Space closure in adult patients using the segmented arch technique

By Clemens Manhartsberger, DDS, MD; John Y. Morton, BS; and Charles J. Burstone, DDS, MS

Orthodontists accomplish space closure in different ways, depending on the diagnosis and treatment plan. Frictionless systems of space closure are superior to systems which introduce friction as a means of space closure. An appliance system without friction allows greater control of tooth movement during space closure.[1] Specialized precalibrated springs for space closure are an integral part of the segmented arch technique. Precalibrated attraction springs have three characteristics of interest: 1) the alpha (anterior) moment produced by the spring; 2) the beta (posterior) moment produced by the spring; and 3) the horizontal force generated. The type of movement is dictated by the moment to force ratio (M/F) generated by the appliance at the attachments.[1,2,3] Typically, M/F ratios of approximately 7:1 millimeters result in controlled tipping, 10:1 millimeters result in translational movements, and values of 12:1 millimeters or greater accomplish root movement. These ratios are based on the assumptions that the root lengths are 12 millimeters, the distance from the bracket slot to the alveolar crest is five millimeters, the alveolar bone condition is normal, the axial inclination of the teeth is normal, and the center of resistance is located apically a distance .40 times the root length when measured from the alveolar crest to the apex. The variation of the center of resistance with differing levels of bony support is shown in Figure 1. With a change in the center of resistance the M/F ratio must be modified (Figure 2); thus, in adult patients with periodontal loss, higher M/F values must be attained.

A vertical loop of six millimeters height produces a M/F ratio of 2:1 millimeters.[2] This value is too low to maintain root control, and a mesial displacement of the root will result. To obtain higher M/F ratios a number of strategies can be employed. The loop can be made as long as possible in an apical direction. By increasing the height of the loop to 11 millimeters, one will

Abstract
Periodontally compromised adult patients may benefit from modified appliance designs for space closure. TMA T-loops of .016" x .022" and .017" x .025" cross sections, with angulations incorporated via concentrated bends and gradual curvature bends are presented. The force systems these appliances produce are measured, and their clinical performances discussed. Templates for these T-loops are presented. By producing lower forces and higher moment to force ratios, this type of T-loop may benefit patients with bony loss.
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Key Words
Space closure • Bony loss • Moment to force ratio • Retraction

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Figure 1
The variation of the center of resistance with differing levels of bony support.

Figure 2
More bone loss necessitates an increase in the M/F ratio to produce translational movement. The ratios above are calculated making assumptions concerning the root length, axial inclination, and the position of the center of resistance.

Figure 3
With increasing gingival horizontal length of a T-loop (G), the M/F increases and the load deflection rate (F/△) decreases.[2]

Figure 1

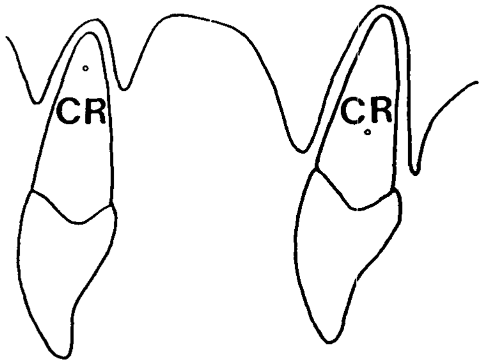


Figure 2

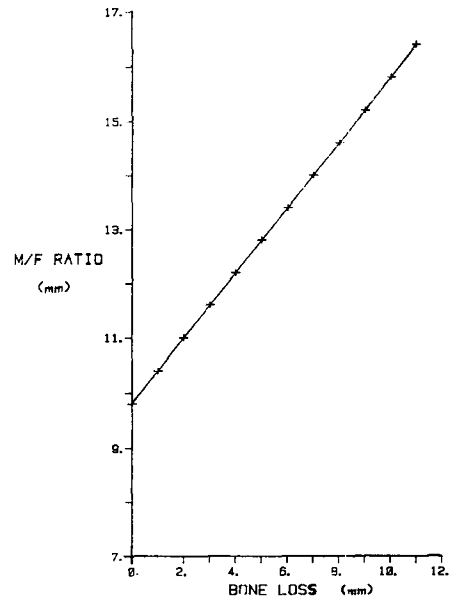


Figure 3

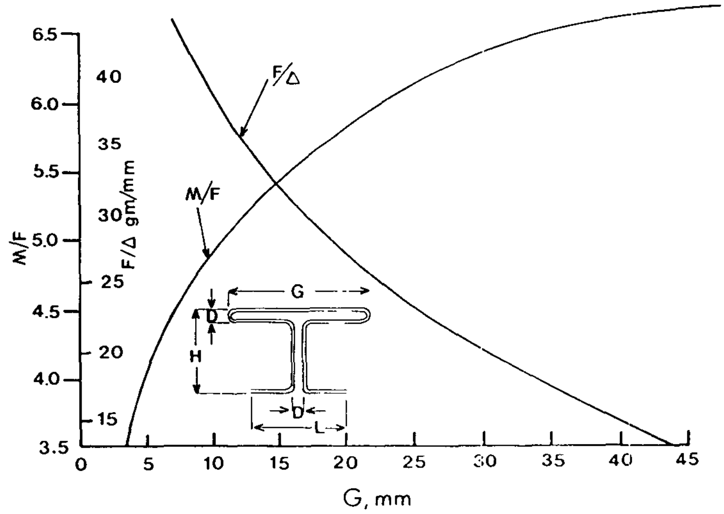


Figure 4

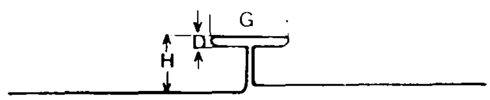


Figure 5

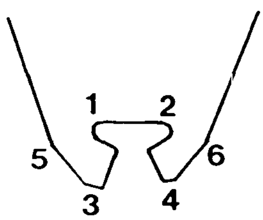
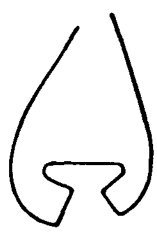


Figure 4
The T-loop dimensions (H = 7mm, D = 2mm, G = 10mm).

Figure 5
TMA T-loop with concentrated angulation. The positions at which the spring is bent are marked by the numbers.

Figure 6
TMA T-loop with gradual curvature angulation.

Figure 6



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approximately double the M/F ratio. However, there are limitations to how far apically the loop can extend before irritation is produced in the mucobuccal fold. Another approach is to increase the amount of wire placed gingivally at the top of the loop, as in the T-loop. Figure 3 shows that increasing the gingival length of wire (dimension G) increases the M/F ratio and reduces the load deflection rate. The advantages of the T-loop design over a vertical loop is that the T-loop produces a higher M/F ratio, a lower load-deflection rate, and delivers a more constant force and M/F ratio.[2]

Often in adult patients, where no growth is anticipated, extraction therapy is performed. The situation is often complicated through loss of bone. In order to maintain an assumed stress magnitude and distribution under the condition of reduced bony support area, force magnitude must be reduced and the M/F ratio must be increased. The necessity of producing a lower load deflection rate in such cases suggests the use of a wire with lower stiffness. This study will evaluate the effect of reducing the wire cross-section upon the force system produced and will establish a spring design for attraction (anterior retraction and posterior protraction), which renders possible lower force *and* higher M/F values for the compromised periodontal cases.

Material and methods

TMA T-Loops* of cross-sections .017" x .025" and .016" x .022" were tested (Figure 4). Two different methods of angulation were employed in this study: 1) TMA T-loops with concentrated bends (Figure 5); and 2) TMA T-loops with gradual curvature bends (Figure 6). An average distance from the buccal tube to the canine bracket of 28 millimeters was used as the inter-bracket distance for the study. The force system was measured over the range of seven millimeters of deactivation from this value. A "spring tester" developed at the University of Connecticut, Department of Orthodontics measured the uniplanar force system produced by the appliances[4] (Figures 7 and 8). Nine springs of each type were tested. Means and standard deviations were calculated.

Results

Use of a lower stiffness wire in configuring the T-loop results in a lower force magnitude and lower moment magnitude irrespective of the method of angulation employed. As desired in an attraction spring, the anterior and posterior moments are approximately the same. For the purpose of discussion, the anterior and posterior moment values were pooled and a representative mean calculated.

A comparison of the force systems produced by the .017" x .025" TMA T-loops and the .016" x .022" loops, both with concentrated bends at seven millimeter activation, shows a decrease of the horizontal force from 360 grams to 244 grams and a decrease of the moment from 1935 gram-millimeters to 1486 gram-millimeters. The

*Ormco Corporation, Glendora, CA

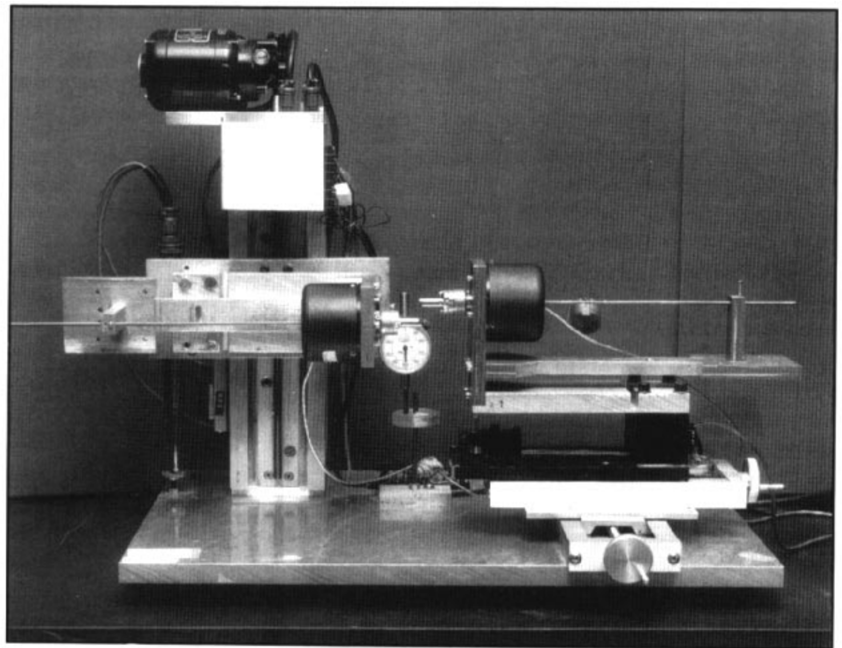

Figure 7

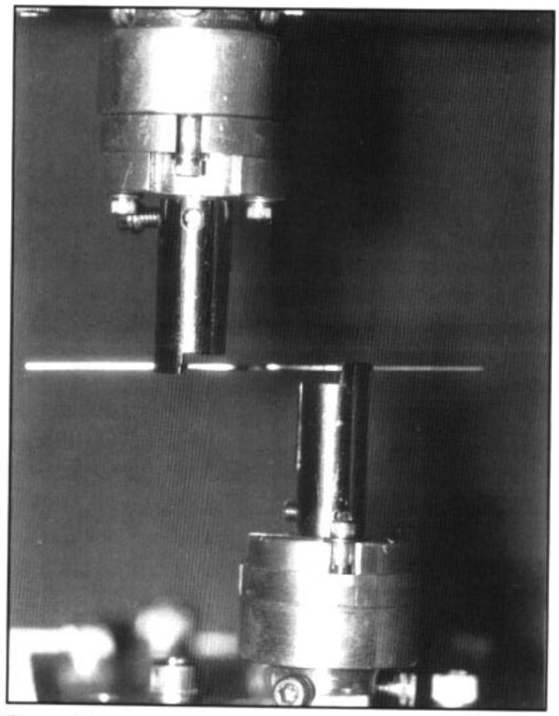

Figure 8

Figure 7
Force-Transducer system for measuring uniplanar forces and moments.

Figure 8
T-loop mounted in testing device.

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Table I
Attraction spring with concentrated angulation; TMA 0.017" x 0.025"; centered placement.

TABLE I

Δ mm	F_H Gm.	F_V Gm.	Mα Gm.-mm	Mβ Gm.-mm	F/Defl Gm.-mm	Mα/F mm	Mβ/F mm
0.0	5.1	2.8	1060.61	1079.2	0.0	X	X
0.5	24.1	4.3	1150.5	1156.6	47.3	51.9	52.2
1.0	48.7	3.8	1234.21	1235.6	48.9	25.9	25.8
1.5	73.6	3.8	1272.8	1318.8	49.0	17.4	18.0
2.0	96.9	4.9	1326.8	1392.4	47.4	13.7	14.4
2.5	121.6	5.5	1374.6	1462.9	49.0	11.3	12.0
3.0	147.2	7.4	1426.1	1531.0	51.3	9.7	10.4
3.5	174.5	7.8	1504.8	1591.3	55.4	8.6	9.1
4.0	195.1	7.8	1597.9	1648.4	40.3	8.2	8.4
4.5	220.4	7.7	1661.3	1703.3	51.2	7.5	7.7
5.0	246.4	9.3	1745.4	1754.5	51.4	7.1	7.1
5.5	274.0	9.4	1797.5	1796.4	56.3	6.6	6.5
6.0	302.8	11.0	1850.9	1858.1	57.7	6.1	6.1
6.5	331.2	10.4	1880.5	1907.0	57.1	5.7	5.7
7.0	360.3	11.6	1926.2	1945.1	56.7	5.3	5.4

Table II
Attraction spring with concentrated angulation; TMA 0.016" x 0.022"; centered placement.

TABLE II

Δ mm	F_H Gm.	F_V Gm.	Mα Gm.-mm	Mβ Gm.-mm	F/Defl Gm.-mm	Mα/F mm	Mβ/F mm
0.0	0.0	10.7	835.3	884.9	0.0	X	X
0.5	35.2	11.1	918.6	1021.9	74.4	26.0	29.6
1.0	50.7	11.6	970.0	1070.9	30.9	18.5	20.9
1.5	67.0	11.4	994.0	1117.5	32.6	14.4	16.2
2.0	82.8	10.7	1042.0	1165.2	31.7	12.2	13.6
2.5	98.0	10.7	1077.4	1205.6	31.1	10.6	11.9
3.0	114.0	10.4	1121.9	1244.2	31.2	9.5	10.6
3.5	130.0	9.9	1143.6	1293.9	31.9	8.5	9.6
4.0	147.4	9.5	1189.4	1331.0	35.4	7.8	8.8
4.5	163.4	8.8	1224.0	1366.0	30.1	7.3	8.1
5.0	181.1	8.7	1273.9	1397.0	33.3	6.9	7.6
5.5	195.3	8.4	1331.4	1428.0	32.4	6.6	7.1
6.0	210.0	8.4	1366.1	1464.2	27.8	6.4	6.8
6.5	226.6	8.8	1419.3	1490.6	33.1	6.1	6.4
7.0	243.6	10.5	1457.2	1516.0	34.8	5.8	6.0

M/F ratio is essentially unaffected by the change in cross-section. The values are 5.4:1 millimeters and 5.9:1 millimeters (Tables I and II).

A comparison of the force systems produced by the .017" x .025" TMA T-loops and the .016" x .022" loops, both with concentrated bends at five millimeter activation, shows a decrease of the horizontal force from 246 grams to 181 grams, and a decrease of the moment values from 1750 gram-millimeters to 1335 gram-millimeters. The M/F ratios remain relatively constant. Values of 7.1:1 millimeters and 7.3:1 millimeters are produced (Tables I and II).

A comparison of the force system produced by the .017" x .025" and the .016" x .022" TMA T-loops, both with gradual curvature bends at seven millimeter activation, demonstrates a decrease of the horizontal force from 346 grams to 243 grams, and a decrease of the moment values from 2605 gram-millimeters to 1835 gram-millimeters. The M/F ratios are equivalent at 7.5:1 millimeters (Tables III and IV).

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Table III
Attraction spring with gradual curvature angulation; TMA 0.017" x 0.025"; centered placement.

TABLE III

Δ mm	F_H Gm.	F_V Gm.	Mα Gm.-mm	Mβ Gm.-mm	F/Defl Gm.-mm	Mα/F mm	Mβ/F mm
0.0	5.5	4.9	1681.3	1595.7	0.0	X	X
0.5	76.9	5.2	1779.7	1780.3	148.0	23.4	23.6
1.0	96.5	6.1	1844.5	1861.8	41.5	19.1	19.4
1.5	117.9	6.9	1907.4	1931.7	40.3	16.2	16.5
2.0	136.6	7.6	1953.2	2019.4	37.3	14.3	14.9
2.5	155.8	8.8	2040.4	2079.1	38.3	13.0	13.3
3.0	177.3	9.5	2082.6	2158.2	43.5	11.7	12.1
3.5	200.5	10.7	2149.4	2225.0	45.2	10.7	11.1
4.0	215.9	11.5	2227.8	2284.5	31.4	10.3	10.6
4.5	236.3	12.1	2314.2	2344.6	41.4	9.7	9.9
5.0	257.9	13.1	2372.4	2408.7	41.8	9.1	9.3
5.5	277.8	14.6	2445.2	2461.4	39.2	8.7	8.9
6.0	300.9	14.1	2493.1	2505.5	47.2	8.3	8.3
6.5	323.9	15.9	2530.2	2566.6	46.6	7.7	8.0
7.0	346.3	16.2	2578.4	2631.6	43.6	7.4	7.6

Table IV
Attraction spring with gradual curvature angulation; TMA 0.016" x 0.022"; centered placement.

TABLE IV

Δ mm	F_H Gm.	F_V Gm.	Mα Gm.-mm	Mβ Gm.-mm	F/Defl Gm.-mm	Mα/F mm	Mβ/F mm
0.0	2.9	0.9	1190.5	1074.3	0.0	X	X
0.5	49.9	1.2	1325.3	1254.5	98.6	27.3	25.8
1.0	63.7	1.2	1362.3	1307.5	27.2	21.6	20.7
1.5	78.1	2.0	1402.7	1352.1	27.5	17.9	17.3
2.0	92.4	3.0	1438.3	1400.2	28.8	15.5	15.1
2.5	107.5	4.1	1473.6	1466.7	30.0	13.6	13.6
3.0	121.7	4.7	1505.6	1514.4	28.5	12.3	12.4
3.5	136.0	5.4	1535.2	1560.8	28.6	11.2	11.4
4.0	150.2	6.4	1568.8	1596.7	27.9	10.4	10.6
4.5	165.6	7.0	1617.4	1644.5	30.5	9.7	9.8
5.0	182.5	7.7	1661.2	1684.3	33.6	9.1	9.2
5.5	198.3	9.0	1708.9	1719.6	33.1	8.5	8.7
6.0	213.6	10.0	1757.4	1750.6	30.3	8.2	8.1
6.5	228.8	10.3	1805.2	1785.0	30.6	7.8	7.7
7.0	242.7	13.1	1847.4	1822.2	28.2	7.6	7.5

Comparing the values produced by the .017" x .025" and .016" x .022" TMA T-loops with gradual curvature bends at five millimeter activation shows a decrease of the horizontal force from 258 grams to 182 grams and a decrease of the moment values from 2391 gram-millimeters to 1673 gram-millimeters. The M/F ratios are equivalent at 9.2:1 millimeters (Tables III and IV).

All standard deviations produced were less than 6.3 percent of the mean.

Discussion

The level of bone support should be determined and an estimate of centers of resistance should be made for each patient. Differences in bony anatomical geometry should also be noted between anterior and posterior segments. Actual force systems must be individualized for each patient by altering wire cross-section, angulation, and activation. Generally, the force magnitude must be decreased, and the M/F value in-

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creased. The force magnitude can be lowered by reducing the cross-section and/or the amount of activation of the spring. The M/F ratio can be increased by augmenting the angulation of the T-loop.

For example, a TMA T-loop composed of .016" x .022" wire, with gradual curvature for angulation, and only activated to five millimeters in comparison to an activation of seven millimeters for a .017" x .025" T-loop produces a 47 percent lower force and M/F values that are 23 percent higher.

Also, .016" x .022" TMA T-loop with concentrated angulation bends can be used with initial horizontal activation of five millimeters. The lower M/F ratios incurred during the first two millimeters of deactivation in comparison to the gradual curvature spring will result in more controlled tipping of the segment initially. This effect should be taken into consideration; hence, the spring should be left in place for greater space closure allowing the M/F ratios to increase.

Summary

Appliance designs for accomplishing space closure in adult patients with bony loss were described. To maintain an assumed stress magnitude and distribution under such conditions, force magnitude was reduced, and the M/F ratio increased. TMA T-loops of two cross-sections (.017" x .025", .016" x .022"), and two methods of incorporating angulations (using concentrated bends and using gradual curvature bends) were investigated. An automated "spring tester" apparatus measured the forces and moments produced by each spring. The data showed that the force magnitude can be lowered by reducing the cross-section and/or the amount of activation of the spring. The M/F ratio was increased by augmenting the angulation of the T-loop. A .016" x .025" TMA T-loop activated five millimeters with gradual curvature bends in comparison to a .017" x .025" TMA T-loop activated seven millimeters produced a 47 percent lower horizontal force, and a 23 percent higher M/F ratio. Although the spring designs investigated in this study produced lower force magnitudes and higher M/F ratios, the actual spring must be individualized for each patient by altering wire cross-section, angulation, and activation.

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