THE EFFECTS OF BUCCOLINGUAL ROOT TORQUE ON THE MESIODISTAL ANGULATION WHEN VIEWED ON A PANORAMIC RADIOGRAPH.

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A THESIS

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The effects of buccolingual root torque on the mesiodistal angulation when viewed on a panoramic radiograph.

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Abstract

It is common practice for orthodontists to use panoramic radiographs to assess root parallelism during and after orthodontic treatment. The purpose of this study was to examine the effects of applying buccolingual root torque to anatomic typodont teeth on the mesiodistal angulation image of maxillary lateral incisors and second premolars and mandibular first and second premolars on panoramic radiographs. Using a typodont model buccal or lingual root torque was applied to the teeth in 5 degree increments, totaling up to 15 degrees in each direction. A digital photograph as well as a panoramic radiograph was taken after each adjustment. The results showed that when buccolingual torque was applied to the test teeth, distortion was produced on the panoramic radiograph that appeared as though there was mesiodistal angulation or tipping of the root. The resultant image was of unparallel roots in the mesiodistal direction. When the panoramic radiograph was compared with its corresponding digital photograph, the photograph clearly showed that the roots remained parallel at all times when viewed from the buccal aspect. Increasing lingual root torque resulted in increasingly more mesial root tip. Conversely, increasing buccal root torque resulted in increasingly more distal root tip. Additionally, lingual crown torque resulted in horizontal magnification causing a more exaggerated tipping image. Due to the potential mesiodistal image distortion on panoramic radiographs, it is recommended that a careful clinical examination be performed prior to placing adjustment bends in the wire if roots appear unparallel. Supplemental radiographs can also be taken to help determine the actual position of the roots.

Introduction

One of many goals of orthodontic treatment is to align the roots of the teeth in their proper axial inclination so that they are positioned parallel to one another. By positioning the roots parallel to one another, it allows sufficient bone to remain between the adjacent teeth (Casko et al, 1998). It is thought that by achieving parallel roots, the stability of the orthodontic results would be improved (Edwards, 1971; Graber, 1966) and the health of the periodontium would be less compromised (Jaraback and Fizzel, 1972).

Panoramic radiographs are commonly used during orthodontic treatment or upon completion of treatment to assess how the roots are positioned relative to the adjacent teeth (Brueggemann, 1967; Lucchesi, Wood, and Nortje, 1988; Mayoral, 1982). The panoramic radiograph is often chosen over a full mouth survey because of its broad view of anatomic structures, lower radiation exposure (Proffit, 2000) and simplicity of use (Brueggemann, 1967). In fact, the panoramic radiograph is the method of choice to assess the relative root angulation in a portion of The American Board of Orthodontics (ABO) phase III examination (Casko et al, 1998). Generally, the ABO requires that the roots of the maxillary and mandibular teeth be parallel to one another and orientated perpendicular to the occlusal plane. They state that although this is not the ideal record for evaluating root angulation, it is probably the best means possible for making this assessment (Casko et al, 1998). The ABO reports that in past field tests, common mistakes in root angulation occurred in the maxillary lateral incisors, canines, and second premolars as well as the mandibular first premolars (Casko et al, 1998). It may be speculated that the regions that often showed poor root angulations could be related to inherent distortions in panoramic radiography. If true, it would be difficult to determine if apparent poor root angulation was due to a true mesiodistal root angulation problem or a distorted image issue. This leads to questioning the reliability of panoramic radiographs in assessing root parallelism.

Past research has extensively examined image distortion of panoramic radiographs (Tronje et al,1981; Brueggemann, 1967; Frykholm et al, 1977). From past literature, it has been shown that this type of radiographic imaging has inherent distortion factors and other variables that can contribute to the distortion of the image (Tronje et al, 1981). Studies have examined different clinical situations and how they affect image distortion (McKee et al, 2001; Phillip and Hurst, 1978). These included alterations in patient head positioning in a vertical dimension (Philipp and Hurst, 1978), anteroposterior dimension (McIver et al, 1973), and side-to-side rotation (McKee, 2001). To further complicate the issue of image distortion, positions of the teeth relative to the focal trough may also contribute to a distorted image (Langland et al, 1989).

There are limited studies available that have examined the effects of torque (buccolingual inclination) on the mesiodistal angulation when viewed on a panoramic radiograph using anatomic teeth. Samawi and Burke (1984) examined torque effects on the angulation image using a wire mesh model with lead shots (balls) to simulate the dental arch and long axis of the teeth. They also tilted the model to simulate torque instead of actually applying torque to individual teeth. Another study by Lucchesi and colleagues (1988) examined torque effects on the mesiodistal angulation image using stainless steel pins. Obviously, this type of apparatus did not simulate the actual appearance and dimensions of the teeth. Using anatomical teeth could be important because magnification factors may lead to added image distortion. For example, it has been established that mesiodistal widths of teeth are magnified if they are positioned inside of the central image layer (Langland et al, 1989). If excessive buccolingual torque were present, this could potentially put the crown or roots out of the central image layer, causing increased distortion of the resultant image.

The purpose of this study is to examine if applying various amounts buccal or lingual root torque (BRT or LRT) to anatomic typodont teeth affects the mesiodistal angulation image on panoramic radiographs. In other words, will the roots appear as though there is varying mesiodistal tipping when only buccolingual torque is changed? The specific regions of the dental arches to be targeted are the maxillary laterals and second premolars as well as the mandibular first and second premolars. The teeth chosen for examination were partially based on the ABO observations of commonly misangulated roots (Casko et al, 1998).

Background

Root Parallelism

The importance of assuring parallel roots after orthodontic treatment is frequently mentioned in orthodontic literature (Graber, 1966; Edwards, 1971; Jaraback and Fizzel, 1972; and Casko et al, 1998). Positioning the roots in a parallel manner, helps to align the teeth within their respective boney jaw structure (apical bases) and provides an orientation such that occlusal forces are parallel to the long axis of the tooth. It was said that these factors could play an important role in maintaining a stable treatment result (Graber, 1966; Edwards, 1971).

Jarabak and Fizzel (1972) stated that if the roots were not parallel on either side of the extraction site the distribution of occlusal forces would exert a rotational force, causing the posterior teeth to tilt and rotate mesially and the canines to rotate distally. They also stated that in cases where parallelism is not achieved, there would be potential for greater periodontal injuries in the presence of poor oral hygiene (Jarabak and Fizzel, 1972). Graber (1966) stated that the extraction sites could potentially reopen if the roots of the adjacent teeth are not parallel. Edwards (1971) stated that the conscientious clinician should ensure that the teeth adjacent to the extraction sites have good contact and that the roots be parallel before starting the retention phase.

Panoramic Radiography

According to the textbook by White and Pharoah (2004), the panoramic x-ray machine uses a continuously moving center of rotation in order to create the optimal shape of the image layer or focal trough (Fig 1). As exposure of the panoramic image is initiated, the center of rotation is first located near the lingual surface of the right body of the mandible. The center of rotation then moves forward along an arc that ends a short distance lingual to the symphysis of the mandible. The arc is then reversed as the opposite side of the arch is imaged with the final position of the center of rotation ending near the lingual surface of the left body of the mandible.

The focal trough or image layer of the panoramic machine is where the patient's dental arches should be positioned in order to obtain a relatively well defined (Fig 2). The textbook by White and Pharoah (2004), depicts the focal trough as a three dimensional curved zone in which the structures lying within the focal trough are reasonably well-defined on the final panoramic radiograph. The general shape of the focal trough is elliptical or horseshoe shaped but the exact shape and size can vary between different manufacturers. The factors that affect its size are: 1) arc path, 2) velocity of the film cassette and x-ray tube head, 3) alignment of the x-ray beam and 4) collimator width

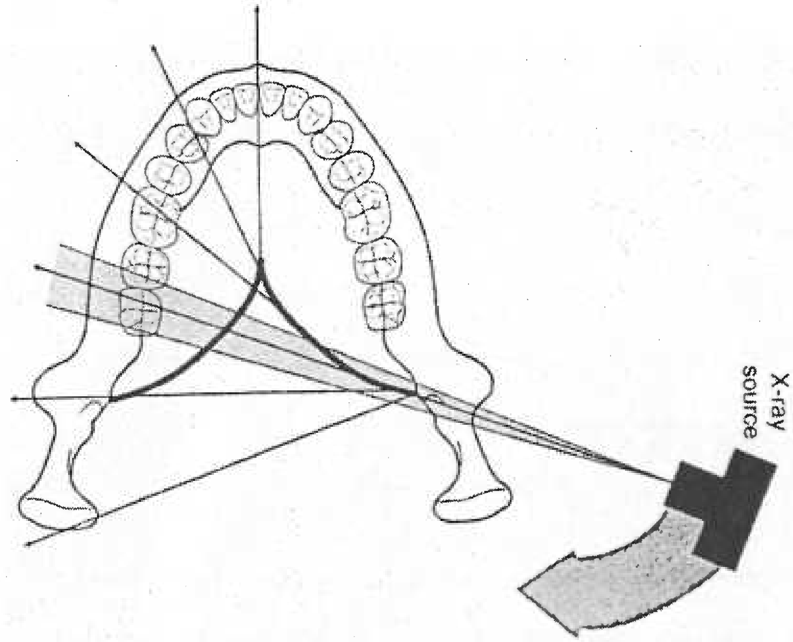


Fig 1. Continuously moving center of rotation (White and Pharoah, 2004)

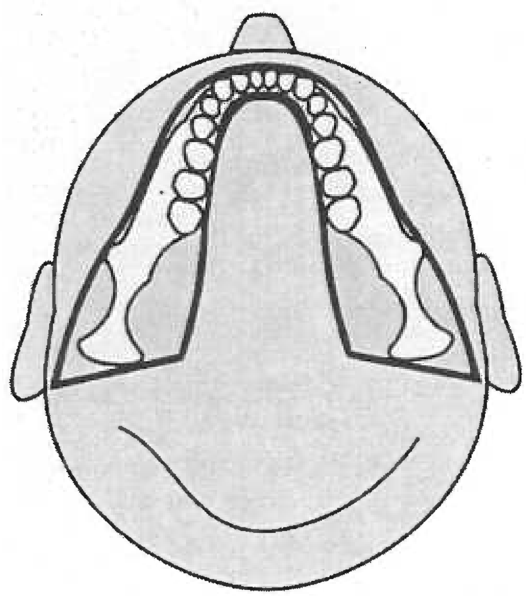


Fig 2. Focal trough shape of Orthopantomograph OP 100 (Orthopantomograph OP 100 instructions manual)

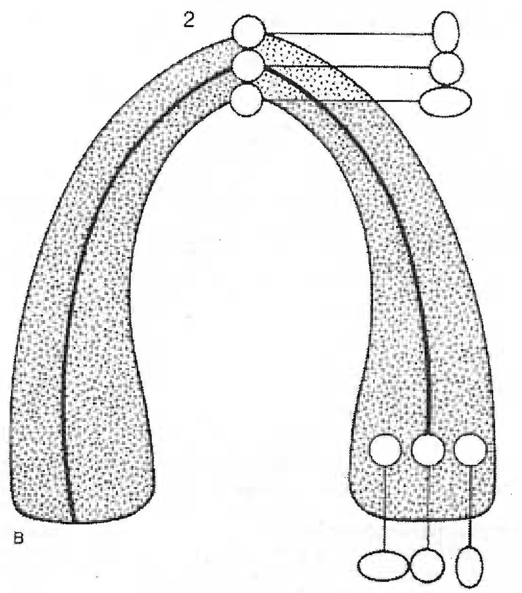


Fig 3. Focal trough showing horizontal magnification widening and narrowing of circle relative to the central image layer (Langland et al, 1989).

(slit where x-ray beam exits). In the center of the focal trough, there is a small central image layer where images are the most well-defined when an object is positioned within it. As the object is positioned farther away from the central image layer, the quality of the image increasingly diminishes with evidence of magnification, blurriness or narrowing depending on the position of the object. It has been established that when an object is positioned inside or lingual to the central image layer, the magnification increases mostly in the horizontal dimension (Langland et al, 1989; White and Pharoah, 2004). Conversely, when an object is positioned outside or buccal to the central image layer, the magnification decreases in mostly the horizontal dimension and the image becomes narrowed (Langland et al, 1989; White and Pharoah, 2004; Fig 3). The amount of magnification that is produced on the panoramic radiograph can vary between 19% to 30% depending on the machine manufacturer (Langland et al, 1989).

According to Farman and associates (1997), the Orthopantomograph OP 100, which was used in this study, has an elliptical focal trough with dimensions of 17 mm in the anterior region, 22 mm in the premolar region, 32 mm in the molar region and 44 mm in the temporal mandibular joint region. The central image layer width is much less than the width of the focal trough. The central image layer is 5 mm in the anterior region and reaches a maximum of 15 mm in the posterior region (Fig 2).

Images on panoramic radiographs often suffer from a variable degree of distortion. Distortion arises primarily from the combined effects of different magnification factors in the horizontal and vertical planes at different positions and depths within the image layer (Yeo et al, 2002). The degree of distortion is dependent on the distance of the object from the central plane of the image layer. However, an object lying within the central layer does not guarantee an undistorted image. The object must also be placed perpendicular to the central ray of the x-ray beam for vertical and horizontal magnifications to be equal (McDavid et al, 1986). However, for various reasons the x-ray beam may be directed at an oblique angle to the targeted object causing distortion of the image (Brueggemann, 1967). As discussed below, there are several known causes for image distortion including errors in patient positioning (McKee et al, 2001; Phillip and Hurst, 1978), anatomic variances (Langland et al, 1989) or inherent faults of the machine (Tronje et al, 1981; Yeo et al, 2002).

Patient Positioning Errors

When an image of the jaws is projected, many variables exist that could contribute to image distortion. Patient positioning is a major contributor to image distortion. It has been found that head positioning errors in a vertical, horizontal, or rotational dimension result in image distortion (McKee et al, 2001; Phillip and Hurst, 1978).

Using an Orthopantomograph OP 100 and an Ormco typodont test model, Mckee and colleagues (2001) studied whether vertical and horizontal head positioning would affect mesiodistal tooth angulations. To locate the positions of the teeth, they used small chromium steel balls. Custom designed software was utilized to calculate the mesiodistal angulation of the typodont teeth on the panoramic radiograph. They found that the maxillary teeth were more sensitive to vertical head tilt than to horizontal head rotation. The results of the study showed that 5 degrees of vertical head tilt upward caused mesial projection of the maxillary roots and 5 degrees of vertical head tilt downward caused distal projection of the roots. They found that the maxillary canines, first premolars and second premolars displayed the most distortion. The maxillary central incisor was found to display the least amount of distortion. Mandibular anterior teeth were more sensitive to horizontal rotation than to vertical head tilt. They found that if the head was rotated to the right, the anterior teeth on the right side of the arch tilted to the right and had a greater mesiodistal angulation (in reference to the archwire) than the anterior teeth on the left side of the arch. The opposite was true when the head was rotated to the left. They concluded that assessment of mesiodistal tooth angulation on panoramic radiographs should be approached with caution due to the distortion that can be produced.

Philipp and Hurst (1978) found that when the occlusal cant was changed from -4 to +20 degrees relative to a horizontal plane parallel to the floor, the greatest distortion of parallelism occurred in the canine-premolar region of both dental arches. They also found that as the occlusal cant was raised in the anterior from -4 to +20 degrees, the greatest amount of distortion of the tooth's long axis to the occlusal plane occurred in the molar regions with the maxillary molars angulated mesially and the mandibular molars angulated distally. With the change in occlusal plane cant from –4 to +20, the maxillary roots were found to converge apically and the mandibular roots diverged apically.

McIver, Brogean, and Lynman (1973) studied the effects of head position upon the width of mandibular tooth images on panoramic radiographs. Tests were conducted using a human skull with a dental age of 5 years. The teeth examined were the lower canines and premolars. Twelve positional changes were made to the skull. The positional changes were in a horizontal rotational movement (10 degrees), head tilt side-to-side (10 degrees), head tilt anteroposteriorly (10 degrees), bodily movement side-to-side (1 cm), bodily movement anteroposteriorly (1 cm) and mechanical repositioning of the x-ray source and film 2 cm above and below the manufacturer's advised position (representing the head being higher or lower than the chin rest). Results showed that all altered head positions produced significant image-width distortion but the most significant change was produced by the alteration in the anteroposterior direction. Also, it was found that for a given head position, all tooth images were not distorted to the same degree.

Anatomical Variances

Another factor that can contribute to image distortion is asymmetry of the jaws. According to Langland and colleagues (1989) there are several reasons a patient can be asymmetric: 1) developmental disturbances, 2) neoplasia or 3) skeletal disharmony. This may cause all or part of the jaws to be positioned out of the focal trough or image layer resulting in a distorted image. In patients with asymmetries or significant anteroposterior discrepancies, it may be necessary to take more than one panoramic image of the jaws to correct for the differences in dental arches. For example, if the maxilla is retrognathic or the mandible is prognathic, it may be necessary to take one exposure for the mandible with the lower incisors positioned in the notch of the bite fork, then another exposure taken of the maxilla with the maxillary teeth in the notch.

Inherent Distortions

Lund and Manson-Hing (1975) examined arch forms of various people to see if they fell within the established focal troughs of three panoramic machines. The panoramic machines examined were the Panorex, Orthopantomograph, and the GE 3000. The sample consisted of 240 patients selected on the basis of race, sex, age, number of teeth, and occlusion. The races involved were African American and Caucasian and all had normal, functional occlusions. Three age groups were chosen: (a) 4 to 10 years, (b) 11 to 18 years, and (c) 19 years and over. These age groups were categorized in this manner because of the growth spurts that often occur at approximately 5 to 7 years and 10 to 12 years. Impressions were taken and the positions of the teeth were located on the dental casts. The locations of the teeth were plotted and superimposed over the outline of the established focal troughs of the 3 panoramic machines. Results showed that little variation was evident between the two races and sexes. When different age groups were considered separately, the plots of the males and females of each race were almost identical. Comparison of the two races of the same sex were also similar. It was found that all the machines produced focal troughs that could encompass the tooth positions of the sample group. More specifically, the Panorex easily encompassed all tooth positions, the Orthopantomograph encompassed all tooth positions but a few plotted points of the canines fell on the outer edge and a few points of the premolars lie to the inner edge of the focal trough, and the GE 3000 had some premolar points that were positioned near the inner and outer borders of the focal trough. Therefore, the most common areas to appear distorted on panoramic radiographs were the canine and premolar regions.

Another study showed that inconsistencies in the focal trough or image layer existed among panoramic machines of the same manufacturer (Razmus, Glass, and McDavid, 1989). Razmus and colleagues (1989) examined the central plane locations in five of each of the Orthopantomograph-5, Panorex-I, Panelipse, and Panoral panoramic machines using a test object device consisting of a spherical steel ball. The results indicated that machines within each group exhibited different central plane locations. Also, it was found that machines of the same type had central plane locations that differed from a calibrated (according to manufacturer's directions) machine of the same type. Furthermore, machines calibrated at one time had a different central plane location when checked at a later time and a given machine calibrated at different times exhibited different central plane locations when checked after each calibration. It was suggested that due to the inconsistencies that were found, quality assurance tests needed to be developed for verifying the location of the image layer so that an image with minimal distortion can be produced.

Many panoramic machines are currently available on the market. Of these, four panoramic machines were recently tested for their accuracy to project the true mesiodistal angulation of the teeth (McKee et al, 2002). The four machines tested were the Orthopantomograph 100 (Instrumentarium), Cranex 3+ (Soredex), Orthophos (Sirona), and PM 2002 EC Proline (Planmeca). The test device used was an Ormco clear base typodont model fixed in a human skull and was positioned in the panoramic machine according to manufacturers' instructions. Small steel balls were placed strategically to obtain measurements using a coordinate measuring machine with custom designed software to determine the true mesiodistal angulation. Results showed that a common trend existed among all four machines. It was found that for the maxillary teeth, the images projected the roots of anterior teeth more mesially and the roots of posterior teeth more distally, creating the appearance of exaggerated root divergence between the canine and the first premolar. For the mandibular arch, the images projected the roots of almost all teeth more mesially than they really were, with the canine and the first premolar the most severely affected. The largest angular difference for adjacent teeth occurred between the mandibular lateral incisor and the canine, with relative root parallelism projected as root convergence.

Effects of torque on root parallelism

Samawi and Burke (1984) studied mesiodistal angular distortion of a panoramic machine. They used a wire mesh frame, shaped to represent the curvature of the human archform. Lead shots (balls) were cemented to the wire mesh to represent the long axis of the teeth. Six degrees of lateral tilt was applied on both the right and left sides of the wire mesh model to simulate a change in buccolingual inclination or torque. The results showed that when lateral tilt was applied, it was projected on the film as a change in the mesiodistal angulation of the simulated teeth. It was found that when buccal root inclination was simulated, the panoramic radiograph produced an image that appeared to have distal root angulation and when lingual root inclination was simulated, the image appeared to have mesial root angulation. The magnitude of change depended on the location of the tooth along the arch curvature. The results showed that the maxillary and mandibular canines displayed the greatest amount of mesiodistal angular change and the second molars displayed the least amount of change.

The single study found that actually applied different degrees of torque to a test model with individual teeth was performed by Lucchesi and colleagues (1988). They examined if the panoramic radiograph was suitable for assessing the mesiodistal angulation of teeth in the buccal segments. A plane film technique was compared to the panoramic technique in order to evaluate the distortion produced between the two. The plane film technique used in this study was described as an intraoral "occlusal-type" radiographic film that was placed perpendicular to the lingual side of the test pins. Using stainless steel pins to simulate teeth, they placed mesiodistal angulations to the pins that ranged from –20 to +20 degrees. A minus value represented distal angulation and a positive value represented mesial angulation. Experimental measurements were made by varying the degree of lingual crown torque which ranged from 0 to 25 degrees. Results showed that overall, the panoramic radiograph produced a more distorted image than the plane film technique. Furthermore, the panoramic radiograph tended to accentuate pin angulation at increased levels of lingual crown inclination. It was found that both techniques were less accurate at greater degrees of lingual inclination of the steel pins. Deviations were found to be greater in the anterior regions of the jaws.

Many who have studied the effects of patient variability factors agree that the clinical assessment of mesiodistal tooth angulation with panoramic radiography should be examined carefully because inherent image distortions can be further complicated by patient variability (Tronje et al, 1981; Lucchesi et al, 1988; McKee et al, 2001). Due to the unreliability of dimensional measurements on panoramic radiographs, it has been recommended that the panoramic radiograph be supplemented with intraoral films for a more accurate and detailed view of the teeth (Brueggemann,1967). Clinical examination of root prominence and clinical examination of buccal and lingual cuspal heights should also be evaluated to help determine whether or not the roots could be malpositioned (Bishara, 2001).

Materials and Methods

Panoramic radiographs were taken in the Pathology & Radiology Department at the Oregon Health & Science University, School of Dentistry, using the Orthopantomograph OP 100 (Instrumentarium) panoramic x-ray machine. To produce an image with acceptable density and contrast, the settings of the machine were set to a low exposure of 57 kVp and 2 mA. In addition, a black film was inserted into the film cassette to block out the back screen to reduce the film exposure by one half in order to further lighten the radiograph's appearance. A single, white-light exposed and processed panoramic film was used for this purpose.

A test model was developed using Ormco's (Ormco Corporation Glendora, CA) typodont model (Fig 4). The typodont contains 28 removable plastic teeth set in a semi-rigid plastic housing, simulating fully occluded dental arches from left second molar to right second molar. To give the teeth a radioopaque appearance when projected on the panoramic radiograph, the teeth were removed and painted with a mixture of zinc phosphate powder and clear nail polish. GAC Micro-Arch stainless steel brackets with vertical slots were affixed to the crowns of the teeth into their proper positions using superglue. A straight, passive .018 stainless steel round archwire, configured to the arch form of the typodont, was secured into the brackets of the upper and lower test models with elastic modules to prevent displacement of the test teeth out of the archform and to allow free rotation around the archwire as buccolingual root torque was applied.

To allow the test typodont model to be positioned in the panoramic machine reproducibly each time an exposure was made, a positioning device was developed using light bodied polyvinylsiloxane (Fig 5). The positioning device was made by expressing polyvinylsiloxane onto the chin rest of the panoramic machine, making sure the vertical slots of the chin rest were included in the impression. While the material was still at its unset stage, the typodont was placed into the impression material to simulate the position of a patient. The occlusal cant was adjusted +5 to +10 degrees in the sagital plane and the dental arch midline was using the vertical light guide. The incisal edges were placed in the upper and lower notch of the bite fork to position the anterior teeth within the focal trough of the panoramic machine. A small amount of Regisil bite registration material was placed between the molars to prop the bite open by approximately 2-3 mm to simulate an actual patient. The upper test model was secured to the lower test model using a 1/8" 3.5 oz small diameter elastic band that extended bilaterally from the upper to lower canines and from the upper first molars to lower first molars.

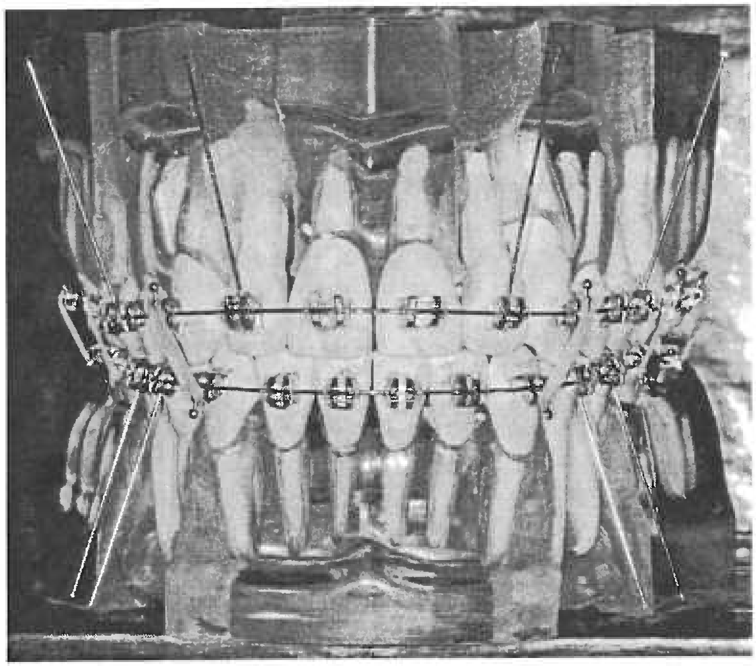


Fig 4. Ormco Typodont test model with reference wires in the vertical bracket slots of the teeth tested and elastic bands holding arch together

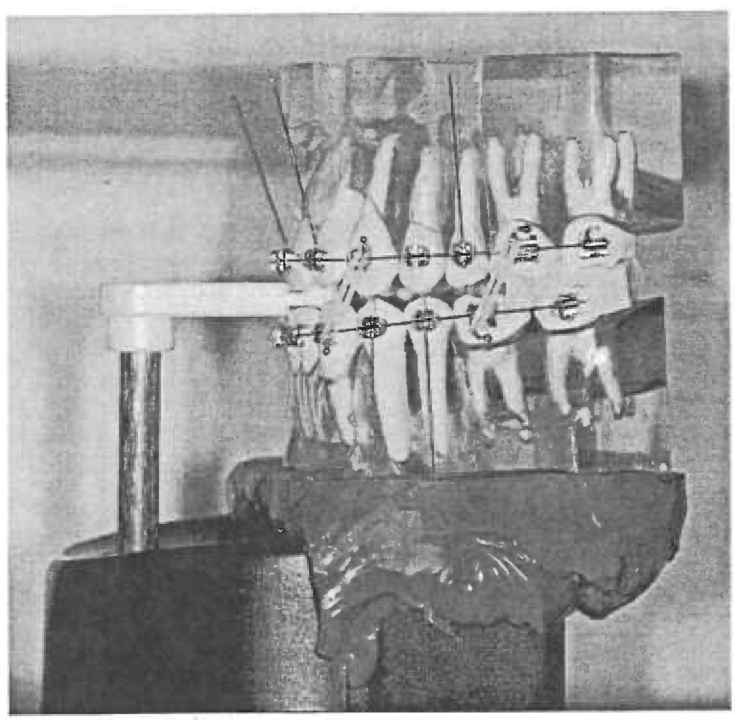
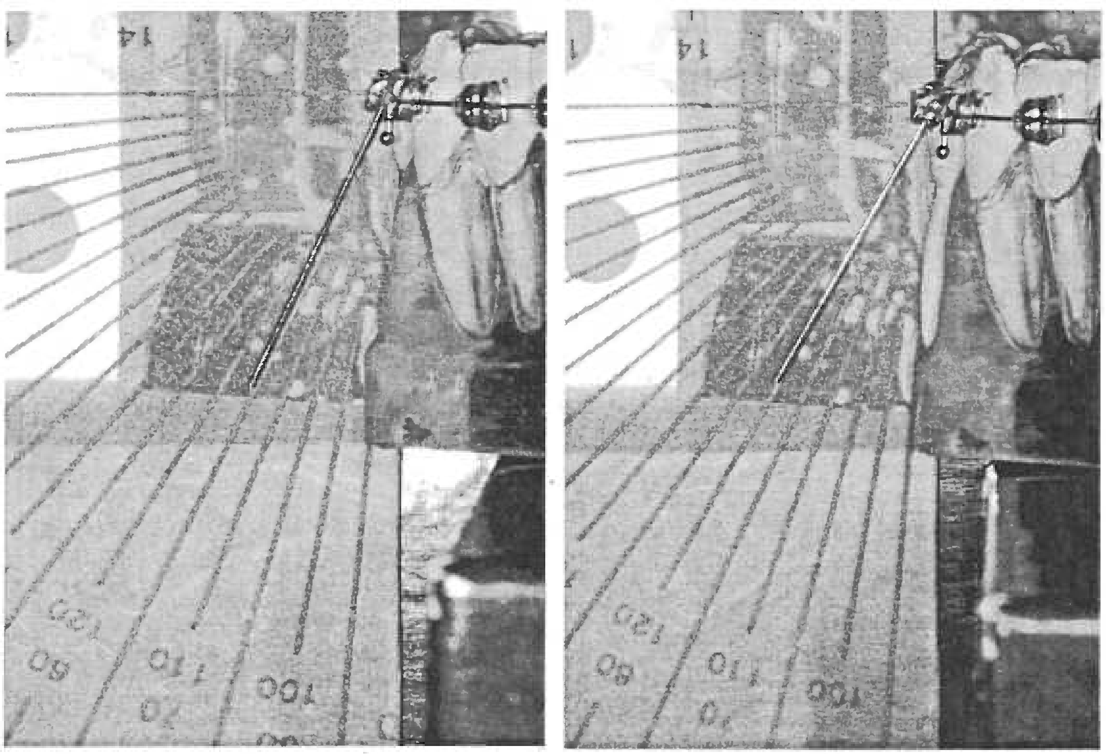


Fig 5. Typodont positioned in the panoramic machine using the bite fork and polyvinylsiloxane impression material on the chin rest. Regisil between the upper and lower molars.

To allow for movement of the test teeth in the typodont, the plastic that housed the teeth was completely removed allowing the test teeth to rotate around the archwire without interference. Buccal root torque or lingual root torque was applied to the targeted teeth in 5 degree increments three consecutive times for a maximum change of 15 degrees in one direction. A large increment of 5 degrees was chosen so that the root movement could be easily detected clinically and measured on the panoramic radiograph. A positive value indicated buccal root torque and a negative value indicated lingual root torque. The teeth were secured in new positions by using heated white baseplate wax. Right and left sides were adjusted simultaneously (but will be reported separately for clarity). After each adjustment, a panoramic radiograph was taken as well as a digital photograph from the buccal view. It was decided that a photograph would provide more detailed information than a periapical radiograph. An additional photograph of the typodont arches from the apical view was taken after each adjustment in order to visualize the amount of change in torque. Figures 20 through 23 show examples from the apical view of the mandibular first and second premolars when of a series of torque adjustments were made. A red reference line indicated where the apices were lined up at the baseline measurement.

To allow measurement of the change in torque, a short segment of 0.018 stainless steel wire was inserted and glued into the vertical slot of the targeted teeth (Fig 4). All of the vertical wires were pre-adjusted to have a 30 degree measurement to vertical for the baseline measurement. This measurement was arbitrarily chosen because it allowed the wire to be set far enough away from the base of the typodont so that when torque was added, the wire did not interfere with the base. A measuring device, to measure the degrees of change, was fabricated using an A-company protractor that was sectioned in half and taped on a metal L-shaped bracket. Figure 6 shows an example of how the protractor was used when measuring 5 and 10 degrees of buccal root torque of the mandibular right first premolar. The L-shaped bracket provided stability for the protractor to be held upright while the other end of the L-shaped bracket stabilized the device on the table. The protractor measurements were taken from the distal surface of the most distal wing on the bracket and oriented perpendicular to the facial surface of the tooth (Fig 7). A reference line was drawn across the center of the occlusal surface to assist in orienting the protractor parallel to the central axis of the tooth in the transverse plane (Fig 7).



a. b.

Fig 6. Sectioned protractor to measure degrees of change using .018 SS reference wire. a) example of 5 degrees BRT of LR 4 b) example of 10 degrees BRT of LR 4

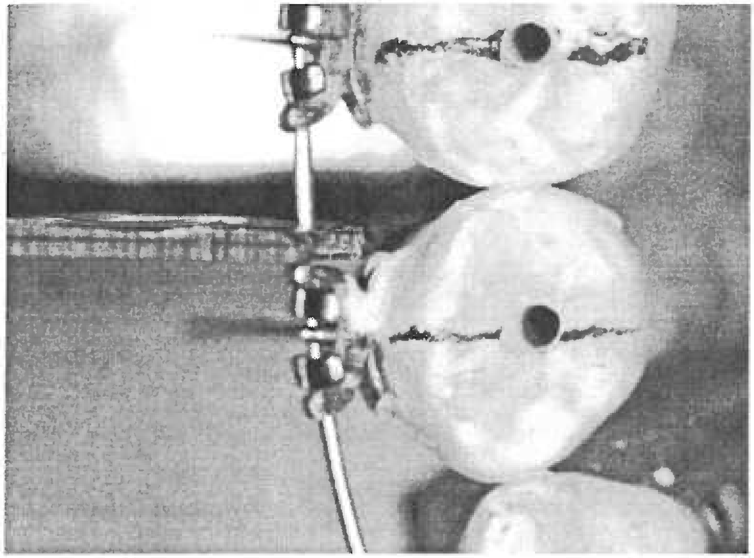


Fig 7. Occlusal reference line

The teeth examined in the maxillary arch were the lateral incisors and second premolars on both the right and left sides. The incisors of the upper test model were positioned in the incisal notch of the panoramic bite fork (Fig 5). There were a total of three torque adjustments for each of the four teeth that were examined. Buccal root torque or lingual root torque was applied to the targeted teeth in 5 degree increments three consecutive times for a maximum change of 15 degrees in one direction. For the maxillary right second premolar and lateral incisor, BRT was applied incrementally. For the left second premolar and lateral incisor, LRT was applied incrementally. Table 1 shows the test teeth and torque adjustments made.

Change in Right 2nd Premolar (BRT)	Change in Right Lateral Incisor (BRT)	Change in Left Lateral Incisor (LRT)	Change in Left 2nd Premolar (LRT)`
+5°	+5°	-5°	-5°
+10°	+10°	-10°	-10°
+15°	+15°	-15°	-15°

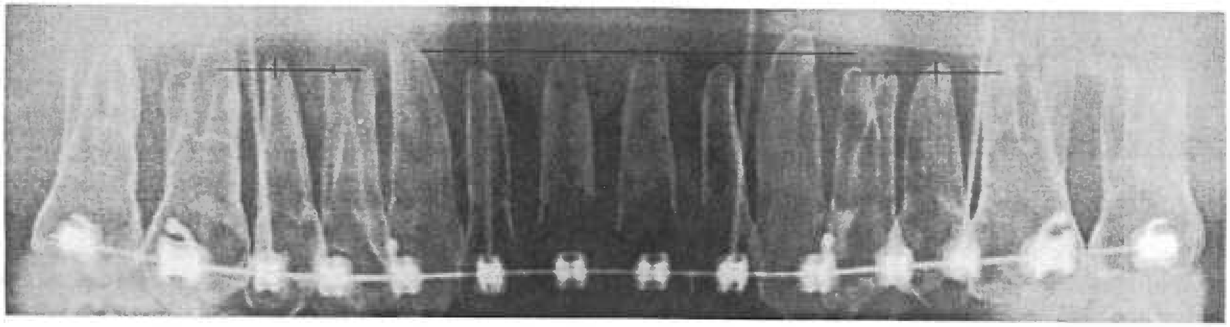
Table 1. Torque angulation changes for teeth tested in the maxillary arch

The teeth that were examined in the mandibular arch were the first and second premolars. The maxillary typodont model was removed from the lower arch when testing the mandibular teeth. As with the maxillary arch, buccal root torque or lingual root torque was applied to the targeted teeth in 5 degree increments three consecutive times for a maximum change of 15 degrees in one direction. The affects on apparent root angulation on the radiograph were assessed in three ways. First, the mandibular first premolars were examined individually. For the right first premolar, BRT was applied incrementally and for the left first premolar, LRT was applied incrementally. Second, the mandibular second premolars were examined individually. For the right second premolar, LRT was applied incrementally and for the left second premolar, BRT was applied incrementally. Lastly, both the first and second premolars were adjusted simultaneously but in opposing directions. For the right side, BRT was applied to the first premolar and LRT was applied to the second premolar. For the left side, LRT was applied to the first premolar and BRT was applied to the second premolar. Five degrees of root torque was applied in three increments in opposing directions. This produced a combined distance between the roots of 10 degrees after the first torque application, 20 degrees after the second torque application and 30 degrees after the third torque application. Table 2 shows the test teeth and torque adjustments made.

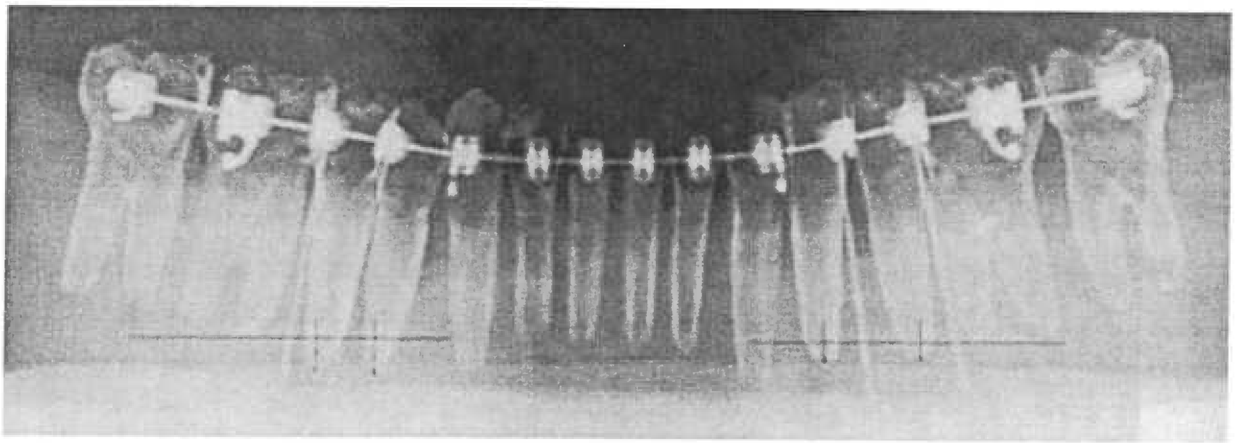
Change in Right 1st Premolar Buccal Root Torque (BRT)	**Change in Left 1st Premolar Lingual Root Torque (LRT)**
+5°	-5°
+10°	-10°
+15°	-15°
Right 2nd Premolar (LRT)	**Left 2nd Premolar (BRT)**
-5°	+5°
-10°	+10°
-15°	+15°
Right 1st Premolar (BRT) & Right 2nd Premolar (LRT) apices toward on film	**Left 1st Premolar (LRT) & Left 2nd Premolar (BRT) apices away on film**
5° + 5° = 10° total	5° + 5° = 10° total
10° + 10° = 20° total	10° + 10° = 20° total
15° + 15° = 30° total	15° + 15° = 30° total

Table 2. Torque angulation changes for teeth tested in the mandibular arch.

All panoramic films (Kodak T-MatL/RA-15) were processed through an automatic processor (Allied Model P-10) according to the manufacturer's directions. The targeted teeth on the panoramic radiographs were used to measure the change in mesiodistal angulation with each bucco-lingual torque adjustment. A pinhole was placed in the panoramic radiographs at the center of the root apex of all tooth images used for measurement. To measure changes in tooth angulation, a sliding digital caliper was used to measure the distance between the root apices of adjacent teeth. For maxillary lateral incisors, a horizontal line was drawn from the apices of the maxillary central incisors, extending past the lateral incisor apices. This horizontal line was used as a reference plane to which a perpendicular line was drawn from the location of the apex of the lateral incisor. All test teeth were measured using a fixed reference plane (from a non-test tooth) to which a perpendicular line was drawn through it to obtain a measurement (Fig 9). For the maxillary arch, the apices of the right and left central incisors and lateral incisors were used to derive a measurement for the lateral incisor torque change. The apices of the maxillary right and left premolars were used to derive a measurement for the second premolar torque change (Fig 8 a). For the mandibular arch, the apices of the right and left first molars were used to derive a measurement for each of the three series of torque adjustments made for the first and second premolars (Fig 8 b). These measurements were used to graph the results and to derive measurements regarding the amounts of change between each adjustment.



a.



b.

Fig 8. Method of measuring mesiodistal change on panoramic radiograph using a horizontal reference line and perpendicular lines drawn to it.

a) example of maxillary measurements at baseline
b) example of mandibular measurements at 10 degrees of change for the combination of premolar adjustments (first adjustment)

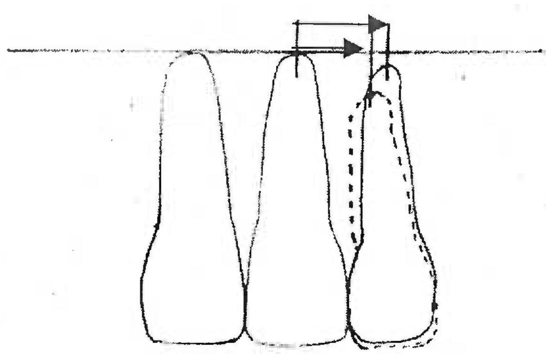


Fig 9. Example of the method of measurement of UL 2 from baseline to 15 degrees of LRT.

Error of Method

One investigator performed all of the torque adjustments and made all of the measurements. The total error for each change in torque was a combination of possible errors in the root torque measurement technique using the protractor combined with mesiodistal distance measurement technique using the digital caliper. The error of method was calculated by analyzing repeated measurements made three times for all the maxillary test teeth and the combination movements of mandibular first and second premolars. It was calculated using the equation: $S_x = \sqrt{\Sigma D^2/2N}$ where D is the difference between duplicate measurements and N is the number of measurements (Dahlberg, 1940). The error of method showed the method to be was relatively accurate (Table 3).

Max R5	.17 mm
Max R2	.07 mm
Max L2	.22 mm
Max L5	.09 mm
Md R4+5	.56 mm
Md L4+5	.34 mm

Table 3. Error of method for all maxillary test teeth and mandibular first and second premolars (when moved simultaneously).

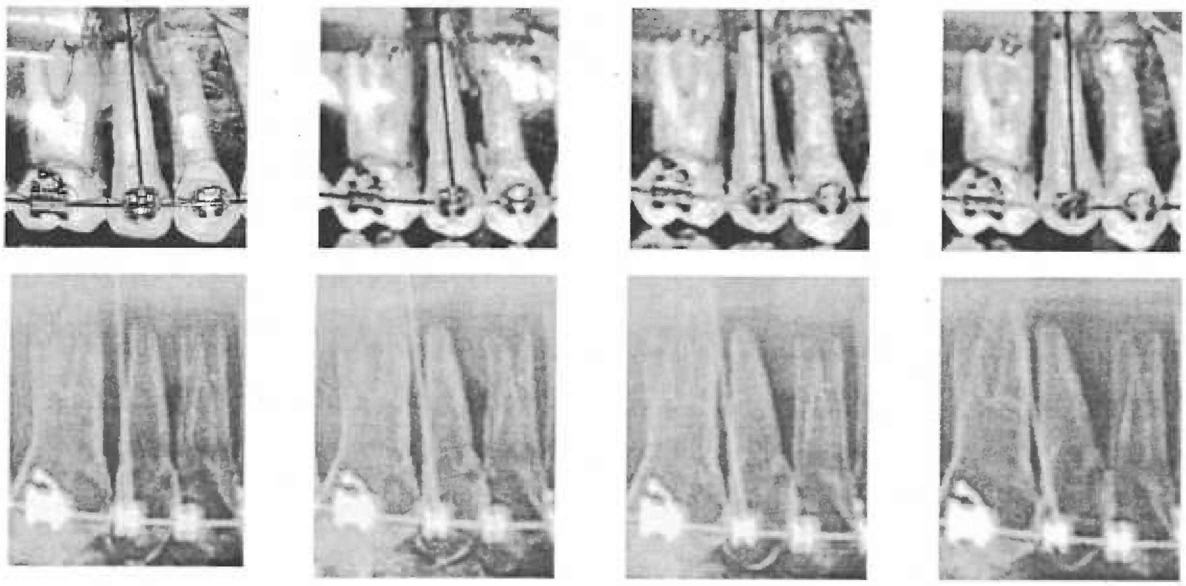
Results

In general, when lingual root torque is increased, the root of that tooth appears to have more mesial root tip in the image. Conversely, when buccal root torque is increased, the root of that tooth appears to have more distal root tip in the image. In the maxillary arch, the right second premolar apex appeared to move farther away from the first premolar root and the distal root tip appearance increased as BRT was applied (Fig 10). On the left side, the second premolar apex appeared to move closer to the first premolar root and the mesial root tip appearance increased as LRT was applied (Fig 13). The maxillary lateral incisors had similar effects but to a lesser extent, especially the right lateral incisor. The right lateral incisor displayed small amounts of distal movement as BRT was applied (Fig 11). The left lateral incisor appeared to move more in the horizontal dimension than the right lateral incisor but less than the premolar tooth movements. As LRT was applied to the left lateral incisor, the root appeared to have increased mesial root tip and moved closer toward the central incisor (Fig 12). Figure 14 shows the panoramic radiograph taken at maximum torque change (15 degrees) for each tooth.

In the mandibular arch, the right side produced an image that made the premolar roots appear closer to each other or converging apically as more torque adjustments were applied. This was the side with buccal root torque on the first premolar and lingual root torque on the second premolar (Fig 16). On the left side, the roots appeared to move farther away from each other or diverging as more torque adjustments were applied. This was the side with lingual crown torque on the first premolar and buccal root torque on the second premolar (Fig 17). Figure 18 shows the panoramic radiograph taken at maximum torque change (30 degrees between the two roots) and at baseline.

a.

b.



c. baseline | 5 degrees BRT .65 mm | 10 degrees BRT 1.00 mm | 15 degrees BRT .25 mm

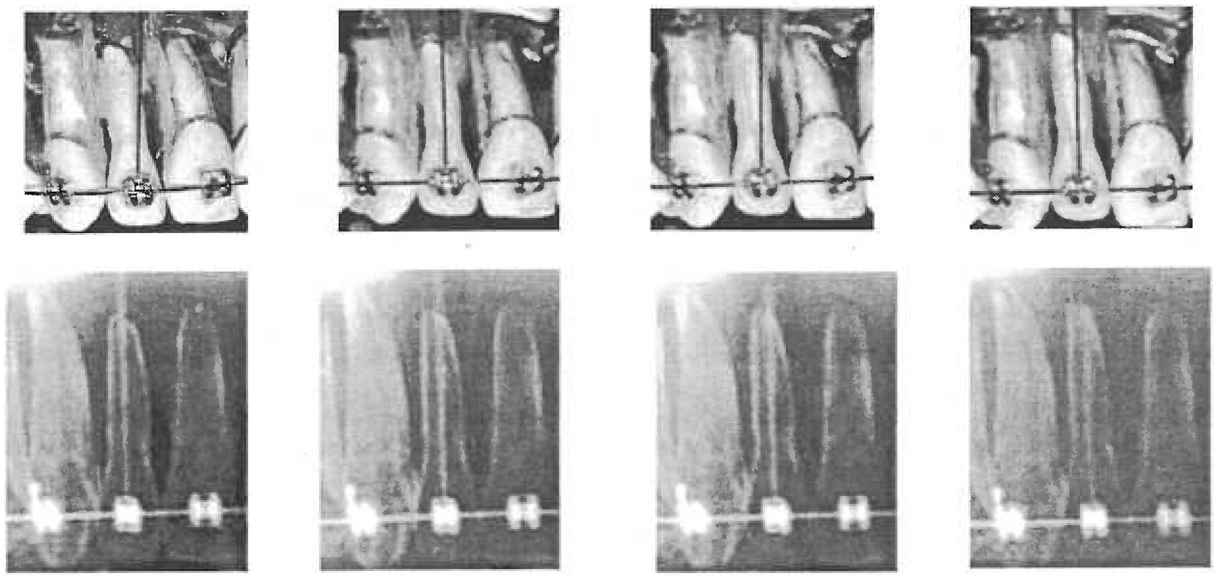
d. Method error: **.17 mm**

Fig 10. UR 5 (BRT):

a. digital photographs
b. panoramic radiographs
c. millimeters of change between each adjustment
d. error of method

a.

b.



c.	baseline	5 degrees BRT .02 mm	10 degrees BRT .09 mm	15 degrees BRT .06 mm

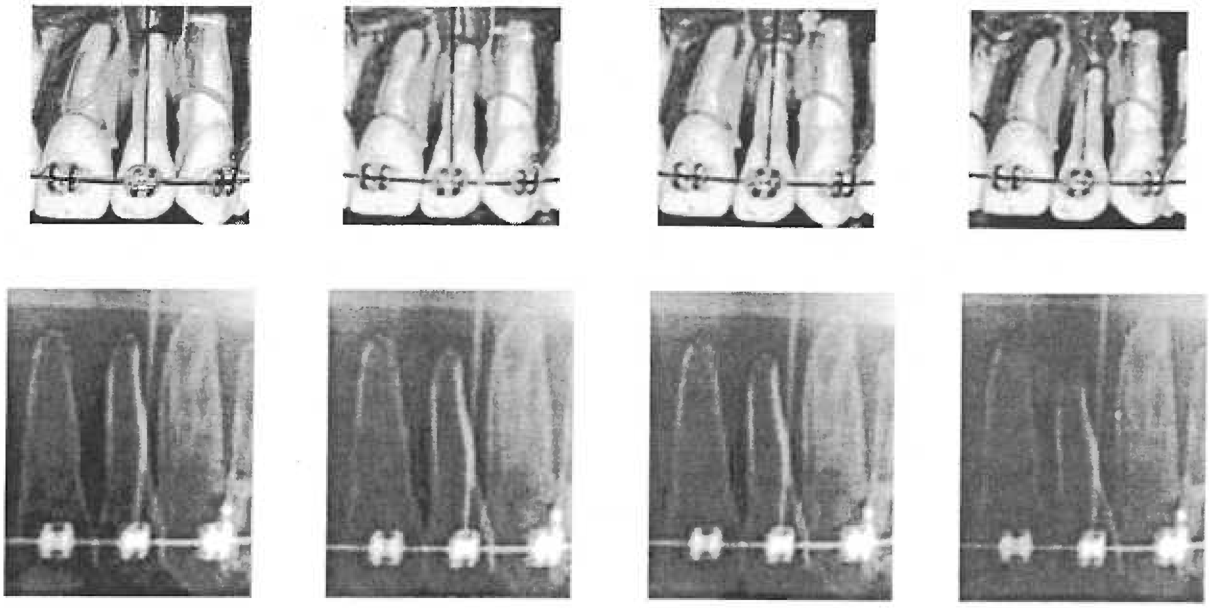
d. Method error: **.07 mm**

Fig 11. UR 2 (BRT):

a. digital photographs
b. panoramic radiographs
c. millimeters of change between each adjustment
d. error of method

a.

b.



c.

baseline	5 degrees LRT	10 degrees LRT	15 degrees LRT
	.62 mm	.49 mm	.13 mm

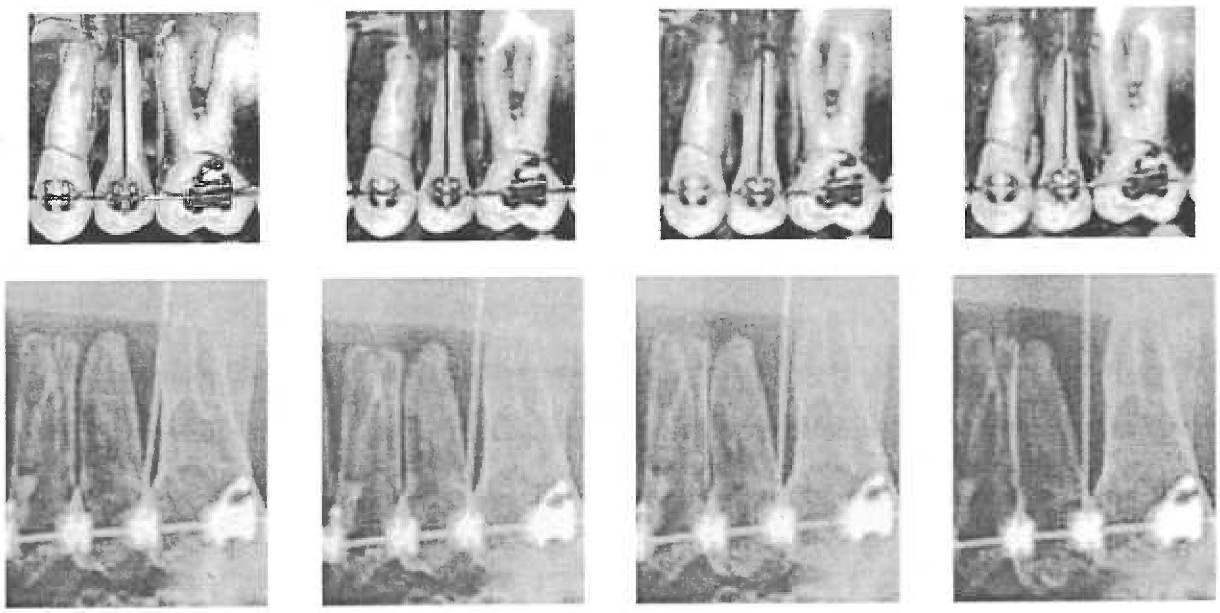
d. Method error: **.22 mm**

Fig 12. UL 2 (LRT):

a. digital photographs
b. panoramic radiographs
c. millimeters of change between each adjustment
d. error of method

a.

b.



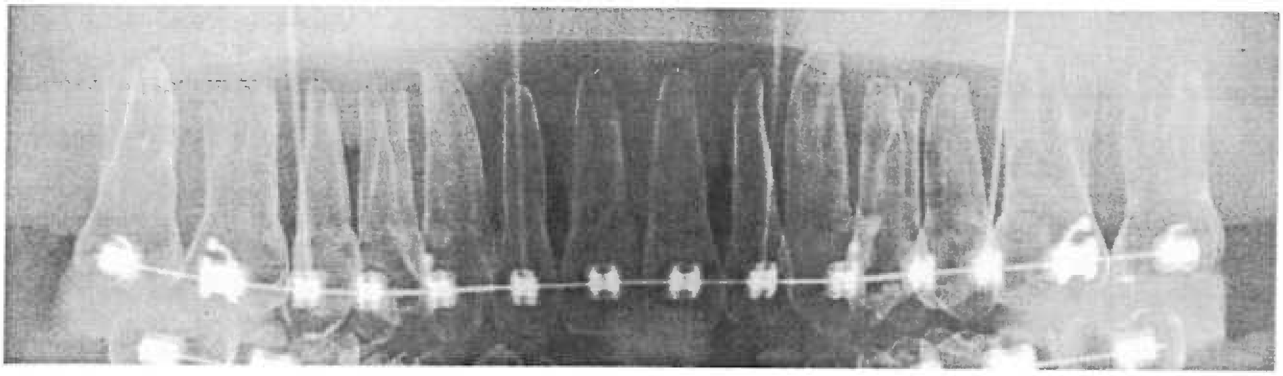
c.

baseline	5 degrees LRT .65 mm	10 degrees LRT 1.00 mm	15 degrees LRT .25 mm

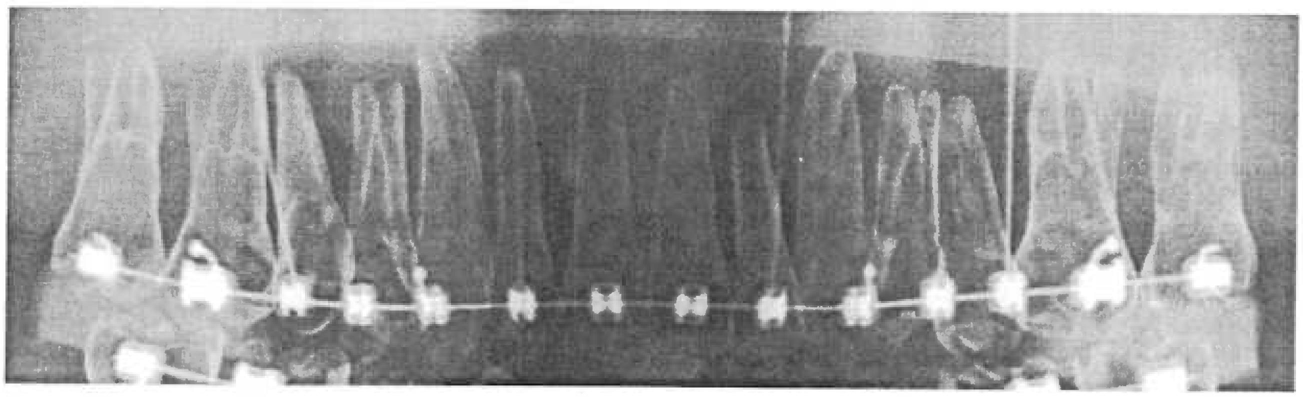
d. Method error: **.09 mm**

Fig 13. UL 5 (LRT):

a. digital photographs
b. panoramic radiographs
c. millimeters of change between each adjustment
d. error of method



a.



b.

Fig 14. Panoramic radiograph of maxillary arch:

a. at baseline
b. at maximum torque adjustment (15 degrees)

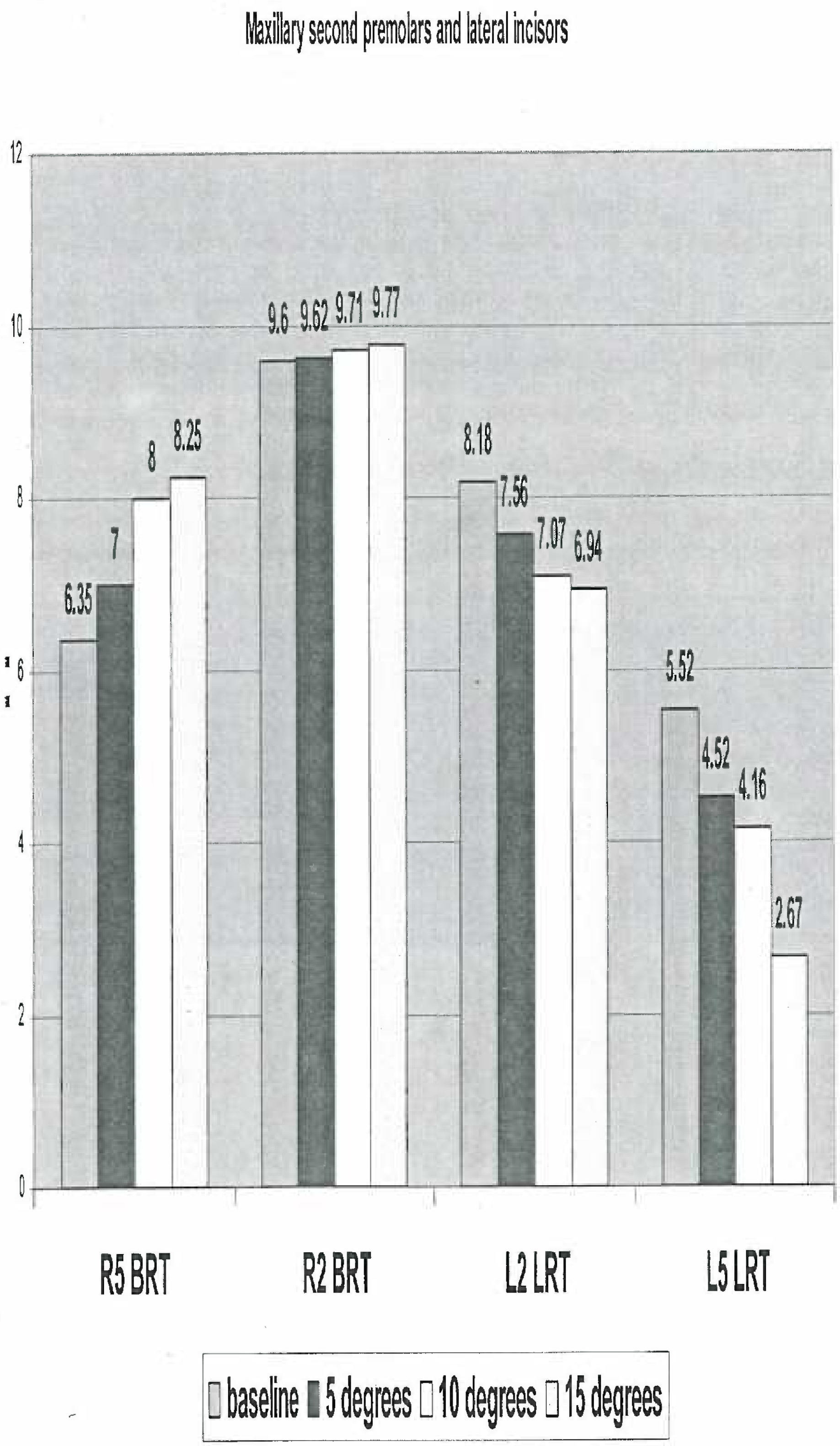
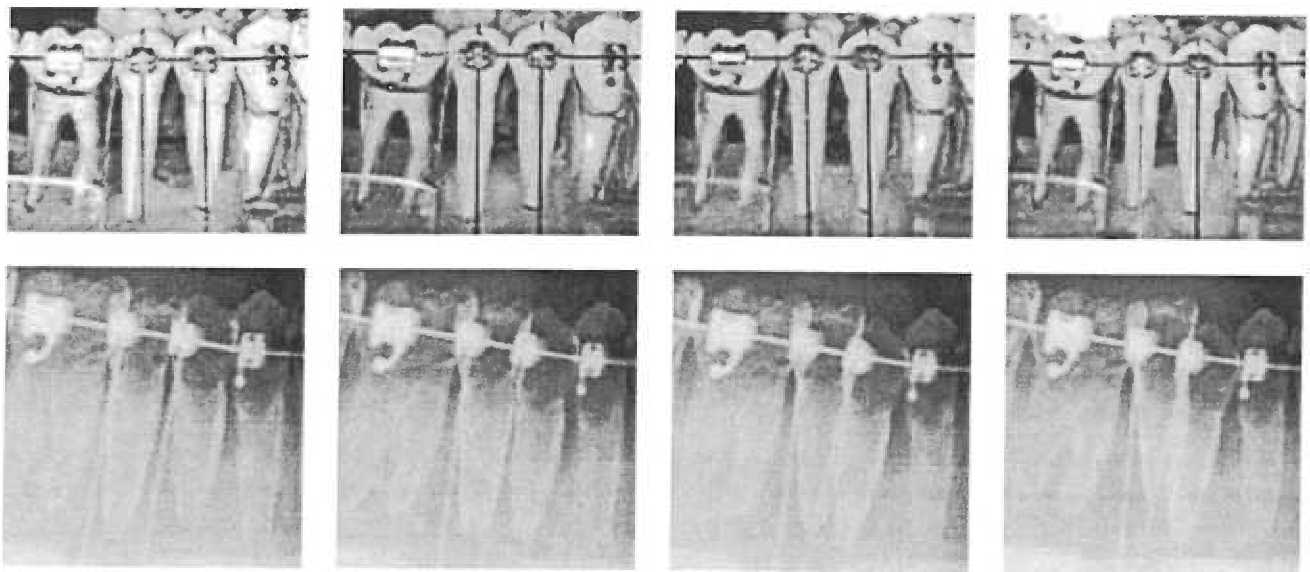


Fig 15. Graph of UR 5 (BRT), UR 2 (BRT), UL 2 (LRT) and UL 5 (LRT) after the three torque adjustments

a.

b.



c. baseline | 10 degrees 2.59mm | 20 degrees 2.08 mm | 30 degrees 1.79 mm

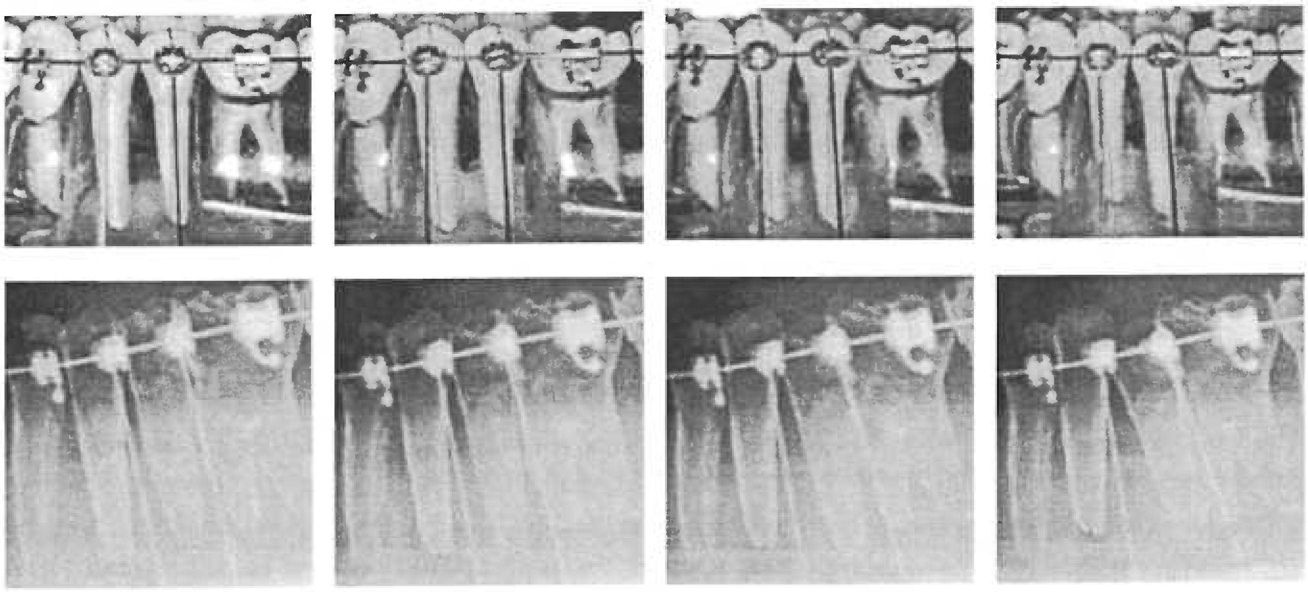
d. **Method error: .56 mm**

Fig 16. LR 4 (BRT) and LR 5 (LRT):

a. digital photographs
b. panoramic radiographs
c. millimeters of change between each adjustment
d. error of method

a.

b.



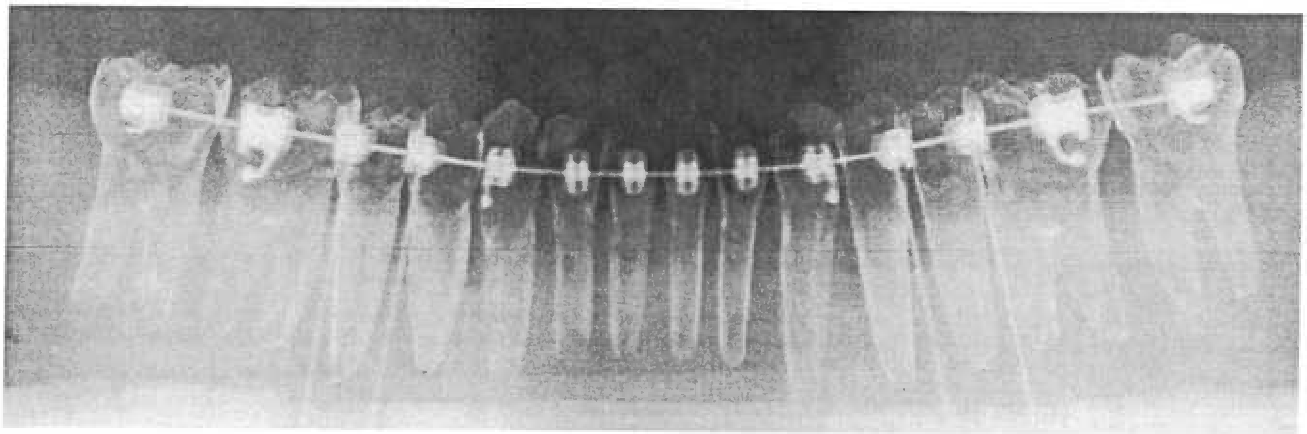
c.

baseline	10 degrees 1.08 mm	20 degrees 1.89 mm	30 degrees 2.09 mm

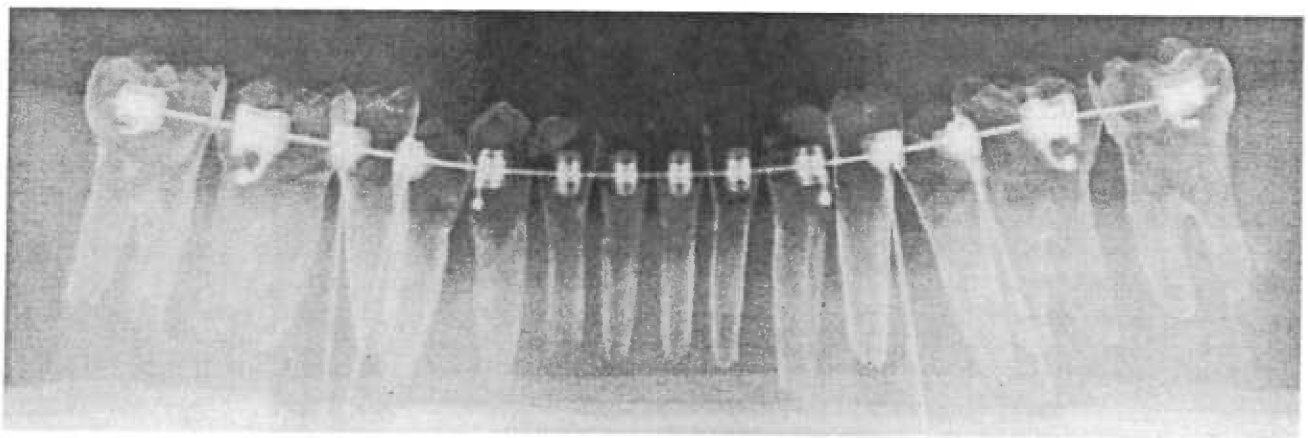
d. **Method error: .34 mm**

Fig 17. LL 4 (LRT) and LL 5 (BRT):

a. digital photographs
b. panoramic radiographs
c. millimeters of change between each adjustment
d. error of method



a.



b.

Fig 18. Panoramic radiograph of mandibular arch:

a. at baseline
b. at maximum torque adjustment (15 degrees)

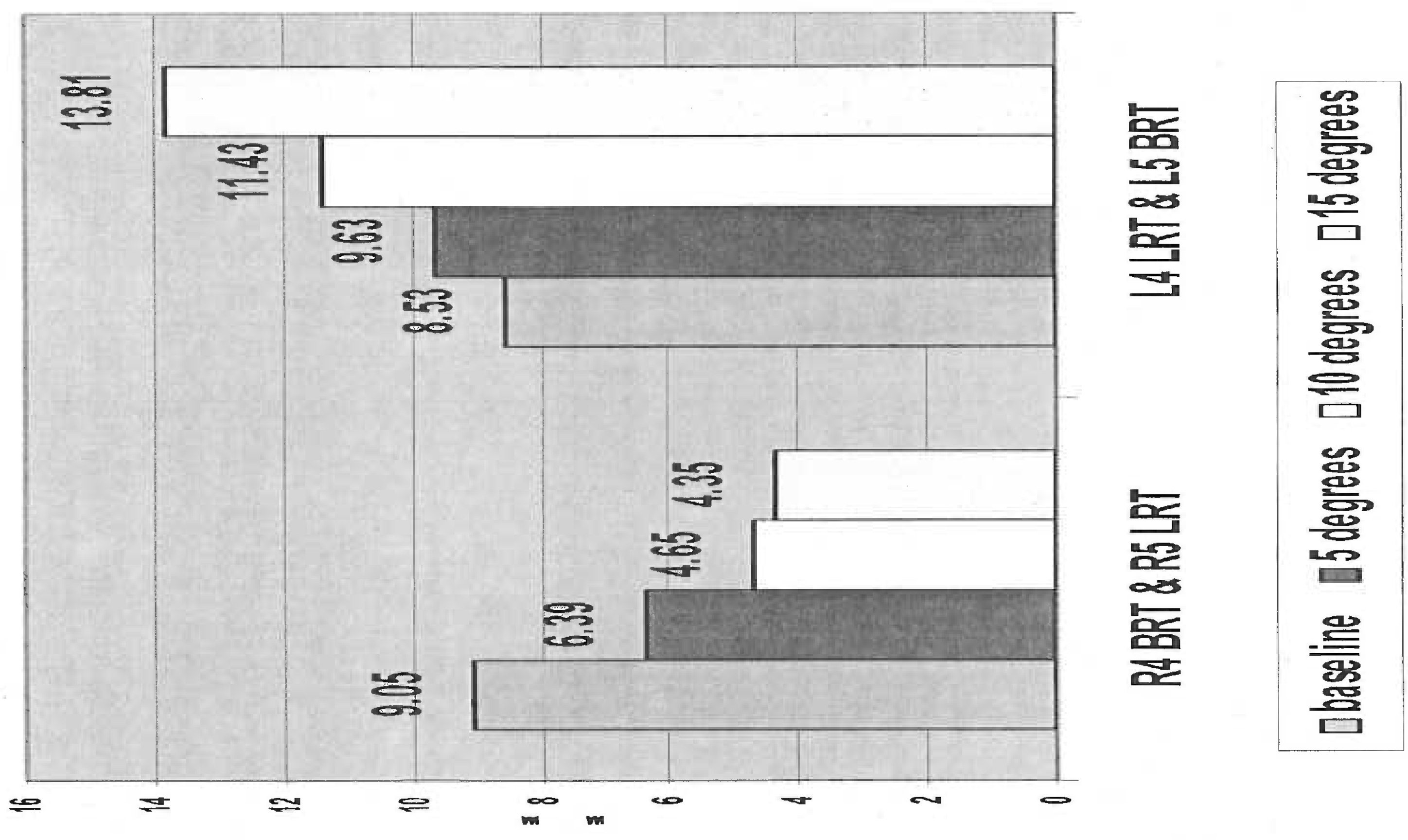


Fig 19. Graph of LR 4 (BRT) and LR 5 (LRT); LL 4 (LRT) and LL 5 (BRT) after the three torque adjustments

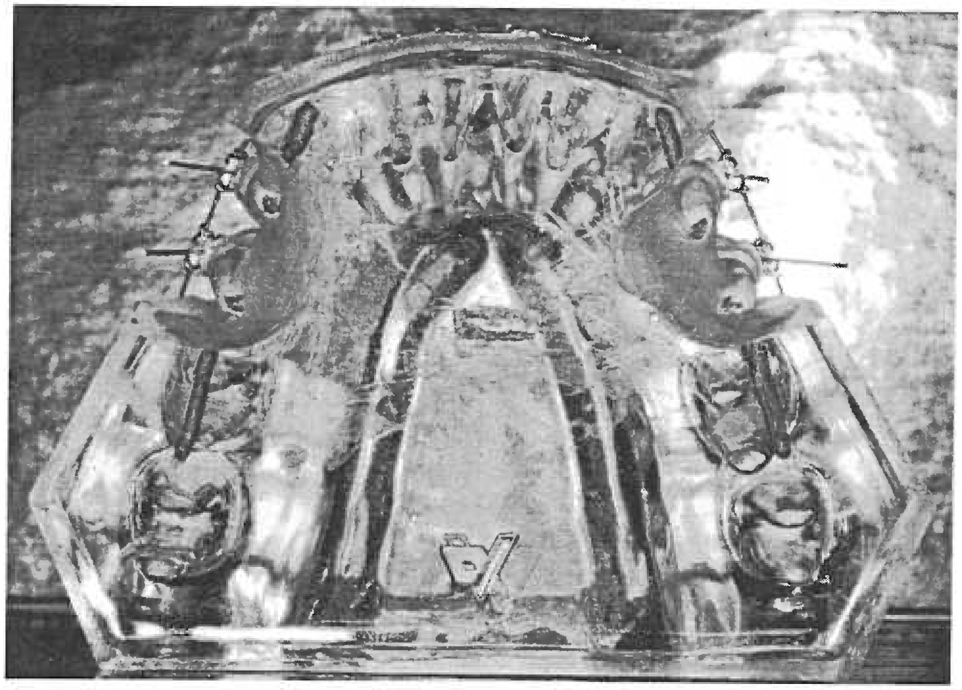


Fig 20. Digital photograph of mandibular premolars at baseline (apical view)

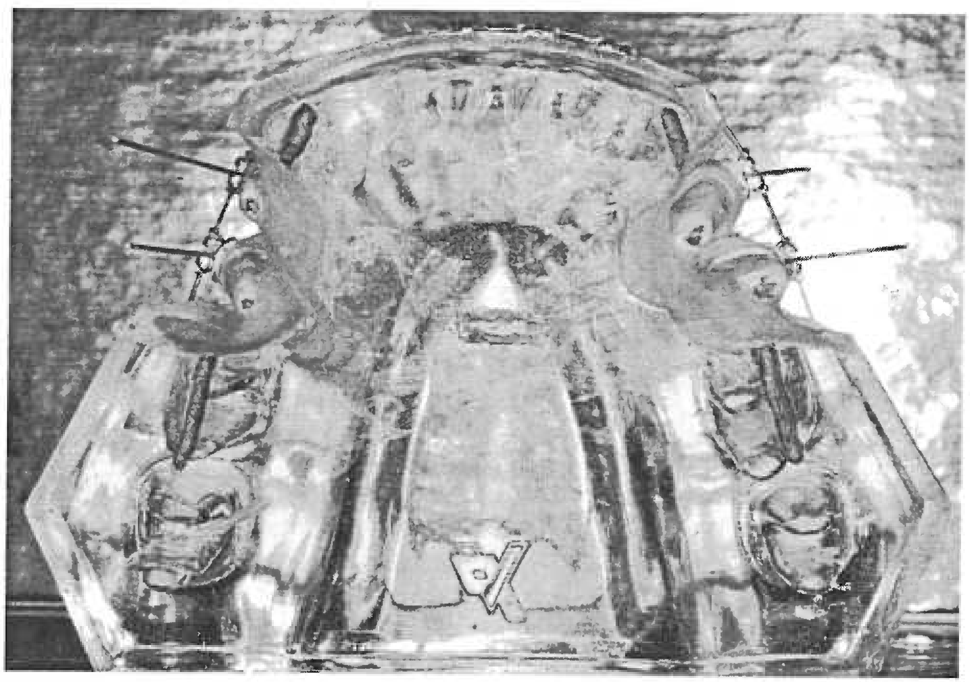


Fig 21. Digital photograph of mandibular 1st premolars and 2nd premolars at 5 degrees of change each in opposite directions (total of 10 degrees of change between the 1st and 2nd premolars)

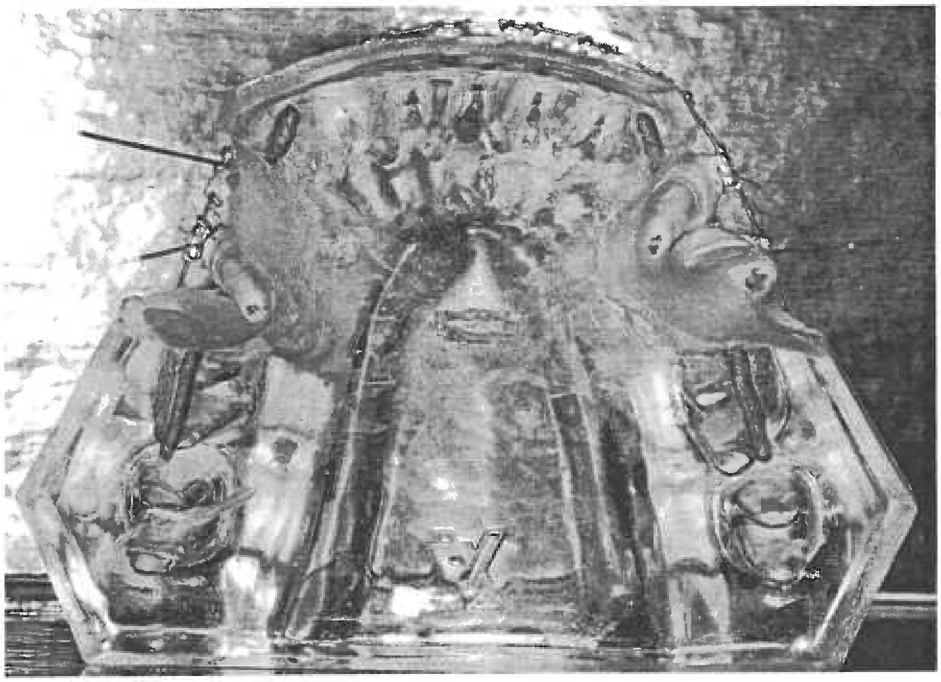


Fig 22. Digital photograph of mandibular 1st premolars and 2nd premolars at 10 degrees of change each in opposite directions (total of 20 degrees of change between the 1st and 2nd premolars)

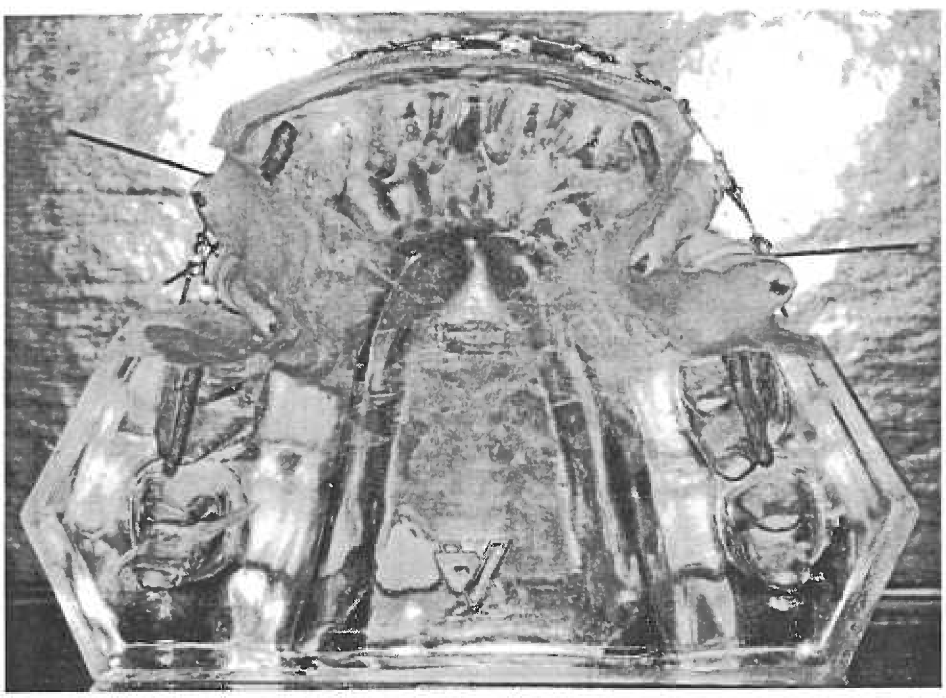


Fig 23. Digital photograph of mandibular 1st premolars and 2nd premolars at 15 degrees of change each in opposite directions (total of 30 degrees of change between the 1st and 2nd premolars)

Graphically, a common trend of either decreasing or increasing order was displayed depending on which root movement was achieved. This showed that as buccolingual root torque was applied incrementally, the mesiodistal distance between the teeth changed incrementally as well. Figure 15 shows the results in a graph for the maxillary test teeth. Reporting from right to left, the baseline measurement for the second premolar when measured against the first premolar was 6.35 mm. Buccal root torque was applied to the tooth in +5 degree increments 3 consecutive times, the new measurements each time an adjustment was made were 7.00 mm, 8.00 mm and 8.25 mm for a difference of 0.65 mm after the first adjustment, 1.00 mm after the second adjustment, and 0.25 mm after the third adjustment. The difference was calculated from one adjustment to the next adjustment and was not a cumulative change from baseline (Table 4). The total change from baseline to the third adjustment was 1.90 mm and the corresponding graph displayed an ascending order. The maxillary right lateral incisor had a baseline measurement of 9.60 mm as it was measured from the apex of the right central incisor. After applying +5 degrees of buccal root torque 3 consecutive times, the measurements were 9.62 mm, 9.71 mm and 9.77 mm for a change of 0.02 mm, 0.09 mm and 0.06 mm for the first, second and third adjustments respectively (Table 5). The graph displayed a slight ascending pattern as did the right second premolar when BRT was applied. There was a 0.17 mm total change from baseline to the last adjustment. On the left lateral incisor, lingual root torque was applied in the same manner and measurements were taken from the left central incisor. The measurements starting from baseline were 8.18 mm, 7.56 mm, 7.07 mm and 6.94 mm for a change of 0.62 mm, 0.49 mm and 0.13 mm for a total change of 1.24 mm (Table 6). The left second premolar had a baseline measurement of 5.52 mm and was obtained by measuring from the apex of the left first premolar. After lingual root torque was applied, the measurements were 4.52 mm, 4.16 mm and 2.67 mm. The change that occurred from the first, second and third adjustments were 1.00 mm, 0.36 mm and 1.49 mm for a total change of 2.85 mm (Table 7).

Maxillary right second premolar BRT	
Baseline 6.35 mm	
1st Δ	.65 mm
2nd Δ	1.00 mm
3rd Δ	.25 mm
Total Δ	1.90 mm

Table 4. Amount of change in millimeters after the 1st +5° BRT adjustment, 2nd +10° BRT adjustment, 3rd +15° BRT adjustment and total amount of change from baseline to 3rd adjustment.

Maxillary right lateral incisor BRT	
Baseline 9.60 mm	
1st Δ	.02 mm
2nd Δ	.09 mm
3rd Δ	.06 mm
Total Δ	.17 mm

Table 5. Amount of change in millimeters after the 1st +5° BRT adjustment, 2nd +10° BRT adjustment, 3rd +15° BRT adjustment and total amount of change from baseline to 3rd adjustment.

Maxillary left lateral incisor LRT	
Baseline 8.18 mm	
1^{st} Δ	.62 mm
2^{nd} Δ	.49 mm
3^{rd} Δ	.13 mm
Total Δ	1.24 mm

Table 6. Amount of change in millimeters after the 1^{st} -5° LRT adjustment, 2^{nd} -10° LRT adjustment, 3^{rd} -15° LRT adjustment and total amount of change from baseline to 3^{rd} adjustment.

Maxillary left second premolar LRT	
Baseline 5.52mm	
1^{st} Δ	1.00 mm
2^{nd} Δ	.36 mm
3^{rd} Δ	1.49 mm
Total Δ	2.85 mm

Table 7. Amount of change in millimeters after the 1^{st} -5° LRT adjustment, 2^{nd} -10° LRT adjustment, 3^{rd} -15° LRT adjustment and total amount of change from baseline to 3^{rd} adjustment.

The mandibular first and second premolars were examined next. When photographs and panoramic radiographs were taken of the torque adjustments, the maxillary test model was removed from the lower test model. The baseline measurement for the mandibular premolars on the right side was 8.80 mm when measured between the two apices. This measurement was used as the baseline for all tooth movements on the lower right side. Reporting from the right side of the arch to the left, lingual root torque was applied to the lower right second premolar in –5 degree increments. The graph displayed a descending pattern indicating that the root tips moved closer incrementally. By recalling that lingual root torque produces a distorted image of mesial root tip, it is understandable that the measurement between these two premolar apices would lessen because the apex of the second premolar was projected closer to the apex of the first premolar and appears to be converging apically. The measurements for the 3 torque changes were 7.76 mm, 6.47 mm and 5.09 mm for a difference of 1.04 mm, 1.29 mm and 1.38 mm after the first, second and third adjustment respectively. The total change was 3.71mm (Table 8). For the mandibular right first premolar, after applying buccal root torque in +5 degree increments 3 consecutive times, the new measurements were 7.76 mm, 6.47 mm and 5.09 mm for a difference of 1.95 mm after the first adjustment, 0.46 mm after the second adjustment and 0.27 mm after the third adjustment. The total change was 2.68 mm (Table 9). The corresponding graph displayed a descending order as well. When the two torque movements were combined, there was a larger measurement difference. Figure 19 is a graph of the results when the first and second premolars were adjusted simultaneously on each side. The measurements for the combined 3 torque adjustments were 6.21 mm, 4.13 mm and 2.34 mm for a difference of 2.59 mm, 2.08 mm and 1.79 mm. The total change was 6.46 mm (Table 12). The corresponding graph showed a descending pattern indicating that the distance between the apices decreased.

There were similar findings for the lower left premolars except that the measurements increased instead of decreasing. Also, the graphs showed an ascending pattern because the root apices appeared to be diverging apically or moving away from each other in the mesio-distal aspect which can be seen in figure 19. The baseline measurement between the premolar apices on the lower left side was 8.29 mm. After adding –5 degree lingual root torque incrementally in 3 consecutive movements, the measurements for the lower left first premolar were 9.42 mm, 10.65 mm and 12.69 mm for a difference of 1.13 mm, 1.23 mm and 2.04 mm for the first, second and third adjustments respectively. The total change was 4.40 mm (Table 10). Buccal root torque was applied to the lower left second premolar in +5 degree increments and the resulting measurements were 8.85 mm, 9.94 mm and 11.11 mm for a difference of .59 mm, 1.09 mm and 1.17 mm. The total change was 2.82 mm (Table 11). Figure 19 is a graph of the results when the first and second premolars were adjusted simultaneously on each side. When the two torque movements were combined, the measurements were 9.37 mm, 11.26 mm and 13.35 mm for a difference of 1.08 mm, 1.89 mm and 2.09 mm. The total change from baseline to the last adjustment was 5.06 mm (Table 13).

Mandibular right second premolar LRT	
Baseline 8.80 mm	
1st Δ	1.04 mm
2nd Δ	1.29 mm
3rd Δ	1.38 mm
Total Δ	3.71mm

Table 8. Amount of change in millimeters after the 1st -5° LRT adjustment, 2nd -10° LRT adjustment, 3rd -15° LRT adjustment and total amount of change from baseline to 3rd adjustment.

Mandibular right first premolar BRT	
Baseline 8.80 mm	
1st Δ	1.95 mm
2nd Δ	.46 mm
3rd Δ	.27 mm
Total Δ	2.68 mm

Table 9. Amount of change in millimeters after the 1st +5° LRT adjustment, 2nd +10° LRT adjustment, 3rd +15° LRT adjustment and total amount of change from baseline to 3rd adjustment.

Mandibular left first premolar LRT	
Baseline 8.29 mm	
1^{st} Δ	1.13 mm
2^{nd} Δ	1.23 mm
3^{rd} Δ	2.04 mm
Total Δ	4.40 mm

Table 10. Amount of change in millimeters after the 1^{st} -5° LRT adjustment, 2^{nd} -10° LRT adjustment, 3^{rd} -15° LRT adjustment and total amount of change from baseline to 3^{rd} adjustment.

Mandibular left second premolar BRT	
Baseline 8.29 mm	
1^{st} Δ	.56 mm
2^{nd} Δ	1.09 mm
3^{rd} Δ	1.17 mm
Total Δ	2.82 mm

Table 11. Amount of change in millimeters after the 1^{st} +5° LRT adjustment, 2^{nd} +10° LRT adjustment, 3^{rd} +15° LRT adjustment and total amount of change from baseline to 3^{rd} adjustment.

Mandibular R4 BRT & R5 LRT	
Baseline 8.80 mm	
1st Δ	2.59 mm
2nd Δ	2.08 mm
3rd Δ	1.79 mm
Total Δ	6.46 mm

Table 12. Amount of change in millimeters after the 1st combined 10 ° torque adjustment, 2nd combined 20° torque adjustment, 3rd combined 30° torque adjustment and total amount of change from baseline to 3rd adjustment.

Mandibular L4 LRT & R5 BRT	
Baseline 8.29 mm	
1st Δ	1.08 mm
2nd Δ	1.89mm
3rd Δ	2.09 mm
Total Δ	5.06 mm

Table 13. Amount of change in millimeters after the 1st combined 10 ° torque adjustment, 2nd combined 20° torque adjustment, 3rd combined 30° torque adjustment and total amount of change from baseline to 3rd adjustment.

A comparison of values and graphs showed that lingual root torque produced a greater change in the mesiodistal image on the panoramic radiograph. The amount of total change produced in every tooth that was given lingual root torque exceeded that of its contralateral side, which was given buccal root torque. A comparison of the total change between teeth with lingual root torque versus buccal root torque can be found in Table 14. A possible explanation for the greater measurement when lingual root torque is applied may be due to magnification of the roots in the horizontal dimension as they are positioned lingually to the central image layer of the panoramic x-ray machine and closer to the center of rotation of the x-ray beam. Also, when the values of the maxillary second premolars were compared with the values of the mandibular second premolars, it appears that a greater amount of distortion occurs in the mandibular second premolars than in the maxillary second premolars.

Lingual Root Torque		VS	Buccal Root Torque	
Tooth	**Total Change**	vs	**Tooth**	**Total Change**
Max L 2	1.24 mm	vs	**Max R2**	0.17 mm
Max L5	2.85 mm	vs	**Max R5**	1.90 mm
Mand L4	4.40 mm	vs	**Mand R4**	2.68 mm
Mand R5	3.71 mm	vs	**Mand L5**	2.82 mm

Table 14. Comparison of total change between teeth with LRT and BRT

Discussion

According to the ABO Objective Grading System (Casko et al, 1998), the heights of the buccal and lingual cusps of the maxillary and mandibular molars and premolars should be level or near level. In attempting to accomplish this, these teeth are subjected to buccolingual torque. When buccolingual torque is applied, this could result in unparallel roots in the transverse dimension. The results of this study showed that when buccolingual torque was applied to the test teeth, distortion was produced on the panoramic radiograph that appeared as though mesiodistal angulation or tipping was present and the resultant image was of unparallel roots in the mesiodistal direction. Mesial or distal angulation or tipping bends applied to the teeth would be an improper decision to correct the issue of this root proximity as seen on the panoramic radiograph. The correction to this problem should be adjustment in buccal or lingual torque. However, it is difficult to determine which of the two is the real problem or if it is a combination of angulation and torque issues. Unfortunately there is no sure way of determining this.

In the current study, the mesiodistal angulation of the roots tended to increase as more buccal or lingual root torque was applied. This supports the results found in the study by Lucchesi and colleagues (1988) where they also found that the panoramic radiograph accentuated mesiodistal pin angulation at increased levels of lingual crown torque. Some differences existed between the current study and the Lucchesi and colleagues' study. In the current study, anatomic teeth were used instead of stainless steel pins. Using anatomic teeth was important because it has been established that placing an object lingual to the central image layer produces horizontal magnification (Langland et al, 1989; White and Pharoah, 2004). This study demonstrated this fact when it was shown that the teeth subjected to LRT had a greater measurement change in the mesiodistal dimension than the teeth that were subjected to BRT. As the root was displaced lingually and out of the central image layer, the teeth were magnified horizontally, causing the location of the apex to become further displaced. Also, the current study used a typodont model with a U-shaped archform similar to a preformed U-shaped archwire that is available from various companies. The study by Lucchesi and colleagues placed the pins in a straight line on both sides and did not consider arch width or form.

The results of the current study also support the results of the study by Samawi and Burke (1984). They also found that buccolingual torque produces a mesiodistal angular change on the panoramic radiograph. Their study however did not adjust individual teeth. To apply torque, the entire wire mesh model was tilted instead of actually manipulating the teeth as it was done in the current study. Also, their study used lead shots to simulate teeth and the current study used anatomic teeth. Not much consideration was placed in positioning the teeth accurately in their axial relationships. This would be important due to the limited width of the central image layer and distortions that can be produced when an object deviates from it (White and Pharoah, 2004).

An interesting observation was made from the images seen on the panoramic radiographs that might be an indication that there could be related distortion issues with the root image. When the bracket position on the panoramic radiograph was compared with its position clinically, they did not correspond. Although clinically they were centered mesiodistally, the panoramic radiograph produced a distorted image with the brackets being positioned to the distofacial surface of the crown. No conclusion can be drawn from this study but future research can examine how different arch forms can affect the bracket positions and how buccolingual torque is affected on various teeth. This would be valuable to research since different panoramic machines have different focal trough sizes and shapes and different central image layer widths.

Future research could also examine how torque changes are affected on panoramic radiographs when combined with various improper patient positioning factors. Perhaps by adding additional variables such as improper head positioning in different dimensions, the radiographic distortion could be more exaggerated. Further research could also be done on quantifying how much root torque would produce a specified amount of root tip on the panoramic image. In order to do this, a more controlled method of moving the teeth would need to be developed as well as a more precise way of measuring. Another factor to consider is the magnification that is produced on panoramic radiographs. A 30% magnification factor would need to be corrected for to make any clinical comparisons. Another topic for future research can exam how different arch forms affect mesiodistal angulation when torque changes are applied.

A limitation to this study was that a small amount of slop or additional movement was present in the mesiodistal dimension. This was due to the extra space remaining when the .018 round wire was placed in the .022 x .025 bracket slot. This limitation was controlled to a certain degree by being able to clearly visualize the final placement of the roots in the typodont test model. Also, the error of method analysis showed that the ability to make torque adjustments and to record a measurement of change on the panoramic radiograph was relatively accurate. Another limitation in this study was that this study only examined the effects of how one panoramic machine produced distortion effects when torque adjustments were applied. Therefore, the results cannot be generalized to say that all panoramic machines produce the same distortion effects and to what degree. However, in a study by Mckee and associates (2002), it was found that the principles of how four panoramic machines function was similar. It was shown that similar inherent distortion trends existed in the four panoramic machines that were studied using the same typodont model used in this study. The degree of distortion was different from one machine to another but similar distortion trends existed. The degree of distortion might be dependent on the different magnification factor that exists, which ranges from 19% to 30% depending on the machine manufacturer (Langland et al, 1989). If the magnification is greater, the distortion may be exaggerated more.

A clinical observation that requires discussion is the vertical discrepancy of the adjusted teeth that is seen on the digital photographs. When buccal root torque was added to the specified teeth, that tooth was rotated to a lower level in the occlusal plane or more apically. Conversely, as lingual root torque was added, the tooth was rotated to a higher level in the occlusal plane or more coronally. In a clinical situation, these teeth would be adjusted for accordingly in the vertical dimension. However, it was decided that vertical adjustments would only add another undesired variable to the test teeth that could potentially distort their positions. Another observation made was that all test teeth showed some degree of foreshortening or elongation as lingual root torque or buccal root torque was applied respectively but it was not measured in this study.

Conclusion

While the panoramic radiograph is considered to be a convenient method to assess root parallelism, it is up to the discretion of the orthodontist to make clinical judgments based on what is seen on the panoramic radiograph and what is seen in the mouth. It has been shown in previous studies as well as the current one that images may not appear as they actually are for various reasons. An example of this is shown in Fig 24. It was found in this study that when lingual root torque is present, the root of that tooth appears to have mesial root tip and the apex is positioned closer to the root of the tooth anterior to it. Conversely, when buccal root torque is present, the root of that tooth appears to have more distal root tip and the apex appears farther away from the root of the tooth anterior to it. Also, lingual crown torque produces a magnified image in the horizontal dimension which causes a more exaggerated tipping appearance in the image.

Too often panoramic radiographs are interpreted incorrectly due to the fact that it is a two dimensional image of a three dimensional structure. It would seem logical to place mesial or distal angulation bends to create the appearance of parallel roots when a panoramic radiograph shows evidence of closely approximating roots. Unfortunately, torque considerations are often overlooked because it is difficult to see evidence of torque problems on a panoramic radiograph as well as clinically. Radiographically, a suggestion can be made to compare pre-treatment radiographs to the current panoramic radiograph in question. If the tooth in question was positioned correctly to start, a comparison can be made to see if the current panoramic radiograph shows any alterations in root length or width. If there is a difference, there should be thoughts of possible distortion and misrepresentation of the true position of the tooth. However, if this is inconclusive, supplemental radiographs can also be taken such as periapical or lateral oblique radiographs. Another option that has recently become available is to take a multiplanar, three dimensional image using Cone Beam Volumetric Tomography, but accessibility to this type of imaging is currently limited. There should also be a careful clinical evaluation. Clinically, root alignment can be assessed by examining the position of the crown tips, examining marginal ridge discrepancies, palpating root prominence and examining buccal and lingual cusp heights. The pre-treatment casts can also be utilized to make comparisons of tooth anatomy and position but only if the tooth in question was in proper alignment to start.

When it comes time to examine root parallelism during treatment, it is important to consider torque as a possible treatment option, especially when the panoramic radiograph shows that the roots are not parallel. If the doctor is unaware of the consequences that are created by excessive buccal or lingual torque, the panoramic radiograph may be interpreted incorrectly and improper adjustments could be made to the teeth. Due to the unreliability of dimensional measurements on panoramic radiographs, it is recommended that the doctor carefully evaluate the teeth clinically and refer to supplemental resources such as periapical radiographs, lateral oblique radiographs or possibly newly developing 3D imaging as needed before any adjustments are made to the teeth.

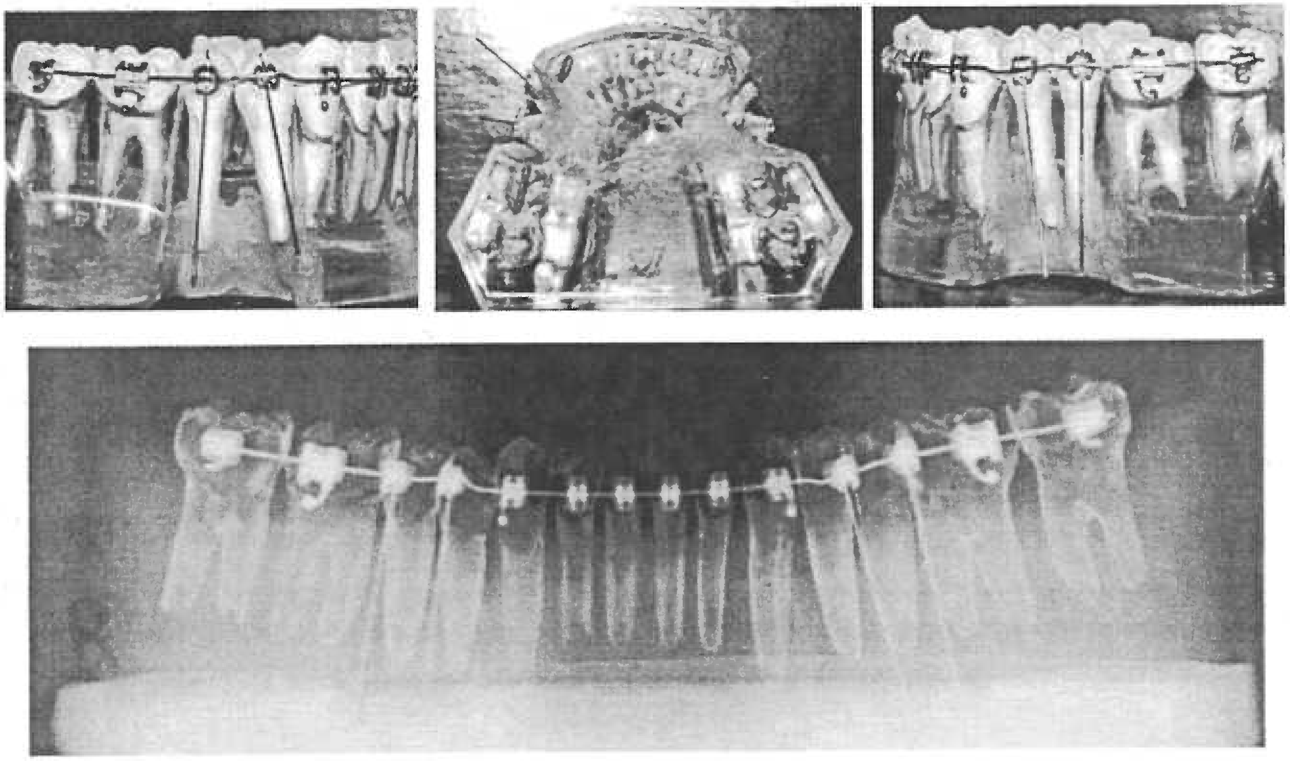


Fig 24. Example of distortion displayed on panoramic radiographs. Digital photographs of mandibular first premolars with unparallel roots and the corresponding panoramic radiograph showing parallel roots.

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