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Original article

Tooth angulation and dental arch perimeter-the effect of orthodontic bracket prescription

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Summary

Objective: The aim of this study was to evaluate the effects of upper incisors and canine angulations introduced by different bracket prescriptions on dental arch perimeter.

Materials and methods: Cone beam computerized tomography scans collected using I-Cat (Imaging Sciences International, Hatfield, PA, USA) were selected conveniently from a database of routine exams of a clinical radiology center. Crown and radicular measurements of upper incisors and canines were made and exported to the Autocad 2011 software to create a virtual dental model. The virtual teeth were positioned with an angulation of zero; thereafter, a reference value for the perimeter of the arch was measured. Furthermore, teeth angulations were applied according to the standards of the Edgewise bracket system and the Straight-wire systems: MBT, Capelozza, Andrews, and Roth. The largest linear distances for tooth crown (anterior arch perimeter) and root (radicular distance) were obtained for each bracket prescription.

Results: The anterior perimeter for well-aligned incisors and canines without angulation was used as reference (crown: 47.34 mm; root: 39.13 mm). An increase in the arch perimeter was obtained for all bracket prescriptions evaluated, which ranged from 0.28 and 3.19 mm in the Edgewise technique, for the crown and root measurements, respectively, to 1.09 and 11.28 mm for the Roth prescription.

Conclusion: Bracket prescriptions with greater angulation led to an increased use of space within the dental arch, mainly in the radicular region. The consequence of this radicular angular displacement will need to be further investigated.

Introduction

Angle developed the fixed orthodontic appliance that became known as the Edgewise appliance (1). In this system, tooth angulations of 3 degrees were established in the upper central and lateral incisors, while angulations of 5 degrees were established in the upper canines. In 1972, Andrews developed the Straight-wire appliance, in which pre-adjusted orthodontic brackets have in-built torque, tip and in-out prescriptions that are optimized for average cases (2, 3). In comparison to the original standard Edgewise technique, Andrews' system results in an increased tooth angulation.

Several additional Straight-wire bracket prescriptions have since been developed. Roth modified Andrews' original prescription into a more widespread form, the fully adjustable second-generation type (4). In his system, Roth increased the angulation of upper canines to 13 degrees.

There are argumentations that the changes introduced by the Roth system produced undesirable effects because increased angulation of canines promotes anchorage loss. Furthermore, we frequently observe a proximity between the roots of canines and first premolars on radiographs (5). Thus, MBT released the versatile unit, and the angle was decreased to 4 degrees in the upper central incisors and to 8 degrees in the upper lateral incisors and upper canines. Capelozza questioned the use of an upper canine angulation of 11 degrees, reporting that it was not unusual that bends or rebonds be required to compensate for excessive angulation (6). Thus, he suggested that the angle values for the upper incisors should be equal to Andrews' original values and decreased the angle values of the upper canines to 8 degrees. The goal of these adjustments was to promote a more appropriate relationship between the roots of the canines and the first premolars.

Despite the great variation in the bracket characteristics of each prescription, few studies have examined the effects that such variations have on dental arch morphology, particularly on dental arch perimeter. Theoretically, an increase in the angulation of approximately rectangular teeth should increase the space requirements, leading perhaps to an increased need for extractions in borderline cases. Information on the effects of increased angulation on the root area is also lacking.

The aim of this study was to evaluate the effects of upper incisor and canine angulations introduced by standard Edgewise orthodontic brackets and by four Straight-wire bracket prescriptions (Andrews, Capelozza, Roth, and MBT) on dental arch perimeter.

Materials and methods

The study was accepted and approved by the research ethics committee of Federal University of Para, under protocol number 442.089.

A virtual dental model was conceived to represent real anterior dentition, built from the average dental dimensions of men and women. In order to construct the virtual dental model using the AUTOCAD 2011 software, cone beam computerized tomography (CBCT) scans of 31 patients (15 males and 16 females) selected, with a mean age of 23.4 years. The CBCT scans were collected using I-Cat Classic (Imaging Sciences International, Hatfield, PA, USA), configured with 5 mA, 120 kV, field of view from 6 × 16 cm and basic voxel size of 0.25 mm, and selected conveniently from a database of pre-existing exams for single dental implant in the posterior region of the upper dental arch at a dental radiology clinic. Thus, no CBCT scan was taken in order to carry out this work. It is important to state that the ALARA principle and www.sedentexCT.eu guidelines have been adhered to.

The inclusion criteria were adult patients with fully erupted anterior teeth and closed apex. The exclusion criteria were syndromic patients, anterior tooth loss, upper tooth loss, restorations or tooth wear, presence of prosthodontic rehabilitation in the anterior region of dental arch, and previous orthodontic treatment.

Measurements of teeth of CBCT scans were performed using I-CAT vision software and were obtained from the upper right central incisor (U1R), the upper right lateral incisor (U2R), and the upper right canine (U3R) of each patient. The following parameters were examined: the width of the tooth crown on its incisal, middle, and cervical thirds and the clinical crown height that were measured with a coronal slice with an increase of 7 mm in thickness to measure the entire crown. The radicular width in its cervical and middle thirds were measured with an axial slice, in which the greater mesiodistal diameter was measured, and inciso-apical radicular length, measured in a sagittal view, seeking the greatest inciso-apical length. All measurements were made using the tool 'distance', which provided the value in millimetres (Figure 1). The values for the left hemiarch were replicated from the right hemiarch.

All measurements were performed by the same, previously calibrated operator. To avoid inflation of type I error (false positive), that occurs when it reaches a result that is statistically significant when in fact it happened by chance, 10 random measurements of the sample were performed and repeated after a 15-day interval to evaluate random and systematic errors. The random error was obtained using the Dahlberg formula, and the systematic error was evaluated using the paired Student t-test at $P < 0.05$.

Virtual dental models have been developed using the AUTOCAD 2011 software (Autodesk Inc., San Rafael, CA, USA) taking into consideration the size and shape of the six anterior teeth using data measurements obtained from the width of the tooth crown on its incisal, middle, and cervical thirds, and the radicular width in its cervical and middle thirds, the clinical crown height and inciso-apical radicular length (Figure 1). First we built the central incisor, using data obtained from the previous measurements. We drew a vertical line that would become the inciso-apical tooth length. This length was divided into two unequal parts according to the average measurements obtained: the smaller part of the length was designated to be the crown and the greater part was designated to be the root length. After that, in the region that would become the dental crown, three horizontal lines were drawn, respecting the values previously obtained for the incisal, middle, and cervical thirds. Finally, in the region of the tooth root, two horizontal lines with values of the cervical and middle thirds were inserted. The apex of the tooth was marked on the length from the incisal-apical distance. Then, those lines were linked in order to provide the anatomic contour of the central incisors. This procedure was repeated for the virtual construction of the lateral incisors and canines. The labial axis point

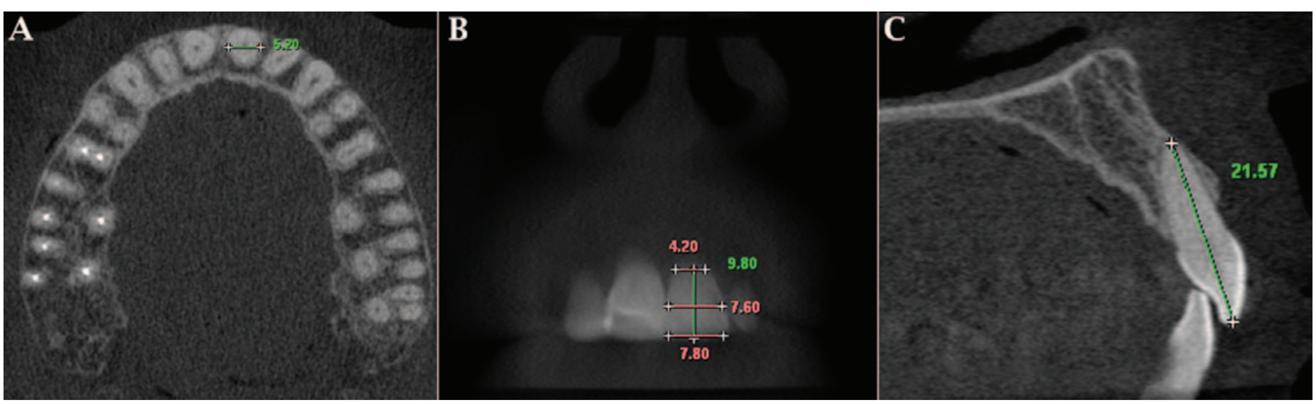

Figure 1. (A) The axial view of the cone beam computerized tomography scan was used to measure the radicular width in its cervical and middle thirds. (B) The coronal slice view was used to measure the width of the tooth crown on its incisal, middle, and cervical thirds and the clinical crown height. (C) The inciso-apical radicular length was measured in a sagittal view.

of each tooth was marked and the dental units were levelled in the Andrews plane (Figure 2).

The teeth were positioned with an angulation of zero, and a reference value for the perimeter of the arch was measured (Figure 2). Measurements of the distance between the left and right upper canines at the level of the root apex and of the greatest distance between the distal surfaces of left and right canines were obtained using the tool 'Linear Dimension'. Using the tool 'Rotation' in the AUTOCAD, tooth angulations were applied according to the standards of the Edgewise bracket system (U1 = 3 degrees, U2 = 3 degrees, U3 = 5 degrees) and the various Straight-wire systems: MBT (4 , 8, and 8 degrees); Capelozza (5, 9, and 8 degrees); Andrews (5, 9, and 11 degrees), and Roth (5, 9, and 13 degrees). The largest linear distances for tooth crown (anterior arch perimeter) and root (radicular distance) were obtained for each bracket prescription.

Results

The random error was small, ranging from 0.22 to 0.89 mm. CBCT measurement is very precise and random error is very small, overall less than 0.4 mm (Table 1). However, for two measurements, the cervical third of the crown (P = 0.02) and the middle third of the root (P = 0.03) were found to have systematic errors. This might happen because statistical analysis for paired data is able to detect even small differences between the two moments, mainly when several measurements are compared using a paired t-test, without α-adjustment. For each patient we obtained 20 measurements, so to replicate them would increase error measurement. This is one more reason for not including all patients.

Overall standard deviation was very small for each variable, around 10% of the mean. The sample size of 31 subjects gave us 80% of power to detect 0.25 mm of difference, the human eye resolution (7).

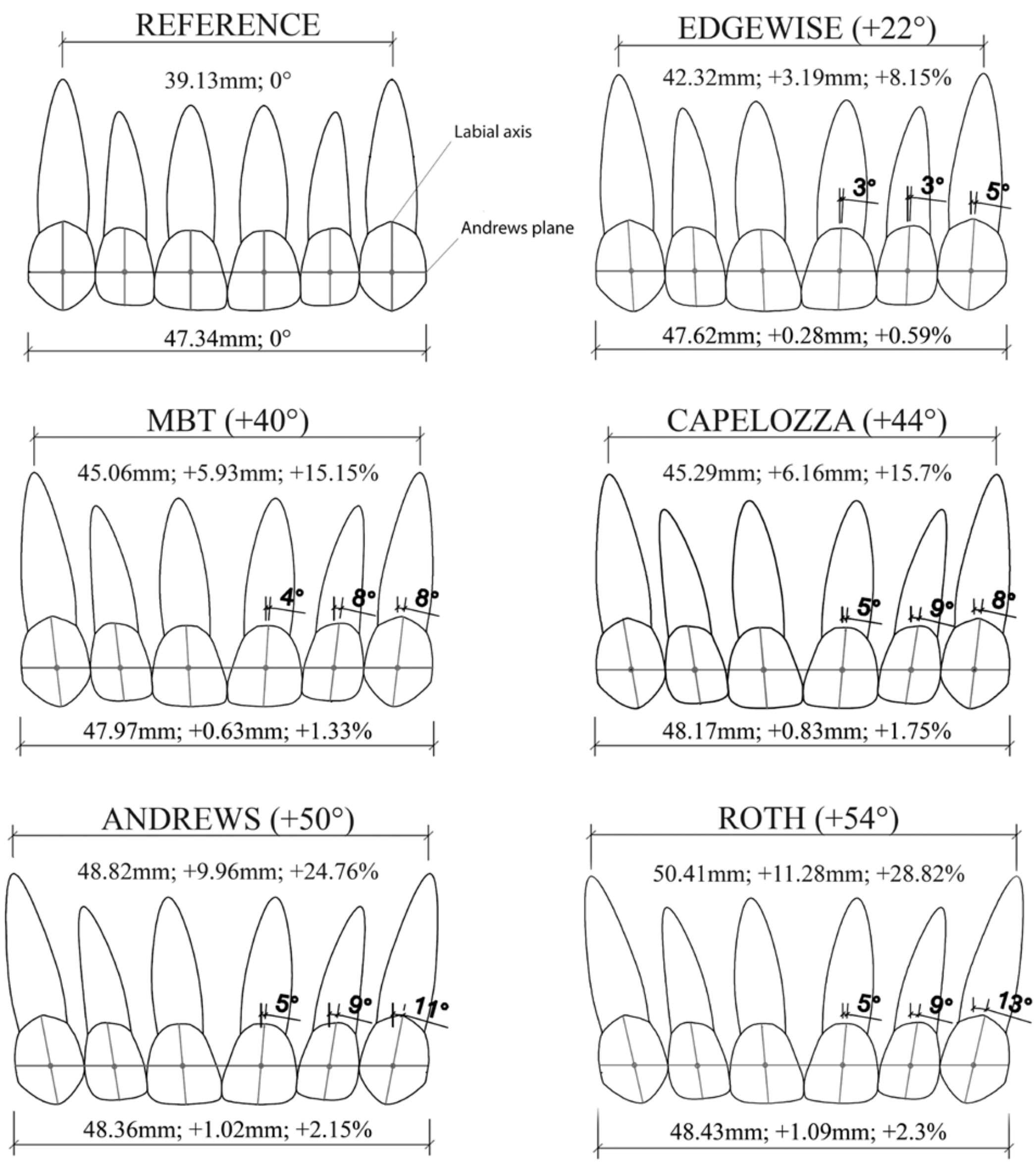

Figure 2. Virtual dental model, built in the AUTOCAD software. The upper anterior teeth with no angulation was used as reference value. The influence of upper incisor and canine angulations required by the various prescriptions on the arch perimeter at the crown and the root levels was evaluated. The values shown refer to the angulation in degrees, and the absolute and relative (per cent) increase in millimetres compared to the standard reference value of 0 degrees (no angulation).

Table 1. Mean standard deviations for the measurements of the upper right central incisors (U1R), the upper right lateral incisors (U2R), and the upper right canines (3R), according to random error (Dahlberg) and systematic error (*t*-tests) calculations.

	Descriptive values (n = 31)		Error analysis (n = 10)	
Tooth size	Mean	Standard deviation	Random	*P* value
U1R				
Crown				
Incisal third	7.89	0.71	0.33	0.31
Middle third	8.68	0.98	0.22	0.93
Cervical third	5.52	0.95	0.45	0.69
Root				
Cervical third	6.08	0.70	0.38	0.19
Middle third	5.15	0.68	0.45	0.07
Crown height	9.10	0.85	0.39	0.99
Inciso-apical root	24.29	1.51	0.43	0.29
U2R				
Crown				
Incisal third	5.65	0.71	0.39	0.23
Middle third	6.99	0.57	0.24	0.34
Cervical third	4.08	0.64	0.43	0.57
Root				
Cervical third	4.95	0.57	0.32	0.63
Middle third	4.23	0.65	0.47	0.03*
Crown height	7.94	0.70	0.48	0.08
Inciso-apical root	23.01	1.38	0.30	0.57
U3R				
Crown				
Middle third	8.11	0.63	0.25	0.11
Cervical third	5.68	0.72	0.89	0.21
Root				
Cervical third	5.96	0.56	0.37	0.02*
Middle third	5.24	0.68	0.47	0.06
Crown height	9.11	1.02	0.36	0.17
Inciso-apical root	27.44	1.85	0.36	0.47

*$P \leq 0.05$.

The anterior arch perimeter with zero angulation was used as a reference. For this reference model, the value of a 3-3 at crown level was 47.34 and 39.13 mm for the largest distances between the root apices of the canines. The values obtained for the coronary perimeter are described in Figure 2. Compared to the reference value obtained from the crown perimeter, there was an increase of 0.28 mm for the Edgewise brackets, 0.63 mm for the MBT brackets, 0.83 mm for the Capelozza brackets, 1.02 mm for the Andrews brackets, and 1.09 mm for the Roth brackets. Compared to the reference values obtained in the radicular area (Figure 2), there was an increase of 3.19 mm for the Edgewise brackets, 5.93 mm for the MBT brackets, 6.16 mm for the Capelozza brackets, 9.69 mm for the Andrews brackets, and 11.28 for the Roth brackets.

Discussion

Brackets angulation employed on each different technique produces a specific position to the tooth and should be taken into consideration in clinical practice because in borderline cases, small changes in the perimeter of the arches can influence the orthodontic treatment plan.

The literature describes several methods to measure tooth angulation using panoramic radiographs (8, 9) dental casts (10) and images obtained from them (11), virtual models (12), and CT scans (9, 13, 14). Panoramic projections are commonly used, but tend to magnify and distort the final image. The resulting increases in the horizontal and vertical dimensions vary according to the location and depth of the object (15). Exams performed with CBCT cause less radiation exposure than standard medical scans and provide high-quality three-dimensional visual information that researchers can manipulate and use to obtain reliable measurements from any desired perspective (13, 14). However, it is necessary to remark that no CBCT scan was collected to this study, only. We have used images from a database of pre-existing CBCT exams for implant purpose.

The influence of the angulation of the upper central incisors angulation and inclination in length of the arch perimeter had been investigated previously (15), with the assumption that the teeth are rectangular in shape. Increases in angulation were found to be correlated with a higher consumption of space within the dental arch. The greater the height-to-width ratio of these teeth, the greater the circumference of the arch that was required to accommodate them.

In this study, CBCT scans were used to obtain actual dental dimensions for more accurate analysis. Here, increases in tooth angulation produced a mild increase in the perimeter of the anterior arch at the crown level; however, this increase was more significant in the radicular area. At the crown level, the smallest increase was 0.28 mm with the Edgewise standard, and the greatest increase was 1.09 mm with the Roth prescription. In the radicular area, the smallest increase was 3.19 mm with the Edgewise prescription and the greatest increase was 11.28 mm with the Roth prescription. These data confirm the previous results using virtual models (14), in which greater distal displacement of the root tips was observed when higher angulations were used. It is important to point out that the prescriptions for the used appliances were based on Andrews' analysis of 120 dental casts, so not enough attention has been given to the roots positions (16).

We noted that variations in the tipping of the six anterior upper teeth produce a direct effect arch length, such that arch length increases with increasing tooth angulation. These data corroborate Andrews' assessment of his own prescription (3). Andrews reported a 0.8-mm increase in arch perimeter at crown level with the maxillary incisor angulations as indicated in his model.

The interaction between inclination and angulation was previously evaluated (15). They reported that the lingual root torque associated with a distal angulation of 10 degrees reduces the lingual inclination by 1.5 per cent. However, they found that in most cases, the interaction between inclination and angulation is minimal.

The relationship between crown size and dental angulation could also affect arch length; however, our results show that the additional space required at the crown level when tooth angulation is increased is small. Of note, increases in tooth angulation should be evaluated with caution, given its possible effects on the root region. Indeed, increases in angulation could lead to excessive root divergence, which could in turn lead to an invasion of the maxillary sinus or other anatomical structures.

Excessive angulation may also be aesthetically displeasing (17, 18). Functionally, some degree of angulation is required to allow mandibular-guided movements that are required to optimally distribute forces. This means that the incisal edges of the incisors should be parallel to the occlusal plane during protrusion and the maxillary canines must be in contact with the mandibular teeth in lateral excursive movements (6, 15).

Since the time of Angle, the appropriate angulation of teeth following orthodontic treatment has been greatly debated (1). The importance of the final angulation within the dental arch has been even more evident with the introduction of newer Straight-wire techniques, which incorporate this information in the brackets to optimize both functional and aesthetic aspects of the overall occlusion.

Conclusion

The increases in tooth angulation that accompany Straight-wire bracket use cause mild increases in the anterior perimeter of the upper dental arch. However, prescriptions making use of higher bracket angulations cause a marked radicular divergence and space consumption within the root regions. The consequence of these changes and the resulting relationships between tooth roots and other anatomical structures should be further investigated.

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