

Anterior tooth morphology and its effect on torque

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SUMMARY This study was undertaken to determine the variation in crown–root angle (CRA) of the upper incisors and canines as well as the variation in their labial contour. In addition, the influence of the variability of the labial contour and of different bracket heights on torque was evaluated. Proximal radiographs were taken of 160 extracted maxillary teeth (81 incisors and 79 canines). They were digitized and analysed with Jasc® Paint Shop Pro 7™ and Mathcad 2001 Professional®. The incisal edge, the centre of the cemento-enamel junction (CEJ), and the root apex were digitized to define the crown and root long axis. For all teeth the CRA was measured. At several heights of the labial surface a tangent was determined, enabling measurement of the inclination of the labial surface.

The CRA had great variability, ranging from 167 to 195 degrees for the canines (mean value 183 degrees) and from 171 to 195 degrees for the incisors (average 184 degrees). The mean inclinations of the labial surfaces for the incisors varied greatly. Between 4 and 4.5 mm from the incisal edge the standard deviations (SD) were the smallest and between 2 and 4.5 mm from the incisal edge the labial surface angle differed by approximately 10 degrees. For the canines the mean inclinations of the buccal surface also varied. This angle differed by around 10 degrees between 2 and 4.5 mm from the incisal edge, but the SD were much larger than for the incisors.

It can be concluded that placement of a bracket on a tooth at varying heights, still within a clinically acceptable range, results in important differences in the amount of root torque.

Introduction

When Angle (1928) introduced the edgewise appliance, the final tooth position was achieved by the ligation of rectangular archwires into rectangular slots. Andrews (1976) recommended the use of the straightwire appliance, which used the same concept of rectangular archwires and slots but without the need to bend the wires. Therefore, for each tooth a bracket with specific torque and mesiodistal angulation needed to be manufactured. The Tip-Edge technique also used specific torque and angulations in the bases of the maxillary and mandibular brackets (Kesling, 1988).

Using pre-adjusted brackets, the position of the bracket on the crown determines the tooth's final tip, torque, height and rotation (Carlson and Johnson, 2001). According to some authors (Taylor and Cook, 1992; Creekmore and Kunik, 1993) the final tooth position lies within the bracket and is not dependent on archwire bending because of the bracket design. Only if the bracket is not placed correctly or the crown morphology does not correspond with that for which the bracket was developed, will the final tooth position not be optimal (Meyer and Nelson, 1978; Germane *et al.*, 1986; Balut *et al.*, 1992; Creekmore and Kunik, 1993).

All pre-angulated brackets have their own built-in torque, which differs for all brackets and varies between 12 and 22 degrees for the upper central incisors and between –4 and 7 degrees for the upper canines. This means that every clinician has their own specific perception of the right amount of torque for incisors and canines. To obtain their optimal final inclination, a prescribed bracket height has

been proposed. Those advised heights are different for each type of bracket (Alexander, 1983; Ricketts, 1984; Kesling, 1988; Bennett and McLaughlin, 1997), varying between 4.0 and 5.0 mm from the incisal edge for the incisors, and between 4.5 and 5.0 mm from the incisal edge for the canines. Taking into consideration that a clinician is able to bond brackets with an accuracy of 0.5 mm (Balut *et al.*, 1992; Taylor and Cook, 1992), the position of an upper incisor bracket may vary between 3.5 and 5.5 mm from the incisal edge and between 4.0 and 5.5 mm for the canines. Creekmore and Kunik (1993) suggested bonding brackets according to the overbite, can result in a difference in height of almost 1.0 mm. Muchitsch *et al.* (1990) proposed varying the bond height for canines by 0.5 mm depending on their incisal shape. All these suggestions will result in a different effect on the final torque of a tooth, because of a different vertical position.

In order to obtain good treatment results with pre-adjusted brackets without any wire bending, two conditions have to be fulfilled. Above all, the brackets have to be accurately placed in a specific position on the labial or buccal surface of each tooth, attempting to express the desired amount of torque and tip. This will only be the case when the tooth–crown morphology (tooth surface curvature and crown–root angle; CRA) is standardized (Bryant *et al.*, 1984). Therefore, some authors have suggested bending the wire to obtain a perfect final tooth position, even for pre-adjusted appliances (Balut *et al.*, 1992; Miethke, 1997; Miethke and Melsen, 1999). Differences in tooth

morphology may result in varying amounts of torque. According to the literature, however, a large variability in tooth morphology has to be taken into consideration. Wheeler (1984) found that the maxillary central incisors were the most consistent in their shape than any other teeth in the oral environment. However, variations in morphology among maxillary central incisors have been reported. Even a difference between the left and right teeth in the same patient can occur (Mavroskoufis and Ritchie, 1980). Germane *et al.* (1986) showed a significant variation in the buccal surface contour of canines and Chaushu *et al.* (2003) reported a variation in crown morphology of palatally and buccally displaced canines compared with a control group regarding their buccolingual and mesiodistal dimensions.

In addition, the CRA may limit the degree to which the roots can be torqued palatally due to an increased proximity of the roots to the palatal cortical plate of the alveolar process (Bryant *et al.*, 1984). Several studies on dental anatomy give the impression that the long axes of the crown and root are colinear, although illustrations of actual teeth typically refute this stereotype (Harris *et al.*, 1993). When the long axis of the root is drawn separately from the long axis of the crown, it is often noted that these two axes do not coincide (Bryant *et al.*, 1984). According to Taylor (1969), the relationship of the root to the crown varies considerably because both are subject to variations in curvature. Some investigators have found the CRA to vary by as much as 13 degrees (Carlsson and Rönnerman, 1973) or even more (Bryant *et al.*, 1984).

The aim of this investigation was to study the morphology of the maxillary central incisors and maxillary canines in order to determine the variation in CRA and the variability in the angle formed by a tangent at several heights on the labial or buccal surface of the crown and the long axis of the crown from a proximal view, both with respect to torque.

Materials and methods

In this study, 81 extracted maxillary central incisors and 79 maxillary canines obtained from the University Hospital of Ghent, Belgium, were randomly selected. Extraction of these teeth was carried out for different, non-traceable, reasons. Abraded teeth, as well as those with restorations, were excluded. Only upper central incisors and upper canines were used, because torque is primarily observed in the upper anterior region. The lateral incisor, although considered as having a comparable morphology as an upper central incisor (but smaller), was not included in this investigation. For each tooth, a standardized proximal radiograph was taken at a constant object to film distance. As a reference, a small piece of wire exactly 1 cm in length was also exposed on the film. The films were developed, magnified ($\times 3$), and digitized using Agfa ScanWise 1.2.0.5® (Mortsel, Belgium). The images were then traced in Jasc® Paint Shop Pro 7™ (Eden Prairie, USA) and the incisal edge, cemento-enamel junction (CEJ) and root apices were marked and used to define the crown and root long axis (Figure 1).

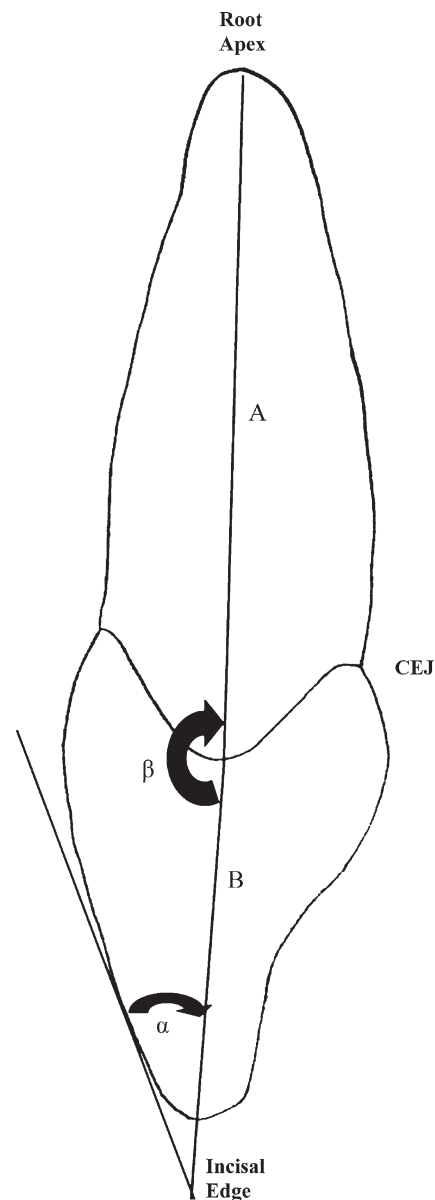


Figure 1 Tooth morphology variables. CEJ, cemento-enamel junction; A, root long axis; B, crown long axis; α , labial/buccal surface angle; β , crown-root angle.

The longitudinal axis of the root was defined as a line connecting the root apex and the midpoint of a line connecting the labial and lingual CEJ. The longitudinal axis of the crown was a line connecting the incisal edge and a line connecting the labial and lingual CEJ. The CRA was defined as the angle formed by the intersection of the longitudinal axis of the crown and the longitudinal axis of the root. The mean, standard deviation (SD) and range of these angles were calculated.

The labial surface curvature was defined as the angle between a tangent to the labial surface at different heights along this surface and the longitudinal axis of the crown. To define the labial surface curvature, several tangents at

different heights on the labial or buccal surface were determined. All images were edited in Jasc® Paint Shop Pro 7™. The histograms were stretched and filtered with a median filter, which made the outline clearer. The labial or buccal surface was transferred to Mathcad 2001 Professional® (Cambridge, UK), which calculated the curvature of the labial or buccal surface of the incisors and canines every 0.1 mm starting at 0.5 mm until 8 mm from the incisal edge. The mean, SD and range of the curvature of the labial or buccal surfaces were calculated.

Error of the method

The potential error in the tracing and measurement technique were estimated by randomly selecting 10 incisors and 10 canines and repeating the tracing and measuring procedures. Dahlberg's (1940) formula was used to assess the error of the method by carrying out these duplicate measurements. An error of $s = 0.4$ degrees was found for the labial surface angle of the incisors and $s = 0.7$ degrees for the buccal surface angle of the canines. The error for the CRA was $s = 0.4$ degrees for the incisors and $s = 0.3$ degrees for the canines.

Results

The CRA had a large variability. This angle for the maxillary central incisors ranged between 170.7 and 194.8 degrees, a spread of 24.1 degrees. A mean value of 183.9 degrees (SD ± 6.2) and a median value of 184.8 degrees were found. The upper canines showed a mean CRA value of 183.0 degrees (SD ± 6.2), ranging between 167.0 and 195.3 degrees. This was a spread of 28.3 degrees. The median was 184.0 degrees.

The average inclinations (± 1 SD) of the labial surface curvature of the incisors and the canines are shown in Figures 2 and 3, respectively. The values of these angles, formed by the tangent of the labial surfaces and the long axes of the crown, are presented in Table 1. Because most brackets are usually placed in an area between 2 and 6 mm from the incisal edge, this table is simplified and the angulations are given only for every 0.5 mm starting from 2 mm until 6 mm from the incisal edge.

The mean inclinations of the labial surface curvature for the incisors varied between 28.7 (± 3.3) and 11.6 (± 4.9) degrees. Between 4 and 4.5 mm from the incisal edge the SD were the smallest. At 4 mm from the incisal edge, the minimum of the curvature was 15.3 degrees and the maximum 26.6 degrees. At 4.5 mm from the incisal edge, the labial surface angle ranged between 12.3 and 24.9 degrees. Between 2 and 4.5 mm from the incisal edges the average labial surface angle differed by around 10 degrees.

For the canines the mean inclinations of the buccal surfaces varied between 30.0 (± 4.2) and 10.2 (± 7.9) degrees. The average buccal surface angle between 2 and 4.5 mm from the incisal edge of the canines also differed by around 10 degrees, but the SD were much larger than for the incisors.

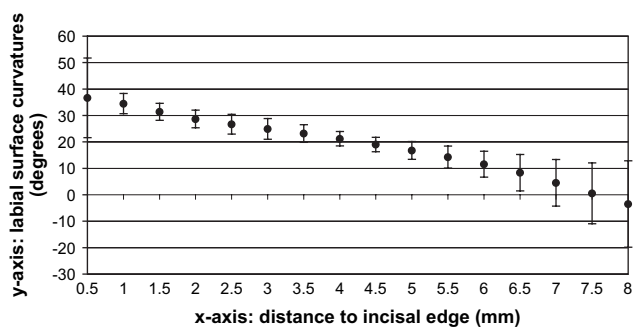


Figure 2 Labial surface curvature at different heights of the incisor crown (± 1 standard deviation).

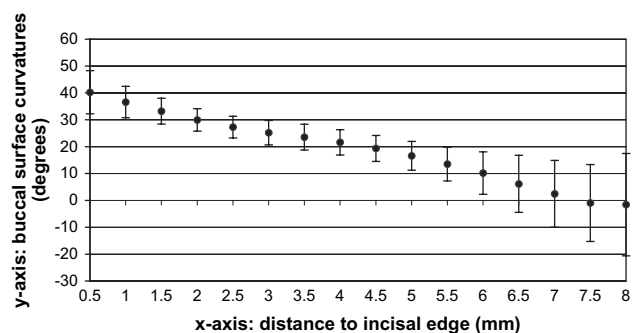


Figure 3 Buccal surface curvature at different heights of the canine crown (± 1 standard deviation).

Discussion

The shape, form and size of incisors and canines showed a wide variation. The difference between the minimum and maximum values of the CRA was more than 24 degrees for the incisors and more than 28 degrees for the canines. This range is higher than the values found in some other studies (Carlsson and Rönnerman, 1973; Bryant *et al.*, 1984), while others have reported approximately the same values (Germane *et al.*, 1986). During orthodontic treatment, the CRA is of major importance for final tooth position. Taking into consideration that a root, moved against the cortical plate, is at higher risk for root resorption, care should be taken to torque a tooth with a large CRA (Ten Hove and Mulie, 1976; Hall, 1978; Bryant *et al.*, 1984).

Using pre-angulated brackets, the labial or buccal surface of every maxillary incisor or canine will end up in the same relationship to the archwire at the end of treatment, while the long axis of the crown will vary its relationship to the wire (Bryant *et al.*, 1984).

The labial contour of the crown surface differs at different heights on the crown of the same tooth. Therefore, an archwire, fully engaged into a bracket, will produce a different axial inclination of the tooth (Germane *et al.*, 1986).

Between 2 and 6 mm from the incisal edge of all central maxillary incisors the curvature of the facial surface varied significantly. When a clinician intends to bond a pre-angulated bracket on the labial or buccal surface, it should be bonded at least 4 mm from the incisal edge to express the

Table 1 Labial/buccal surface curvatures at different heights for the incisors and the canines.

mm	Incisors						Canines					
	Minimum	Maximum	Δ Minimum–maximum	Mean	Δ Mean	SD	Minimum	Maximum	Δ Minimum–maximum	Mean	Δ Mean	SD
2.0	21.0	36.2	15.2	28.7	2.0	3.3	18.8	40.8	22.0	30.0	2.7	4.2
2.5	15.8	39.4	23.6	26.7	1.8	3.7	14.1	34.4	20.3	27.3	2.1	4.1
3.0	13.7	41.7	28.0	24.9	1.7	3.9	11.3	33.5	22.2	25.2	1.7	4.6
3.5	15.7	35.8	20.1	23.2	2.2	3.3	10.8	32.8	22.0	23.5	1.9	4.8
4.0	15.3	26.6	11.3	21.2	2.2	2.7	10.7	32.2	21.5	21.6	2.3	4.7
4.5	12.3	24.9	12.6	19.0	2.2	2.7	7.8	31.3	23.5	19.3	2.7	4.8
5.0	5.2	25.0	19.8	16.8	2.5	3.4	-3.4	29.5	32.9	16.6	3.1	5.3
5.5	0.5	23.2	22.7	14.3	2.7	4.2	-21.3	26.9	48.2	13.5	3.3	6.3
6.0	-8.0	21.2	29.2	11.6		4.9	-24.4	23.4	47.8	10.2		7.9

Δ Mean, difference between two successive measurements; SD, standard deviation.

most reliable and consistent built-in torque of the pre-adjusted bracket (smallest SD). On the other hand, a bracket position higher than 4.5 mm from the incisal edge gives a less consistent expression of the torque built into the bracket, because the curvature of the crown's labial surface is likely to differ more in this area.

The placement of a bracket on a maxillary canine is subject to more individual variation, because the SD of the buccal surface angle is much larger than for incisors. The SD of the curvatures measured between 2 and 4.5 mm from the incisal edge was found to be relatively constant for all canines in this study.

Placing a bracket between 2 and 4.5 mm from the incisal edge for both incisors and canines, average torque expression may result in an average difference of 10 degrees at the end of treatment in the same patient using one type of bracket system. More gingivally placed brackets will cause a larger difference in torque.

These findings are based on the average values found for the labial surface curvatures. The actual differences between the minimum and maximum of these curvatures were considerable, resulting in an even more pronounced variation in torque.

According to Creekmore and Kunik (1993), the bracket height relative to all other brackets is important, rather than the actual height on the tooth. They also suggested that the bracket height will not change the final torque. On the contrary, the results of the present study show that bracket height does change the amount of torque because of the curvature of the labial surface. By comparing different types of bracket, an even more widespread final torque effect can be expected. The prescribed torque will be expressed when the bracket is placed at the exact height stipulated. Table 2 gives an indication of the differences in the amount of torque by bonding the brackets at different heights from the ideal position proposed when using the technique. Placing a bracket closer to the incisal edge or more gingivally will result in a different inclination of the bracket due to the curvature of the labial surface. The built-in torque of every design was adjusted to all possible bracket heights. By changing the

bracket height from that proposed, an increase or decrease in the torque will be noticed as a result of an average change in the labial surface angle at different heights.

Table 2 shows mean values of torque at clinically acceptable heights between 3.5 and 5.5 mm from the incisal edge for the incisors and between 4.0 and 5.5 mm for the canines, according to the average inclination of the labial surface angles found in this study starting from the built-in torque given. Depending upon the technique and the bracket height, torque can vary between 5.1 and 24.0 degrees for the upper central incisors even though the brackets are placed at a clinically acceptable height. For the canines torque varies between -9.8 and 9.3 degrees.

Because the effective torque on the teeth is dependent on the size of the archwires and slots, the effect of bracket placement can be reduced by the absence of full engagement when smaller archwires are used relative to the dimension of the bracket (Germane *et al.*, 1986). However, using a 0.022 × 0.028 inch rectangular archwire in a Tip-Edge slot (full engagement), the accuracy of bracket placement is decisive for the expression of the amount of built-in torque.

Conclusions

The findings of this study show that after full archwire engagement the same archwire in the same pre-angulated bracket results, for each tooth, in different root torque due to variable labial crown morphology and a varying CRA. Moreover, placement of the same bracket on the same tooth at different heights results in important differences in the amount of root torque.

The assessment of tooth angulation and torque remains a clinical feature that allows some 'art' in orthodontics. Thus, the results of the present study highlight the necessity for individual wire bending to obtain appropriate torque due to both the variability of the CRA and the crown morphology.

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Table 2 The effect of bracket height on torque comparing different bracket types. The figures in bold indicate the advised built-in torque and bracket height.

	Incisors		Canines	
	Bracket height (mm)	Torque (°)	Bracket height (mm)	Torque (°)
Alexander (1983)	3.5	18.2		
	4.0	16.2	4.0	2.0
	4.5	14.0	4.5	-0.3
	5.0	11.8	5.0	-3.0
	5.5	9.3	5.5	-6.1
Bennett and McLaughlin (1997)	3.5	23.4		
	4.0	21.4	4.0	5.0
	4.5	19.2	4.5	2.7
	5.0	17.0	5.0	0.0
Ricketts (1976)	3.5	24.0	5.5	-3.1
	4.0	22.0	4.0	9.3
	4.5	19.8	4.5	7.0
	5.0	17.6	5.0	4.3
	5.5	15.1	5.5	1.2
Tip-Edge (Kesling, 1988)	3.5	14.0		
	4.0	12.0	4.0	-1.7
	4.5	9.8	4.5	-4.0
	5.0	7.6	5.0	-6.7
	5.5	5.1	5.5	-9.8

Torque, mean torque values at different heights according to the average inclination of the labial surface angles.

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