ORIGINAL ARTICLE

A comparison of dental and dentoalveolar changes between rapid palatal expansion and nickel-titanium palatal expansion appliances

Christopher Ciambotti, DDS, MS,[a] Peter Ngan, DMD, Cert Orth,[b] Mark Durkee, DDS, PhD,[c] Kavita Kohli, DDS,[d] and Hera Kim, DMD, MMSc[e]

Yokota, Japan, and Morgantown, WVa

A tandem-loop nickel titanium temperature-activated palatal expansion appliance was developed that produces light, continuous pressure on the midpalatal suture and requires little patient cooperation or laboratory work. The purpose of this study was to compare the effectiveness of the nickel titanium palatal expansion appliance with that of a rapid palatal expansion appliance. The study sample comprised 25 patients who required palatal expansion as part of their orthodontic treatment. The sample was divided into 2 groups, with 13 patients in the nickel titanium group and 12 patients in the rapid palatal expansion group. Study models were taken before treatment and at the end of the retention period after expansion. Intermolar width, palatal width, palatal depth, alveolar tipping, molar tipping, and molar rotation were analyzed. In addition, occlusal radiographs were obtained before and 2 weeks after expansion to evaluate for sutural separation by the appliances. Results showed significant increases in midpalatal sutural separation, tipping of the alveolus, and tipping of the molars after expansion in both groups. However, greater midpalatal sutural separation was found in the rapid palatal expansion group and greater molar rotation was found in the nickel titanium group. Stepwise multiple regression analysis showed that alveolar tipping, palatal width change, and molar tipping are the best predictors of intermolar width change in the rapid palatal expansion group. Radiographic evidence of midpalatal sutural separation was less obvious in the nickel titanium group. These results suggest that both the nickel titanium and the rapid palatal expansion appliances are capable of expanding the maxillary dentition and alveolar process and are equally capable of correcting posterior crossbites. In the current study, the rapid palatal expander widened the palate more reliably, whereas the nickel titanium expander tipped the molars buccally to a greater extent and caused more distal molar rotation. The clinician's choice of expander will depend on his or her initial diagnosis and treatment goals. (Am J Orthod Dentofacial Orthop 2001;119:11-20)

The incidence of posterior crossbites in white American children is approximately 7%.[1,2] The occurrence is higher in European children (13%-23%)[3,4] and lower in African American children (1%-2%).[2,5] Correction of posterior crossbites in young patients is often accomplished by a combination of skeletal and dental expansion. Skeletal expansion involves separating the right and the left maxillary halves at the midpalatal suture; dental expansion results from buccal tipping of the maxillary posterior teeth.[6-17] The proportion of skeletal and dental movement is dependent on the rate of expansion and the age of the patient during treatment.[6-9] The goal of palatal expansion is to maximize skeletal movement and minimize dental movement, while allowing for physiologic adjustment of the suture during separation.[10-12]

Expansion appliances can be classified as rapid or slow. Rapid palatal expansion (RPE) appliances produce large forces at the sutural site over a short period.[11,13] These heavy forces maximize skeletal separation of the midpalatal suture by overwhelming the suture before any dental movement or physiologic sutural adjustment can occur.[15,16] This form of midpalatal suture separation may induce patient discomfort.[17] RPE appliances also require patient or parent cooperation in appliance activation and labor-intensive laboratory procedures in fabricating the appliance. Slow-expansion appliances, such as the quad-helix and W-arches, have been shown in animal experiments to allow for more physiologic adjustment to sutural separation with less potential for relapse.[12] In 1993, Arndt[18] developed a tandem-loop nickel-titanium (NiTi) temperature-activated palatal expander with the ability to produce light, continuous

[a]Private Practice, Yokota, Japan.
[b]Professor and Chair, Department of Orthodontics, West Virginia University School of Dentistry.
[c]Department of Orthodontics, West Virginia University School of Dentistry.
[d]Division of Pediatric Dentistry, West Virginia University School of Dentistry.
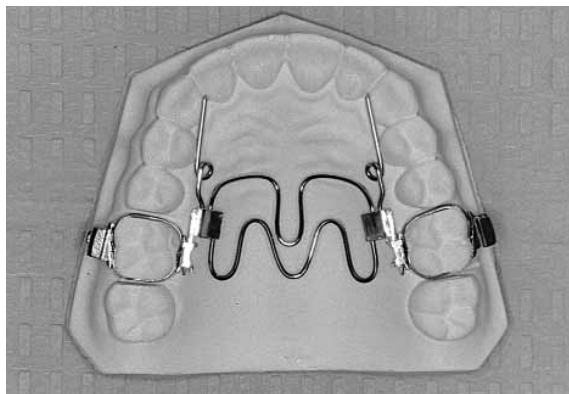[e]Private Practice, Flushing, New York.
Reprint requests to: Dr Peter Ngan, Department of Orthodontics, West Virginia University, HSCN, PO Box 9480, Morgantown, WV 26506-9480; fax, 304-293-2327; e-mail, pngan@hsc.wvu.edu.

Fig 1. NiTi expander.
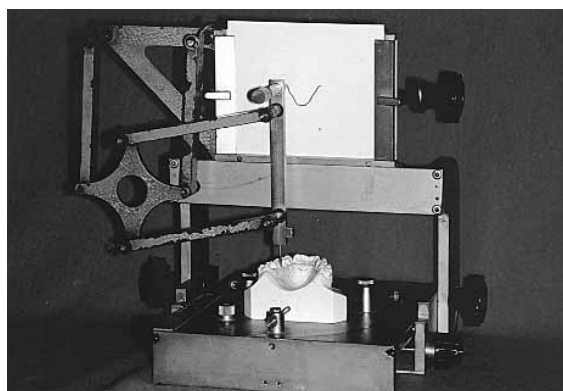
Fig 2. Symmetrograph.

pressure on the midpalatal suture. This appliance is capable of correcting molar rotation and requires little patient cooperation or laboratory work.

The objective of this study was to compare the maxillary dental and dentoalveolar changes between RPE and NiTi palatal expansion appliances. Specifically, the amount of midpalatal suture separation, maxillary alveolar tipping, maxillary first molar tipping, maxillary first molar rotation, and palatal depth changes in response to treatment were quantified, and the advantages and disadvantages of the 2 types of appliances were discussed.

MATERIALS AND METHODS

The study comprised 12 patients treated with RPE appliances and 13 patients treated with NiTi palatal expansion appliances at the West Virginia University Department of Orthodontics. The criteria for patient selection included patients in mixed or early permanent dentition who required palatal expansion as part of their comprehensive orthodontic treatment. The RPE group comprised 6 males and 6 females with an average age of 11.1 years. Eight of the 12 patients had either a unilateral or a bilateral posterior crossbite at the start of the treatment. The average treatment time was 127 days. The NiTi expansion group comprised 3 males and 10 females with an average age of 9.4 years. Eleven of the 13 patients had a unilateral or bilateral posterior crossbite at the start of the treatment. The average treatment time for this group was 153 days.

The RPE appliance was a tooth-borne appliance that could be banded or bonded to the maxillary anchor teeth. Expansion was carried out by means of a midpalatal jackscrew. Patients were instructed to activate the jackscrew 2 times per day (0.5 mm), once in the morning and once in the evening. Expansion was considered adequate when the occlusal aspect of the maxillary lingual cusp of the permanent first molars or the

primary second molars contacted the occlusal aspect of the mandibular facial cusp of either the permanent first molar or the primary second molar. The amount of overexpansion was designed to compensate for relapse after expansion. The appliance was left in place for approximately 3 months after active expansion.

The NiTi expander was a tandem-loop temperature-activated expansion appliance (GAC International; Central Islip, NY), previously described by Arndt.[18] The appliance consisted of 2 tandem, temperature-sensitive, 0.035-in diameter NiTi transpalatal loops that were connected bilaterally to the lingual sheaths of the maxillary molar bands. Anteriorly, a 0.032-in diameter stainless steel wire formed a helical loop fingerspring designed for lateral expansion in the canine and premolar region (Fig 1). The appliance is manufactured in 8 sizes in 3-mm increments. The proper size was selected by measuring the intermolar width on the pretreatment study casts from the maxillary molar lingual groove at the gingiva, to the opposite lingual groove, and then adding 3 to 4 mm. For placement of the appliance, the NiTi transpalatal loops were sprayed with a tetrafluoroethane refrigerant (Chill Refrigerant Spray; GAC International). The martensitic transformation and superelastic properties of the NiTi wires assist in the insertion of the expander into the lingual sheaths of prefit bands, which are then cemented to both maxillary first molars. Expansion was considered adequate once the occlusal aspect of the maxillary lingual cusp of either the permanent first molar or the primary second molar contacted the occlusal aspect of the mandibular facial cusp of either the permanent first molar or the primary second molar. The appliance was left in place for approximately 3 months after active expansion.

Study cast evaluation

Study casts were taken before and after treatment to analyze the differences between the appliances in
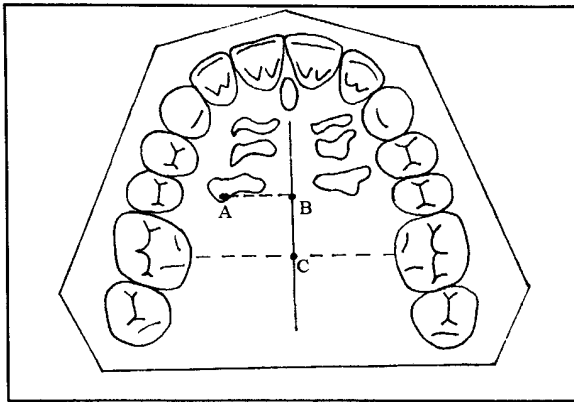
**Fig 3.** Identification of dental cast landmarks.

Fig 4. Transverse palatal contour tracing with identification of median palatal raphe *(A)* and measurement of palatal width change to the right *(A)*.

Fig 5. Construction of lines representing pretreatment and posttreatment alveolar processes.

palatal width changes, maxillary alveolar tipping, maxillary molar tipping, maxillary molar rotation, and palatal depth changes.

Palatal width. Transverse palatal contour tracings of the casts were made by using a symmetrograph, as described by Korkhaus[19] (Fig 2). A symmetrograph is a specialized form of a pantograph used to copy a shape, in this case the palatal contour of the study models to any desired scale. To compare palatal width changes, the pretreatment cast was secured on the rotating platform so that the median palatal raphe was parallel to the recording plate and the occlusal plane was parallel to the base. The median palatal raphe was then traced onto the recording plate. This tracing was later used to orient the posttreatment cast. The pretreatment cast was then rotated 90° so that the median palatal raphe was perpendicular to the recording plate. Once the cast had been rotated, a distinct palatal rugae, point A, was located (Fig 3). A perpendicular line was projected from point A to the median palatal raphe. The point of intersection was referred to as point B (Fig 3). Next, another line was projected to connect the lowest contours of the lingual gingival margin of the first molars; its intersection with the median palatal raphe was referred to as point C (Fig 3). By using the same reference points, the transverse palatal contour was then traced to the recording plate, with point C also being marked on the tracing (Fig 3). The distance from point B to point C was also recorded from the pretreatment casts.

The posttreatment cast was then placed on the rotating platform so that its median palatal raphe was coincident with the median palatal raphe tracing of the pretreatment cast. Once these were coincident, the posttreatment cast was rotated 90° and points A and B were located. With the tracing arm located at point B, the cast was moved via the sliding base and according to the measurement made on the pretreatment cast
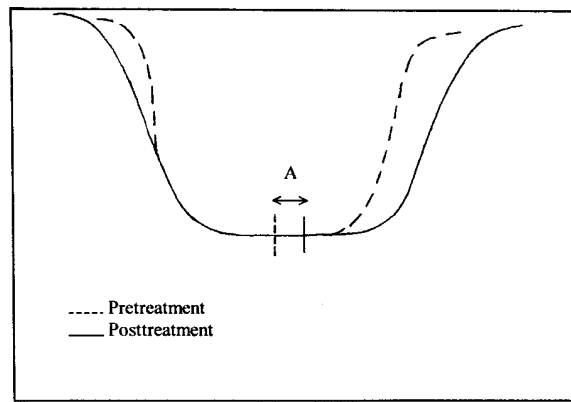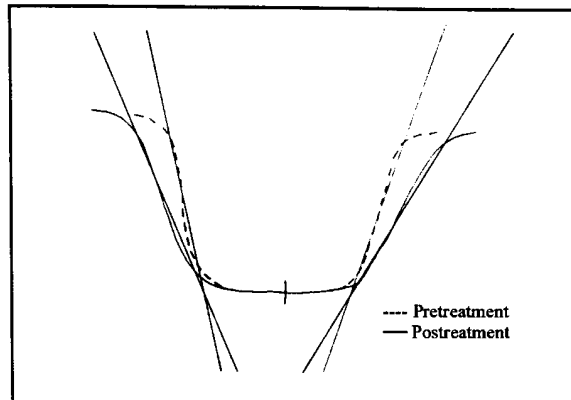
(point B to point C) so that the tracing arm was now located at point C. The transverse palatal contour was now located at the same place as the transverse palatal contour of the pretreatment cast and was traced onto the recording plate along with point C.

The pretreatment and posttreatment tracings were then superimposed on the horizontal palatal shelves and at the curvature joining the left alveolar process and palatal shelf. The difference between the 2 raphes (A) was the amount of palatal width change to the right (Fig 4). The same procedure was repeated on the right side. Thus, the difference between the 2 raphes (B) was the amount of palatal width change to the left. The right and left side differences in the median palatal raphes were then added (A + B) to indicate the total amount of skeletal expansion across the midpalatal suture.
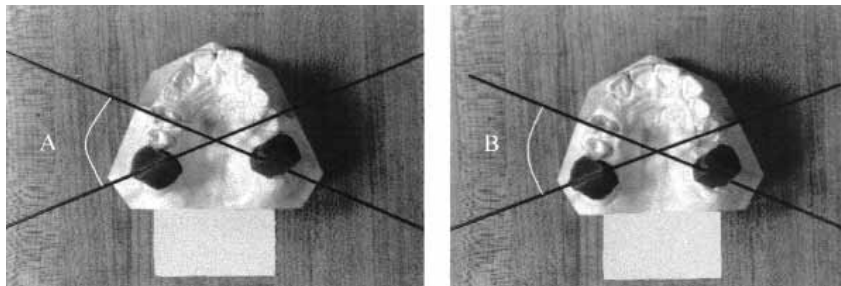
Fig 6. Measurement of molar rotation (*angle B minus angle A*).
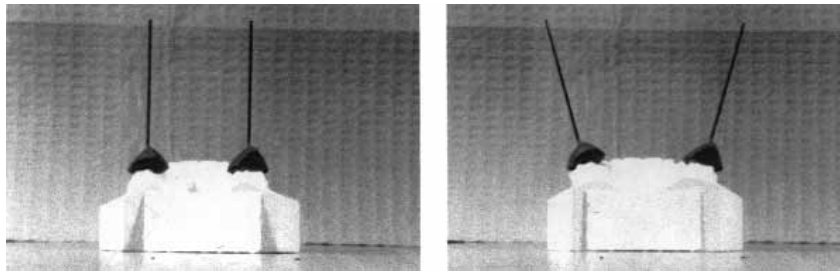
Fig 7. Alternative methods of evaluating molar tipping.

Maxillary alveolar tipping. Transverse palatal contour tracings were made as described above. A line was drawn from the midpoint of the curve of the junction of the alveolar process and tooth to the midpoint of the curve of the junction of the alveolar process and palatal shelf. This was done for both the right and the left sides of the pretreatment and posttreatment tracings (Fig 5). The pretreatment and posttreatment tracings were then superimposed on the lines representing the left alveolus. The angle formed between the lines on the right side (A) indicates the total amount of alveolar tipping in degrees.

Maxillary molar rotation. Polyvinylsiloxane impression putty caps were placed on the maxillary first molars of the pretreatment dental casts to evaluate the amount of molar rotation. While the putty was still soft, orthodontic wire (0.040 in) was inserted into the putty of each first molar so that the wires were parallel to the occlusal plane and intersected at a 45° angle when viewed from directly above the casts. A photograph was taken from above the cast with a 200-mm lens at a distance of 175 cm (wire to film) to minimize distortion of the wires. The putty caps with wires (goniometers)[20] were transferred to the posttreatment casts, and the photograph was repeated. The angle formed on the posttreatment casts (B) minus the angle formed on the pretreatment casts (A) was then a measurement of the amount of molar rotation (Fig 6). A positive change indicated mesiobuccal rotation and a negative change indicated mesiolingual rotation.

Maxillary molar tipping. Polyvinylsiloxane impression putty caps were placed on the maxillary first molars of the pretreatment dental casts to evaluate the amount of molar tipping. While the putty was still soft, orthodontic wire (0.040 in) was inserted into the putty of each first molar over the central fossa and perpendicular to the base of the dental cast (Fig 7). A photograph was taken from the heel of the cast parallel to the median palatal raphe with a 200-mm lens at a distance of 175 cm (wires to film) to minimize distortion of the wires. The putty caps with wires were then transferred to the posttreatment casts and the photograph was repeated. Tracings of the pretreatment and posttreatment wires were then made. The left-side wires of the pretreatment and posttreatment tracings were superimposed on each other, and the angle formed by the wires on the right side was the total amount of molar tipping. Molar tipping data used for statistical analysis and comparison were evaluated by using this method.

Palatal depth. Palatal depth changes were measured by using a square sheet of hard clear acrylic (2 mm) that extended beyond the teeth. A rectangular orthodontic wire (0.040 in) was inserted perpendicularly into the acrylic so that it could slide up and down. A horizontal line was drawn across the acrylic so it intercepted the sliding wire. This horizontal line was positioned across the mesiolingual cusps of the first molars for reproducible alignment. The acrylic was placed on the occlusal surface of the casts so that it contacted the most
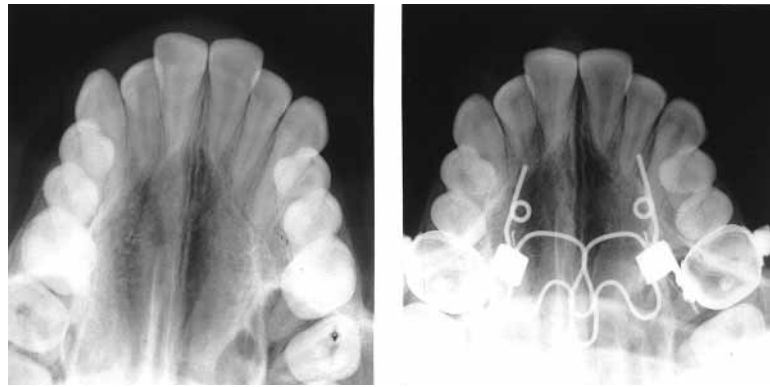
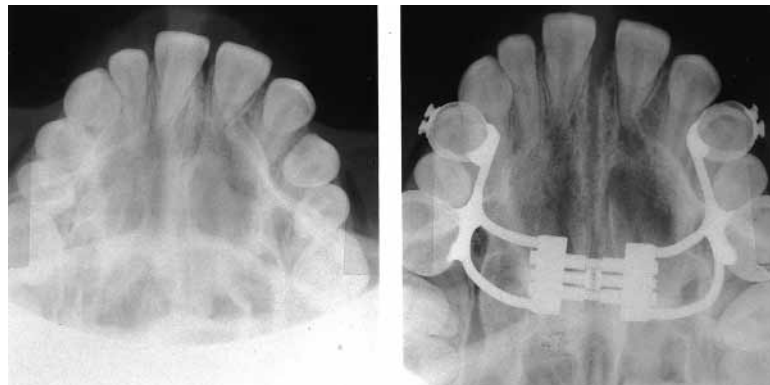**Fig 8.** Pretreatment and posttreatment occlusal radiograph of a patient treated with NiTi expander.

Fig 9. Pretreatment and posttreatment occlusal radiograph of a patient treated with rapid palatal expander.

prominent cusp of the first molars bilaterally and the first contact mesially. The wire was then extended until it touched the palate, and a measurement was recorded in millimeters. The pretreatment and posttreatment measurements were then used to assess palatal depth changes.

Radiographic evaluation

Maxillary occlusal radiographs were obtained before treatment and 2 weeks after active expansion. The radiography was performed with the maxillary occlusal plane parallel to the floor and the x-ray cone positioned at a 60° angle to the film and parallel to the patient's facial midline (Figs 8 and 9). Four orthodontic faculty members judged the patients' pretreatment and posttreatment radiographs for evidence of sutural opening. No attempt was made to evaluate the amount of midpalatal sutural opening. Evidence of sutural expansion was demonstrated by a radiolucent widening of the suture.[21]

Statistical methods

The arithmetic mean (mean) and standard deviation (SD) were calculated for all measurements. Paired *t* tests were used to assess significant changes before and after treatment. The level of significance was set at $P < .05$. The correlation between the measurement changes in the 2 expansion groups was tested by using a matrix of the Pearson correlation coefficient. A stepwise multiple regression analysis was used to evaluate the possible factors related to the overall amount of expansion.

For error measurements, dental casts of 10 patients before and after treatment were used. All measurements were recorded twice independently on 2 separate occasions with a 3-week interval. For all measurements, differences between the independent repeated measurements of each individual before and after treatment were calculated. A 2-tailed *t* test showed no significant difference between the repeated measurements, and the mean differences were less than 0.4 mm or 0.4° (Table I).

RESULTS

Table II shows the treatment changes in the RPE group. Significant increases were found in palatal width (1.41 mm), intermolar width (4.76 mm), alveolar tipping (5.08°), and molar tipping (6.08°). No sig-

Table I. Error study results

Measurement	Mean difference	SE	P value
PWC (mm)	0.01	0.038	0.819
IMWC (mm)	0.10	0.062	0.139
PDC (mm)	0.02	0.051	0.748
AT (°)	0.10	0.179	0.591
MR (°)	0.40	0.520	0.462
MT (°)	0.30	0.559	0.604

PWC, Palatal width change; *IMWC,* intermolar width change; *PDC,* palatal depth change; *AT,* alveolar tipping; *MR,* molar rotation; *MT,* molar tipping.

Table II. Changes in the RPE group

Measurement	Mean	SD	Minimum	Maximum
PWC (mm)	1.41**	1.09	0.00	3.56
IMWC (mm)	4.76***	1.55	2.42	7.31
Ratio PWC/ IMWC	0.28	0.17	0.00	0.53
AT (°)	5.08**	5.43	–4.00	13.00
PDC (mm)	–0.07	0.89	–1.37	1.39
MR (°)	1.58	2.74	–2.00	6.00
MT (°)	6.08**	6.25	–2.00	15.00

 $*$ $P < .05$; $**$ $P < .01$; $***$ $P < .001$.
PWC, Palatal width change; *IMWC,* intermolar width change; *PDC,* palatal depth change; *AT,* alveolar tipping; *MR,* molar rotation; *MT,* molar tipping.

Table III. Changes in the NiTi group

Measurement	Mean	SD	Minimum	Maximum
PWC (mm)	0.99***	0.45	0.33	2.03
IMWC (mm)	6.26***	1.65	3.40	8.62
RATIO PWC/ IMWC	0.16	0.08	0.07	0.33
AT (°)	6.61***	3.73	1.00	12.00
PDC (mm)	–0.04	0.70	–1.44	0.98
MR (°)	26.61***	16.29	6.00	72.00
MT (°)	11.69**	10.47	–3.00	28.00

$*$ $P < .05$; $**$ $P < .01$; $***$ $P < .001$.
PWC, Palatal width change; *IMWC,* intermolar width change; *PDC,* palatal depth change; *AT,* alveolar tipping; *MR,* molar rotation; *MT,* molar tipping.

Table IV. Comparison of changes between the NiTi group and the RPE group

Measurement	NiTi group		RPE group	
	Mean	SD	Mean	SD
PWC (mm)	0.99	0.45	1.41	1.09
IMWC (mm)	6.26	1.65	4.76	1.55
Ratio PWC/ IMWC	0.16	0.08	0.28	0.17
AT (°)	6.61	3.73	5.08	5.43
PDC (mm)	–0.04	0.70	–0.07	0.89
MR (°)	26.61	16.29	1.58	2.74
MT (°)	11.69	10.47	6.08	6.25

PWC, Palatal width change; *IMWC,* intermolar width change; *PDC,* palatal depth change; *AT,* alveolar tipping; *MR,* molar rotation; *MT,* molar tipping.

nificant changes were found in palatal depth (–0.07 mm) and molar rotation (1.58°). The ratio of palatal width to intermolar width was found to be 0.28. Table III shows the treatment changes in the NiTi expansion group. Significant increases were found in palatal width (0.99 mm), intermolar width (6.26 mm), alveolar tipping (6.61°), molar rotation (26.61°), and molar tipping (11.69°). No significant changes were found in palatal depth (–0.04 mm). The ratio of palatal width to intermolar width was found to be 0.16.

Table IV compares the changes between the RPE and the NiTi expansion groups. Statistical comparison was not performed for these data because of the differences in the amount of expansion in the 2 groups. Both the NiTi expansion and the RPE groups produced significant increases in maxillary intermolar width, 6.26 mm and 4.76 mm, respectively. Both the NiTi expansion and the RPE groups produced significant increases in palatal width, 0.99 mm and 1.41 mm, respectively. The ratio of skeletal to total expansion was found to be greater in the RPE group (0.28) than in the NiTi expansion group (0.16). Both the NiTi expansion and the RPE groups produced significant increases in the amount of alveolar tipping (6.61° and 5.08°, respectively) and molar tipping (11.69° and 6.08°, respec-

tively), with the NiTi group producing nearly twice as much tipping of the molars than the RPE group. A difference between the groups was found in the ability to rotate molars during expansion. The change in molar rotation in the NiTi and the RPE groups was 26.61° and 1.58°, respectively. Both the NiTi and the RPE groups demonstrated no significant changes in palatal depth (–0.04 mm and –0.07 mm, respectively).

Table V shows the matrix of Pearson correlation coefficients (*r*) for changes in the RPE group. Four of the 28 correlations were found to be statistically significant ($P < .05$). Both the palatal width change and the alveolar tipping demonstrated a significant positive correlation with intermolar width change of 0.62 and 0.67, respectively, whereas palatal width change and molar rotation also showed a statistically significant positive correlation ($r = 0.61$). A significant negative correlation was found between tipping of the alveolus and palatal depth change ($r = –0.58$). No significant correlation was found between age or treatment time and any of the variables. Table VI shows the results of the stepwise

Table V. Matrix of Pearson correlation coefficient for changes in the RPE group

	PWC	*IMWCC*	*PDC*	*AT*	*MR*	*MT*
PWC	1.00					
IMWC	0.62*	1.00				
PDC	0.14	−0.23	1.00			
AT	0.22	0.67*	−0.58*	1.00		
MR	0.61*	0.14	0.17	−0.26	1.00	
MT	0.19	0.42	−0.35	0.50	−0.13	1.00

* $P < .05$.
PWC, Palatal width change; *IMWC,* intermolar width change; *PDC,* palatal depth change; *AT,* alveolar tipping; *MR,* molar rotation; *MT,* molar tipping.

Table VI. Stepwise multiple regression analysis for the RPE Group

Step	*Predictor*	P *Value*	R^2
1	AT	.0173	0.4476
2	PWC	.0296	0.6827
3	MT	.0344	0.8247

PWC, Palatal width change; *AT,* alveolar tipping; *MT,* molar tipping.

Table VII. Matrix of Pearson correlation coefficient for changes in the NiTi group

	PWC	*IMWC*	*PDC*	*AT*	*MR*	*MT*	*AGE*
PWC	1.00						
IMWC	0.4	1.00					
PDC	−0.58*	−0.11	1.00				
AT	0.11	0.10	−0.42	1.00			
MR	−0.31	−0.01	−0.09	0.25	1.00		
MT	−0.08	0.26	0.28	−0.28	−0.22	1.00	
Age	−0.30	−0.01	0.06	−0.07	0.29	0.23	1.00
Treatment time	−0.29	0.08	−0.01	0.18	0.51	−0.42	0.03

* $P < .05$.
PWC, Palatal width change; *IMWC,* intermolar width change; *PDC,* palatal depth change; *AT,* alveolar tipping; *MR,* molar rotation; *MT,* molar tipping.

multiple regression analysis for the RPE group. Alveolar tipping was selected as the best predictor of intermolar width change ($R^2 = 0.4476$) followed by palatal width change, and molar tipping. All 3 predictors were found to be statistically significant contributors to the regression model. These 3 factors together explained 82% of the variability in the total amount of expansion (intermolar width change) in the RPE group.

Table VII shows the matrix of Pearson correlation coefficients for changes in the NiTi expansion group. Only 1 of the 28 correlations was found to be significant, with palatal depth change and palatal width change having a significant negative correlation ($r = -0.58$). Palatal width change, alveolar tipping, and molar tipping all demonstrated no significant correlation with intermolar width change. No significant correlation was found between age or treatment time and any of the variables in the NiTi group. Table VIII shows the results of the stepwise multiple regression analysis for the NiTi expansion group. The only predictor that met the 0.250 significance level for inclusion in the regression model was palatal width change, which was not a significant contributor to the model ($P = .1771$). Palatal width change explained only 16% of variability in the total amount of expansion in the NiTi group. The other predictors, alveolar tipping and molar tipping, were not significant factors in explaining the total amount of expansion in the NiTi group.

Table IX shows the results of the analysis of occlusal radiographs. In the RPE group, 9 of the 12

patients had occlusal radiographs available for evaluation. In all 9, opening of the midpalatal suture was demonstrated, as indicated by a yes response 100% of the time (36 of 36 responses). In the NiTi group, 12 of the 13 patients had occlusal radiographs available for evaluation. In this group, opening of the midpalatal suture was demonstrated in 85.42% (41 of 48) of the responses, whereas 14.58% (7 of 48) of the responses showed no evidence of sutural opening. Individual evaluator variation was observed in the NiTi expansion group, with evaluators 1 and 2 reporting sutural opening in 75% (9 of 12) of the responses, evaluator 3 reporting opening in 100% (12 of 12) of the responses, and evaluator 4 reporting opening of the midpalatal suture in 92% (11 of 12) of the responses. χ^2 analysis of all responses showed a statistically significant difference ($P = .017$) in radiographic evidence of midpalatal sutural opening between the 2 groups.

DISCUSSION

Because of incomplete information on appliance activation in the NiTi and RPE groups, a statistical comparison between the groups was judged impractical. In the RPE group, the amount of appliance activation varied from patient to patient, depending on the transverse discrepancies and the operators. In the NiTi group, the amount of activation was performed according to the manufacturer's direction. However, the NiTi expander is available in only 8 sizes. For in-between sizes, operators may have chosen the next available size, which can be smaller or larger than the recommended 3 to 4 mm.

Another limitation of this study is the sample size and the inability to match the age and the gender of the 2 samples. The 2-year mean age difference between the groups could make a difference in the relative effec-

Table VIII. Stepwise multiple regression analysis for the NiTi group

Step	Predictor	P value	R^2
1	PWC	.1771	0.1590

PWC, Palatal width change.

Table IX. Results of occlusal radiographic analysis survey

	Rapid palatal expander		Nickel titanium expander	
Evaluator	Yes	No	Yes	No
1	9	0	9	3
2	9	0	9	3
3	9	0	12	0
4	9	0	11	1
Total	36	0	41	7

tiveness of expansion therapy. In addition, bonded and banded rapid palatal expansion appliances were included in the sample. The acrylic coverage of the bonded appliance may alter the occlusal forces and attachment mechanism.

Intermolar width change is a reflection of the total amount of dental and dentoalveolar expansion produced by the appliances. It was found to be significantly increased in both groups. Posterior crossbites were corrected in all patients following expansion. Similar results were reported by other studies that used slow and rapid expansion appliances.[22-26]

Palatal width change, which approximates the amount of midpalatal sutural separation, increased significantly in both the RPE (1.41-mm) and NiTi (0.99-mm) groups. The percentage of palatal width to intermolar width change was calculated to be greater in the RPE group (28%) than in the NiTi group (16%). This is in agreement with studies that reported higher sutural separation (40%-58%) with RPE appliances[6,20,23,27] and lower sutural expansion (16%-40%) with slow expansion appliances.[6,7,25,26,29] RPE appliances generate heavy forces, as much as 2 to 5 kg per activation.[11,16] NiTi expansion appliances generate only 400 g of force, which may be insufficient to separate a progressively maturing suture. However, animal studies with slow-expansion appliances have demonstrated orthopedic effects comparable to those of RPE appliances.[7,30]

Both the RPE group and the NiTi groups demonstrated significant buccal tipping of the alveolar process, 5.08° and 6.61°, respectively. The changes observed agree with the literature that has reported on buccal tipping of the alveolar process during expansion that results from an initial lateral bending of the alveolus followed by a triangular separation of the maxillary halves with the apex located near the frontomaxillary suture and the base located near the alveolar region.[9,10,15,16,23]

Because RPE appliances are rigid and are fabricated from pretreatment dental casts, it was expected that during expansion there would be little, if any, rotation of the molars. This was confirmed by the small mesiobuccal rotation of the molars in the RPE group (1.58°). On the other hand, NiTi expansion appliances

are flexible and are effective in correcting molars that are mesiolingually rotated. The average mesiobuccal rotation of the molars was 26.61° in the NiTi group.

Both expansion groups showed significant increases in buccal molar tipping. The NiTi expansion group produced almost twice as much molar tipping as did the RPE group. Hicks[8] and Cotton[7] reported 2° to 24° of buccal molar tipping with the use of slow expansion appliances. Herold[31] found that minimal buccal tipping of the molars occurred with RPE and that more buccal tipping was observed with slow-expansion.

Palatal depth changes resulting from expansion have been reported to occur because of a lowering of the palatal shelves of the maxilla[10] or from changes in dentoalveolar height.[6,32] Haas[10] reported a decrease in palatal depth due to a lowering of the palatal shelves after expansion. Ladner and Muhl[6] demonstrated an increase in palatal depth in both rapid and slow palatal expansion, which they attributed to eruption of the dentition. Other studies have shown no significant changes in palatal depth after expansion.[24] In the present study, no significant changes in palatal depth were found. It is possible that an increase in dentoalveolar height and a lowering of the palatal shelves offset each other and result in no significant changes in palatal depth.

For the RPE group, alveolar tipping, palatal width change, and molar tipping were significant contributors to the multiple regression model, explaining 82% of the variability in the overall amount of expansion in the RPE group. The results suggest that as the total amount of expansion increases, so does midpalatal suture separation and buccal tipping of the alveolus. On the other hand, no significant predictor for intermolar width was found with the NiTi group. The only significant correlation found was between palatal width and palatal depth change. This was a negative correlation, indicating that as the midpalatal suture separates or increases during expansion, palatal depth decreases. Overall, these data suggest that there are no consistent factors responsible for the total amount of expansion in the NiTi expansion group.

Four examiners evaluated midpalatal suture separation on radiographs and found opening of the midpalatal suture 100% of the time in the RPE group and 85.4% of the time in the NiTi group. Individual evaluator variation was observed in the NiTi group, with evaluators 1 and 2 reporting radiographic sutural opening in 9 of 12 patients, evaluator 3 reporting sutural opening in all 12 patients, and evaluator 4 reporting opening in 11 of 12 patients. These results suggest that NiTi expansion produces a less obvious radiographic separation of the midpalatal suture when compared with RPE. One possible explanation is that NiTi expansion appliances produce slow continuous forces and that obtaining a radiograph after only 2 weeks may not allow enough time for the appliances to fully demonstrate their capabilities. In addition, physiologic sutural adjustment may occur, leading to bony deposition as expansion occurs.[12,30] Other radiographic studies with slow expansion appliances reported similar findings, with evidence of midpalatal suture separation ranging from 50% to 80% of patients.[21,25]

CONCLUSIONS

1. Two types of maxillary expansion appliances were compared. Both the RPE and the NiTi expanders are capable of expanding the maxillary dentition and alveolar process and are equally capable of correcting posterior crossbites.
2. Stepwise multiple regression analysis showed that alveolar tipping, palatal width change, and molar tipping are the best predictors for intermolar width change in the RPE group.
3. Radiographic evidence of midpalatal suture separation was found to be less obvious in the NiTi than in the RPE group.
4. No correlation was found between age and the amount of dentoalveolar expansion in either group.
5. The RPE appliance widened the palate more reliably, whereas the NiTi appliance tipped the molars buccally to a greater extent and caused more distal molar rotation.

The clinician's choice of expander will depend on his or her initial diagnosis and treatment goals. The 2 types of expanders evaluated in this study are designed very differently and seem to produce changes in the teeth and the palate that might be expected based on the ultimate expression of force on the teeth to which they are attached.

REFERENCES

1. Kutin G, Hawes RR. Posterior crossbites in the deciduous and mixed dentitions. Am J Orthod 1969;56:491-504.
2. Infante PF. Malocclusion in the deciduous dentition in white, black and Apache Indian children. Angle Orthod 1975;45:213-8.
3. Kurol J, Berglund L. Longitudinal study and cost-benefit analysis of the effect of early treatment of posterior crossbites in the primary dentition. Eur J Orthod 1992;14:173-9.
4. Kisling E. Occlusal interferences in the primary dentition. ASDC J Dent Child 1981;48:181-91.
5. Kerosuo H. Occlusion in the primary and early mixed dentitions in a group of Tanzanian and Finnish children. ASDC J Dent Child 1990;57:293-8.
6. Ladner PT, Muhl ZF. Changes concurrent with orthodontic treatment when maxillary expansion is a primary goal. Am J Orthod Dentofacial Orthop 1995;108:184-93.
7. Cotton LA. Slow maxillary expansion: skeletal versus dental response to low magnitude force in Macaca mulatta. Am J Orthod 1978;73:1-22.
8. Hicks EP. Slow maxillary expansion: A clinical study of the skeletal versus dental response to low-magnitude force. Am J Orthod 1978;73:121-41.
9. Krebs AA. Expansion of the midpalatal suture studied by means of metallic implants. Trans Eur Orthod Soc 1958;34:163-71.
10. Haas AJ. Rapid expansion of the maxillary dental arch and nasal cavity by opening the mid-palatal suture. Angle Orthod 1961;31:73-90.
11. Issacson RJ, Ingram AH. Forces produced by rapid maxillary expansion, II: forces present during treatment. Angle Orthod 1964;34:261-70.
12. Storey E. Tissue response to the movement of bones. Am J Orthod 1973;64:229-47.
13. Zimring JF, Issacson RJ. Forces produced by rapid maxillary expansion, III: forces present during retention. 1965;35:178-86.
14. Bishara SE, Staley RN. Maxillary expansion: clinical implications. Am J Orthod Dentofacial Orthop 1987;91:3-14.
15. Haas AJ. Palatal expansion: just the beginning of dentofacial orthopedics. Am J Orthod 1970;57:219-55.
16. Wertz RA. Skeletal and dental changes accompanying rapid midpalatal suture opening. Am J Orthod 1970;58:41-66.
17. Melsen B. A histological study of the influence of sutural morphology and skeletal maturation on rapid palatal expansion in children. Trans Eur Orthod Soc 1972:499-507.
18. Arndt WV. Nickel titanium palatal expander. J Clin Orthod 1993;27:129-137.
19. Korkhaus GA. A new orthodontic symmetrograph. Int J Orthod 1930;16:665-8.
20. Thorne NAH. Experiences on widening the median maxillary suture. Trans Eur Ortho Soc 1956;31:279-90.
21. Harberson VA, Myers DR. Midpalatal suture opening during functional posterior cross-bite correction. Am J Orthod 1978;74:310-3.
22. Bell RA, LaCompte EJ. The effects of maxillary expansion using a quad-helix appliance during the deciduous and mixed dentitions. Am J Orthod 1981;79:156-61.
23. Silva Filho OG, Prado Montes LA. Rapid maxillary expansion in the deciduous and mixed dentition evaluated through posteroanterior cephalometric analysis. Am J Orthod Dentofacial Orthop 1995;107:268-75.
24. Davis WM, Kronman JH. Anatomical changes induced by splitting of the midpalatal suture. Angle Orthod 1969;39:126-32.
25. Sandikcioglu M, Hazar S. Skeletal and dental changes after maxillary expansion in the mixed dentition. Am J Orthod Dentofacial Orthop 1997;111:321-7.
26. Frank SW, Engel AB. The effects of maxillary quad-helix appliance expansion on cephalometric measurements in growing orthodontic patients. Am J Orthod 1982;81:378-89.

27. Timms RJ. A study of basal movement with rapid maxillary expansion. Am J Orthod 1980;77:500-7.
28. Angell EH. Treatment of irregularity of the permanent or adult teeth. Dental Cosmos 1860;1:540-44.
29. Lebret ML. Changes in the palatal vault resulting from expansion. Angle Orthod 1965;35:97-105.
30. Ohshima O. Effect of lateral expansion force on the maxillary structure in Cynomolgus monkey. Osaka Dental Univ 1972;6:11-50.
31. Herold JS. Maxillary expansion: a retrospective study of three methods of expansion and their long term sequelae. Br J Orthod 1989;16:195-200.
32. Bjork A, Skieller V. Growth in width of the maxilla studied by the implant method. Scand J Plast Reconstr Surg 1974;8:26-33.

COMMENTARY

This article addresses 2 of the key decisions that orthodontic providers are required to make: first, creating a treatment plan that fits the diagnosis and, second, choosing an appliance that reliably provides expected outcomes. When considering patients with transverse discrepancies, the orthodontist frequently relies on orthodontic study models alone to make a diagnosis and to differentiate a skeletal problem from a dental problem. In this article, the authors make the same mistake. They state, "The clinician's choice of type of expander will depend on his or her initial diagnosis and treatment goals." The authors rely on the presence of unilateral or bilateral crossbite and on measurements from study models to make their diagnosis of a transverse discrepancy. Without the use of a posteroanterior cephalogram to differentiate a transverse problem that is merely dental from one that has a maxillary/mandibular basal bone discrepancy, the diagnostic assessment becomes a guess.

Therefore, future research that attempts to compare the skeletal impact of expanders should be prospective and should include posteroanterior films before and after appliance therapy. Can you imagine a research project comparing protraction appliances for Class III patients without the use of pretreatment and posttreatment lateral cephalograms to measure the impact on basal bone? In research papers discussing transverse discrepancies and asymmetries, it is incumbent on researchers to incorporate the posteroanterior cephalogram as a primary diagnostic tool, similar to the use of the lateral cephalogram when one is discussing anteroposterior and vertical problems.

The authors were able to find similar numbers of patients with transverse discrepancies (as determined by a clinical examination and models) to which to apply the 2 different types of expanders; however, they were unable to keep the mean age of each sample within an acceptable range. For the RPE group the mean age was 11.1, and for the NiTi expander group the mean age was 9.4. The authors did acknowledge that the approximate 2-year difference in mean age could make a difference in the relative effectiveness of expansion therapy. In addition, within the RPE group different methods of expansion were used; some patients had occlusal coverage bonded expanders and some had banded Hyrax-type expanders. The occlusal coverage expanders have the advantage of reducing the functional shift component of the malocclusion early in the expansion process and may accelerate the response of the maxilla to the expansion force.

The authors did impressive work in model measurement and assessment of molar tipping and molar rotation. Their findings in this area will help clinical orthodontists understand the mechanisms that each expander uses to accomplish specific clinical objectives. In addition, their findings support what most orthodontists intuitively understand—rigid expanders have more capacity to open the midpalatal suture and tend to tip molars less than the more flexible NiTi expander does.

The authors state, "These results suggest that both the nickel titanium and the rapid palatal expansion appliances are capable of expanding the maxillary dentition and alveolar process and are equally capable of correcting posterior crossbites." As the design of expanders continues to change, orthodontic clinicians will continue to strive to select reliable, simple-to-use expanders to correct transverse problems. This article contributes to our understanding of the clinical differences between 2 types of expansion appliances. However, this research leaves room for further studies that will actually tell which of the many expanders on the market (Haas-type [jackscrew with acrylic against palate], Hyrax-type [jackscrew without acrylic], Ormco mini-expander [Ormco, Orange, Calif], SUPERscrew [Orthodesign, Lake Forest, Ill] etc.) will actually be the most predictable when correcting true skeletal transverse discrepancies. There are several other questions that can be investigated: Is one of these expansion mechanisms more reliable in producing long-term stability than the others? What is the role of a significant mouth breathing habit in causing instability? Is there an age limitation to orthopedic expansion? Can the age limitation be determined by chronological age (for both males and females) or wrist films? Or is patient response the best criteria?

I commend the authors on their work, which contributes to our clinical understanding of the relative effectiveness of 2 types of maxillary expanders.

David R. Musich, DDS
Clinical Professor of Orthodontics,
University of Pennsylvania School of Medicine
and University of Illinois at Chicago,
School of Dentistry
Schaumburg, Ill