Arch perimeter changes on rapid palatal expansion

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Relationships between changes in arch perimeter and arch width resulting from rapid palatal expansion with the Hyrax appliance were analyzed with the use of dental study casts of 21 adolescent patients. Photographs and measurements from the dental casts obtained before treatment and approximately 3 months after stabilization were used. Regression analysis indicated that changes in premolar width were highly predictive of changes in arch perimeter (r^2 = 0.69) at approximately 0.7 times the premolar expansion. Without any orthodontic appliances attached to the mandibular teeth in 16 of the 21 patients, buccal uprighting of the posterior teeth was observed because of the redirection of occlusal forces. In addition, posterior movement of the maxillary incisors and buccal tipping of the anchor teeth were quantified. The prediction of arch perimeter change for a given amount of expansion is helpful in the treatment planning of rapid palatal expansion cases and may facilitate nonextraction orthodontic treatment. (Am J Orthod Dentofac Orthop 1990;97:194-9.)

The current trends in the practice of orthodontics have shifted toward the principles of dentofacial orthopedics and nonextraction treatment modalities.[1-4] The use of headgear and functional appliances has demonstrated orthopedic effects mostly in the sagittal and vertical dimensions. One of the most impressive orthopedic procedures is the transverse separation of the maxillae through rapid palatal expansion. This procedure has lately been the subject of renewed interest in orthodontic treatment mechanics because of its potential for increasing arch perimeter to alleviate crowding in the maxillary arch without adversely affecting facial profile. In addition, it assists in the correction of disharmonies in the transverse plane between the maxillary and the mandibular arches.[1,5-9]

Rapid palatal expansion (RPE) treatment has been advocated by Haas[8] as a preferred method for the correction of maxillary arch constriction. Since the appliance produces orthopedic movements, the expansion was deemed to be skeletal and therefore more stable. In the frontal plane the RPE is said to separate unequally the two halves of the maxilla superoinferiorly, the fulcrum of rotation being somewhere close to the frontomaxillary suture.[7,10,11]

Krebs[10] studied the effects of RPE with the use of metallic implants in the infrazygomatic ridge and in the alveolar process lingual to the upper canines. He found the gain in the width of the dental arch was about twice that of the basal maxillary segments.

Haas[8] found in patients treated with RPE the maxilla is displaced downward and forward. Similarly, Wertz[11] noted the maxilla moved downward 1 to 2 mm on a regular basis. The forward movement was not consistent, however, and was rarely more than 1.5 mm. He also commented on the consistent uprighting or posterior movement of the maxillary incisors.

A review of the literature supports the contention that the RPE device, in addition to its other effects, can provide additional space in the arch to relieve crowding. The appliance, if used within certain age limits where indicated, is a useful adjunct to orthodontic treatment. The separation of the maxillae and the effect on the arch perimeter has not yet been quantified. The purpose of this investigation was to estimate increase in dental arch perimeter following RPE of the maxillae. In addition, other changes in the maxillary and mandibular dental arches associated with this treatment procedure were evaluated.

MATERIAL AND METHODS

Sample

The sample included 21 consecutively treated orthodontic patients who required the use of a RPE device on the basis of their individual treatment plans. All the patients were in the late transitional or early permanent dentition stage. None of the patients had craniofacial anomalies such as cleft lip, cleft palate, or both. No other orthodontic appliances were used in the maxillary arch during the study. In the mandibular arch, 5 of the

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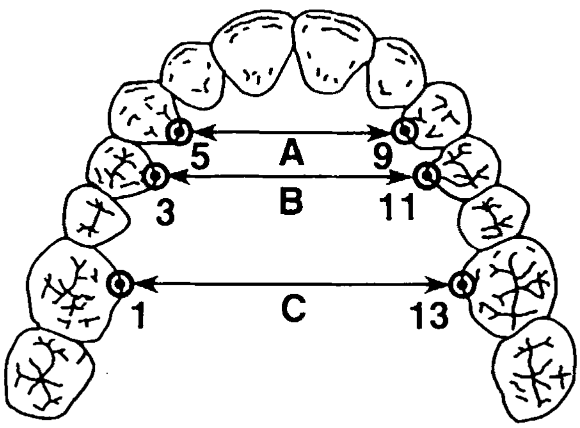

Fig. 1A. Arch width measurement. *A* is the intercanine width from points *5* to *9*, *B* is the interpremolar width from points *3* to *11*, *C* is the intermolar width from points *1* to *13*. All points are the most lingual points at the gingival margin.

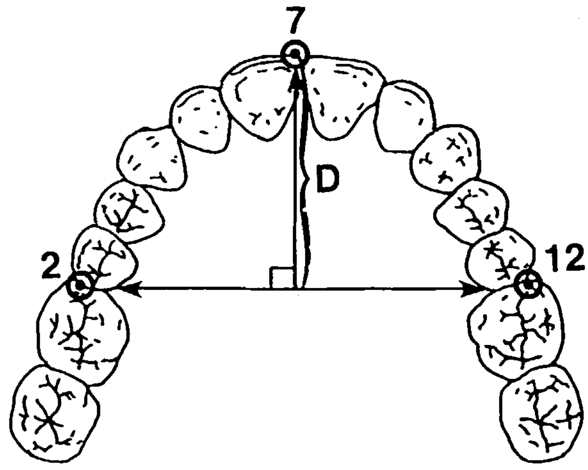

Fig. 1B. Arch length measurement. *D* is arch length, which is the perpendicular distance from point *7* to a line constructed between points *2* and *12*. Points *2* and *12* are contact points, mesial of the permanent first molars. Point *7* is the most facial point on the most prominent central incisor.

21 patients had full-banded appliances; therefore only the remaining 16 were used in the appraisal of mandibular arch changes accompanying the use of RPE.

The patients ranged in age from 11 years 6 months to 17 years. There were 14 girls and 7 boys. Within the sample, eight patients had no posterior crossbite. Of the 13 patients who exhibited posterior crossbite, 9 had unilateral crossbite with a functional shift and 4 had bilateral crossbite without a functional shift.

Clinical procedures

Each patient was treated with a Hyrax (OSI, Wilmington, Del.) expansion appliance. The arms of the expansion screw were soldered to the bands that were fitted on the first premolar and first permanent molar. The Hyrax device was centered in the maxillary arch and was sagittally placed parallel to the mesial half of the permanent first molar and second premolar region. The expansion screw was vertically placed at the level of the cervical margins of the premolars and first molars.

The appliances were activated twice a day with one-quarter turn in the morning and in the evening until the desired expansion was attained. The amount of expansion anticipated was 0.5 mm per day. The average stabilization period was 14.5 weeks with a range of 10 to 21 weeks. Maxillary and mandibular study casts were obtained before treatment and again at the end of the stabilization period when the appliance was removed.

Cast analysis

The casts were trimmed with the base parallel to the occlusal plane. Points from which measurements were to be taken were marked with a fine-lead pencil to facilitate identification. Once marked, the casts were then photographed from an occlusal view with a 35 mm camera. A camera stand was employed to support the casts and to hold the camera at a fixed focal length of 30 cm from the occlusal plane of the casts. To provide a scale of distance, a millimeter rule was fixed at the heel of each cast at the level of the occlusal plane. Several 5 × 7 inch photographs were obtained of each cast.

Measurements

The points marked and digitized on the maxillary dental casts were the most lingual points at the gingival margin of the first molars, the first premolars, and the canines, as shown in Fig. 1A. The contact points on the mesial surface of the first molars, the mesial surface of the first premolar, and the distal surface of the central incisors, as well as the most facial point on the most prominent central incisor, were also marked and digitized (Figs. 1B and 1C). All points, which were digitized, and measurements made were identical for both the maxillary and the mandibular arches with the exception of mandibular molar arch width. The mandibular molar arch width was measured at the central groove in the distal central fossa because the gingival margin of the mandibular first molars could not be visualized from an occlusal view. Measurement of width at the gingival margin of the teeth minimized the error that could have resulted from buccal crown tipping during the expansion procedures.

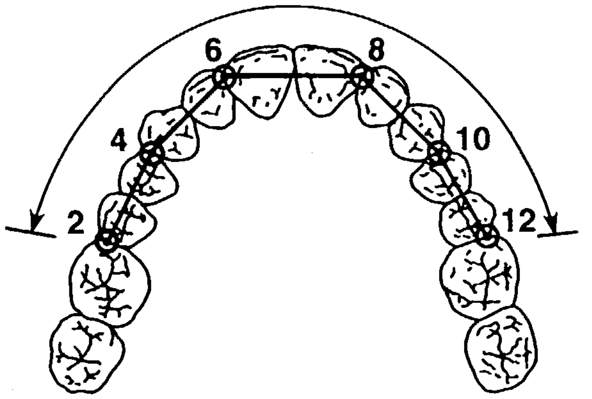

Fig. 1C. Arch perimeter measurement. Arch perimeter is the sum of the lengths of the segments connecting points *2, 4, 6, 8, 10,* and *12.* Points *2* and *12* are contact points, mesial to the permanent first molars. Points *4* and *10* are contact points, mesial to the first premolars. Points *6* and *8* are contact points, distal to the central incisors.

Arch perimeter measurement points (Fig. 1C) were chosen on the mesial aspect of the first premolars and the distal aspect of the central incisors because the maxillary canines and lateral incisors were often blocked out labially or lingually. Arch perimeter is a curve described on the dental arch form. The method of using segments in this study would underestimate the true arch perimeter. However, within the clinical limitations, the estimated measurements were considered reasonable in evaluating the changes in arch perimeter.

To measure the changes in the angulation of anchor teeth, each maxillary dental cast was sectioned at the first premolar and at the first molar. Before sectioning, the first premolars were marked with a fine-lead pencil at the mesiodistal midpoint of the teeth. Similarly, the first molars were marked at a point of intersection of the buccal groove with the buccal and occlusal surfaces of the teeth. Sections were obtained by trimming the casts on a model trimmer, first with a rough wheel and then with a fine wheel, until the marked points were reached. After drying, the casts were traced. A tangent was carefully constructed to the occlusal outline of each tooth and the resulting angles were measured. Fig. 2 illustrates the typical tracing and measurement of preexpansion and postexpansion dental casts.

Experimental error and statistical analysis

Evaluating the error in landmark identification, photographic magnification, and digitization of the measurements, all of the preexpansion maxillary casts were photographed and digitized at one time. The same casts were photographed and digitized again after 1 week.

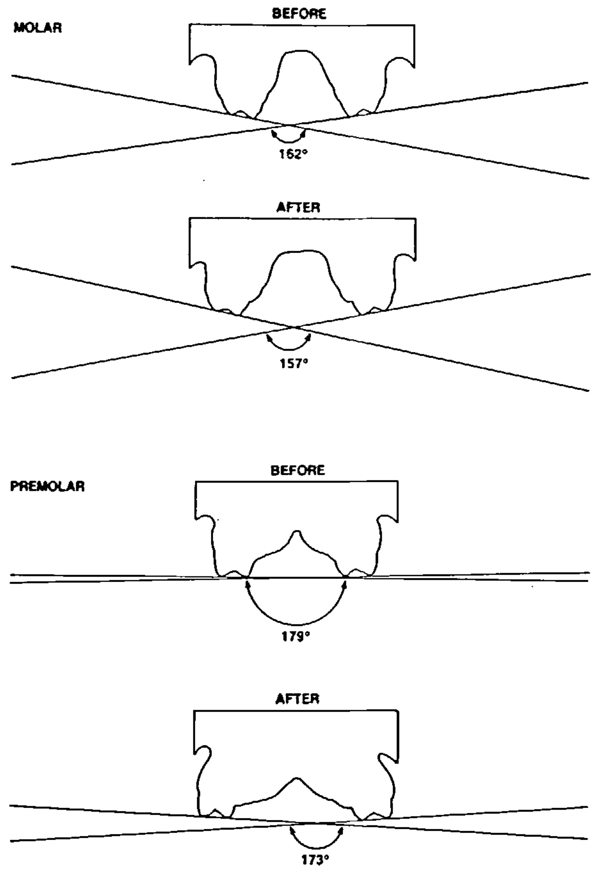

Fig. 2. Typical tracing and measurement of sectioned duplicate casts. Tangents were constructed through the cusp tips to produce angular measurements for sections of molar and premolar anchor teeth before and after rapid palatal expansion.

Measurement error was determined as the standard deviation of the differences between the first and second measurements. The measurement error was ±0.19 mm for intercanine width, ±0.15 mm for interpremolar width, ±0.16 mm for intermolar width, ±0.26 mm for arch length, and ±0.49 mm for arch perimeter. Possible sources of error for angulation measurements included inconsistencies in the location of landmarks, the trimming of dental casts, and the tracing and construction of tangent lines. The error was assessed by repeating the measurement procedures 2 weeks later on duplicated casts. Again the measurement of error was determined as the standard deviation of the differences between the first and second measurements. The error was found to be as follows:

Molar angulation	Before treatment ± 2.6°
	After treatment ± 2.9°
Premolar angulation	Before treatment ± 2.6°
	After treatment ± 2.7°

Table I. Mean, standard deviation, and range of postexpansion changes in maxillary measurements

Measurement	*Mean (mm)*	*SD*	*Min (mm)*	*Max (mm)*
Molar width change	6.5	1.2	4.8	8.9
Premolar width change	6.1	1.3	3.8	8.7
Canine width change	2.9	1.4	0.6	6.4
Arch length change	−0.4	0.5	−1.4	1.0
Arch perimeter change	4.7	1.1	2.6	6.5

The errors for all of the measurements were found to be small and were considered not clinically significant.

For prediction of arch perimeter changes, a stepwise multiple linear regression analysis was performed to determine the best set of independent variables, which were molar, premolar, and canine width changes.

RESULTS

Means, standard deviations, and range for postexpansion changes in the maxillary measurements are given in Table I. Expansion averaged 6.5 mm at the first molars, 6.1 mm at the first premolars, and 2.9 mm at the canines. Arch length demonstrated an average decrease of 0.4 mm during the period of study. The resultant arch perimeter after correction for anteroposterior movement of the incisors showed a mean increase of 4.7 mm.

Stepwise multiple linear regression analysis of the three independent variables (i.e., molar, premolar, and canine width increase) indicated that premolar width increase was the best predictor of the increase in arch perimeter. This relationship was found to be linear and was represented by the following equation: $y = 0.68\,x + 0.56$ where y is arch perimeter change and x is molar width change. Predictability of this relationship was found to be strong ($r^2 = 0.69$, $p = 0.0001$). The r^2 values for changes in arch perimeter and molar width was 0.54 with $p = 0.0002$.

Postexpansion changes in angulation of the maxillary anchor teeth showed a mean molar change of 7.3 ± 5.8° and a mean premolar change of 5.2 ± 5.1°. The variability was found to be high in these measurements.

Regression analysis was performed to investigate any possible effect of existing crossbite, initial width of the arch, amount of expansion obtained, and age on the postexpansion buccal tipping of the maxillary anchor teeth. The statistical values of r^2 obtained ranged from 0.01 to 0.07 for the different variables tested. They indicated no statistically significant relationships.

Descriptive statistics for mandibular digitized measurements indicated the overall changes were small (less than 0.8 mm) and the variable with standard deviation values greater than the mean changes found.

All patients were divided into subgroups according to presence of bilateral crossbites, unilateral crossbite, or no crossbite to compare the changes for the mean mandibular molar and for premolar width. Changes in mean width increased, moving from patients with bilateral crossbite (0.2 mm molar, −0.4 mm premolar), to patients with unilateral crossbite (0.7 mm molar, 0.6 mm premolar), to those patients with no crossbite (1.4 mm molar, 1.0 mm premolar).

DISCUSSION

RPE is an accepted procedure to relieve deficiencies in arch perimeter. During the past 20 years, with the increasing emphasis on nonextraction therapy, the procedure has gained in popularity because of the relief of crowding it provides. RPE compensates for arch perimeter deficiencies through transverse expansion of the alveolar and dental arches. Recent literature[10-14] has documented the skeletal as well as the dental changes that occur with rapid expansion of the maxilla. However, the magnitude of change in arch perimeter with transverse expansion of the dental arch has not been evaluated. Determination of a simple method for projecting increases in arch perimeter would be beneficial in planning orthodontic treatment.

The principal goal of this study was to determine the relationship between transverse maxillary expansion and the resultant gain in arch perimeter. Linear regression analysis of both molar width and premolar width changes produced statistically significant linear relationships with the arch perimeter change (molar $r^2 = 0.54$, $p = 0.0002$; premolar $r^2 = 0.69$, $p = 0.0001$). Prediction equations for molar and premolar width changes yielded slopes of 0.65 and 0.68, respectively, and intercepts of 0.48 mm and 0.56 mm, respectively. From a clinical standpoint, these are very small differences and the intercept is close enough to zero that perimeter gain could be practically predicted as 0.7 times the amount of posterior expansion. These findings are different from those of Berlocher et al.,[15] who reported increases in arch perimeter to be equal to

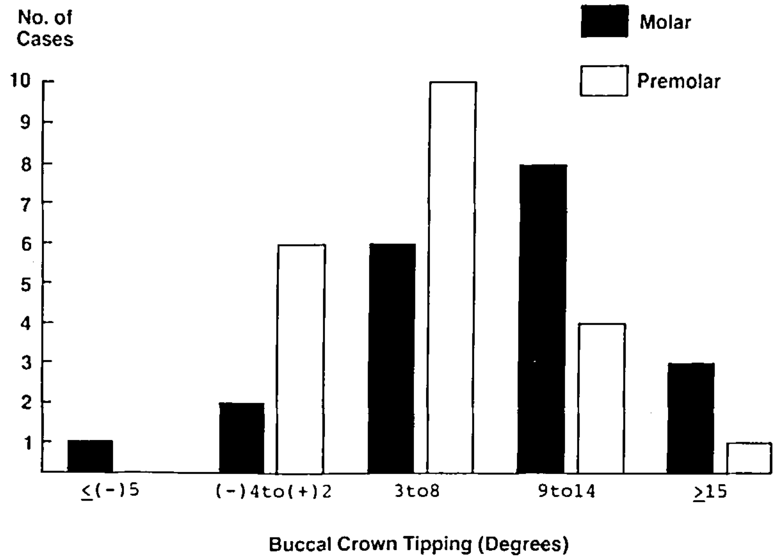

Fig. 3. Distribution of sample for degree of tipping of maxillary molar and premolar anchor teeth.

the gain in arch width. Their sample was from a younger age group (3 to 7 years), included patients with cleft palate (10 of the 29), and had a primary dentition stage of dental development. These factors, in addition to variations in method, can easily account for the differences in the findings.

The palatal movement of maxillary incisors as reflected in the reduction of arch length was noted in the study. This finding was in agreement with those of Wertz.[15] The magnitude of this movement was small and variable (0.4 mm ± 0.5). However, it was noted in 18 of a total sample of 21 patients.

Both maxillary molar and premolar teeth demonstrated buccal crown tipping with expansion. The results, however, were highly variable to the extent that some patients' teeth demonstrated little or no tipping, while others demonstrated tipping of more than 15°. Fig. 3 shows the distribution of the degree of tipping for the sample.

Regression analysis was performed to study the relationship of buccal crown tipping, if any, to age, initial palatal width, amount of expansion, and crossbite. Statistical analyses showed no significant relationships. Buccal tipping of anchor teeth is a factor to be considered as a part of the RPE procedure.

To determine whether the large variations in buccal tipping of anchor teeth were due to crossbite, the sample was divided among groups with bilateral, unilateral, and no crossbite. Because of the small sample of patients in each category, it was not possible to draw any conclusions. However, there were indications of greater crown tipping in patients with bilateral crossbite, less with unilateral crossbite, and least within the group with no crossbite.

It appears that in patients with bilateral crossbite, during RPE, there is a stage when the palatal inclines of the palatal cusps of the maxillary teeth occlude with the buccal inclines of the lingual cusps of the mandibular teeth, thus producing occlusal forces that may enhance the buccal tipping of the maxillary teeth. In patients with no crossbite, the buccal inclines of the palatal cusps of the maxillary teeth move directly in contact with the lingual inclines of the buccal cusps of the mandibular teeth, which may tend to make the maxillary teeth more upright. In the mandibular arch, these same occlusal forces may be responsible for the small buccal uprighting of the mandibular posterior teeth.

CONCLUSIONS

Rapid palatal expansion with the Hyrax appliance produces increases in maxillary arch perimeter at the rate of approximately 0.7 times the change in first premolar width. In planning treatment, it would be helpful to be able to predict this gain in arch perimeter for a given amount of transverse expansion. The ability to predict this relationship could promote an increased use of bony expansion facilitating nonextraction orthodontic treatment.

Slight palatal movement of the maxillary incisors was noted in 18 of 21 patients after stabilization of the Hyrax appliance. This movement was variable at approximately 0.5 ± 0.5 mm, with a range from −1.4 mm palatal movement to 1.0 mm labial movement.

Mild buccal crown tipping of the anchor teeth occurred with the Hyrax appliance in these adolescent patients, but the extent of tipping was variable at approximately 6 ± 6°. Regression analyses found no statistically significant relationships between tipping of the anchor teeth and age, initial palatal width, and the amount of expansion.

Slight compensatory buccal uprighting of the mandibular posterior teeth resulted from expansion of the maxillary arch and the resultant occlusal forces. During the stabilization period, greater buccal uprighting of the mandibular posterior teeth was associated more with patients who exhibited no posterior crossbite.

REFERENCES

1. Haas AJ. Just the beginning of dentofacial orthodpedics. AM J ORTHOD 1970;57:219-55.
2. Harvold EP. The activator in interceptive orthodontics. St. Louis: CV Mosby, 1974.
3. Pancherez H. Treatment of Class II malocclusions by jumping the bite with the Herbst appliance: a cephalometric investigation. AM J ORTHOD 1979;76:423-41.
4. Subtelny JD. Oral respiration: facial maldevelopment and corrective dentofacial orthopedics. Angle Orthod 1980;50:147-64.
5. Angell EH. Treatment of irregularities of the permanent or adult teeth. Dent Cosmos 1860;1:540-4.
6. Bishara SE, Staley RN. Maxillary expansion: clinical implications. AM J ORTHOD DENTOFAC ORTHOP 1987;91:3-14.
7. Haas AJ. Rapid expansion of the maxillary dental arch and nasal cavity by opening the midpalatal suture. Angle Orthod 1961; 31:73-90.
8. Haas AJ. The treatment of maxillary deficiency by opening the midpalatal suture. Angle Orthod 1965;35:200-17.
9. Haas AJ. Longterm post treatment evaluation of rapid palatal expansion. Angle Orthod 1980;50:189-217.
10. Krebs A. Rapid expansion of midpalatal suture by fixed appliance: an implant study over a 7 year period. Trans Eur Orthod Soc 1964:141-2.
11. Wertz RA. Skeletal and dental changes accompanying rapid midpalatal suture opening. AM J ORTHOD 1970;58:41-66.
12. Davis MW, Kronman JH. Anatomical changes induced by splitting of the midpalatal suture. Angle Orthod 1969;39:126-32.
13. Gardner GE, Kronman JH. Cranioskeletal displacements caused by rapid palatal expansion in the rhesus monkey. AM J ORTHOD 1971;59:146-55.
14. Timms DJ. A study of basal movement with rapid maxillary expansion. AM J ORTHOD 1980;50:500-7.
15. Berlocher WC, Mueller BH, Tinaoff N. The effect of maxillary palatal expansion on the primary dental arch circumference. Pediatr Dent 1980;2:27-30.

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