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Multitomographic evaluation of the dental effects of two different rapid palatal expansion appliances

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SUMMARY Rapid palatal expansion (RPE) is widely used in the treatment of transverse maxillary deficiencies. Generally, there are two types of RPE appliances: banded and bonded expanders. The purpose of this prospective study was to compare the dental effects of banded and bonded appliances. The study consisted of 23 patients (13 females and 10 males) with a bilateral maxillary deficiency. Twelve patients (seven females and five males) with a mean age of 14.8 ± 0.3 years were treated with banded RPE and 11 patients (six females and five males) with a mean age of 15.1 ± 0.7 years with bonded RPE. Multitomographic radiographs were taken before (T0) and at the end (T1) of expansion while the patients were wearing an acrylic mandibular appliance in which ball bearings and bars were embedded. Statistical analyses of the measurements at T0 and T1 were undertaken with a paired *t*-test, and the difference between the groups assesed with a Student's *t*-test.

In both groups, the angle between the radiographic image of the bar and the axial inclination of the upper first premolar and molar teeth was (5.34 and 2.73 degrees for the right premolars, 5.17 and 2.28 degrees for the left premolars, 11.83 and 3.73 degrees for the right molars, and 9.75 and 5.64 degrees for the left molars in the banded and bonded groups, respectively. The distance from the vestibular cortical plate to the palatal root of these teeth (1.17 and 1.23 mm for the right premolars, 2.46 and 1.09 mm for the left premolars, 2.75 and 0.64 mm for the right molars, 2.23 and 0.96 mm for the left molars in the banded and bonded groups, respectively) increased (both $P < 0.01$). These increases indicated buccal tipping of the teeth. Comparison of the two groups showed that tipping of the first molar and premolar teeth in the banded group was significantly more than in the bonded group ($P < 0.01$ and $P < 0.001$, respectively).

Introduction

The earliest cited report of maxillary expansion was by Angell (1860) who claimed to have achieved opening of midpalatal suture in 19th century. Although the technique was discredited at that time, rapid palatal expansion (RPE) has been commonly used since the beginning of the 20th century.

RPE is recommended (Sarver and Johnston, 1989; Sarver, 1995) for the following:

1. Correction of a unilateral or bilateral crossbite.
2. Mobilization of maxillary sutures to facilitate correction of a Class III midface deficiency.
3. Increasing maxillary arch width and length.
4. Increasing the apical base width to facilitate buccal root torque of the posterior teeth.
5. Reducing nasal resistance and providing a normal breathing pattern.

The design of the RPE appliance should be determined according to the biomechanical requirements of the patient. There is considerable resistance to sutural separation so the rigidity of the expansion appliance is an important factor to obtain nearly parallel opening of the suture and to minimize buccal tipping of the posterior teeth. Chaconas and de Alba y Levy (1977) have shown, experimentally, that the form of the appliance determines the shape of the expansion. Several studies have revealed that increasing the rigidity of the RPE appliance decreases the rotational component of the force along the long axis of the tooth (Byrum, 1971; Timms, 1981; Spolyar, 1984; Sarver and Johnston, 1989).

Many different RPE appliance designs have been developed to eliminate extrusion and tipping of the posterior segments (Haas, 1961, 1970; Cohen and Silvermann, 1973; Litt and Mondro, 1977; Bishara and Staley, 1987). The most frequently preferred types are banded and bonded expanders. Banded expanders consist of bands placed on the maxillary fist premolars and molars. A midline jackscrew may be incorporated into the two acrylic pads that closely contact the palatal mucosa (Haas-type expander) or may be located in the palate in close proximity to the palatal contour (Hyrax-type expander). The bonded expander is characterized by full coverage of the occlusal surface and partial coverage of the buccal and palatal surfaces of the buccal teeth, commonly using an acrylic material, integral to a midline jackscrew. The retention of the appliance is through a close fit of the acrylic material to the tooth surface with luting cement. Bonded appliances have been popular since the studies of Howe (1982), Spolyar (1984), Sarver and Johnston (1989), and McNamara and Brudon (1993).

Bonded expanders not only affect the transverse dimensions but also change the vertical and sagittal dimensions. Sarver and Johnston (1989) and Asanza *et al.* (1997) showed that bonded appliances reduced the extrusive effects of RPE. The acrylic occlusal coverage acts as a posterior bite block and inhibits eruption of the posterior teeth during expansion, which allows this appliance to be considered in individuals with a vertical growth pattern. The acrylic occlusal coverage also facilitates the correction of anterior crossbites in patients with a Class III malocclusion by opening the bite (McNamara and Brudon, 1993).

Transversal tomograms are usually produced in a conventional spiral or linear mode. Hypocycloidal and trispiral imaging modes have also been used for dental implant planning (Ekestubbe and Gröndahl, 1993; Ekestubbe *et al.*, 1993; Lecomber *et al.*, 2001). In a conventional cross-sectional imaging system, the slice thickness varies between 1 and 4 mm, which is convenient for identifying anatomical landmarks.

When compared with computed tomography (CT), the radiation dose is lower in cross-sectional tomographic imaging. The effective organ dose for CT is 100 times greater and the resolution is also lower than that of conventional cross-sectional tomography (Ekestubbe *et al.*, 1999; Harris *et al.*, 2002). It does not appear that cross-sectional tomographic radiographs have been used previously for the evaluation of dental and skeletal changes obtained with RPE.

Panoramic radiographs represent a lateral view of the mandible or maxilla while transverse conventional tomograms offer a frontal view. In dental practice, the indications for conventional tomograms include pre-surgical implant planning, visualization of the mandibular canal before removal of impacted mandibular third molars, root fragment location, impacted teeth, or osteolytic lesions, and visualization of impacted teeth before orthodontic adjustment (Kaeppler *et al.*, 1995; Harris and Brown, 1997; Roberts-Harry and Carmichael, 1998; Kaeppler, 1999; Peltola and Mattila, 2004).

In this study, the aim was to determine and compare tipping of posterior teeth during maxillary expansion with banded and bonded RPE appliances using a multitomographic system.

Materials and methods

The Ethical Committee of Gulhane Military Medical Academy approved this investigation, and informed consent was obtained from the parents or guardians of all subjects.

This prospective study consisted of 23 patients (13 girls and 10 boys). The criteria for the selection were as follows: (1) skeletal maxillary arch deficiency, (2) bilateral posterior crossbite, (3) adequate clinical crown length so as to provide sufficient anchorage for the RPE appliance, and (4) no missing teeth in the upper dental arch.

Transverse deficiency was determined by calculating the difference between the distance of the distal or median cusp tips (if the lower molars included two buccal cusp tips, the measurement was performed at the distal; in the case of three cusp tips, measurement was performed at the median) of the right and left mandibular molars and the distance between the median sulcus of the right and left maxillary molars (Figure 1). The amount of maxillary arch deficiency was similar in both groups (approximately 8 mm). The patients were divided randomly into two groups. The subjects in group 1 (banded RPE) were 12 children (7 girls and 5 boys) with a mean age of 14.8 ± 0.3 years and in group 2 (bonded RPE) 11 children (6 girls and 5 boys) with a mean age of 15.1 ± 0.7 years.

The appliances were fabricated in the same laboratory. The banded appliance used in the study consisted of an all-wire framework. Impressions were taken after insertion of bands on the upper first premolar and molar teeth. Orthodontic models were obtained and the arms of the expansion screw were soldered to the bands (Figure 2).

The bonded appliance, with posterior occlusal coverage, was prepared as described by Sarver and Johnston (1989). Impressions were taken, models obtained, and the acrylic occlusal coverage with a thickness of 3 mm extended from the upper second molars to the first premolars (Figure 3). The expansion screw was centred in the maxillary arch and the appliance was bonded on the teeth following equilibration of the acrylic surface. For both appliances, the expansion screw and frame were placed as close as possible to the roof of the palate without impinging on the palatal surface.

The patients underwent a standardized protocol of expansion (including an amount of over-treatment) with two turns a day (approximately 0.25 mm per turn) until the desired expansions were obtained. The average amount and duration of expansion were 7.8 ± 1.53 mm and 19.0 ± 3.3

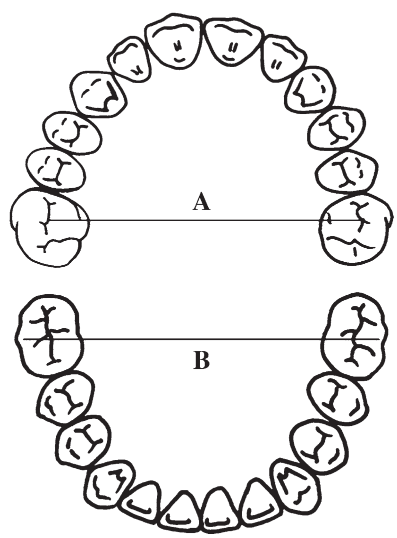

Figure 1 Measurements for estimating transverse deficiency: (A) upper arch, (B) lower arch.

days for group 1 and 7.7 ± 1.49 mm and 18.2 ± 2.4 days for group 2. The expanders were *in situ* during the retention period of 3 months and then removed.

Radiographic evaluation

Images were obtained before (T0) and after (T1) expansion with the cross-sectional tomogram, Proscan (Planmeca OY, Helsinki, Finland). Proscan makes use of corrected linear tomography in cross-sectional imaging. Image layer thickness ranges from 1 to 9 mm (at 3 mm intervals) with a magnification factor of 1.50.

The patients wore individually constructed mandibular appliances. Ball bearings (5 mm Ø) and bars (1 mm Ø × 30 mm length), which create radiopague images, were embedded in the acrylic blocks at the level of upper first premolars and first molars (Figures 4–6). Ball bearings for the calibration of the magnification, and radiopaque images of the bars to perform linear and angular measurements. The same appliances were used while the multitomographic images were being taken at T0 and T1. The alterations in the axial inclinations of the first molars and first premolars were determined by linear and angular measurements between the images of the bars and the long axis of the related teeth. The angle between the axial inclination of the palatal root of the molar and the radiographic image of the bar was measured. Additionally, a line perpendicular to the radiographic image of the bar was drawn from the cortical plate to the apex of the palatal root of the molar, and the distance between the cortical plate and the apex was measured. The same measurements were performed to the first premolars.

One author (HO) traced the radiographs, and the landmarks were verified by two other investigators. The measurements were repeated four times and the mean values were calculated according to Gröndahl *et al.* (1991) and Ekestubbe and Gröndahl (1993). The points measured for the maxillary first molar and first premolars are shown in Figure 7. One investigator (HO) remeasured the parameters 1 week later in order to evaluate measurement errors. The method error (ME) was determined using Dahlberg's formula (Zar, 1996): $ME = \sqrt{\sum d^2/2n}$, where '*n*' is the number of subjects and '*d*' is the difference between first and second measurements. The method error did not exceed 0.36 mm for the linear measurements or 0.49 degrees for the angular measurements.

Statistical analysis

Statistical analyses were performed using the Statistical Package for Social Sciences (SPSS Inc., Chicago, Illinois, USA) and the results were shown as the mean ± 1 standard deviation. After the parametric assumptions were assessed by Kolmogorov–Smirnov test to determine if the variables were suitable for parametric tests, the difference between the measurements at T0 and T1 were evaluated with the paired *t*-test and between two groups with a Student's *t*-test. *P* values less than or equal to 0.05 were considered statistically significant.

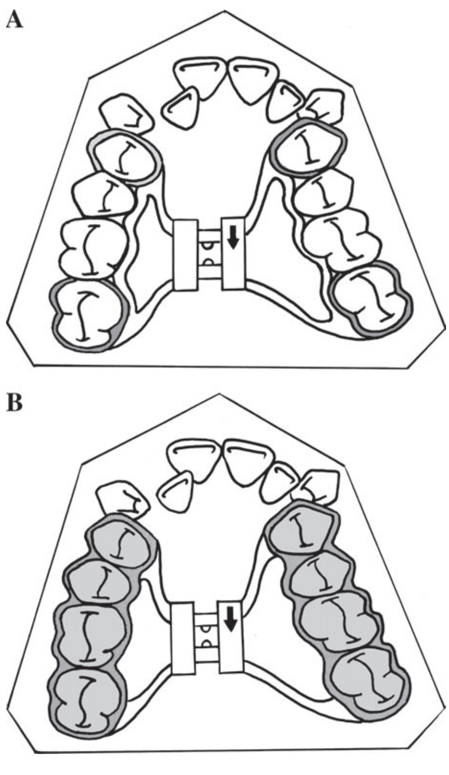

Figure 2 Schematic representation of (A) banded and (B) bonded rapid palatal expander.

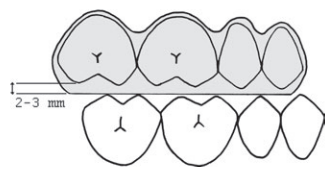

Figure 3 Schematic representation of occlusal coverage with the bonded rapid palatal expander.

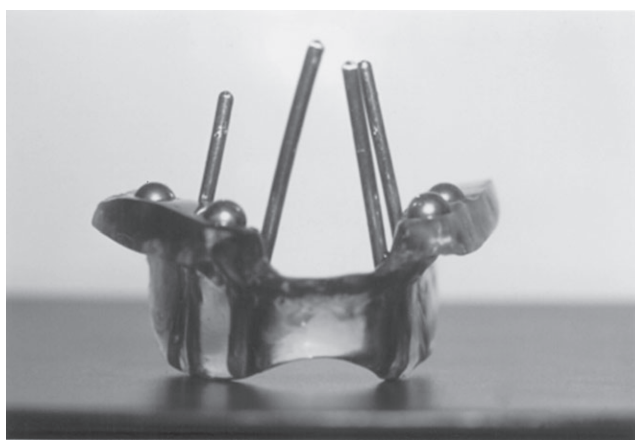

Figure 4 Mandibular appliance used for radiographic purposes.

Figure 5 Intraoral view of the mandibular appliance.

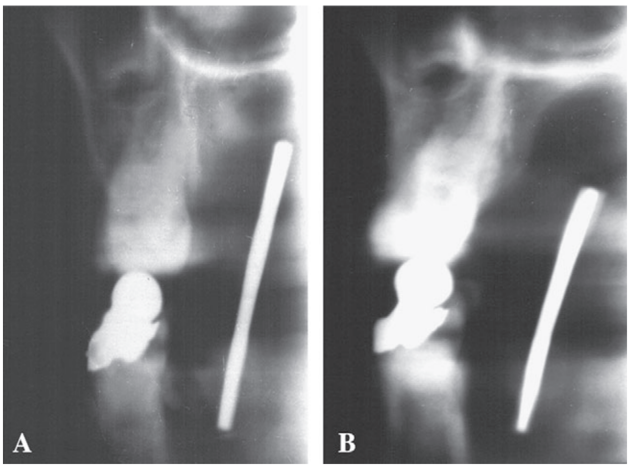

Figure 6 Cross-sectional tomogram of maxillary left first molar before (A) and after (B) expansion.

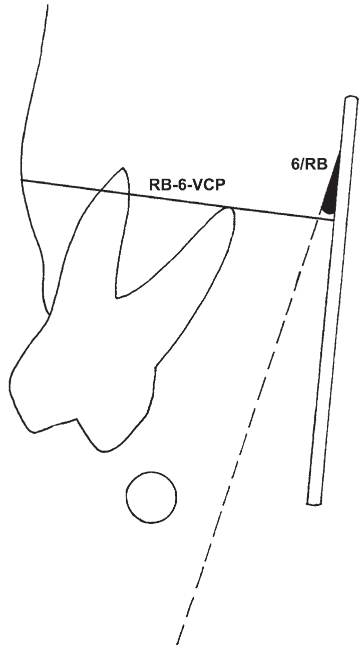

Figure 7 Measurements used in the cross-sectional tomographic radiographs. 1. 6/RB: inner angle between the long axis of the maxillary first molar and the radiographic image of the bar (RB) on the mandibular appliance (guide). 2. RB-6-VCP: distance from the vestibular cortical plate (VCP), to the apex of the palatal root of the upper first molar, perpendicular to the long axis of RB (the same measurements were also used for the first premolars).

Results

T0 to T1 changes for groups 1 and 2 are shown in Tables 1 and 2, respectively. Significant increases were found for all variables in both groups ($P < 0.01$). The distance from the palatal roots of the upper first molars and premolars to the vestibular cortical plate increased, indicating buccal tipping of these teeth.

Between-group comparison showed statistically significant changes for all variables and demonstrated more tipping for the first molar and premolar teeth ($P < 0.01$ and $P < 0.001$, respectively) in group 1 (Table 3).

Discussion

RPE is an accepted procedure in the treatment of maxillary transverse deficiencies and correction of crossbites with relief of dental crowding. Improved breathing due to a reduction of nasal airway resistance (Doruk *et al.*, 2004), and improved conductive hearing loss caused by middle ear and eustachian tube problems (Gray, 1975; Laptook, 1981) are the other reported benefits.

The main reasons for the popularity of bonded RPE over recent years are easy fabrication of the appliance, and the bite-block effect to facilitate correction of anterior crossbites (Sarver, 1995), and reduced tipping of the posterior teeth (Reed *et al.*, 1999). The principal aim of this research was to compare tipping of posterior teeth which occurred during RPE with banded and bonded appliances.

In previous RPE studies, lateral or postero-anterior cephalometric radiographs and study model have been used (Asanza *et al.*, 1997; Reed *et al.*, 1999). Computed tomography (CT) was used by Garib *et al.* (2005) for comparison of the dentofacial effects obtained with tooth-tissue and tooth-borne expanders. A disadvantage of this technique is the radiation exposure, which resulted in a restriction of the number of patients to four in each group. The present study was carried out using cross-sectional tomograms. This technique allowed measurement of the transverse dimensions in any area of the arch. Until recently, cross-sectional imaging has necessitated CT with reformatting, or the use of costly tomographic facilities usually not found in dental offices. The multitomographic system used in this study produces a single or multisectional tomogram of any part of the maxilla and mandible. A section thickness of approximately 3 mm is suitable for dental evaluations. Cross-sectional radiographs were taken at T0 and T1 to evaluate the pure effects of the appliances on the maxillary posterior teeth. Although the vertical and horizontal magnification of 1.50 is consistent, the use of markers such as ball bearings is recommended in critical areas for calibration purposes.

According to Baccetti *et al.* (2001), patients treated with RPE before the pubertal peak show significant and more 'effective' long-term changes at the skeletal level in both the maxillary and circummaxillary structures. When

Table 1 Descriptive statistics of cross-sectional measurements before (T0) and after (T1) treatment and T1−T0 for the banded rapid palatal expansion group.

	T0		T1		T1 − T0		*Z*	*P*	Significance
	Mean	SD	Mean	SD	Mean	SD			
UR4/RB (°)	4.58	2.16	9.92	6.02	5.34	0.80	−3.11	0.00	**
UR6/RB (°)	3.00	1.35	14.83	2.48	11.83	3.43	−3.06	0.00	**
UL4/RB (°)	4.83	2.71	10.00	5.17	5.17	2.25	−3.08	0.00	**
UL6/RB (°)	3.67	1.07	13.42	1.68	9.75	1.71	−3.07	0.00	**
UR4-VCP (mm)	5.96	0.99	7.13	0.98	1.17	0.54	−3.07	0.00	**
UR6-VCP (mm)	5.33	1.50	8.08	1.35	2.75	0.54	−3.09	0.00	**
UL4-VCP (mm)	8.17	1.05	9.63	1.32	2.46	1.13	−3.10	0.00	**
UL6-VCP (mm)	7.75	1.08	9.88	1.19	2.23	0.93	−3.08	0.00	**

RB, radiographic bar; SD, standard deviation; VCP, vestibular cortical plate.
**$P < 0.01$.

Table 2 Descriptive statistics of cross-sectional measurements before (T0) and after (T1) treatment and T1−T0 for the bonded rapid palatal expansion group.

	T0		T1		T1 − T0		*Z*	*P*	Significance
	Mean	SD	Mean	SD	Mean	SD			
UR4/RB (°)	4.09	2.66	6.82	4.51	2.73	1.34	−2.944	0.003	**
UR6/RB (°)	3.36	1.91	7.09	2.02	3.73	1.42	−2.953	0.003	**
UL4/RB (°)	4.36	2.70	6.64	4.32	2.28	1.61	−2.937	0.003	**
UL6/RB (°)	2.91	2.39	8.55	2.02	5.64	1.80	−2.947	0.003	**
UR4-VCP (mm)	4.82	0.75	6.05	0.72	1.23	0.47	−3.070	0.002	**
UR6-VCP (mm)	5.91	1.14	6.55	1.21	0.64	0.23	−3.071	0.002	**
UL4-VCP (mm)	7.36	1.14	8.45	0.96	1.09	0.54	−2.971	0.003	**
UL6-VCP (mm)	7.45	1.04	8.41	0.89	0.96	0.52	−2.971	0.003	**

RB, radiographic bar; SD, standard deviation; VCP, vestibular cortical plate.
**$P < 0.01$.

Table 3 Comparison of the between-group differences for the banded and bonded palatal expansion (RPE) groups.

	Banded RPE		Bonded RPE		*Z*	*P*	Significance
	Mean	SD	Mean	SD			
UR4/RB (°)	5.34	0.80	2.73	1.34	−4.110	0.001	***
UR6/RB (°)	11.83	3.43	3.73	1.42	−3.963	0.001	***
UL4/RB (°)	5.17	2.25	2.28	1.61	−3.679	0.001	***
UL6/RB (°)	9.75	1.71	5.64	1.80	−3.717	0.001	***
UR4-VCP (mm)	1.17	0.54	1.23	0.47	−3.390	0.001	***
UR6-VCP (mm)	2.75	0.54	0.64	0.23	−4.187	0.001	***
UL4-VCP (mm)	2.46	1.13	1.09	0.54	−2.937	0.003	**
UL6-VCP (mm)	2.23	0.93	0.96	0.52	−2.913	0.002	**

RB, radiographic bar; SD, standard deviation; VCP, vestibular cortical plate.
**$P < 0.01$; ***$P < 0.001$.

RPE is performed after the pubertal growth spurt, maxillary adaptation to expansion therapy results in a shift from the skeletal to the dentoalveolar level. In the present investigation, the sample group mean ages were 14.8 ± 0.3 in group 1 and 15.1 ± 0.7 years in group 2, and it was assumed that the changes were primarily dentoalveolar.

The maxillary left and right first premolars and molars showed less buccal tipping in group 1 compared with group 2. It was therefore concluded that the axial inclination of the posterior teeth was more stable in the bonded appliance group. Contrary to these findings, Garib *et al.* (2005) reported more buccal tipping of posterior teeth with tooth-tissue borne expanders (Haas), than tooth-borne expanders (Hyrax). The amount of tipping of the posterior teeth was significant in their combined group, which comprised patients treated with both Hyrax and Haas expanders. It would appear that, due to the lack of occlusal coverage, the appliances resulted in similar effects and the level of significance in the combined group originated from the Haas group in which tooth-tissue borne expanders were used.

The deficiencies in the present study may be the lack of measurements for the second premolars, which were included in the occlusal coverage, and the measurements for the maxillary width. A new investigation is being undertaken to overcome the first problem. However, alterations of maxillary width cannot be determined with cross-sectional tomographic radiographs as this method provides only sectional images.

When the distances from the long axis of the upper first premolar and molar teeth to the vestibular cortical plate were evaluated, it was found that the mean differences were less in the bonded compared with the banded RPE group indicating less buccal tipping of the posterior teeth. This tipping in the bonded RPE group has been attributed to lateral rotation of the maxillary halves and was dependent on the buccal movement of the related teeth (Bishara and Staley, 1987). As a result, the axial inclination of the posterior teeth in the bonded RPE group appears to be more stable.

As the maxilla articulates superiorly and posteriorly with the rest of the midface, the palatal suture is opened in a 'V' shape during RPE. The most anterior and inferior points move the greatest distance, with a fulcrum somewhere within the nasal airway. In young patients, the fulcrum may be higher than the frontomaxillary suture, while it is lower in adolescents (Timms, 1981). These results support the common view that increasing the rigidity of an appliance decreases the rotational component of the force along the long axis of the teeth (Timms, 1981; Spolyar, 1984; Bishara and Staley, 1987; Sarver and Johnston, 1989).

Conclusion

1. RPE of the maxilla was effectively achieved in both groups.
2. Buccal tipping of the maxillary first premolars and molars was significantly less in the bonded RPE group than in the banded RPE group.
3. The findings do no show superiority of one type of RPE technique over another, because these results represent an early stage in treatment and the effect of these appliances should be reinvestigated after completion of fixed orthodontic treatment, and at follow-up. However, it seems that bonded RPE has an advantage over banded RPE at the end of the expansion phase with regard to tipping of the teeth.
4. The multitomographic system is a technique, which is available to determine tipping of teeth during orthodontic treatment. This system may be a valuable tool to evaluate alterations in the axial inclinations of teeth which may occur during orthodontic treatment.

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