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Original Article

Comparison of force and moments of T-loop using software and manual methods

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ABSTRACT

Background: *T loops are most commonly used in space closure in Orthodontics hence the comparative force and moments were determined using both the methods*

Objectives: *To determine and compare moments and forces generated by T loop spring using software and manual spring testing method.*

Materials & Methods: *Using the Loop software program (dHal, orthodontic loop simulator 1.7.0.0) force and moment and their ratios were calculated at various positions and for various activations for a standard design of T loop (.017 x .025 TMA) given by Kuhlberg & Burstone. The values were then compared with the corresponding values determined by manual spring tester method. Statistical analysis was done using Independent t-test and multivariate regression analysis.*

Results: *The results showed that the alpha/beta moment ratio was dependant only on the spring position and independent of spring activation. The force system produced by a spring placed 1 mm closer to alpha attachment with 3.5 mm activation provided for bodily movement of anterior segment with M/F ratio of 9.7. This was lesser than that determined by spring tester by 0.7 for same amount of activation and same position.*

Conclusion: *The comparison of the two methods for designing T loop showed statistically insignificant differences in M/F values. The loop software provided for good simulation of T loop design similar to manual method. The values determined by software and manual methods were highly correlated.*

Key Words: *T loop, loop software, moment, orthodontic loops, segmented arch mechanics*

Introduction

The segmented arch mechanics proposes the application of differential moments for efficient space closure. [1] The two distinct advantages of closing loop mechanics over sliding mechanics lies in the fact that they are frictionless and are capable of producing various kinds of tooth movements ranging from tipping, bodily movement to root movement depending upon the M:F ratio. [2, 3] T loops are very efficient force system for attaining such

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movements. Various designs of T loops along with various degrees of pre activations have been proposed in literature previously. The most commonly used being the one suggested by Kuhlberg & Burstone with alpha and beta angles of 30° each approximately, producing a total pre activation of 60°. [4-7](Fig.1) Loop software (dHAL, orthodontic loop simulator, Greece) simulates and calculates the moment and force values at the level of the brackets. It can be used for evaluating all kinds of springs and for planning future designs and modifications of existing ones. [8]

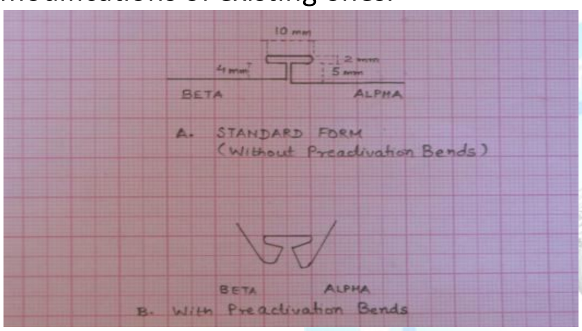

Fig.1 .017 X .025 TMA T loop spring for 6 mm activation with pre-activation bends

This study intends to determine and compare moments and forces generated by T loop spring using software and manual spring testing methods. It is hypothesized that the moment differential (represented by a ratio of the moments) is dependent on the spring position and spring activation.

Materials & Methods

A loop software program, dHal, orthodontic loop simulator version 1.7.0.0 was used to design a standard T loop, as described by Andrew J. Kuhlberg and Charles J. Burstone in the year 1997. The loop was designed using .017 X .025 TMA wire. All loops were tested in the wire having same dimensions and same material. (Fig.2)

The program simulates loop designs that are attached by their ends at two orthodontic attachments. Initially wire is attached at only one bracket slot; user draws the desired T loop and then activates it till the other attachment where it is inserted in the other slot. (Fig.3,4) Forces, moments and M/F ratios were noted at both the ends.

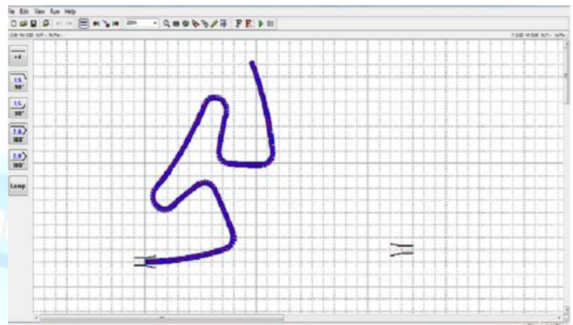

Fig.2 .017 X .025 TMA T loop spring for 6 mm activation in neutral position

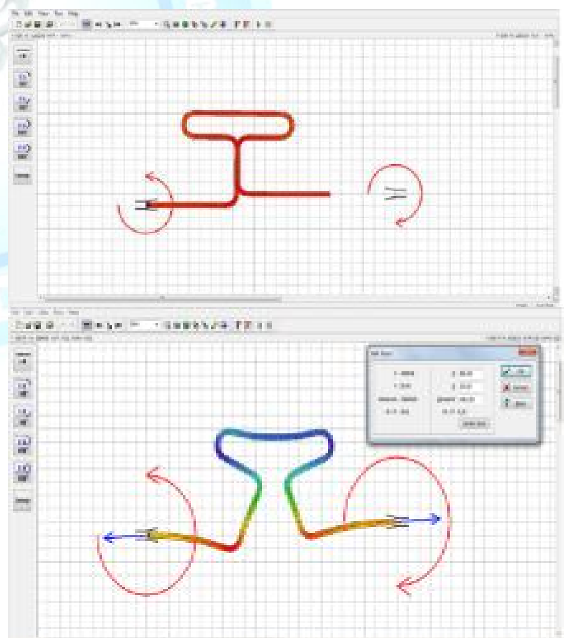

Fig. 3,4 .017 X .025 TMA T loop spring for 6 mm activation upon activation

Loop specifications were as follows:

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- Total length of wire between two brackets: 193 nodes of .25 mm each at true thickness.
- Total length of T loop: 10 mm
- Length of α vertical arm : 5 mm
- Length of β vertical arm : 4 mm
- Total vertical length at α node : 7 mm (5+2)
- Total vertical length at β node : 6 mm (4+2)

The inter-bracket distance was kept at 23 mm. The angulation of both brackets was zero. i.e slots were aligned on X-axis to avoid the error due to gabling effect. The loops were subjected to a range of activations as 6.0, 5.5, 5.0, 4.5, 4.0, 3.5, 3.0, 2.5, 2.0, 1.5 and 1 mm. For each activation the values were determined for seven positions; at centre, 1, 2, 3 mm anteriorly and 1, 2, 3 mm posteriorly.

The Moment/Force values were tabulated for all the activations and all the positions. These values were then compared and analysed statistically with the values determined by Kuhlberg and Burstone using spring tester. [9]

Mean, Standard deviation and standard error were determined for both the groups. Levenes test for equality of variances and parametric Independent samples T test was used to calculate equality of means at 95% confidence level.

Results

The force system produced by a spring placed 1 mm closer to alpha attachment with 3.5 mm activation provided for bodily movement of anterior segment with a M/F ratio of 9.7. This was lesser than that determined by spring tester by 0.7 for same amount of activation and same position. Also when spring was placed 2 mm anteriorly from centre with 2.5 mm activation yielded a moment of 12.5 required for root movement (Table: I) whereas the spring tester yielded a moment of 12 in centre position for same activation. The comparison of the two methods for designing T loop showed statistically insignificant differences in M/F values. (Table: II)

Table I- Moment/Force values by spring tester and dHal software for all activations

Activations	Position	dHal Software		Spring Tester	
		M/F at α position	**M/F at β position**	**M/F at α position**	**M/F at β position**
6 mm	**Centre**	**-5.81**	**6.2**	**-6**	**6.2**
	1 mm anteriorly	**-6.75**	**5.27**	**-6.9**	**5**
	2 mm anteriorly	**-7.5**	**4.3**	**-7.8**	**3.7**
	3 mm anteriorly	**-8.06**	**3.31**	**-8.1**	**2.9**
	1 mm posteriorly	**-4.65**	**7.04**	**-3.7**	**6.8**
	2 mm posteriorly	**-3.54**	**7.53**	**-3.1**	**7.4**
	3 mm posteriorly	**-2.78**	**7.73**	**-2.2**	**7.6**
5.5 mm	**Centre**	**-6.11**	**6.54**	**-6.4**	**6.6**
	1 mm anteriorly	**-6.77**	**5.23**	**-7.3**	**5.3**
	2 mm anteriorly	**-7.94**	**4.18**	**-8.3**	**3.9**
	3 mm anteriorly	**-8.17**	**3.03**	**-8.5**	**3.1**
	1 mm posteriorly	**-5.04**	**7.2**	**-4**	**7.2**
	2 mm posteriorly	**-4.06**	**7.34**	**-3.3**	**7.8**
	3 mm posteriorly	**-3.16**	**7.69**	**-2.4**	**8.1**

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5 mm	Centre	-6.53	6.91	-7	7.1
	1 mm anteriorly	-7.08	6.07	-7.8	5.7
	2 mm anteriorly	-7.93	4.96	-8.9	4.2
	3 mm anteriorly	-8.47	3.98	-9.2	3.3
	1 mm posteriorly	-5.38	7.69	-4.4	7.8
	2 mm posteriorly	-4.36	8.09	-3.6	8.3
	3 mm posteriorly	-3.31	8.41	-2.6	8.5
4.5 mm	Centre	-6.97	7.24	-7.7	7.7
	1 mm anteriorly	-7.98	5.93	-8.5	6.2
	2 mm anteriorly	-8.66	4.41	-9.8	4.7
	3 mm anteriorly	-8.79	3.08	-9.8	3.5
	1 mm posteriorly	-5.76	7.95	-4.6	8.2
	2 mm posteriorly	-4.82	8.32	-4	9
	3 mm posteriorly	-3.91	8.59	-2.9	9
4.0 mm	Centre	-7.53	7.72	-8.3	8.2
	1 mm anteriorly	-8.58	6.33	-9.2	6.6
	2 mm anteriorly	-9.02	4.6	-10.4	4.9
	3 mm anteriorly	-8.91	3.31	-10.5	3.8
	1 mm posteriorly	-6.19	8.47	-5.1	9
	2 mm posteriorly	-5.21	8.82	-4.3	9.6
	3 mm posteriorly	-4.35	8.78	-3.2	9.6
3.5 mm	Centre	-8.39	8.38	-9.1	9.1
	1 mm anteriorly	-9.7	6.99	-10.4	7.4
	2 mm anteriorly	-9.96	5.38	-11.4	5.4
	3 mm anteriorly	-10.28	3.97	-11.6	4.3
	1 mm posteriorly	-6.64	9.03	-5.7	9.9
	2 mm posteriorly	-6.16	9.17	-4.8	10.4
	3 mm posteriorly	-5.16	9.19	-3.6	10.5
3.0 mm	Centre	-8.88	9.47	-10.3	10.2
	1 mm anteriorly	-10.11	8.03	-11.4	8.1
	2 mm anteriorly	-11.09	6.57	-12.9	6.1
	3 mm anteriorly	-10.42	4.77	-12.6	4.6
	1 mm posteriorly	-8.55	9.95	-6.3	10.9
	2 mm posteriorly	-6.9	10.32	-5.3	11.4
	3 mm posteriorly	-6.24	10.39	-4.1	11.5
2.5 mm	Centre	-11.51	9.54	-12	11.9
	1 mm anteriorly	-11.48	7.9	-13.2	9.5
	2 mm anteriorly	-12.54	6.33	-14.3	6.8
	3 mm anteriorly	-12.13	4.27	-14.1	5.1
	1 mm posteriorly	-9.69	10.99	-7.2	12.4
	2 mm posteriorly	-8.29	11.43	-6.1	13.2
	3 mm posteriorly	-6.77	11.55	-4.5	12.7
	Centre	-14.48	11.81	-13.9	13.8

2.0 mm	1 mm anteriorly	-14.65	9.64	-15.3	10.9
	2 mm anteriorly	-14.74	7.06	-16.9	8
	3 mm anteriorly	-13.28	6.03	-16.3	6
	1 mm posteriorly	-12.92	13.23	-8.4	14.4
	2 mm posteriorly	-9.76	13.39	-7.1	15.1
	3 mm posteriorly	-8.38	12.86	-5.5	15
1.5 mm	Centre	-18.8	15.31	-18.5	18.2
	1 mm anteriorly	-18.67	12.77	-19.4	13.8
	2 mm anteriorly	-19.02	9.61	-20.8	10
	3 mm anteriorly	-17.33	7.1	-20.5	7.7
	1 mm posteriorly	-15.48	16.29	-10.4	17.8
	2 mm posteriorly	-13.33	16.71	-9	18.7
	3 mm posteriorly	-10.12	15.73	-6.9	18.2
1.0 mm	Centre	-28.32	23.04	-26.4	26
	1 mm anteriorly	-29.28	19.8	-26.8	19.1
	2 mm anteriorly	-24.9	12.67	-30.7	14.8
	3 mm anteriorly	-23.25	8.19	-26.7	10.1
	1 mm posteriorly	-24.29	23.72	-14.6	25.1
	2 mm posteriorly	-17.79	21.42	-12.8	26.5
	3 mm posteriorly	-14.99	20.59	-9.6	24.3

TABLE II- Group statistics n=7 in each group

	Groups	Mean±SD
For 6 mm activation	1	5.91±1.68
	2	5.66±1.83
For 5.5 mm activation	1	5.88±1.78
	2	6.00±1.94
For 5 mm activation	1	6.58±1.66
	2	6.41±2.05
For 4.5 mm activation	1	6.50±2.11
	2	6.90±2.16
For 4 mm activation	1	6.86±2.19
	2	7.38±2.33
For 3.5 mm activation	1	7.44±2.07
	2	8.14±2.49
For 3 mm activation	1	8.50±2.15
	2	8.97±2.75
For 2.5 mm activation	1	8.85±2.80
	2	10.22±3.18
For 2 mm activation	1	10.57±3.04
	2	11.88±3.66
For 1.5 mm activation	1	13.36±3.71
	2	14.91±4.50
For 1 mm activation	1	18.49±5.81
	2	20.84±6.37

Discussion

The force system produced by T loop springs depends on many factors as amount of spring activation, spring positions, spring design, shape, wire size and material. [9, 10] In this study, moment differential was achieved only by eccentric positioning of spring without changing the spring shape. Off centre positioning maintains constant moment differential throughout the phenomenon of spring deactivation. This in turn improves anchorage control and force system predictability. [9]

The preactivation curvature bends of 30° were incorporated in the spring anteriorly and posteriorly. [9] The curvature preactivated T loop spring generates lower and constantly degenerating force levels compared to bend preactivated T loop spring. Moreover, curvature bends promote better internal stress distribution during bending. Also it minimizes post insertion permanent deformation by avoidance of microcracks in areas of stress distribution.[11-13] The non preactivated closing loops are unable to generate an optimum M/F for translation tooth movement. [14] As previously determined by Halazonetis, the loop software reported higher force levels by 12%. Hence a correction factor should be included in the force values only; although the M/F ratio remains almost same. [15]

When the M/F values obtained from the two methods were compared, they were almost similar with small differences. These differences occurred due to the standard deviations inherent to the error of the spring tester, spring manufacturing and also because of the mathematical calculations of the software. [16] There are definite errors in the values obtained from both the manual method and software simulation method. The errors in the manual method are due to error in fabrication and in placing loop in spring tester. These errors can indeed be large in magnitude and cannot be neglected. [16] The errors due to computer simulation are due to inability to exactly model complex phenomenon as plastic deformation, strain hardening and crystal imperfections in mathematical equations. [16]

The comparison of the two methods for designing T loop showed statistically insignificant differences in M/F values. Hence the design simulation by software provides the clinician with a handy, economical and more determinate tool for fabrication of loops before placing it in patient, enabling better prediction of planned tooth movements.

The comparison of the two methods for designing T loop showed statistically insignificant differences in M/F values. The values determined by software and manual methods were highly correlated. A standard shaped T-loop can be used for differential anchorage requirements by altering the activation and mesio-distal position of the spring. Loop software provided for excellent simulation of loop design and provides the clinician with a handy tool for treatment planning. The use of this software should be promoted as it is time saving and provides for more predictable results by eliminating manufacturing and human error factors.

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