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Torque expression of 0.018 and 0.022 inch conventional brackets

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SUMMARY The aim of this study was to assess the effect of the moments generated with low- and high-torque brackets. Four different bracket prescription–slot combinations of the same bracket type (Mini Diamond® Twin) were evaluated: high-torque 0.018 and 0.022 inch and low-torque 0.018 and 0.022 inch. These brackets were bonded on identical maxillary acrylic resin models with levelled and aligned teeth and each model was mounted on the orthodontic measurement and simulation system (OMSS). Ten specimens of 0.017 × 0.025 inch and ten 0.019 × 0.025 inch stainless steel archwires (ORMCO) were evaluated in the low- and high-torque 0.018 inch and 0.022 inch brackets, respectively. The wires were ligated with elastomerics into the brackets and each measurement was repeated once after religation. Two-way analysis of variance and *t*-test were conducted to compare the generated moments between wires at low- and high-torque brackets separately.

The maximum moment generated by the 0.017 × 0.025 inch stainless steel archwire in the 0.018 inch brackets at +15 degrees ranged from 14.33 and 12.95 Nmm for the high- and low-torque brackets, respectively. The measured torque in the 0.022 inch brackets with the 0.019 × 0.025 inch stainless steel archwire was 9.32 and 6.48 Nmm, respectively. The recorded differences of maximum moments between the high- and low-torque series were statistically significant. High-torque brackets produced higher moments compared with low-torque brackets. Additionally, in both high- and low-torque configurations, the thicker 0.019 × 0.025 inch steel archwire in the 0.022 inch slot system generated lower moments in comparison with the 0.017 × 0.025 inch steel archwire in the 0.018 inch slot system.

Introduction

The criteria determining bracket selection are often subjective and a vast range of appliances is nowadays available. Regarding torque prescription, the differences between bracket systems include alterations of a few degrees, however, the exact influence of this variation on torque expression can be multiplied or negated by factors far different from this. These factors include the dimensions and material properties of the archwire and the bracket, the angle of twist of the archwire relative to the brackets, the mode of ligation and the relative bracket placement as related to tooth morphology (Germane *et al*., 1989; Morina *et al*., 2008; Huang *et al*., 2009; Archambault *et al*., 2010). As a result, the studies that compared the final outcome of the orthodontic treatment with bracket systems of different prescriptions failed to find significant differences between appliance systems (Kattner and Schneider, 1993; Ugur and Yukay, 1997; Moesi *et al*., 2011).

Slot size is another factor that could potentially influence torque expression. The 0.018 inch systems could have some disadvantage over the 0.022 slot during sliding mechanics, but a definitive advantage when torque is needed later. With stainless steel archwires steel of 0.021 inch as the smaller dimension—close enough to the original 0.022 inch bracket slot size to provide full engagement of the bracket slot—springiness and range in torsion are so limited that effective torque with the archwire is essentially impossible. Alternatives that overcome this limitation include the use of NiTi and β-Ti alloys, torquing auxiliaries or smaller rectangular steel wires, for example 0.019 × 0.025 inch, with exaggerated inclinations (Proffit and Fields, 2000). For this reason, torque prescriptions of the 0.022 inch brackets tend to be exaggerated since heavy 0.021 or 0.022 inch as the smaller dimension archwires may never be used in these brackets.

Currently, only a few investigations have compared the two different slot systems regarding the clinical outcome and the duration of the orthodontic treatment (Amditis and Smith, 2000; Detterline *et al*., 2010). Nonetheless, there is a lack of evidence on the quantitative assessment of the generated moments at the final stages of the treatment between the different slot systems.

It was the aim of this study to assess the effect of bracket torque prescription between 0.018 and 0.022 inch appliances on the moments generated in the sagittal plane on a central incisor from stainless steel rectangular archwires.

Materials and methods

Experimental apparatus

Generated moments (torque) at an upper central incisor was simulated in the orthodontic measurement and simulation system (OMSS), a measuring device used widely in the literature for the quantitative evaluation of various orthodontic force systems (Bourauel *et al*., 1992). This device is capable of registering the force–torque vectors three dimensionally during the tooth movement, which could be potentially simulated (Drescher *et al*., 1991). For this purpose, OMSS has two independently controlled positioning tables equipped with six-component force/torque sensors, which are appropriately connected with the region in question. The resultant tooth movement is calculated with the aid of a mathematical model from the central personal computer and is executed by the positioning tables.

Configuration and materials

Four different bracket prescriptions of the same bracket type (Mini Diamond® Twin, ORMCO, Orange, California, USA) were evaluated: high-torque 0.018 and 0.022 inch and low-torque 0.018 and 0.022 inch. The prescribed torque in the central incisor, lateral incisor, canine, and premolar brackets was 22, 14, 7, and 0 degrees, respectively, in the high-torque series and 14, 7, 0, and −7 degrees, respectively, in the low-torque series. The angulation was the same for both high- and low-torque brackets (5, 8, 10, and 0 degrees, respectively).

Four identical maxillary models with a levelled and aligned dental arch were constructed from acrylic resin, and each model was bonded with brackets up to the second premolars. The 0.018 inch slot brackets were bonded onto the models with the aid of an ideal 0.018 × 0.025 inch stainless steel archwire and in such a way so that the wire will be inserted passively into the bracket slots. An ideal 0.021 × 0.025 inch stainless steel archwire was used for bonding the 0.022 inch brackets. A torque–force sensor of the OMSS replaced the right central incisor and the bracket was bonded directly on the sensor. At this configuration, an adjustment of the system was conducted with the above-mentioned archwire in place and all forces/moments generated were nullified.

Ten specimens of 0.017 × 0.025 inch stainless steel archwires (ORMCO) were evaluated in the low- and high-torque 0.018 inch brackets. In the 0.022 inch series the measured archwires were ten 0.019 × 0.025 inch stainless steel specimens (ORMCO). For the construction of all archwires, a photocopy of the model was used as a template. The archwires were ligated with 0.120 inch (Molded ‘O’; ORMCO) elastomeric ligatures into the brackets. A 15 degrees buccal root torque (−15 degrees) and then a 15 degrees palatal root torque (+15 degrees) was gradually applied to the right central incisor bracket, in steps of 0.5 degree along the central axis of the slot. After each activation, the bracket was set to its initial position and the moments in the sagittal plane were recorded during these rotations of the bracket. Each measurement was repeated once after religation. The measuring range of the torquing moments in OMSS was ±450 Nmm and the torque threshold was 0.2 Nmm.

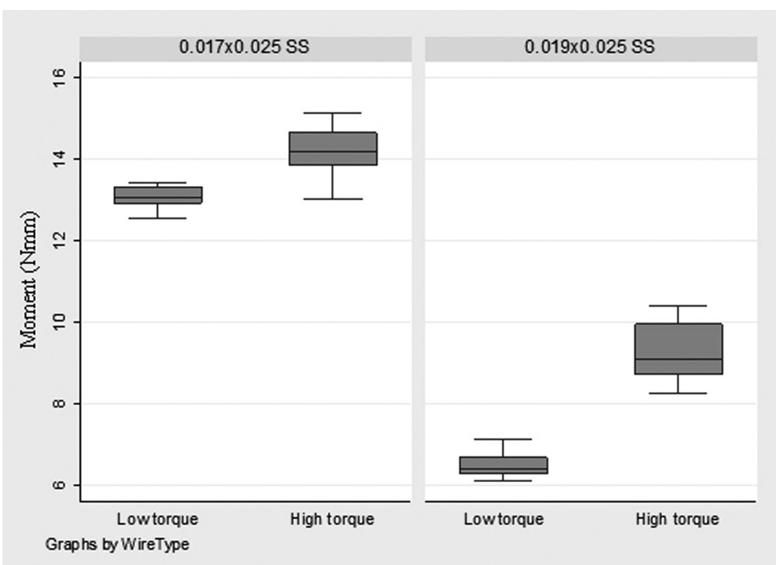

Figure 1 Boxplots displaying the measured moments in Nmm (median values, interquartile range 25–75).

The OMSS during the measurement cycles was installed in a temperature-controlled chamber (VEM 03/400, Vötsch Heraeus, Germany) (Bourauel *et al*., 1992).

Statistical analysis

The mean value of the two repeated measurements in every specimen of the generated moments was calculated at the maximum rotation separately for +15 and −15 degrees. A two-way analysis of variance (ANOVA) model was fitted in order to assess the generated moments by wire type at low- and high-torque brackets. In the presence of significant interaction between torque prescription and wire type student's *t*-tests were used to compare generated moments between wires at low- and high-torque brackets separately, and *t*-test for the comparison of the moments between wires at both bracket series separately. All statistical analyses were performed with the Stata 12 (Stata Corp, College Station, Texas, USA).

Results

Two-way ANOVA indicated significant interaction between wire type and torque prescription and therefore four independent *t*-tests were used for statistical inferences as shown in Tables 1 and 2. At +15 degrees, the insertion of a 0.017 × 0.025 inch stainless steel archwire in 0.018 slot high-torque brackets generated 14.3 Nmm in the central incisor. In the same configuration but in the low-torque series, the measured moment was 12.9 Nmm. The 0.019 × 0.025 inch stainless steel archwire in 0.022 slot brackets, yielded 9.3 Nmm in the high-torque and 6.5 Nmm in the low-torque series (Table 1 and Figure 1).

The same trend was observed at −15 degrees. The recorded values were 14.0 Nmm/13.2 Nmm for the 0.018 inch slot and 9.3 Nmm/6.5 Nmm for the 0.022 inch slot in the high- and low-torque brackets, respectively. All four comparisons from the *t*-test were highly significant ($P < 0.001$). Estimates were precise as indicated by the narrow confidence intervals around them and Monte Carlo simulations.

Table 1 Mean values, standard deviation (SD), mean difference, and *t*-test of the labiopalatal moment (Nmm) on the displaced central incisor between the different experimental configurations ($n = 10$).

		0.017 × 0.025*	0.019 × 0.025**		
Rotation	Torque	Mean (SD)	Mean (SD)	Mean difference (95% CI)	*P*-value
+15	High	14.3 (0.5)	9.3 (0.6)	5.0 (4.5, 5.5)	<0.001
	Low	12.9 (0.2)	6.5 (0.3)	6.4 (6.2, 6.6)	<0.001
–15	High	14.0 (0.6)	9.3 (0.7)	4.7 (4.1, 5.4)	<0.001
	Low	13.2 (0.3)	6.5 (0.3)	6.7 (6.4, 7.0)	<0.001

*Tested in a 0.018-inch bracket slot
**Tested in a 0.022-inch bracket slot

Table 2 ANOVA for the effect of wire type on the generated labiopalatal moments on the displaced central incisor.

Number of obs = 80 | R-squared = 0.9777
Root MSE = 0.475411 | Adj R-squared = 0.9768

Source	Partial SS	Df	MS	F	Prob > F
Model	751.49	3	250.50	1108.32	0.0000
Wire	437.17	1	437.17	1934.24	0.0000
Torque	12.04	1	12.04	53.28	0.0000
Wire × torque	15.27	1	15.27	67.57	0.0000
Residual	17.18	76	0.23		
Total	768.67	79	9.73		

Discussion

Most orthodontic manufacturers offer a variety of brackets with different torque prescriptions. In the present experiment the difference between the high- and low-torque series, at both slot dimensions, was 8, 7, 7, and 7 degrees for the central incisor, lateral incisor, cuspid, and premolar, respectively. This difference influenced the measured moments at the central incisor and resulted in increases of 6–10 per cent in the 0.018 inch and 44 per cent in the 0.022 inch system. The greater increase in the latter system is expected, since the evaluated archwire was 0.019 × 0.025 inch, that is 0.002 inch wider at the smaller dimension in comparison with the measured archwire in the 0.018 inch slot. The increase in stiffness of a cantilever beam accompanying an increase in cross section from 0.017 × 0.025 to 0.019 × 0.025 inch of the same composition is about 55 per cent (Thurow, 1982). Supporting both ends of a beam makes the beam stronger and its dimension in the direction of bending is the primary determinant of its properties, affecting strength in a cubic function. In torsion, shear stress rather than bending stress is encountered and the equations are different but the overall effect is the same. Additionally, if the ends of the beam are tightly anchored, that is they are not allowed to slide freely, the beam stiffness is higher (Proffit and Fields, 2000).

The wires evaluated in this study are most usually inserted as the final archwires during orthodontic treatment. In both torque specifications series, the measured moments generated by the 0.017 × 0.025 inch archwire in the 0.018 slot system were higher, in comparison with the 0.019 × 0.025 inch wire in the 0.022 slot, due to torque loss. The torsional play of a 0.017 × 0.025 inch archwire in 0.018 inch systems could be theoretically estimated at approximately 4 degrees and the double amount for a 0.019 × 0.025 inch in the 0.022 slot (Dellinger, 1978; Thurow, 1982; Sernetz, 1993; Meling *et al.*, 1997). Experimentally, higher torque losses are measured in the literature (Fischer-Brandies *et al.*, 2000; Gmyrek *et al.*, 2002; Harzer *et al.*, 2004). The source of this discrepancy may be attributed to the rounded edges of the bracket and slot as well as the tolerance in size; that is, the slot is slightly larger than described and the wire smaller than defined by the manufacturer (Meling *et al.*, 1998; Gmyrek *et al.*, 2002). The accuracy of the manufacturer's dimension of the archwires is not to be taken for granted (Fischer-Brandies *et al.*, 2000). According to the findings of this study, the combination of a 0.017 × 0.025 inch archwire in the 0.018 slot system was more efficient in torque delivery than the 0.019 × 0.025 inch in the 0.022 slot, at least regarding stainless steel archwires. Alternatively, alloys with lower moduli of elasticity, such as NiTi and β-Ti, which present only a fraction of the torsional stiffness of stainless steel and reduced hardness, could be ineffective in transmitting torque moments to bracket slots (Morina *et al.*, 2008). The stiffness in torsion of a 0.021 × 0.025 inch β-Ti archwire, which could be inserted at the final stages into 0.022 inch brackets, shows a 3-fold decrease relative to the 0.019 × 0.025 inch steel archwire, which in turn possesses more than the double stiffness compared with a 0.019 × 0.025 inch NiTi archwire (Kusy, 1983). It is stated that the wires adjusted to torque individual teeth should be sufficiently undersized (0.002 inch) to allow the adjusted wire to rotate in the slot of the adjacent teeth with no transfer of the torque action. Where all the teeth in an arch need some simultaneous torquing action, a close fit in the slot is not such a problem (Thurow, 1982).

The lower torque amount measured in the 0.022 inch system is not necessarily a disadvantage in the clinical practice, since there is no scientific consensus regarding ideal torquing moment (Burstone, 1966; Reitan, 1964; Bantleon and Droschl, 1988). Most of the authors agree that 5.0 Nmm is the minimum torque required for an upper central incisor (Gmyrek *et al.*, 2002; Harzer *et al.*, 2004; Huang *et al.*, 2009; Major *et al.*, 2011) and recent experimental data suggest that higher magnitudes of torque can cause more root resorption, particularly in the apical region (Casa *et al.*, 2001; Bartley *et al.*, 2011). Nevertheless, a retrospective study among treated patients derived from six different offices failed to establish a significant relationship between slot size and root resorption (Sameshima and Sinclair, 2001).

Both wire types in this experiment were ligated with elastic ligatures. The effect of elastic/metal ligation type is not expected to influence torque magnitude in full slot size wires and in the 0.017 × 0.025 inch steel archwire in the 0.018 inch slot system. However, for the 0.019 × 0.025 inch steel wire in the 0.022 inch slot, the measured moment with elastic ligation could be 20 per cent lower than with metal ligation at 5–15 degrees of torque, since the archwire may not completely seat during torquing (Hirai *et al.*, 2011). The 0.120 inch elastic ligatures presenting high seating force were used in this experiment in order to ensure the initial seating of the archwire with consistent and similar ligation forces between the different bracket systems (Taloumis *et al.*, 1997; Iwasaki *et al.*, 2003). Unfortunately, the main disadvantage of the elastic ligatures still remains their rapid force loss—which could exceed 50 per cent in 24 hours—and consequently this fact makes the engagement of the wire into the slot flexible and incomplete. Steel ligatures should be preferred in cases of maximum torque demands (Taloumis *et al.*, 1997; Gioka and Eliades, 2004).

As in most *in vitro* investigations, there are some limitations and difficulties in extrapolating clinical relevance. This study has focused on the comparison of the initial force systems of specific bracket/archwire combinations, but the actual force system acting on the teeth will probably vary in time because of the presence of the anisotropic periodontal ligament. The OMSS could simulate the initial tooth movement within the periodontium and although it comes very close to the clinical situation, it fails to take account of some factors that have additional influence in practice, such as intraoral ageing and influence of saliva.

Conclusions

High-torque bracket series produce higher torque magnitudes in comparison with low-torque brackets. This difference is exaggerated with a 0.019 × 0.025 inch steel archwire in the 0.022 inch slot systems, in comparison with a 0.017 × 0.025 inch steel archwire in the 0.018 inch slot systems.

The 0.019 × 0.025 inch steel archwire in the 0.022 inch slot system generated lower torque in comparison with the 0.017 × 0.025 inch steel archwire in the 0.018 inch slot system, in high- and low-torque configurations.

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