 52.77% (4.33 mm) of the jackscrew opening, respectively. The midpalatal suture opening was parallel.

4. There was significant buccal tipping of the first molars (P < 0.05), with mean increases of 6.2° for the right molar and 5.6° for the left molar.

We thank Solomon Katz and Sonal Dave for their help.

REFERENCES


