OVERVIEW

Physical and Mechanical Properties Affecting Torque Control

RUPALI KAPUR-WADHWA, BDS, DMD, MS

(Editor's Note: In this quarterly column, JCO provides a brief overview of a clinical topic of interest to orthodontists. Contributions and suggestions for future subjects are welcome.)

Third-order control is critically important during orthodontic treatment to optimize root angulations so that the long axes are centered in the alveolar trough. A torquing force can currently be applied by one of two methods:

1. *Edgewise technique.* A rectangular archwire is twisted through its elastic range and forcefully seated in the bracket slot. The untwisting force on the bracket creates an axial rotation of the tooth along its long axis. Additional 3rd-order control is seldom required during the finishing stages, except in maximum-anchorage cases with .022" slots, where tipping and uprighting are used for anchorage conservation. With .018" slots, an .017" × .025" stainless steel archwire provides sufficient active torque.
2. *Lightwire technique.* Torque is produced by an additional (piggyback) wire that is used to move the roots in a lingual direction after the crowns have been tipped lingually.

A number of physical and mechanical properties of the orthodontic appliance will directly or indirectly influence the effectiveness of torque application (Table 1). These factors are as follows:

Bracket Material

The tensile strength of a metal is a bulk material property that correlates highly with performance, regardless of the surface conditions. The tensile strength of a ceramic is not a simple bulk material property, but is so dependent on the surface condition of the ceramic that tests on bulk samples of the material can be irrelevant and misleading.[1]

Monocrystalline ceramic brackets have a higher mean fracture strength than polycrystalline brackets do. Although the fracture resistance of ceramic brackets appears to be adequate for clinical use, the mean fracture strength of ceramic brackets is less than that of metal brackets during lingual root torquing of the central incisors.[2-4] Ceramic brackets will break under loads that visibly deform but do not break metal brackets.[5]

Flores and colleagues concluded that the raw material has the greatest effect on the force needed to permanently deform metal brackets, and that the brackets that withstand the greatest stress before permanent deformation are made with 17-4HP and 303S steels.[6] Kapur and colleagues found that titanium brackets demonstrate higher load transmission and superior structural stability than conventional stainless steel brackets under torsional forces.[7]

Dr. Kapur-Wadhwa is an Assistant Professor, Department of Orthodontics, School of Dentistry, University of Pittsburgh, 3501 Terrace St., Pittsburgh, PA 15261; e-mail: rkapur@dental.pitt.edu.

TABLE 1
FACTORS INFLUENCING TORQUE APPLICATION

Authors	Bracket Material	Surface Conditions	Bracket Design	Slot Torque	Bracket-Wire Interaction	Ligation	Play	Mfg. Process	Interbracket Distance	Loop Design
Scott[1]	*									
Flores et al.[2]	*	*	*			*				
Aknin et al.[3]	*		*					*		
Holt et al.[4]	*	*	*							
Gunn and Powers[5]	*	*	*					*		
Flores et al.[6]	*		*	*						
Kapur et al.[7]	*									
Dobrin et al.[8]			*							
Feldner et al.[9]			*			*				
Aird and Durning[10]			*		*	*				
Rains et al.[11]			*							
Sebanc et al.[12]							*			
Odegaard et al.[13]							*			
Kang et al.[14]							*			
Meling et al.[15]							*			
Meling and Odegaard[16]							*			
Fischer-Brandeis et al.[17]							*			
Raphael et al.[18]							*			
Lang et al.[19]							*			
Moran[20]									*	
Odegaard et al.[21]										*

Surface Conditions

Ceramic brackets are less tolerant of surface flaws than metal brackets are. Scratching drastically reduces the fracture strength of ceramic brackets, but increases the fracture strength of metal brackets, possibly due to a work-hardening effect. Surface flaws can also contribute to variability in the range of torque, load at failure, and location of failure.[2,4,5]

Bracket Design

Bracket design plays an important role in load deformation. The major factors related to bracket integrity are:

1. *Point of force application.* In a study by Flores and colleagues,[2] placement of force on both sides of the Starfire* ceramic bracket—as opposed to only one side in a report by Holt and colleagues[4]—rendered the bracket less vulnerable to fracture by dividing the force between the mesial and distal wings. Gunn and Powers found that varying the location of the applied load could lead to differences in the load at failure and the location of failure.[5] Bracket design was one of the reasons cited for this variability.

*Formerly manufactured by "A" Company, San Diego, CA.

2. Bracket size and wing type. The force needed to permanently deform a regular twin metal bracket is greater than that required for a miniature twin, modified twin, or single-wing bracket. The reason is that a larger bracket will dissipate the forces over a larger area, thus reducing the stress at any given point.[6]

3. Slot size and design. The slot shape is partially responsible for the load deformation behavior of a bracket. Contact between the wire and bracket slot will be greater in brackets with a narrower slot and sharp edges, compared to brackets with a wider slot and rounded edges. Because the wire fits more loosely in the wider slot, there is a much smaller area to withstand the applied force, and more stress is transmitted to the bracket wings.[8] Slot torque also has a significant effect on the force required to permanently deform metal brackets. Brackets with wider slot angles have less material volume to resist the applied force, resulting in greater local stresses.[6]

4. Metal slot reinforcement. Metal reinforcement of plastic bracket slots appears to strengthen the matrix to the extent that comparable torque can be applied as with metal brackets.[9]

5. Vertical slot. Aknin and colleagues found that the Ceramflex Straight-Edge bracket** fractured exclusively at the incisal edge. They attributed this weakness to the vertical slot.[3]

6. Stalk-base junction. A 90° stalk-base junction angle can contribute to stress concentration, leading to bracket failure at that site.[10]

Rains and colleagues, in evaluating a stress-analysis model of plastic brackets, concluded that bracket design could be improved by: a) increasing the incisogingival and mesiodistal dimensions, b) avoiding sharp angles, c) maximizing the bulk of material between the bracket slot and the gingival ligature-tying slot, and d) minimizing the size of the rotation-control slot.[11]

Bracket-Wire Interaction

Aird and Durning suggested that slot-wing fracture of polycarbonate edgewise brackets occurred as a result of mesiodistal and/or vertical bracket-archwire interaction.[10] Defects on the channel surfaces were attributed to archwire contact. Slot wear, which was most evident on the mesial and distal aspects of the edgewise channels, reduced axial control over the bracketed teeth.

Ligation

Aird and Durning also found that in specimens where microscopic material stress patterns progressed centrally, the ligature wire may have contributed to the initial bracket damage, with subsequent central progression leading to slot-wing fracture.[10] Flores and colleagues stated that the ligature material (elastomeric vs. stainless steel) had no effect on the fracture strength of ceramic and stainless steel brackets.[2] Feldner and colleagues concluded that wire ligation could be a means of increasing the torque-generating potential of plastic brackets.[9]

Play at the Bracket-Wire Interface

Research has demonstrated that the deviant angle (play) at the bracket-wire interface during torsion is considerably greater than might be expected (Fig. 1). The effective torque depends on the manufacturer's tolerance in both the brackets and wires, as well as on the edge bevel of the wires.[12] Mechanically, the amount of play could be either an advantage or a disadvantage. The clinician must be aware of the degree of play for each bracket-wire combination and modify the treatment plan according to the technique and the individual patient.

In general, the load-deflection curve for any bracket-wire combination is relatively shallow at first, but eventually reaches a linear relationship between moment and deflection, reflecting a restraining effect of the ligature. At this point, a small change in the tooth's axial inclination will produce a rapid change in effective rotational moment, which indicates that archwires should be reactivated more frequently. From a

**Formerly manufactured by TP Orthodontics, Inc., 100 Center Plaza, LaPorte, IN 46350.

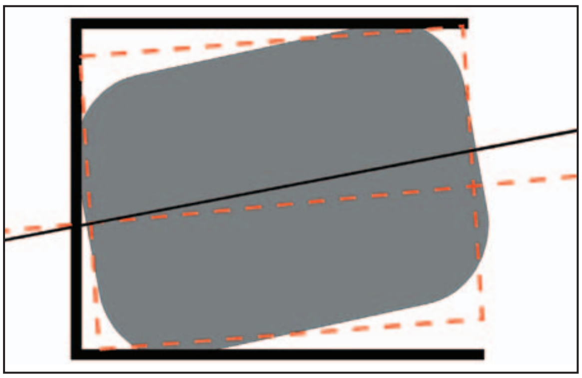

Fig. 1 Play at bracket-wire interface (from Siatkowski, R.E.: Loss of anterior torque control due to variations in bracket slot and archwire dimensions, J. Clin. Orthod. 33:508-510, 1999).

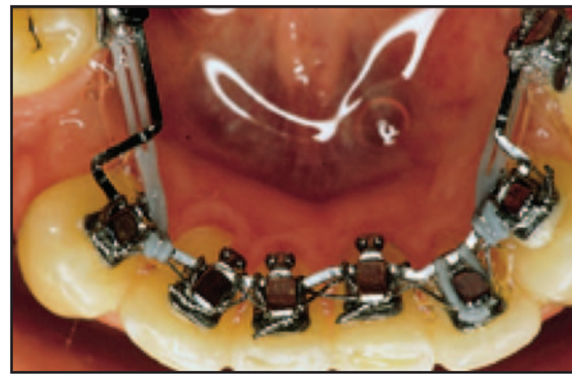

Fig. 2 Lingual interbracket distances (from Rummel, V.; Wiechmann, D.; and Sachdeva, R.C.L.: Precision finishing in lingual orthodontics, J. Clin. Orthod. 33:101-113, 1999).

clinical standpoint, an efficient way to transfer torque to particular teeth would be to use highly elastic wires in combination with brackets of variable torque.[13-17]

There is a great degree of variation in buccal tube dimensions, depending on the method of fabrication and the manufacturer's tolerance. Differences in size become even more critical with the newer preadjusted appliances that have torque built into the molar tubes. Therefore, it is unrealistic to expect clinical control to within a few degrees of torque without the angulation resulting in a change in molar position.[18,19]

Manufacturing Process

Holt and colleagues[4] and Aknin and colleagues[3] concluded that differences in rotation of the archwire at bracket failure could be explained by inadequate quality control in the manufacturing of the brackets. Holt and colleagues reported, however, that the new Allure IV*** and Signature† brackets demonstrated greater fracture strength than their earlier counterparts.[4] Apparently, improvements in manufacturing have increased the resistance of these brackets to torsional forces.

***Registered trademark of GAC International, Inc., 355 Knickerbocker Ave., Bohemia, NY 11716.

†RMO Inc., P.O. Box 17085, Denver, CO 80217.

Interbracket Distance

Because lingual appliances have significantly shorter anterior interbracket distances than labial appliances have (Fig. 2), an archwire will act three times as stiff in 1st- and 2nd-order bends and about 1.5 times as stiff in 3rd-order bends. With this in mind, the lingual orthodontist can adjust archwire flexibility during the initial alignment and final detailing stages of treatment.[20]

Loop Design

The two factors that determine the torsional stiffness of a looped wire are the wire cross-section and the loop geometry. Increasing the amount of wire in the mesiodistal section of the loop and increasing the diameter of the apex will increase the loop's torsional flexibility. Clinically, to reduce torsional stiffness for anterior retraction, the T-loop and the reverse closing loop are the best designs; to increase torsional stiffness, the Bull loop is ideal.[21]

Occlusal Stability and Relapse

Preadjusted appliances are designed to align the teeth in stable positions that will resist relapse. Before a patient is ready for retention, 10

critical treatment goals must be met:
1. Coincident CR and CO.
2. Class I cuspid relationship.
3. Preserved mandibular cuspid width.
4. Normal or near-normal interincisal angle.
5. Normal anterior overbite and overjet.
6. Normal buccal overjet.
7. Leveled arches.
8. All spaces closed and rotations eliminated.
9. Root parallelism.
10. Proper posterior intercuspation.

Torque control of the mandibular and maxillary incisors and the interincisal angle must be addressed during treatment if the corrected overbite and overjet are to be maintained.[22]

Finishing Torque

If flared incisors were tipped lingually while being retracted, lingual root torque will be required before the case is completed. In the Begg system, torquing auxiliaries are used to apply 3rd-order force in the finishing stages. Because precise tooth positions are difficult to achieve with the Begg appliance, however, modifications such as the Tip-Edge‡ appliance have been developed to allow rectangular archwires and slots to be used in finishing (Fig. 3).

In the edgewise appliance, only a small amount of additional torque is needed during the final stages of treatment. With .018" slots, an .017" × .025" stainless steel wire has excellent torsional properties. With .022" slots, however, full-size stainless steel wires are too stiff, and .021" × .025" beta titanium appears to be the best finishing wire. If a stainless steel wire of this size is needed for finishing, it should be preceded by an .021" × .025" beta titanium wire.

Torque Prescriptions

Incisor bracket slots need positive torque so that the roots will finish lingual to the crowns. The canines stand relatively upright, and the posterior teeth require increasing amounts of negative torque to position the roots buccally. A number of important factors are involved in determining the appropriate torque:

1. The normal inclination of the tooth.
2. The distance of the bracket from the incisal edge of the crown.
3. The slot size—.018" brackets generally have more conservative torque than .022" brackets have.
4. Variations in individual tooth morphology.
5. The accuracy of bracket placement—even with preadjusted appliances, some 3rd-order bends are usually required in the finishing stages.[23]

‡Registered trademark of TP Orthodontics, Inc., 100 Center Plaza, LaPorte, IN 46350.

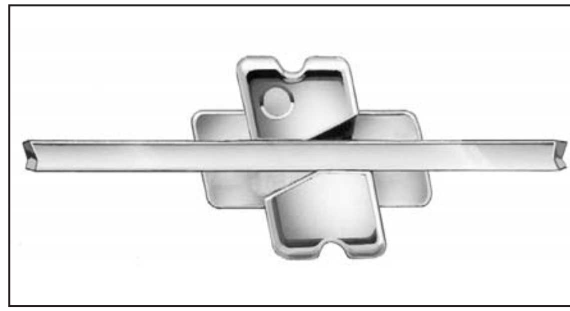

Fig. 3 Tip-Edge Plus maxillary right canine bracket after uprighting with either .014" nickel titanium wire in deep channel or uprighting spring in vertical slot (courtesy of TP Orthodontics, Inc.).

Conclusions

• The choice of the orthodontic appliance, including the bracket composition and design and the archwire type, should be based on the diagnosis and treatment requirements of each individual case.

• The amount of play at the bracket-wire interface is much greater than might be expected and highly unpredictable. Therefore, the clinician should be aware of the degree of play in potential bracket-wire combinations and be prepared to modify the treatment plan according to the technique and the individual patient.

• The effective torque depends on the manufacturer's tolerance for brackets and wires and the edge bevel of the wires.

• The ideal inclinations of individual teeth must be considered during treatment to ensure occlusal stability and long-term retention of results.
• With the increasing demand for esthetic brackets, torque control is a critical treatment factor that requires further study.

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