A Mechanical Evaluation of Buccal Segment Reaction to Edgewise Torque

DAVID W. SCHRODY, D.D.S., M.S.

Use of the edgewise archwire in conjunction with slotted attachments on the teeth gives the orthodontist the potential to control the movement of teeth in three planes of space. Realization of this potential, however, depends on the orthodontist's ability to understand the intricacies of active and reactive forces, their types, directions and magnitudes.

A common three-dimensional problem in orthodontics involves torquing the upper anterior teeth by placing a twist in the anterior section of an edgewise wire to obtain an ideal labiolingual incisor inclination (lingual root torque). The complexities of this mechanical system have been noted by various authors.[1-4] Strang noted that torque "has been termed a dangerous and forbidden force by many operators, its danger lies not in the force but in the ignorance of the one who uses it". Clinical impressions of the reactive components to anterior torque have been offered by numerous clinicians.[5-11]

This study used a mechanical apparatus to simulate the intraoral problem of torquing the four upper incisor roots lingually with a continuous edgewise archwire to improve their labiolingual inclination. It was done under specified simulated conditions to allow three-dimensional analysis of the type, direction and magnitude of the reactive forces in the theoretical intraoral positions of the maxillary canine, second premolar and first molar teeth, assuming anterior lingual root torque is most generally needed in a four premolar extraction treatment.

PROCEDURE

A mechanical apparatus was designed which allowed an ideal, preformed edgewise maxillary archwire to be held and twisted upon itself (torqued) in the area of attachment of the lateral and central incisor brackets (simulating anterior lingual root torque) allowing free reaction of the archwire distal to the lateral incisors (Fig. 1). Plexiglas dummy teeth were positioned and firmly attached in the respective areas of the canine, premolar, and molar teeth (Fig. 2). Using a tension gauge which was accurate to the 5 gm level, the force needed to rotate the dummies back to their neutral (pretorque) positions was measured. The distance from the archwire to the point of gauge placement on the dummies was standardized to allow the expression of countertorque as a force-distance moment (gram-millimeters). Expression of the countertorque in this manner assumed the center of rotation to be at or very near the center of the long axis of the archwire.

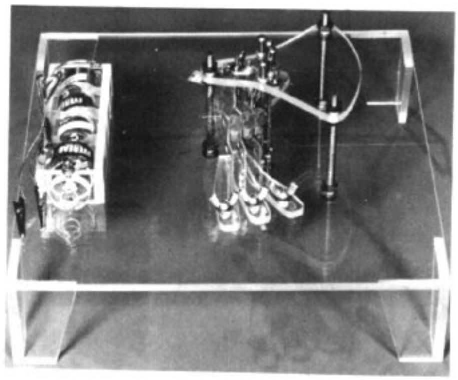

Fig. 1 Perspective view of the torquing apparatus.

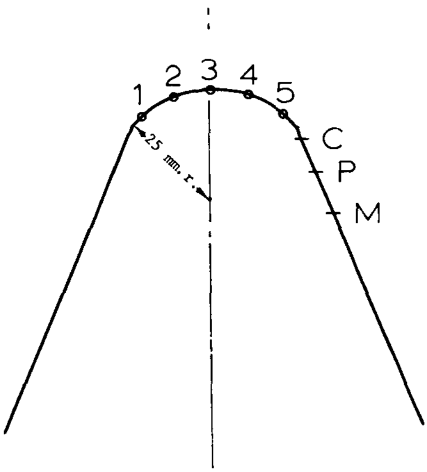

Fig. 2 Preformed archwires as supplied by the manufacturer were held at points 1-5, and allowed to rotate through the center of the wire mass (as viewed in cross section). Reactive forces were measured at points C, P, and M. Distances measured along the archwire perimeter were: Points 1 to 5=31.0 mm, point 5 to point C=4.0 mm, point P=8.0 mm, point P to point M=10.0 mm. Black's averages of maxillary tooth width were used as a guide for the archwire specifications.

Using vertical and horizontal guides in the relative positions of the canine, premolar, and molar, the reactive linear forces (buccolingal and occlusogingival) were measured as the forces (grams) needed to reposition the archwire in its neutral (preactivation) position. In the case of buccolingual reactive force, with the neutral stop being on the inside (comparable to lingual), a contracting force was measured as the difference in force needed to pull the unactivated, as opposed to the activated, wire from the guide post. This was expressed as $F_t=F_{w+t}-F_w$*.

*F_t represents force of constriction due to anterior torque; F_w represents resistance of the unactivated archwire to displacement from its neutral position in a pure horizontal movement; and F_{w+t} represents force needed to displace the activated wire from the guide post.

The vertical, linear reactive force was measured by simply pushing the wire to its preactivation position with a vertical force at each of the three successive guide stops: canine, premolar, and molar.

In this experiment the anterior section of the archwire was rigidly held simulating "perfect" anterior resistance. The countertorque reactive force and linear reactive forces as measured in the canine region were maximum loading reaction forces. As the canine reacted or unloaded, force in the system was transmitted to the premolar and, as the premolar moved (reacted), force was transmitted to the molar. Measuring the reactive forces in the premolar and molar regions demonstrated a maximal end-reaction of the buccal segment, disallowing anterior tooth movement. With the anterior segment of the archwire being rigidly held in this experiment, graphing buccal forces against incremental torque changes in the anterior wire segment served to illustrate reactive force decay in a quantitative manner, for both action and reaction are relative and not absolute.

Sampling

The archwires used were Unitek Permachrome preformed maxillary archwires, selected at random, in the following sizes: .018 x .025, .021 x .025, and .0215 x .028. The archwires were adjusted with minimal hand bending to conform to a plastic template to yield more uniformly shaped wires. The placement of the anterior brackets and the relative positioning of buccal segment measurements were done using Black's averages as a guide for tooth size to yield meaningful results. The archwire was engaged by .022 x .028 twin edgewise brackets positioned to simulate the position of the maxillary central and lateral incisors.

	Archwire Activation	0.018" x 0.025"			0.021" x 0.025"			0.0215" x 0.028		
		5°	15°	25°	5°	15°	25°	5°	15°	25°
Counter-torque gm-mm	Canine	756.500 SD= 78.825	1045.500 SD=140.082	1705.667 SD=151.921	912.333 SD=185.365	1986.167 SD= 72.240	3300.833 SD=288.787	1093.667 SD=101.806	2824.333 SD=411.527	4448.333 SD=205.880
	Premolar	501.500 SD= 38.391	753.667 SD=122.900	1226.833 SD=117.987	541.167 SD=118.470	1266.500 SD=116.670	2051.333 SD=179.164	790.500 SD= 78.089	1685.833 SD= 67.512	2915.500 SD= 71.116
	Molar	317.333 SD=106.799	467.500 SD= 85.845	765.000 SD= 65.400	314.500 SD= 67.787	793.167 SD=128.966	1399.667 SD=114.118	549.667 SD= 38.259	1079.500 SD= 64.286	1841.667 SD= 87.118
Occluso-lingual Linear-gm	Canine		75.500 SD= 3.885	171.167 SD= 10.827		106.667 SD= 3.818	238.000 SD= 14.669		149.167 SD= 35.412	286.667 SD= 15.376
	Premolar	24.167 SD= 6.674	38.500 SD= 2.738	97.000 SD= 10.583	22.5000 SD= 8.479	74.333 SD= 6.381	122.167 SD= 20.485	31.000 SD= 4.560	82.000 SD= 6.723	172.500 SD= 7.816
	Molar	12.833 SD= 2.788	25.500 SD= 4.324	41.000 SD= 8.049	10.000 SD= 3.847	35.333 SD= 8.572	68.167 SD= 6.333	16.667 SD= 3.074	52.833 SD= 7.141	88.167 SD= 7.217
Bucco-lingual Linear-gm	Canine			116.167 SD= 11.048			88.500 SD= 20.275			172.333 SD= 28.418
	Premolar			20.833 SD= 7.112			-0.500 SD= 12.660			14.000 SD= 3.521
	Molar			7.667 SD= 2.336			-13.833 SD= 9.600			-12.000 SD= 7.238
	n=6									

TABLE I

Mean reactive forces and standard deviations group findings.

Torque activation was read in degrees from a protractor positioned on the apparatus. A brass wire indicator was extended from one of the torque arms activating the archwire. Successive increments of active torque were measured from the initial reading where archwire activation began. This eliminated the problem of "play" between the bracket slots and the various sizes of archwires.

Findings

The data were collected independently by two separate investigators (GFA and DWS). Each investigator made three successive force determinations. The first two were not recorded; the third was recorded as a final determination for analysis if it was similar to the first two determinations. If the third reading was dissimilar, the scheme was repeated. Mean values for each size archwire were calculated for each of the reactive forces (countertorque, buccolingual linear, and occlusogingival linear) for the canine, premolar, and molar positions on the archwire at each torque increment. These data are presented in tabular form along with the standard deviation of the mean for each calculated mean (Table I).

Factorial arrangement of treatments was used to analyze the collected data. Factors to be tested for significance were the different wire sizes, stresses on wire of the same size, the location of reactive force measurements, and the two examiners. Statistical tests were conducted to determine if there were significant interinvestigator differences in the force determinations. An analysis of variance between the two investigators' data revealed no significant difference. The factors not involving the investigators demonstrate statistical significance ($p<0.001$) for all interactions.

Graphs are used to demonstrate the load-deflection rates of the various reactive forces. In the case of countertorque, gram-millimeters are plotted against degrees of active archwire twist. The buccolingual linear and occlusogingival linear reactive forces are plotted as force (grams) versus the degree of active anterior torque.

With each of the three simulated

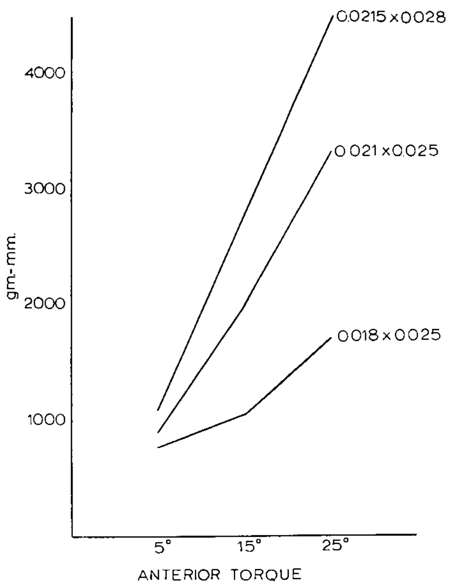

Fig. 3 Reactive canine countertorque (mean values).

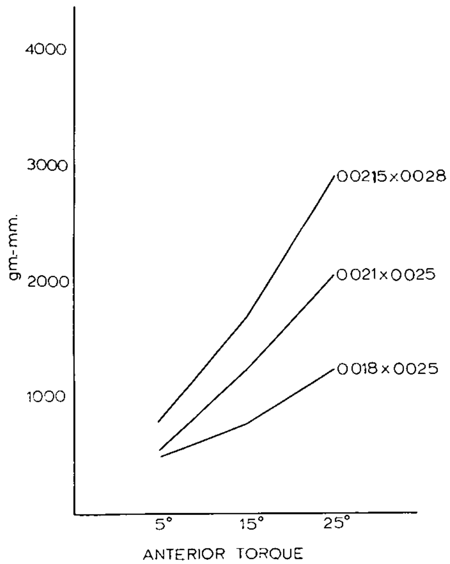

Fig. 4 Reactive premolar countertorque.

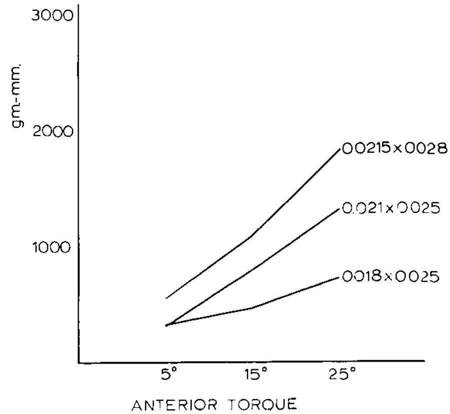

Fig. 5 Reactive molar countertorque.

lingual root torque adjustments, 5°, 15° and 25°, progressive reactions expressed as countertorque, buccolingual linear, and occlusogingival linear displacement of the free buccal segments of the archwire were observed. The mean reactive force determinations of the two investigators and the group mean reactive force determinations are given in Table I.

The countertorque movement was observed to be in a 1:1 ratio with the active anterior torque. The countertorque reactive forces on the canine, premolar, and molar areas are graphed in Figures 3, 4, and 5. The graphs demonstrate a marked decrease in slope from the canine to molar measurement area. The slope (load-deflection rate) of the heavier wire (.0215 x .028) was the most variable, while the rate of reactive force delivery was more constant with the smaller wire (.018-x .025), as would be expected.

The vertical (gingival) linear reactive displacement approached 3.5 mm in the molar region when 25° of active anterior torque was placed in the wire. The vertical displacement in the canine area with 5° active anterior torque was so slight that a force value could not be obtained with the gauge. The mean occlusogingival linear forces ranged

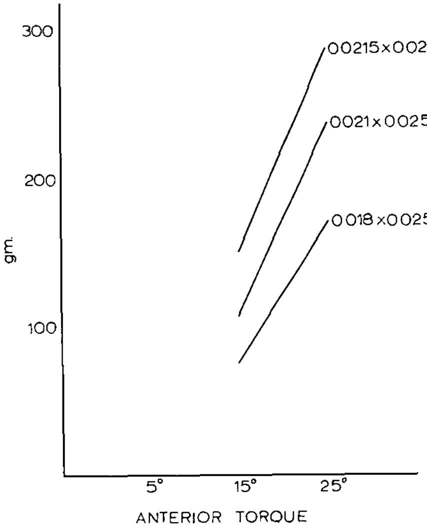

Fig. 6 Reactive canine occlusogingival force (mean values). During anterior lingual root torquing the forces are gingivally directed.

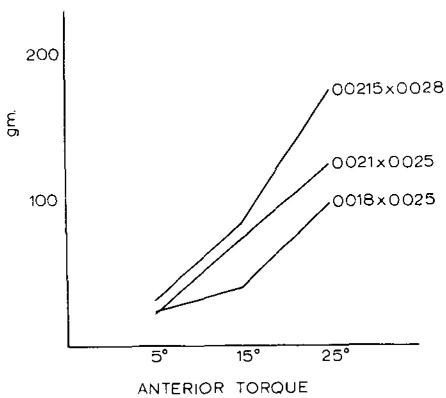

Fig. 7 Reactive premolar occlusogingival force.

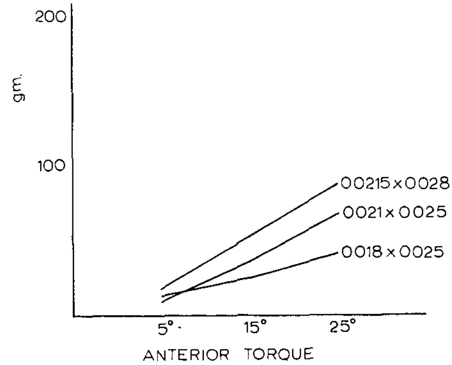

Fig. 8 Reactive molar occlusogingival force (mean values).

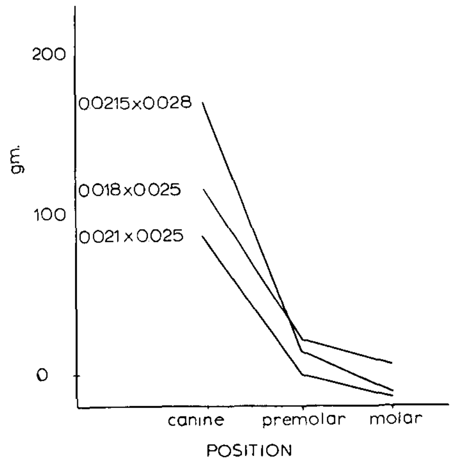

Fig. 9 Reactive buccolingual forces produced during anterior lingual root torquing. Lingually directed forces are graphed as positive forces, buccally directed forces as negative forces.

from a high of 5 ounces to 10 ounces in the canine region for the three wires tested at 25° of anterior torque activation (Fig. 6). The reactive gingival forces produced in the premolar and molar areas where free archwire reaction was allowed are illustrated in Figures 7 and 8.

The lateral (buccolingual) displacement was maximal in the molar region with 25° of active anterior torque. This displacement did not exceed 1 mm in either a buccal or a lingual direction. The buccolingual linear reactive forces on the canine region were consistently contractile although this was not a consistent finding in the premolar and molar areas (Fig. 9). The contractile forces ranged from 95 to 180 gm in the canine region, but did not exceed 20 gm in a buccal or a lingual direction in either the premolar or molar areas. The lateral linear forces were expressed as positive forces when lingually directed, and as negative forces when buccally directed.

Conclusions

1. Buccal segment reaction to anterior lingual root torque is a complex system consisting of a combination of countertorque, buccolingual linear, and occlusogingival linear forces. Anteroposterior denture base displacement was not measured in this experiment.

2. Countertorque force ranged from a mean value of 320 gm/mm to 4500 gm/mm and was the major reactive force component.

3. In the case of active anterior lingual root torque, an intrusive force was placed on the buccal segment teeth. This force was as high as a mean 287 gm as an initial loading force on the canine with 25° active anterior torque in an .0215 x .028 archwire.

4. The lateral linear forces could only be measured at 25° of anterior torque activation as the distance of movement under the experimental conditions was less than 1 mm at the molar measurement station. All wires at each activation demonstrated a contractile force in the canine region. The .021-x .025 wire showed expansion in the premolar and molar regions, while the .0215 x .028 showed an expansile force in the molar region only.

5. Each of the three wires tested provides a useful range of working forces within the elastic limit of these wires as demonstrated by the dispersion of the reactive force yields on the various graphs.

6. With the model used in this experiment, slight buccal expansion of a torquing wire would seemingly help reduce the lingual crown torque force (potentially producing a crossbite) in the buccal segment.

7. A slight gingival curve placed in the buccal segments of the archwire would seemingly distribute the intrusive force more equitably to the buccal segment teeth, thereby limiting the reactive element to this intrusion, namely, incisor extrusion.

8. In using this torquing system one should observe the mechanics closely in light of the heavy forces; progressive torque should be used wherever possible for more equitable reactive force distribution.

9. Further studies are needed to examine other torquing systems thus allowing comparisons of the nature of reactive force components and the levels of these components among various mechanical systems.

401 *Wilson Building*
Clinton, Iowa 52732

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