

Comparison of Mechanical Properties Between three Different Types of T-loop

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Abstract

Statement of Problem: T-loop is one of the most popular closing loops in orthodontic profession. However its activation is in the contrary to Bouschinger effect theory, since the formed bends would be opened during activation. The purpose of this study was to add a helix in a way to be more respondent to the Bouschinger effect theory.

Objectives: To compare the load deflection, maximal elastic load and range between three different types of T-loop.

Materials and Methods: 5 sample of each 3 different designs of T-loop (group 1: original T-loop, group 2: T-loop with the two inner helices, group 3: T-loop with the two helices constructed outside the horizontal part) had been tested with universal testing machine (Instron). The load –deflection curves was plotted and the mechanical properties (load deflection, maximal elastic load and range) were measured. One way ANOVA was used to identify statistical differences between designs.

Results: The mean value of maximal elastic load in group 1 (6.02 ± 0.27) was significantly higher than group 2 (5.16 ± 0.46) and in group 2 were significantly higher than group 3 (4.35 ± 0.25) ($p < 0.001$). A significantly higher load deflection was reported in group 1 (0.73 ± 0.36) in comparison to group 2 (0.56 ± 0.74) and group 3 (0.56 ± 0.69) ($p = 0.002$), with no significant difference between two latest groups ($p = 0.999$). The mean range in group 3 (4.15 ± 0.10) was significantly lower than group 1 (5.43 ± 0.13) and group 2 (5.59 ± 0.15) ($p < 0.001$) with no significant difference between group 1 and 2 ($p = 0.149$).

Conclusions: The results revealed that increasing length of T-loop with helices will decrease Load deflection rate the place and design of helices might not be a crucial factor. The new design of T-loop with helices relevant to Bouschinger effect theory needs a further survey regarding their position.

Introduction

Retraction of the teeth is an important phase in most of the orthodontic treatments in extraction cases [1]. Mechanics can be either a closing loop or sliding with some advantages in each. Closing loops have a friction free mechanics, also if the moment-to-force ratio (M:F) is controlled, any type of tooth movement can be possible. With any changes in the dimensions, material, design of the closing loops, and the inter bracket span their properties can be handled as desired [1,2,3]. The mechanical characteristics of a wire are determined by several factors.

Intrinsic properties are inherent qualities of the wire. These properties are determined by material composition at the molecular or crystalline level and their variations alter the nature of the alloy [4].

In comparison to stainless steel alloy, optimum M:F ratios for orthodontic translation can be achieved by using pre activated nickel titanium (NiTi) and titanium molybdenum alloy (TMA) T-loop, with NiTi loops maintaining the optimum M:F ratio over a greater range of deactivation [4,5]. On the other hand, the extrinsic properties are macroscopic features that can be determined by the clinicians [6,7]. The load deflection (LD) defines as the unit deformation by external force is one of the most important properties. Increasing the length of the wire by incorporating loops into the arch wire is a common method for decreasing LD during tooth movement such as anterior retraction [8,9].

A low LD is considered as an advantage during the tooth movement, but maximal elastic load which signifies as the greatest force applied to a member without causing permanent deformation should also be monitored. Uncontrollable lowering of the maximal elastic load can have side effects such as permanent deformation or breakage of the designed loop during normal oral function, generation of unwanted forces, trauma to the teeth and supporting tissues [10]. It is noteworthy the loop design which effectively reduces the load deflection may also decrease the maximal elastic load. Nevertheless, the design of the loops and their mode of activation can affect their strength [11]. However, the force systems are tooth specific and depend on the location of the loop and geometry and gable angle. Moreover, heat treatment of wire may reduce the LD [11, 12].

T-loop is one of the most preferred closing loops whenever a higher magnitude of displacement is de-

sired [13]. One of the most common method to reduce LD is to increase the length of wire used in the design of the T-loop by incorporating two inner helical loops in the arch wire introduced by Burston [14].

Flexibility of the wire is improved by two inner helices but activation of the loop is in the opposite direction of the bends constructed in the design. It is supposed that one way to decrease LD with enhance on maximal elastic load is to make design according to the Bauschinger effect. Bauschinger effect insists on the direction of loading as a factor that can control many properties of the active part of orthodontic appliances. With considering this effect, there would be a more flexible component with lower LD which is harder to bend when it is activated in the same direction of original bends [15]. For instance, in T-loop (for space closure) with two inner helical loops, activation of the loop is in the opposite direction of the bend constructed in the helices. According to the Bauschinger effect, altering the design of the loop should improve the maximal elastic load and range by inserting the bend in helices in the same direction of activation of the loops [15]. Our hypothesis is that changing the design with adding two helices outside the horizontal portion of the T-loop would decrease the load deflection while increasing the range and the maximal elastic load, may or may not change in comparison to the original T-loop. Since the amount of wire incorporated in the design will be more than that of the original T-loop, outer helices would decrease LD. However according to the Bouschinger effect it may enhance the maximum elastic load and range of activation of the T-loop in comparison to a T-loop with inner helices. This study was aimed to compare the mechanical properties of these three different T-loops.

Materials and Methods

The single loops in 3 different designs had been made of 0.016 × 0.022 inch stainless steel wire (DENTAURUM, Germany), using the plier (DENTAURUM, 139, Germany).

The first design (group1) was the original T-loop. The dimension of this loop was as follow: the height (H), 8 mm; the length of the horizontal arms that signifies the interbracket distance (L), 8.5 mm; the horizontal part of the T-loop (G) 11mm.

The second design (group 2) was the T-loop with the same dimension of the original T-loop with two

inner helices with diagonal of 1mm on each side of the horizontal part.

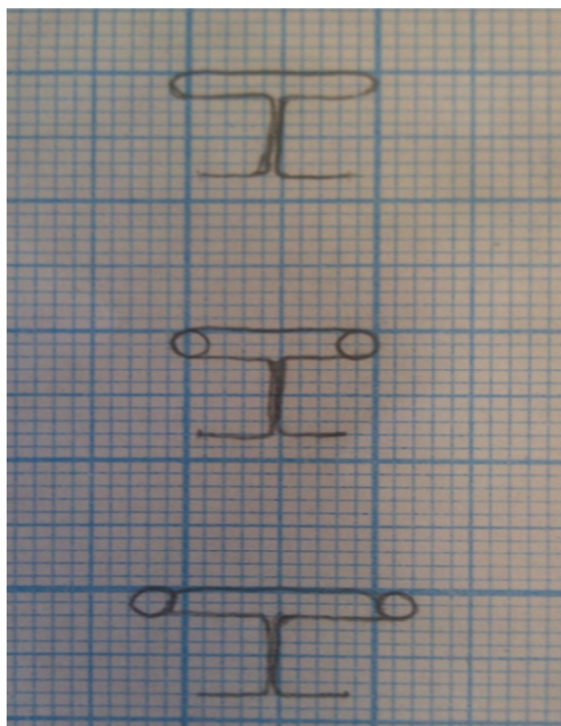


Figure 1: Three types of T-loop

The third design (group 3) was a T-loop with the two helices constructed outside the horizontal part. There was no gable bends incorporated in the samples.

To eliminate the possibility of changes in the physical properties of the wires as a result of stress from repeated measurements, 5 specimens have been tested for each design of T-loop. A template (on a paper with grids of 1×1mm) has been used to set the design of T-loop for each group and to unify all the samples according to their dimensions [Figure 1].

The end of each loop had a retentive bend and embedded in the acrylic blocks (20×10×7 mm). The samples were fixed by lower and upper grips of the universal testing machine (Instron, Zwick Roell Z 020;Ulm,Germany) [Figure 2]. One way ANOVA and Turkey’s HSD were used to identify statistical differences between different groups of T-loop. SPSS V. 17.0(SPSS Inc., Chicago, IL. USA)was used for data analysis. The significant levels were set at 0.05.

Results

Table 1 illustrates the maximal elastic load, LD and range of three types of T-loop.

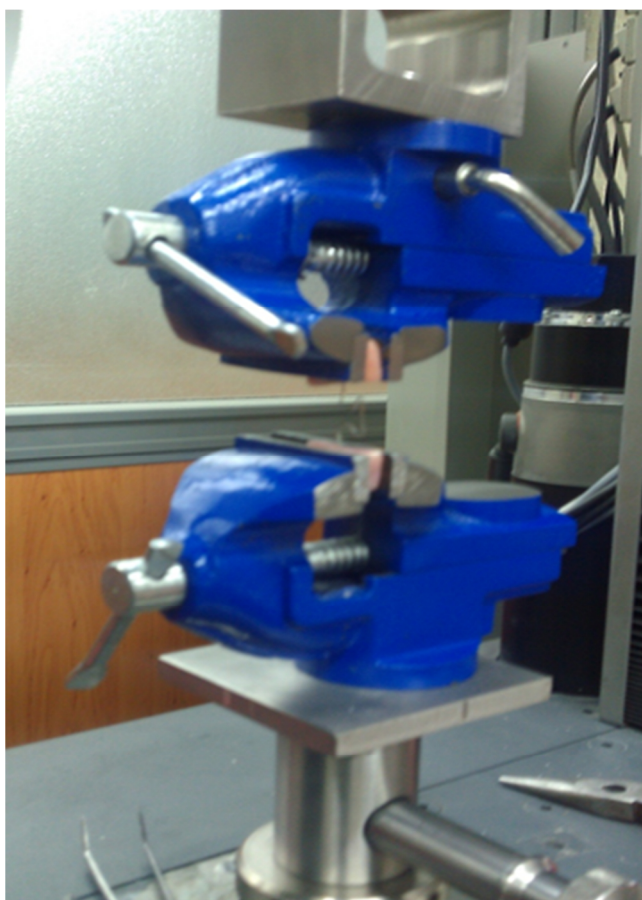


Figure 2: Acrylic blocks fixed by lower and upper grips of the Instron machine

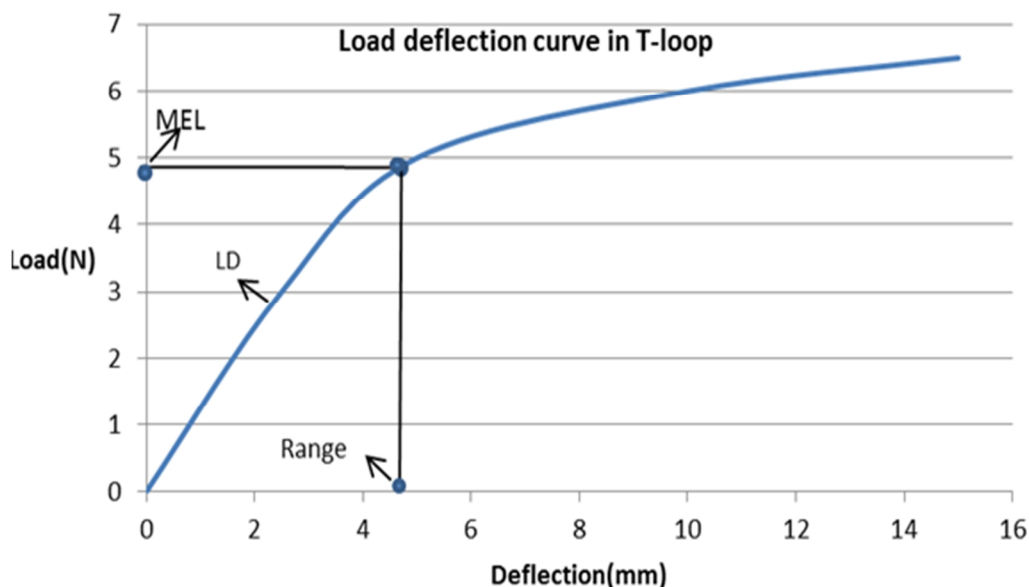


Figure 3: The load deflection curve.

LD =The slop of linear portion, Maximal elastic load (MEL) = The point of abrupt permanent deformation, Range = Amount of changes before permanent deformation

The mean of maximal elastic load in group1 (original T-loop) was 6.02 ± 0.27 , in group 2 (T-loop with the two inner helices) was 5.16 ± 0.46 and in group 3 (T-loop with the two outside helices) was 4.35 ± 0.25 . Maximal elastic loads in group 1 were significantly higher than group 2 and in group 2 were significantly higher than group3 ($p < 0.001$).

The mean of LD in group1 was 0.73 ± 0.36 , in group2 was 0.56 ± 0.74 and in group 3 was 0.56 ± 0.69 . LD in group 1 were significantly higher than group2 and 3 ($p = 0.002$) but there was no significant difference between group 2 and 3 ($p = 0.999$).

The mean of range in group1 was 5.43 ± 0.13 , in group2 was 5.59 ± 0.15 and in group 3 was 4.15 ± 0.10 . Range in group 3 were significantly lower than group 1 and 2 ($p < 0.001$) though, there was no significant difference between group 1 and 2 ($p = 0.149$).

Discussion

Decreasing the LD is not necessarily advantageous for

every type of tooth movements. Use of NiTi wires in the initial stages of treatment is becoming a privilege [16]. However, in the second stage of treatment, it is very crucial to control the type of tooth movement. Controlling M: F ratios in the brackets are the key for a controlled and predictable dental movement [17]. This depends on the force system applied to the tooth and can be manipulated by the design of the closing loop.

Although materials with lower modulus of elasticity such as TMA wire with moderate stiffness and capacity for plastic deformities are better alternatives for middle stages; higher price and limited access to such materials may be a reason to employ different designs of retraction loops to lower LD, increase the maximal elastic load and the range without changing the M: F [18].

The current study evaluated the mechanical properties of these three designs of T-loop. The results showed that the best design regarding the mechanical properties (LD, maximal elastic and range) is a T-loop with an inner helix. Although we postulated that Baus-

Table 1: Comparison of mechanical properties between three different types of T-loop

Group	Maximal elastic Load (N)	Load/ deflection (N/mm)	Range
1	6.02 ± 0.27^A	0.73 ± 0.36^A	5.43 ± 0.13^A
2	5.16 ± 0.46^B	0.56 ± 0.74^B	5.59 ± 0.15^A
3	4.35 ± 0.25^C	0.56 ± 0.69^B	4.15 ± 0.10^B
P value*	<0.001	0.001	<0.001

*Using one-way ANOVA

Mean values with different letters were statistically different (Turkey's HSD)

chinger effect would increase the maximal elastic load and range in the T-loop with external helix in horizontal part of the loop, it seems that the stress raised in the wire (due to the position of the helix) would compromise this effect. However, the mean of 4.15mm for range of activation is acceptable if activation of not more than 2-3 mm in every visit session is considered.

Blaya *et al.* [19] analyzed the mechanical behavior of different orthodontic retraction loops. Two designs of orthodontic loops for closing space were analyzed: teardrop-shaped (T) and circle-shaped loop (C), of two different heights (6 and 8 mm), and two types of orthodontic wires (stainless steel - 0.19' x 0.25'; TMA - titanium molybdenum alloy - 0.016' x 0.016'). They concluded that the alloy of the wire and the height of the loop would be more important than the loop design. The results of our study are similar to finding of this study, though different types of wires were not tested.

Katona *et al.* [20] measured the effects of first- and second-order gable bends on the forces and moments produced by a commercially available closing T-loop arch wire. They concluded that Gable bends alter the orthodontic load systems; however, the three-dimensional interactions produced complex and unpredictable tradeoffs.

As stated by Burston *et al.* [1] lowering the LD by placing helices would decrease the M: F ratio changes for every millimeter of activation. Because there was not access to an orthodontic force tester, our study was limited in evaluating the M: F ration rate and the new design of T-loop with outer helices needed a further survey. Moreover finding a better position for the helix in a T- loop, to gain the more advantages of Bauschinger effect, should still be evaluated in the future studies.

Furthermore, the study of Kuhlberg *et al.* performed in 2003[21] should be considered as a bridge in the gap between the laboratory sector and the clinical-biological realm. They stated that the narrow tolerance and high repeatability in physics was not presented in clinics and variability was a rule rather than an exception. Although the simple T-loop has been endured in the second stage of fix orthodontic treatments, for its undeniable advantage, a revision this design would be a relevant choice for future investigations. Regarding this issues increasing length of T-loop with helices might decrease LD but the place and design of helices has not been considered a critical factor so far. Although many studies [19,20,21] have been investigated this subject,

still more future works and studies adopting new methods and machines are probably required.

Conclusions

The results of this study suggested that:

1. The best design considering the load/deflection, maximal elastic and range is a T-loop with an inner helix.
2. Increasing length of T-loop with helices would decrease load deflection but the place and design of helices might not be a crucial factor.
3. The new design of T-loop with outer helices needs a further survey regarding their position.

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