

Immediate Postexpansion Changes Following the Use of the Transpalatal Distractor

*Pascal X. Pinto, MDS, FDSRCS (Eng),**

Maurice Y. Mommaerts, LDS, MD, DMD, FEBOMS,†

Glyn Wreakes, BChD, FDS, MOrthRCS (Eng),‡

and Walter V.G.J.A. Jacobs, MD, LDS§

Purpose: This study analyzed the immediate postexpansion positional changes of the maxillary halves resulting from the use of the transpalatal distractor (Surgi-Tec NV, Bruges, Belgium).

Patients and Methods: Corticotomies were performed in the same way as surgically assisted rapid palatal expansion, all from a buccal sulcus approach. Titanium abutment plates with box extension were placed horizontally in the vertical wall of the palatal vault overlying the second premolar root through a mucoperiosteal incision and fixed with titanium screws 5 mm in length. An appropriate telescopic distraction module was fitted in the slots of the boxes. Expansion started 1 week after surgery, at a rate of 0.33 mm/d. Digital measurements on digital photographs of the models were obtained from 20 postadolescent patients before and immediately after transpalatal distraction. The distractor was placed at the level of the second premolar. Pterygomaxillary separation was not performed. Changes in the intercanine, interpremolar and intermolar width, in the dental arch perimeter, and in the premolar and molar angulations in the frontal plane were analyzed and correlated.

Results: Width expansions of 35.7%, 31.7%, and 22.7% were noted in the canine, premolar, and molar regions, respectively. There was a mean increase of the arch perimeter of 10.5%, which correlated well ($P < .001$) with the expansion at the canine and premolar level. The mean angulation changes in the frontal plane of the premolar and molar segments were minimal, $-8.3^\circ \pm 9.6^\circ$ and $0.9^\circ \pm 9.9^\circ$, respectively. The change in angulation at the molar level correlated ($P < .005$) with the amount of expansion in that region. Premolar angulation did not correlate with the expansion, and segment angulation did not correlate with age.

Conclusions: The expansion at the canine level was 1.5 times greater than at the molar level (corrected value relative to the original intermolar width). The change in arch perimeter can be predicted from the expansion at the canine and premolar level. Expansion in the frontal plane occurs with little tipping of the segments.

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*Formerly, Visiting Research Fellow, Division of Maxillo-Facial Surgery, General Hospital St John, Bruges, Belgium; Currently, Visiting Specialist Registrar Oral & Maxillofacial Surgery, Royal London and Barts NHS, Whitechapel, London, United Kingdom.

†Consultant, Division of Maxillo-Facial Surgery, General Hospital St John, Bruges, Belgium.

‡Consultant Orthodontist, Royal Surrey County Hospital, Guildford, Surrey, United Kingdom.

§Consultant Oro-Maxillo-Facial Surgeon, General Hospital St Elisabeth, Herentals, Belgium.

Address correspondence and reprints requests to Dr Mommaerts: Division of Maxillo-Facial Surgery, General Hospital St John, Ruddershove 10, B-8000 Brugge, Belgium; e-mail: maurice.mommaerts@azbrugge.be

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Transpalatal distraction is a recently published technique¹ in which distraction osteogenesis (DO) is used to treat maxillary constriction. Correction of transverse maxillary width discrepancies by opening of the midpalatal suture has been an integral part of orthodontic therapy for many years. Maxillary constriction conventionally can be corrected with slow orthodontic expansion (SOE), rapid palatal expansion (RPE), surgically assisted rapid palatal expansion (SARPE), or a 2 segmented Le Fort I-type osteotomy with expansion (LFI-E). Although SOE is used for mild lateral discrepancies, RPE appliances are used successfully in growing children to open the midpalatal suture. However, long-term stability remains problematic.^{2,3,5} Rapid palatal expansion in adults can result in alveolar bone bending, periodontal membrane compression, fenestration of the buccal bone cortex, and lateral tooth displacement, and extrusion.^{2,6,7} Surgi-

cally assisted rapid palatal expansion attempts to overcome some of these problems and is used with increasing frequency in adults, with reports of long-term stability.⁸ However, because the appliance used is toothborne, problems relating to the orthodontic expansion still occur.⁸⁻¹⁰ Surgically assisted rapid palatal expansion has a better transverse stability when compared to a LFI-E type of procedure.^{11,12} Although there have been many studies on the other modes of treatment¹³⁻¹⁸ involving the use of radiographs and dental models, there has not been any investigation of the skeletal and dental changes following the use of the transpalatal distractor (TPD; Surgi-Tec NV, Bruges, Belgium) an orthopedic maxillary distractor. This study focuses on the estimated differential increase in canine, premolar, and molar width and on changes in the arch perimeter and in molar and premolar segment angulation in the frontal plane after the expansion of the maxilla using the TPD.

Patients and Methods

The sample in this prospective study included 20 consecutively treated patients who required the use of the TPD device on the basis of individual treatment plans. The patients ranged from 14 to 30 years of age, with an average age of 21.5 years, and consisted of 11 females and 9 males. All patients were in the permanent dentition phase, and none had craniofacial congenital anomalies. No orthodontic appliances were used on the patients during the study, and all expansion movements were bilateral.

CLINICAL PROCEDURES

Under general anesthesia, each patient had osteotomies made with a round bur no. 33 at the zygomatic buttress, with a short, thick Lindemann bur at the piriform aperture, and with a 1-cm osteotome in the midpalatal sutural region. The margins of the osteotomy were gently pried apart until vertical mobility was gained. The titanium abutment plates of the TPD (Fig 1) were placed horizontally on the vertical wall of the palatal vault overlying the second premolar root through a 12-mm mucoperiosteal incision and fixed with 2 titanium screws 5 mm in length and 2.3 mm in diameter, as described by Mommaerts.¹

Usually a distraction module was fitted immediately into the slots of the abutment plates and the screw was locked passively for 1 week; however, occasionally, the module placement was delayed for a week. Expansion occurred at a rate of 0.33 mm/d, commencing 1 week after surgery. Overexpansion was not deemed to be necessary because the forces were directly applied to the skeletal base. Once the necessary expansion was achieved, the distractor was turned into a fixed retainer by inserting a blocking screw. The average retention period was 6 months. Maxillary study models were obtained before surgery and again at the time the blocking screw was inserted into the distractor. Orthodontic treatment was started 3 months from the start of expansion.

MODEL PREPARATION AND DIGITIZING PROCESS

The original models were carefully duplicated to minimize error and trimmed with the base parallel to the occlusal plane. Points from which measure-

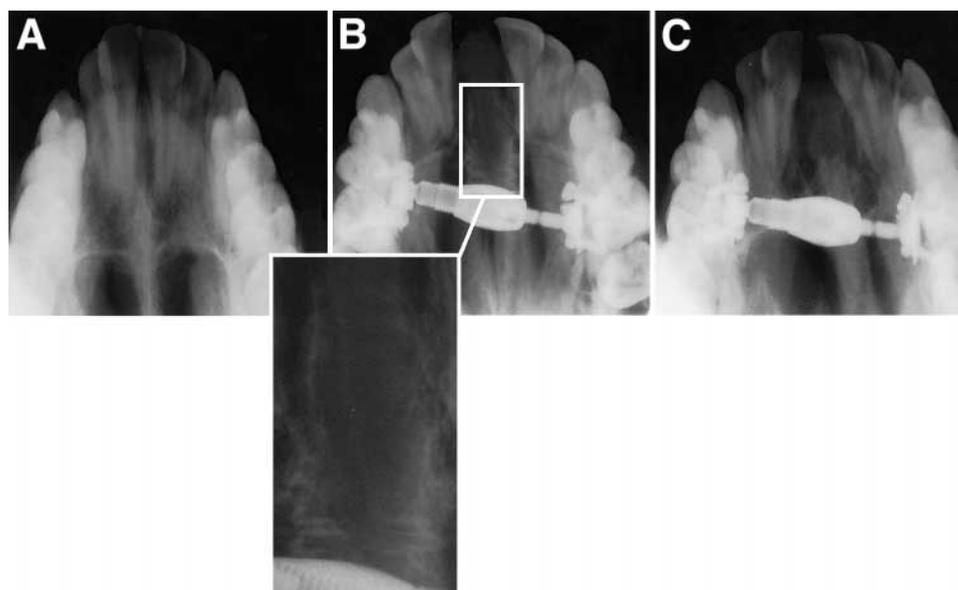


FIGURE 1. Radiographic view of abutment plates, screws, and module of the TPD. *A*, Occlusal view before treatment. *B*, Occlusal view 21 days after the start of the distraction. Horizontal regions of calcification are visible. *C*, Occlusal view 70 days after the start of distraction. Note further calcification and spontaneous mesial tipping of the incisors.

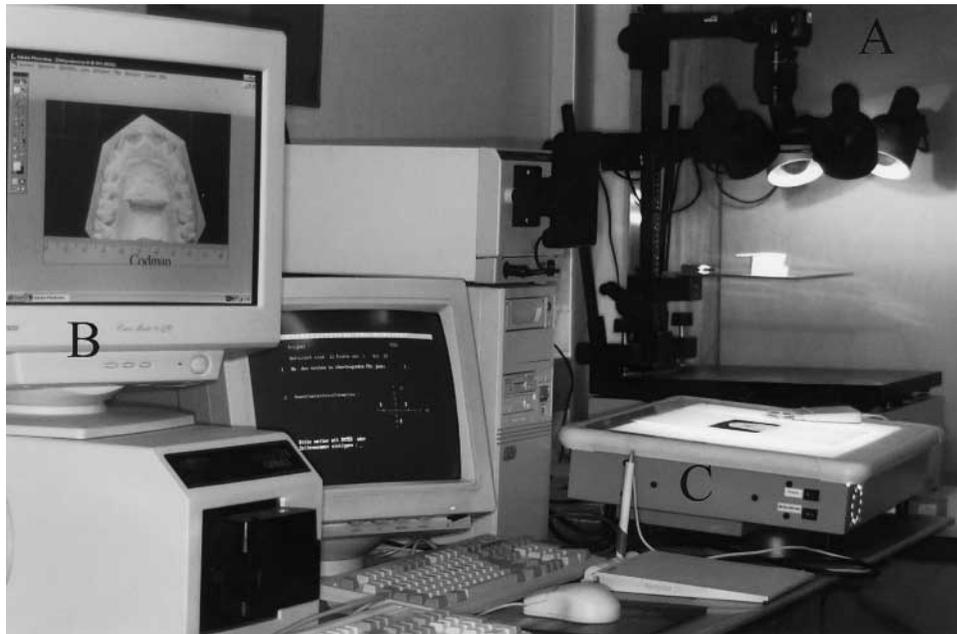


FIGURE 2. Experimental setup. A, Digital camera on a stand with fixed focus-object distance. B, Digital image of the model. Markings were corrected under magnification. C, Backlit digitizer.

ments were to be taken were marked with a fine lead pencil to facilitate identification. Once marked, the models were photographed from an occlusal view with an AF35-70mm f/3.3-4.5 Nikon N90 camera (Nikon Inc, Melville, NV) with a digital converter Kodak Professional DCS 420 (Eastman Kodak Co, Rochester, NY). A camera stand was used to support the models and to hold the camera at a fixed distance of 34 cm from the occlusal surface of the models (Fig 2). Several digital images were made in Macro mode and stored in the digital format using the Adobe Photoshop 5.0 program (Adobe Systems Inc, San Jose, CA).

The study casts were then reduced on a model trimmer perpendicular to the occlusal plane first using a course and then a fine grinding wheel. They were first reduced from the front to the cusp tips of the first premolars and then from the back to the level of the mesial cusps of the first molars. These teeth were chosen because they are the "anchor" teeth in conventional SA-RPE procedures. Digital photographs were taken again using the standardized protocol already described. The digital color images were printed (Epson Stylus Photo 700, Epson Europe BV, Amstelveen, The Netherlands) and the points were digitized on a back-lit digitizer (Numonics Accugrid Backlighted Digitizer A43BL, Numonics Co, Montgomeryville, PA). The software for cephalometric analysis was developed at the University of Zurich Dental Institute. The digitizer was validated, and the working modalities were adapted accordingly.¹⁹ StatMost for Windows 2.01 software (DataMost Corp, Salt Lake City, UT) was

used for the descriptive statistics, the *t*-tests, and the regression analysis.

LANDMARK IDENTIFICATION AND MODEL MEASUREMENTS

The points were marked on the maxillary dental models as described by Adkins et al.²⁰ These were the most lingual points at the gingival margin of the first molars, the first premolars, and the canines (Fig 3A), the contact points on the mesial surface of the first molars, the mesial surface of the first premolar, the distal surface of the central incisors, and the most facial point of the most prominent central incisor (Fig 3B).

Arch perimeter is a peripheral curve described on the dental arch form. Arch perimeter points were chosen on the mesial surface of the first premolars and the distal surface of the central incisors because the maxillary canines and the lateral incisors were often blocked out labially or lingually. The chosen method actually undervalues the true arch perimeter. However, within the clinical limitations, the estimated measurements are reasonable for evaluating changes in arch perimeter.

To measure the changes in the segment angulation in the frontal plane, each maxillary model was sectioned at the first premolar and at the first molar level. After drying, the casts were photographed, and the highest points of the cusps were marked with a lead pencil, digitized, and the resulting angles were computed (Fig 4).

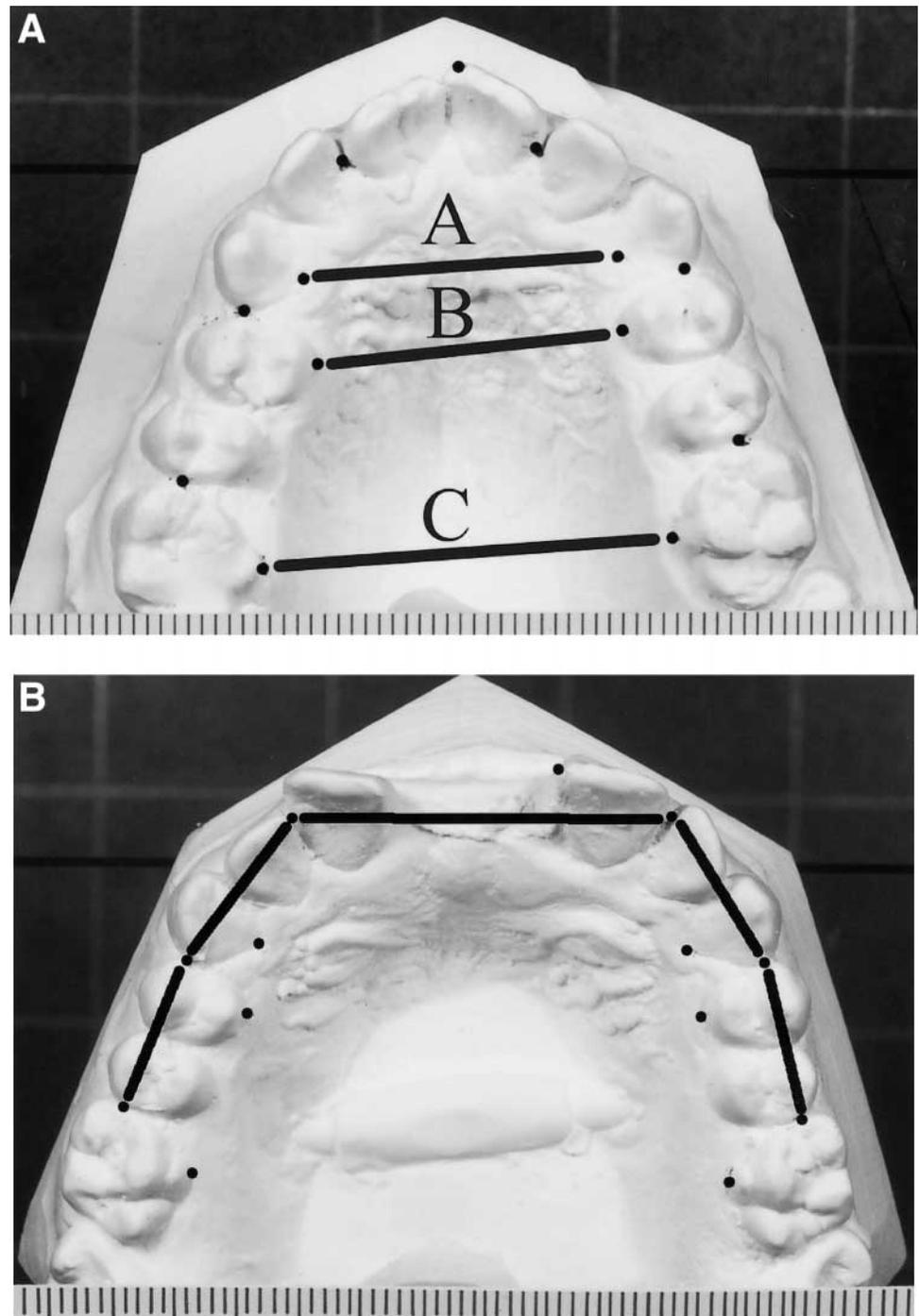


FIGURE 3. The 13 points marked on the occlusal surface of a model. A, Arch width measurement. A is the intercanine width, B is the interpremolar width, and C is the intermolar width. B, Arch perimeter measurement. Arch perimeter is the sum of lengths of the segments connecting the points mesial to the permanent first molars, the contact points mesial to the first premolars, and the contact points distal to the central incisors.

EXPERIMENTAL ERROR

To minimize the error in landmark identification, photographic magnification, and digitization of the measurements, all of the pre and postdistraction maxillary models were photographed and digitized at the same time. The error of measurement was calculated with the Dahlberg formula in a randomly chosen group of 10 patients in whom the points on the digital pictures of the models were located and

digitized twice with a 2-week interval on duplicated casts. The method errors include the intrinsic error of the digitizer¹⁹ and the error of landmark identification and the digitizing process. The degree of error in percentage, together with the variance in the material, the error variance, and the percentage of the error variance compared to the total variance for selected parameters, are seen in Table 1. The method of measurement is acceptable according to

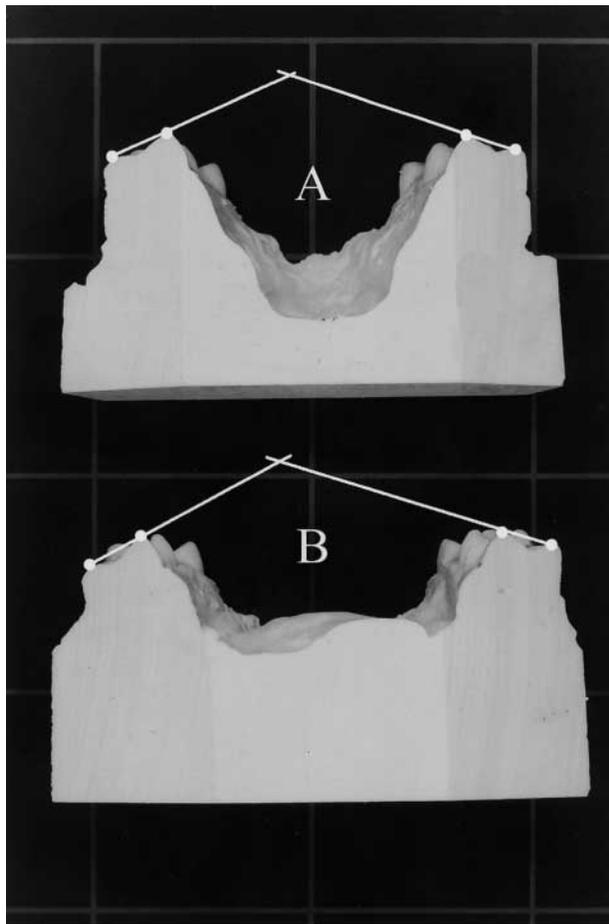


FIGURE 4. Sectioned duplicated casts through the molar region. A, Before distraction, B, After distraction. The software program provided tangents constructed through the cusp tips to produce angular measurements for sections of molar and premolar “anchor” teeth before and after palatal distraction.

Mitgard et al²¹ because the error of variance is less than 10% of the total variance.

Results

Expansion averaged $35.7 \pm 17\%$ at the canines, $31.7 \pm 14\%$ at the first premolars, and $20.4 \pm 8.7\%$ at the first molars. Taking into account that the original intercanine distance was 80.7% of the intermolar distance and that the interpremolar distance was 81.6%, the expansion was 28.8% at the canine level, 25.9% at the premolar level, and 20.4% at the molar level. As a general rule, it can be said that the canine/molar expansion ratio is 3/2. There was a statistical difference (nonpaired *t*-test, confidence interval level 0.95) between the changes in the intercanine distance and the intermolar distance ($P = .012$), and between the change in the interpremolar and intermolar distance ($P = .043$), although not between the change in the intercanine and the interpremolar distance ($P = .138$).

The resultant arch periphery gain after expansion before any orthodontic intervention to correct the anteroposterior incisor position amounted to a gain of $10.5 \pm 4.6\%$.

Postdistraction changes in the angulation of what would be the conventional SA-RPE and RPE maxillary “anchor” teeth showed a mean change at the first molars of $0.9^\circ \pm 9.9^\circ$ and a mean change at the first premolars of $-8.3^\circ \pm 9.6^\circ$. These data suggest that tooth angulation changes result from movement of the maxillary segments rather than the teeth themselves. However, the measurements were found to be moderately variable, considering the standard deviation.

Angulation changes did not correlate with age. Further linear regression analysis was performed after removal of the 2 outlying values in each series (most positive and most negative value for angulation changes). The change in the molar angle correlated statistically ($P < .0001$) and clinically (adjusted $R^2 = 0.62$; Fig 5) with the change in the intermolar distance. However, the change in premolar angulation did not correlate with the change in premolar width.

The change in arch perimeter correlated well with the increase in intercanine width ($P < .001$, adjusted $R^2 = 0.54$) giving the equation “increase in arch perimeter in % = $3.4 + 0.2 \times$ intercanine width in %” (Fig 6). Linear regression analysis gave a similar relationship ($P < .001$; adjusted $R^2 = 0.6$; increase in arch perimeter in % = $2.5 + 0.25 \times$ interpremolar width in %) (Fig 7). The change in arch perimeter did not correlate with the change in the intermolar width.

Table 1. THE DEGREE OF ERROR IN PERCENTAGE DETERMINED BY DOUBLE MEASUREMENT OF THE IMPORTANT PARAMETERS OF A RANDOMLY SELECTED SAMPLE OF 10 PATIENTS, THE VARIANCE IN THE MATERIAL, AND THE ERROR VARIANCE WITH THEIR RELATIONSHIP

	Degree of Error in %	Variance in the Material	Error Variance	% Error Variance to Variance in Total Sample
Intercanine distance	0.64	57.46	0.22	0.38
Interpremolar distance	1.12	70.07	1.19	1.7
Intermolar distance	3.9	237.10	6.88	2.9
Interpremolar angle	3.11	96.76	0.9	0.93
Intermolar angle	4.94	50.79	2.35	4.63

NOTE. Less than 3% of error variance means that the measurement method is very accurate.²¹

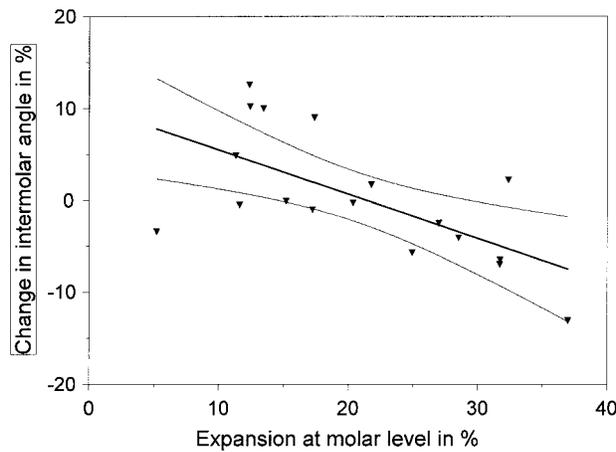


FIGURE 5. Correlation of the changes in the intermolar width and angle.

Discussion

Palatal or maxillary expansion has been an integral part of dentofacial orthopedic therapy for many years. Many radiographic studies have been done on RPE to evaluate the long-term stability and the postexpansion dislocations and movements of the maxilla. Frontal view studies have shown that the movement is greater at the alveolar crest and less at the palatal vault, presenting a triangular expansion pattern with the base near the incisors and the apex toward the nasal area.^{22,23} Haas²³ found that the maxilla was displaced downward and forward, with opening of the bite, in patients treated with RPE. From an occlusal view, the greatest opening of the midpalatal suture has been found anteriorly, with progressively less separation posteriorly.^{5,23,24} Wertz⁵ found a ratio of 2:1 in the separation at the level of the anterior nasal spine to the posterior nasal spine on occlusal radio-

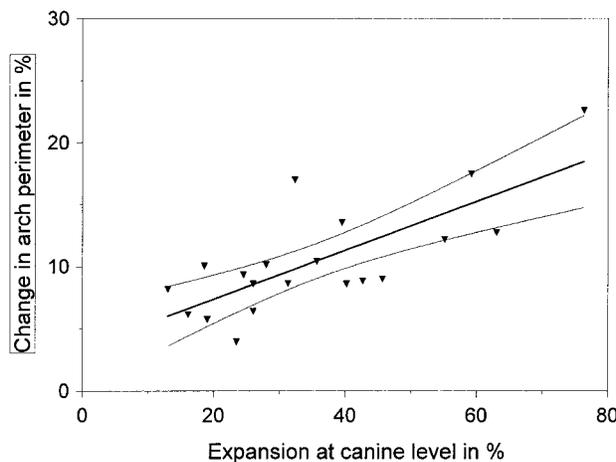


FIGURE 6. Correlation of the changes in the intercanine width and the arch perimeter.

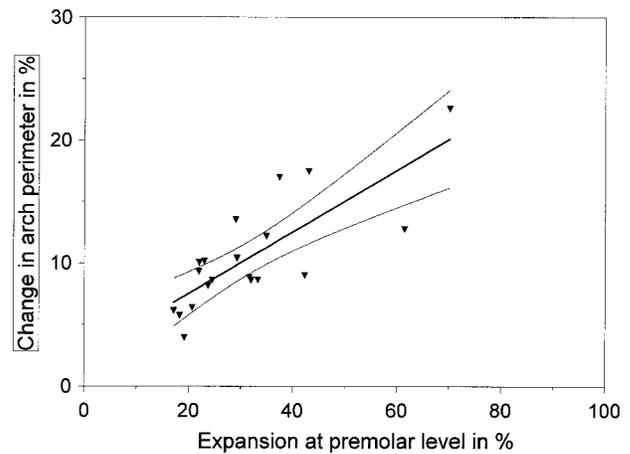


FIGURE 7. Correlation of the changes in the interpremolar width and the arch perimeter.

graphs. Krebs²⁴ using metallic implants, found that in RPE there was a gain in the width of the dental arch that was about twice that of the basal maxillary segments.

It is widely accepted that the SA-RPE causes similar dislocations in the maxillary segments.^{8-10,17} The post-expansion widths of the posterior teeth are more than those of the anterior teeth in both RPE and SA-RPE procedures.^{5,8,15,16,20} Both procedures conventionally use posterior tooth-borne appliances, and the posterior expansion width reflects the buccal tilting of the appliance-carrying abutment teeth.

There are some important differences between TPD and SA-RPE. The TPD uses a bone-borne appliance at a high level in the palatal vault and hence most of the expansion is thought to be orthopedic, with little or no buccal tilting of the bony segments (ie, without induced orthodontic tooth movement). The buccal dentition maintains its original undisturbed position in the bony segments so that there is no danger of tooth position relapse after treatment. In the TPD method, a latency period is required to allow nature to form a callus, and the distraction leads to a regenerate that will readily ossify and stabilize the expanded segments as in other types of DO. Although it would be debatable to label distraction across a patent suture (although in its resting phase) as a DO procedure, DO does occur across the anterior and lateral maxillary osteotomies.

The percentage increase in the intermolar width was on average 0.6 times the percentage increase in the intercanine width. This compares with values of 2.01 for RPE¹⁵ and 1.12 for SA-RPE.¹⁶ This seems to confirm that the dislocation of the maxilla (orthopedic effect), as observed from the occlusal view, is similar to that seen in RPE and SA-RPE, and that the dental movements are the opposite. In effect, in TPD,

the teeth are directly proportionately influenced by the amount of orthopedic movement of the palatal halves.

The magnitude of change in the arch perimeter in percentage terms could be calculated as $2.5 + 0.25$ times the percentage increase of anterior expansion at the first premolar level. Hence, the transverse width gain translates directly into arch periphery increase for the purposes of orthodontic crowding correction.

High-level application of the distraction force favors parallel expansion in the frontal plane. The vertical positioning of the TPD device is governed by the degree of operative access when applying the screws that retain the palatal flanges of the abutment plates. The variation in the material, reflected by the standard deviations of 9.9° for the molar angulation changes and 9.6° for premolar angulation changes, may be, in part, a reflection of the positioning relative to the center of resistance of the maxillary halves. Future research could be directed to the determination of this center of resistance. The degree of segmental tipping showed no relationship to age. Changes in the intermolar width correlated with changes in molar angulation, whereas this was not true for the premolar parameters.

Conclusions

Palatal distraction using the TPD produces an initial dislocation of the maxillary palatal halves in the occlusal plane that is similar to RPE and SA-RPE. Because of the orthodontic effect of tooth-borne appliances in the RPE and SA-RPE procedures, the expansion at the occlusal level is greater in the posterior than in the anterior region. This is the opposite to that which has been observed in this TPD sample, where there is 1.5 times more expansion at the level of the canine than at the first molars, with an associated 10.5% increase in arch perimeter length. Being able to predict the gain in arch perimeter for a given amount of transverse expansion at the canine and premolar level aids planning for nonextraction orthodontic treatment. The nonparallel expansion may be caused by the fact that pterygoid plate detachment was not performed and by the fact that the TPD device was placed at the level of the second premolars in this group.

Although tipping of the segments was minimal, this finding needs to be correlated to a SA-RPE group or clarified in an experimental setup.

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