Original Article

Curvature Versus V-Bends in a Group B Titanium T-Loop Spring

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ABSTRACT

Objective: To compare the system of forces acting on curvature and preactivated V-bends in titanium T-loop springs (TTLSs) made of 0.017- × 0.025-inch TMA (titanium molibdenium alloy) wire.

Materials and Methods: Pictures of TTLSs preactivated by curvature and V-bends were inserted in the LOOP software program to design both TTLSs. Symmetry was assured using the program. Both TTLSs used the same amount (length) of wire and had the same angulation between their anterior and posterior extremities when passive. The loops were activated 7 mm, and forces and moments were registered after each 0.5 mm of deactivation. The brackets were at the same height, separated by 23 mm and angulated 0°.

Results: The preactivated curvature TTLS delivered horizontal forces ranging from 34 gF to 456 gF, while the TTLS preactivated by V-bends delivered forces ranging from 54 gF to 517 gF. The forces decreased more (30 gF vs 33 gF) with every 0.5 mm of activation on the preactivated V-bend TTLS than on the preactivated curvature TTLS. Vertical forces were low and clinically insignificant for both TTLSs. The moment to force (MF) ratios were systematically higher on the preactivated curvature than on the preactivated V-bend TTLS (from 5.8 mm to 38.8 mm vs 4.7 mm to 28.3 mm).

Conclusions: Although both loops show symmetrical moments in their anterior and posterior extremities and can be used for group B anchorage, the curvature preactivated TTLS delivers lower horizontal forces and higher MF ratios than the acute preactivated V-bend TTLS.

KEY WORDS: T-loops; Moment to force ratios; Group B anchorage; TMA; Loop software

INTRODUCTION

Efficient space closure is an important objective in orthodontics. Segmental space closure can be more efficient due to frictionless mechanics and large inter-bracket distances (IBD). The “T” loop used for group B or reciprocal anchorage has a low load/deflection ratio and, if similar vertical dimensions are compared, delivers a more constant force over a larger deactivation span than vertical loops,[1] such as bull loops. The load/deflection ratio can be further improved with the use of TMA (titanium molibdenium alloy).[1–3] The titanium T-loop spring (TTLS) allows for more predictable tooth movements over longer spans of activation than vertical loops and can be used for specific types of movements, including translation. The various designs of the TTLS for group B anchorage[1,4–7] that have been introduced differ primarily in terms of loop size and preactivations.

Although it has been established that increasing the height of the loop also increases the moment to force (MF) ratio,[8–10] the effects of different types of preactivation are not completely understood. More specifically, differences between TTLS preactivated by a curvature vs TTLS preactivated by a V-bend have not yet been systematically studied. Manhartsberger et al[5] reported less horizontal force and higher MF ratios in the preactivation bend with a large activation and more force and a lower M/F with smaller activation. Their study, however, was not designed to compare curva-

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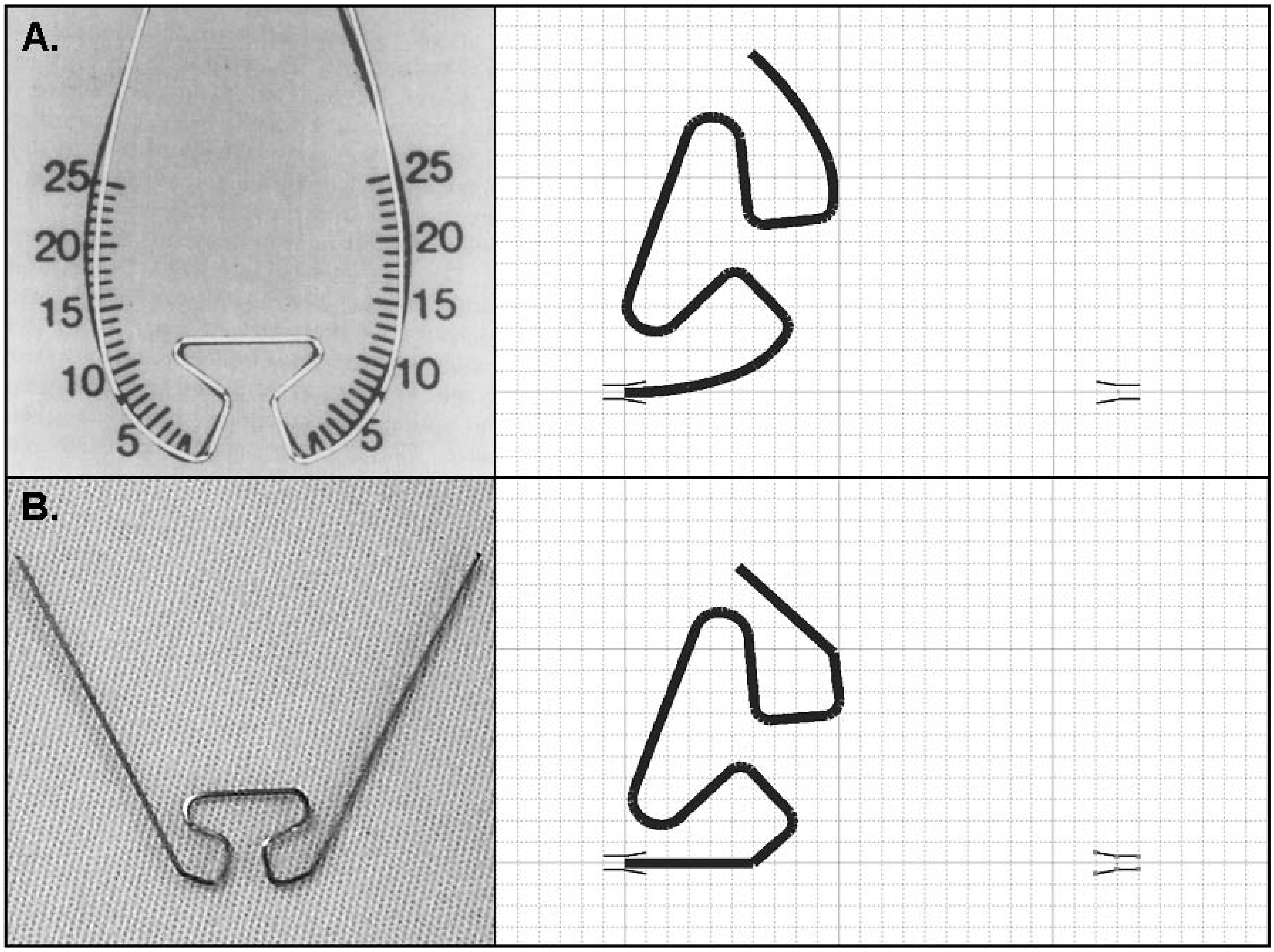

Figure 1. Templates used for the design of the titanium T-loop springs (TTLSs) (left) and simulated by the LOOP software (right). (A) Curvature preactivated TTLS. (B) Bend preactivated TTLS (each square is 1 cm²).

ture and bends. Moreover, the angulations between both anterior and posterior extremities of the loops they used were different, which could confound their results.

The purpose of this study was to evaluate the differences in force levels and MF ratios between group B TTLSs preactivated by a curvature and those preactivated by a V-bend. The LOOP software (dHAL, Athens, Greece) was used to perform the preactivations precisely and to estimate forces and moments.

MATERIALS AND METHODS

Two group B TTLSs, one with curvature preactivation[4] and one with V-bend preactivation[7] (Figure 1), were designed and tested using the LOOP software (dHAL). The TTLSs were designed from 0.017- × 0.025-inch TMA to be 10 mm long and 6 mm high. An IBD of 23 mm, from the canine bracket to the molar tube, was used. Both brackets were positioned at the same level with the same orientation.

Because the planned activation of the loops was 5 mm, the anterior and posterior lengths of wire were estimated to be 9 mm based on the following formula[6,7]: (IBD − Activation)/2. After the loop was designed, it was saved as two files, one for each of the preactivations. The curvature preactivation TTLS was performed by inserting a template[4] as a figure on the software and checked to ensure that both sides were symmetrical (Figure 1). The preactivation V-bend was performed by inserting a picture of a TTLS preactivated according to Marcotte[7] (picture was taken after trial activation) following trial activation on the software as well.

TTLS total wire length, distance to bracket, angulation to bracket, and number of segments were standardized using the software to ensure comparability of the two TTLSs without activation of the springs. The total amount of wire used in both TTLSs was 47.21 mm and, when passive, the angulation between the extremities of the loops was 42°. The linear distances

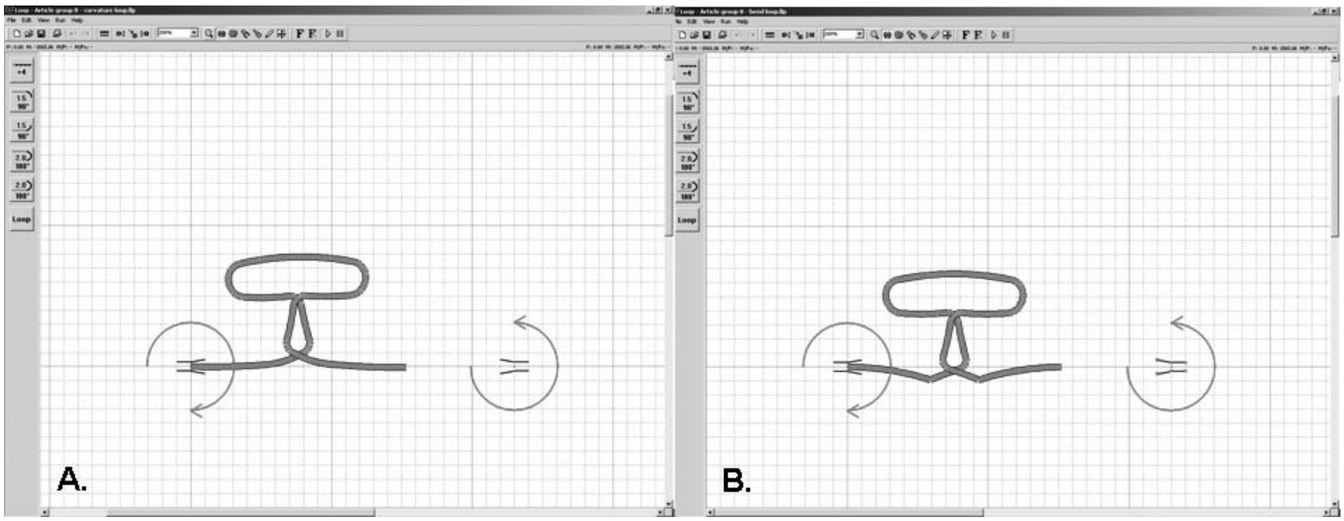

Figure 2. Characteristics of the titanium T-loop springs (TTLSs) when in neutral position. Note the similar amount of overlapping between the vertical extensions of the loop of the two TTLSs. (A) TTLS preactivated by curvature. (B) TTLS preactivated by bends.

Table 1. Values for Force (Horizontal and Vertical) and Moment to Force (M/F) Ratios in Alpha (Anterior Bracket) and Beta (Posterior Bracket) and Differences Between Curvature and Bend Preactivation Over a 7-mm Range of Activation of the Titanium T-loop Spring (TTLS) Tested (Negative Values of Activation Pertain to the Horizontal Force Generated by the Neutral Position)

	Curvature Preactivation				Bend Preactivation				Difference			
Activation, mm	Fx, gf	Fy, gf	M/Fx, mm (alpha)	M/Fx, mm (beta)	Fx, gf	Fy, gf	M/Fx, mm (alpha)	M/Fx, mm (beta)	Fx, gf	Fy, gf	M/Fx, mm (alpha)	M/Fx, mm (beta)
5.0	456.7	−0.9	5.8	5.9	516.6	−0.7	4.7	4.7	60.0	0.2	1.2	1.2
4.5	430.1	−1.4	6.1	6.1	481.0	0.3	4.9	4.9	51.0	1.7	1.1	1.2
4.0	400.3	0.4	6.4	6.4	455.5	0.1	5.1	5.1	55.2	−0.2	1.2	1.2
3.5	374.4	0.5	6.7	6.6	419.6	0.2	5.4	5.4	45.2	−0.3	1.2	1.2
3.0	343.4	−1.5	7.0	7.1	398.4	3.2	5.7	5.5	55.0	4.7	1.3	1.6
2.5	316.8	3.5	7.5	7.3	361.2	4.3	6.1	5.9	44.4	0.7	1.4	1.4
2.0	292.2	0.9	7.9	7.8	334.1	5.3	6.5	6.2	42.0	4.5	1.4	1.6
1.5	262.8	1.0	8.4	8.4	298.8	4.0	7.0	6.7	36.1	3.0	1.5	1.6
1.0	228.1	3.3	9.3	9.1	266.2	3.6	7.6	7.3	38.1	0.3	1.8	1.7
0.5	197.7	2.7	10.3	10.0	232.7	4.0	8.4	8.1	35.0	1.3	1.9	1.9
0.0	166.6	3.3	11.7	11.3	198.7	4.2	9.5	9.1	32.1	0.9	2.2	2.3
−0.5	135.4	3.1	13.7	13.3	163.8	4.5	11.0	10.5	28.4	1.3	2.6	2.7
−1.0	103.5	3.2	16.9	16.3	129.1	3.9	13.3	12.8	25.6	0.7	3.5	3.5
−1.5	72.2	2.1	22.7	22.2	92.4	4.1	17.7	16.9	20.2	2.0	5.0	5.2
−2.0	39.2	2.1	38.8	37.9	54.4	4.3	28.3	27.0	15.2	2.2	10.5	10.9
								Average	38.9	1.5	2.5	2.6

from the unengaged extremity of the TTLS to the bracket were slightly different between the TTLSs (0.77 mm).

The TTLSs were activated from 5 mm to −2 mm (negative values are due to the overlapping of the vertical extensions of the TTLSs in their neutral positions [ie, defined two dimensionally with the extremities of the loop positioned at 180°; Figure 2]), for a total of 7 mm, in increments of 0.5 mm. At each increment the horizontal forces (Fx), vertical forces (Fy), and moment/force ratios (M/Fx) were estimated by the software and copied to a Microsoft Excel worksheet. The absolute values of the forces and moments were corrected by a factor of 0.88.[11,12] Changes in forces were estimated at each 0.5-mm increment of activation. No statistical testing was performed because the software mathematically calculates the M/Fx iteratively based on theoretical beam equations which produce similar results for the same wire configuration.

RESULTS

The TTLS preactivated by curvature delivered horizontal forces increasing from 40 gf to 457 gf between −2 and 5 mm of activation, respectively (Table 1; Figure 3). The force decreased approximately 30 gf for

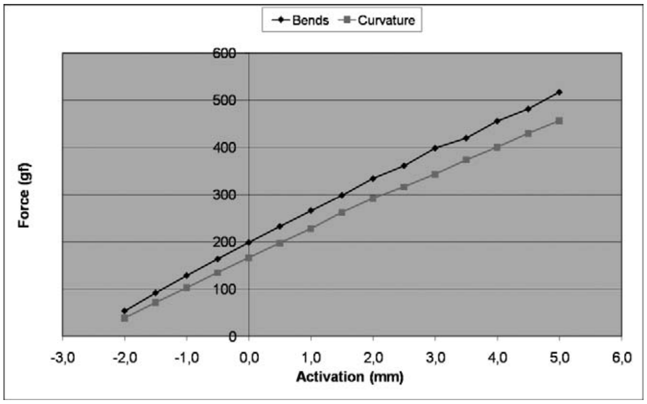

Figure 3. Horizontal force variation in the titanium T-loop springs (TTLSs) preactivated by bends and by curvature over a range of 7 mm of deactivation.

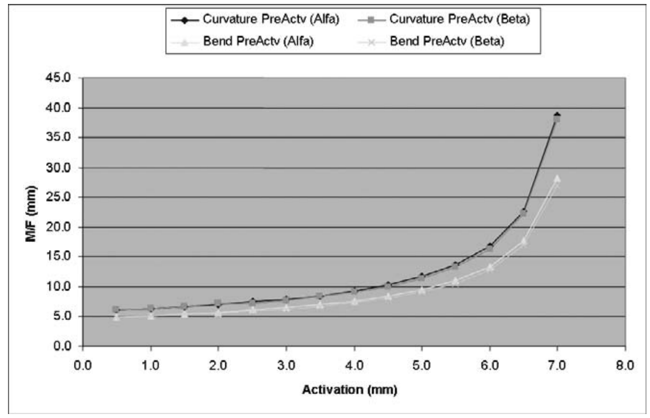

Figure 4. Data from the present study on the moment to force (MF) ratio variation over activation in both titanium T-loop spring (TTLS) preactivations, in alpha (anterior bracket) and beta (posterior bracket).

Table 2. Changes in Force for Every 0.5 mm of Activation in the Curvature and Bend Preactivation Titanium T-loop Springs (TTLSs)

	Variation in Force, gf	
Range, mm	Curvature	Bend
5.0 to 4.5	26.6	35.6
4.5 to 4.0	29.8	25.5
4.0 to 3.5	25.9	35.9
3.5 to 3.0	31.0	21.2
3.0 to 2.5	26.6	37.2
2.5 to 2.0	24.7	27.1
2.0 to 1.5	29.4	35.3
1.5 to 1.0	34.6	32.6
1.0 to 0.5	30.4	33.5
0.5 to 0.0	31.1	34.0
0.0 to (−0.5)	31.2	34.9
−0.5 to (−1.0)	31.9	34.7
−1.0 to (−1.5)	31.3	36.7
−1.5 to (−2.0)	33.0	38.0
Average	29.8	33.0

every 0.5 mm of deactivation (Table 2). Vertical forces ranging from 1.5 gF of intrusive force to 3.5 gF of extrusive force were low and clinically insignificant. The MF ratios increased with deactivation from 5.8 mm to 38.8 mm on the anterior bracket (alpha) and from 5.9 mm to 37.9 mm on the posterior bracket (beta) (Figure 4; Table 1).

The TTLS preactivated by the V-bends delivered horizontal forces increasing from 54 gf to 517 gf in the same range of activation as the preactivated curvature TTLS (Figure 3). The force decreased more (30 gf vs 33 gf) with every 0.5 mm of activation than the preactivated curvature TTLS (Table 2). Vertical forces ranged from 0.7 gf of intrusive force to 5.3 gf of extrusive force. The MF ratio at 5 mm of positive activation was 4.7 mm and increased gradually to 28.3 mm in alpha and from 4.7 mm to 27.0 mm in beta (Figure 4; Table 1).

DISCUSSION

The force delivered by the bend preactivated TTLS was systematically higher than the force delivered by the preactivated curvature TTLS. These results appear to be different from the findings of Manhartsberger et al[5] (Figure 5A,B), which showed initially higher forces for the preactivated V-bend TTLS. While residual stresses/plastic deformation could help explain this difference, it is more likely that the higher forces they report for the preactivated curvature TTLS are due to an error of activation, caused by greater activation of the curvature than the V-bend TTLS. Their data (Figure 5A) show a sudden depression between 0.5 mm and 0 mm of activation for the curvature bend TTLS, which dramatically alters the slope of the line representing its load/deflection rate. Within their elastic limit, TMA loops should display a constant load/deflection rate.[2,7,10,13,14] The limited increase in MF ratios at the curvature preactivated TTLS (Figure 5B) is also indicative of a problem. The lines on the graph should follow the same slopes until they cross the x-axis (Figure 5C), at which point the force delivered by the TTLS would be 0 (neutral position). This indicates that the curvature preactivated TTLS was systematically overactivated by 1.43 mm when compared to the bend preactivated TTLS. In order to compare the differences between loops, their y- and x-intercepts should be made to coincide. When the x-intercepts are made to coincide, measurements are registered at the same increments of activation from neutral position (which does not necessarily mean that the activation measured by the vertical extensions separation will be the same). When the same procedure is performed in the y-intercept, the activations can be measured from 0 (neutral position of each loop). With these adjust-

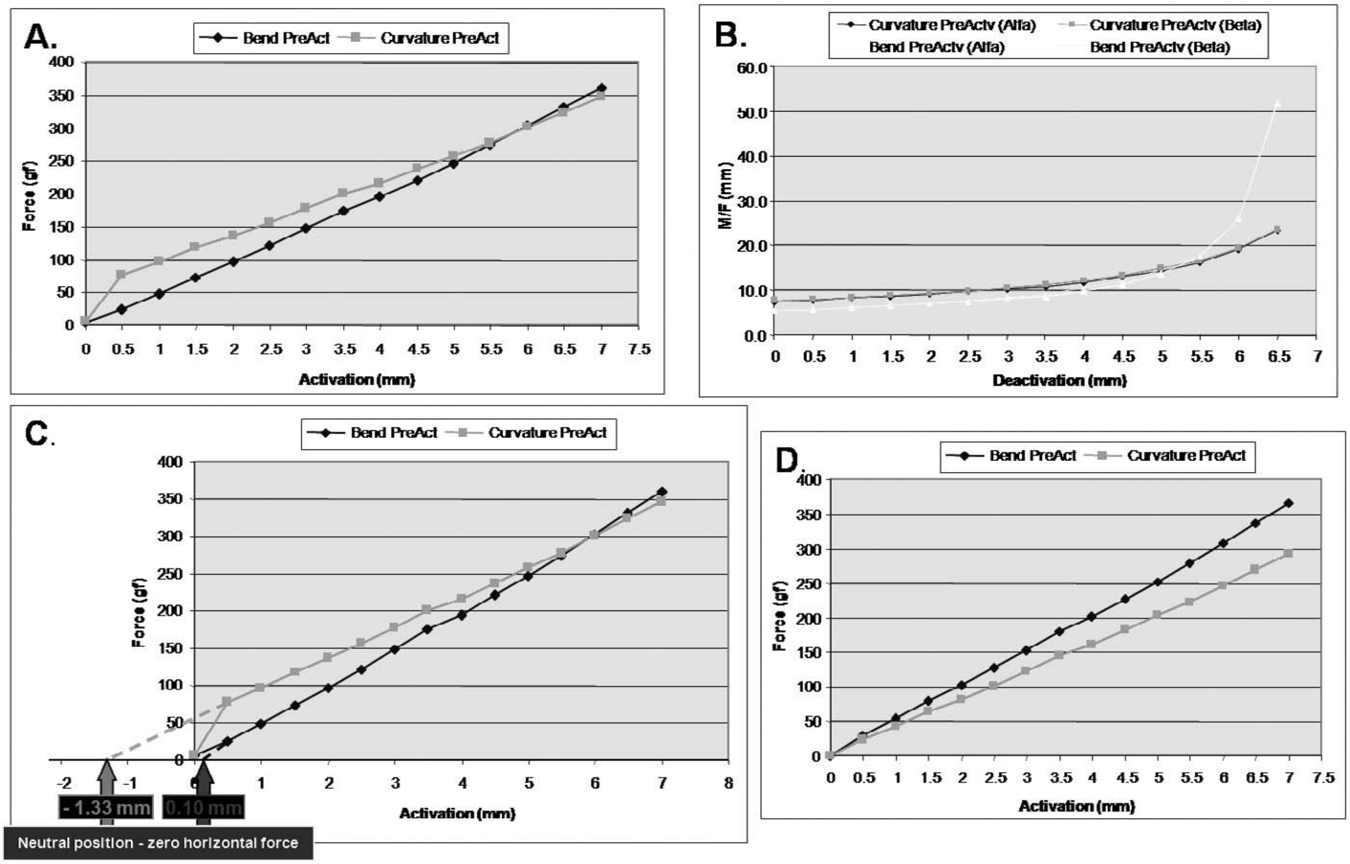

Figure 5. Plotted graph of the data from Manhartsberger et al[5] on a 0.017- × 0.025-inch group B titanium T-loop spring (TTLS) on the effect of deactivation. (A) On moment to force (MF) ratios. (B) On the horizontal force produced. (C) Graph A modified—the values pointed by the arrows depict the approximate relative ''activation'' where horizontal force produced by the TTLSs would be 0. (D) Graph A adjusted so both activations are the same at 0.

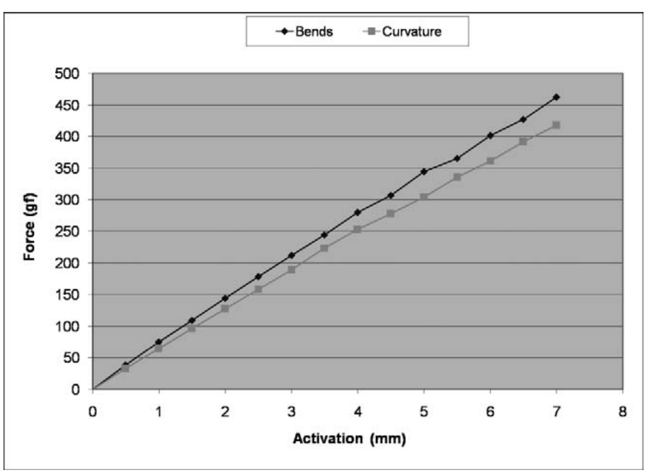

Figure 6. Plotted data from the present study on the effects of preactivation on the horizontal force on a 0.017- × 0.025-inch group B titanium T-loop spring (TTLS), mathematically adjusted so both activations are the same.

ments, the results of the data by Manhartsberger et al[5] (Figure 5D) are similar to the present study (Figure 6).

These adjustments are necessary due to the overlapping of the vertical extensions of the TTLSs (or any other loop) in neutral position, which increases when more angulation is added between the anterior and posterior extremities. Because the angulations of both TTLSs used in the present study were similar, the difference was small (0.17 mm) and resulted in an insignificant increase in force (15 gf/0.5 mm) for the bend preactivated TTLS. This demonstrates that the distance between the vertical extremities of the loop used to access activation is error-prone and should not be used when comparing different loops. Also, the clinician should be aware that the horizontal force increases when extra curvature is added adjacent to the loop or even to archwires with bull loops (ie, when adding more ''gable'' to a bull loop, the same 1 mm of activation generates more force).

It can be concluded that a preactivated curvature TTLS delivers lower forces with the same range of activation as the preactivated V-bend TTLS. Because both force deactivation rates are roughly the same, the curvature preactivation maintains a lower force throughout the entire range of deactivation. However, it appears to be harder to preactivate the TTLS with a specific curvature without the use of a chair-side template, whereas the bend preactivated one should not require the use of a template.

The force decrease per unit of activation was lower on the curvature preactivation than the V-bend preactivation. The difference on average, 3 gf per 0.5 mm of deactivation, is larger than the 1 gf reported by Manhartsberger et al,[5] but clinically insignificant. This implies that both loops have similar slopes and produce similar load/deflection ratios.

Both TTLSs tested in this investigation delivered symmetrical moments throughout the activations. This was expected, since the loops were symmetrically designed, and there was no difference in height or angulations between the brackets. This finding agrees with Manhartsberger et al,[5] who reported relatively symmetrical MF ratios of the preactivations. Their ratios were less symmetric than ours because the height differences in the vertical extensions of the loop generate greater discrepancy between the alpha and beta brackets. This implies that curvature or bend preactivations can be used for reciprocal space closure without major effects on the vertical position of the posterior and anterior segments.

Both TTLSs produced initial MF ratios that were too low for controlled tipping, assuming 7/1 mm produces this movement (Figure 4; Table 1). This is important because the theory of reciprocal space closure with a TTLS depends on moving the teeth initially by controlled tipping, then by translation and finally by root correction, all of which occur as the MF increases.[1,7] Manhartsberger et al[5] found higher MF ratios with bend, and lower with the curvature preactivated TTLS, which can be partially explained by the different sizes of loops, interbracket distances, and the higher degree of curvature used. If higher MF ratios are required initially, the height of the TTLSs used in the present study could be increased. For example, the LOOP software indicates that the MF ratios would have increased by 1.2 mm if the TTLSs had been 1 mm higher.

The TTLS preactivated by curvature delivered higher MF ratios. This happened because the force is lower and the moments are higher in the curvature preactivation. The average 2.5 mm of difference in MF ratios of the TTLSs is equivalent to the difference between a vertical loop 6 mm high, which has an MF ratio of approximately 2 mm,[1] and a simple force being applied to a tooth, such as elastic chains without wires through the brackets. Approximately the same difference in MF ratio will produce controlled tipping of teeth (7/1 mm) from uncontrolled tipping (5/1 mm), when a force is applied 10 mm from the center of resistance of a tooth vertically oriented. Thus, in addition to increasing the height of a TTLS, the MF ratios can be increased by changing its preactivation from bend to curvature. Curvature bends promote better internal stress distribution during bending. Also, it helps to minimize postinsertional permanent deformation by avoiding a compromise in the microstructure of the wire due to microcracks in areas of stress concentration.[15] As a consequence, more preactivation can be incorporated theoretically to the wire by curvature than by acute bends.

CONCLUSIONS

- Both curvature and bend preactivated TTLSs produced symmetrical moments, with small vertical forces, ranging from −1.5 gf to 4.5 gf. They also produced low MF ratios when activated 7 mm (5.9 mm and 4.7 mm for curvature preactivated and bend preactivated, respectively).
- The curvature preactivated TTLS produced horizontal forces that were lighter, 38.9 gf on average, than the bend preactivated TTLS.
- The curvature preactivated TTLS produced MF ratios that were approximately 2.5 mm higher than the bend preactivated TTLS.
- The curvature preactivated TTLS showed less force decrease per 0.5 mm of deactivation (29.8 gf) than the bend preactivated TTLS (33 gf).

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