The effect of different $\alpha$ and $\beta$ gable on stainless steel and TMA segmental T-loop on the resulting force – an in vitro study

A Laviana

Orthodontic Department, Faculty of Dentistry, Universitas Padjadjaran
Jl. Sekeloa Selatan 1, Bandung 40132, Indonesia

E-mail: avi.laviana@fkg.unpad.ac.id

Abstract. Adding more angle to the segmental T-Loop gable can affect the amount of force created to retract the canine on an orthodontic treatment with extraction. In-vitro laboratory experimental design, performed at the Chemistry Laboratory of Faculty of Science, ITB. The samples are 60 segmental T-loop springs with $\alpha$ and $\beta$ angle of 0°–0°; 0°–45°; 45°–0°; 22.5°–22.5°; 15°–30°; 30°–15°. Force was measured using autograph with retraction distance of 1, 2, and 3 mm, then analyzed using ANOVA statistics analysis with a factorial design of 2x3x6 and 5 replications for each cell. The results of the posthoc Student Newman Keuls and Tukey test show that the added angle to the $\alpha$ and $\beta$ gables of SS and TMA T-loop will add more resulting force along with the increase of retraction distance. The added angle to the $\alpha$ and $\beta$ gables of SS and TMA segmental T-loop will add more resulting force along with the increase of retraction distance. The force resulted by the SS T-loop with various $\alpha$ and $\beta$ gables are significantly different, while the force resulted by the TMA T-loop are not (p-value <0.05), as long as $\alpha + \beta$ is the same. The force resulted by the SS T-loop with various $\alpha$ and $\beta$ gables are significantly different. However, on the TMA segmental T-loop, as long as $\alpha + \beta$ is the same, the force resulted will not be different.

1. Introduction

The success rate of coverage in an orthodontic treatment with extraction highly determines the final position of the canine and incisor teeth, which are crucial to the stability of treatment result, the bite functions, and the smile aesthetics. The coverage of the extracted premolar by retracting the canine, followed by the retraction of the four incisors can be done in two ways, which are by using a continuous archwire that can create friction between the braces slot and the archwire during the teeth movement, and by segmental technique, which does not create friction [1,2].

Canine retraction by using the segmental technique can be done using loops with various configurations, materials, placing distance, archwire size, and additional gable to create various force and momentum [3]. The success rate of a force-controlling tool is marked by the type and direction of the teeth movement that are in accordance with expectations, fast teeth movement, minimal teeth or periodontal damage and pain – which correlates to the comfort level of the patient during the orthodontic treatment [1-6].

T-loop is one of the spring configurations that can control the applied force towards teeth at the time of activation. The control mechanism created by adding angle to the gables is aimed to overcome unwanted effects during canine retraction [1-6]. The $\alpha$ and $\beta$ gable angles are commonly the same; however, few clinical operators often reshape them without measuring the symmetry of the two angles.

Since its introduction in the 1930’s, stainless steel (SS) is still commonly used in dentistry, among others is as a material for orthodontic wirings. In the 1980’s, titanium – commonly known as TMA
Titanium Molybdenum Alloy) is developed with high elasticity, low level of stiffness, high formability, able to maintain its resilience during welding, corrosive-resistant, and can be flexed twice as large as SS wiring without permanent damage or change [3, 7-9]. Segmental T-loop retraction springs are now commonly made of TMA [3-5, 8-10].

Based on various α and β gable and different mechanical properties of SS and TMA, a research is conducted to discover the different force created by SS and TMA segmental T-loop retraction springs with various and different α and β gable angles on various retraction distances.

2. Methods
The materials of this research are 60 T-loops – 30 are made of SS and the other 30 are made of TMA archwire size 0.016 x 0.022 inches with 7 mm height, 10 mm width, and 18 mm length, with the combination of anterior (α) and posterior (β) angle of 0°–0°; 0°-45°; 45°–0°; 22.5°–22.5°; 15°–30°; 30°–15°, 5 of each angle. All T-loops are calibrated using a template and measured using glass lab for alignment (figure 1).

This research is a pure experimental research, done in-vitro at the Chemistry Laboratory of Faculty of Science, ITB (Institut Teknologi Bandung). The pre-designed testing tool is made by the Physics Engineering Laboratory, LIPI (Lembaga Ilmu Pengetahuan Indonesia), from aluminum, consists of static part, movable retractor, and gyrating braces holder with edgewise standard size 0.018 inches. The spring is put on the testing tool and tied to the braces using ligature wires and set on distance 0 (zero). The quantity of force is noted using the unit gF on retraction distance 1 mm, 2 mm, and 3 mm.

The result of the experiment is tested using the ANOVA statistic test with experiment design 2x3x6 with 5 replications. The interaction between the three factors (material, gable, and retraction distance) is tested using the posthoc Student Newman Keuls and Tukey test on the level of 5%.

The sample size calculation for three-factor experiment design (SS and TMA, retraction distance, and gable angle) forms 2x3x6 treatments – to calculate the minimum required sample, the Federer sample formula is used:

\[(n - 1)(k - 1) \geq 15 \text{ or } n \geq 1 + \frac{15}{(k - 1)}\]

With: \(n\) = minimum required sample, \(k\) = the number of treatments in the experiment design, the unit number of experiments is \(n \times k\). The research design with two materials, SS and TMA, 3 retraction
distances, and 6 gables will receive 36 different treatments – this means that the minimum sample required is:

\[ n \geq 1 + \frac{15}{(36 - 1)} \]

\[ n \geq 1.4285 \approx 2 \]

In conclusion, the minimum amount of experiment or replication per treatment is 2, with the total of 2 x 36 = 72 required units. This research is done with 5 replications per treatment, with the total of 5 x 36 = 180 replication units, which meet the minimum required sample.

3. Results

Measurements have been conducted of the force created by 60 Stainless Steel and TMA segmental T-loop retraction springs with 0.016 x 0.022 inch, with anterior (α) and posterior (β) gables of 0°–0°; 0°–45°; 45°–0°; 22.5°–22.5°; 15°–30°; 30°–15°; 5 of each angles and materials. The springs are attached one by one to the force-test device and then attached to the Universal Strength Tester Shimadzu Corporation Autograph. Then, activation distance is applied with the measurement of 1, 2, and 3 mm. The measured force is shown on the monitor and then noted. The mean of the results can be seen in table 1.

| SS | Force (gF) | TMA | Force (gF) |
|----|------------|-----|------------|
|    | Mean       | Median | SD         | Mean       | Median | SD         |
| A1B1C1 | 93.20 | 93.00 | 18.75 | A2B1C1 | 52.40 | 60.00 | 17.61 |
| A1B1C2 | 208.60 | 203.00 | 27.37 | A2B1C2 | 94.00 | 90.00 | 11.04 |
| A1B1C3 | 342.20 | 338.00 | 37.14 | A2B1C3 | 149.20 | 149.00 | 14.20 |
| A1B2C1 | 153.40 | 150.00 | 26.08 | A2B2C1 | 84.80 | 83.00 | 19.82 |
| A1B2C2 | 354.40 | 347.00 | 37.60 | A2B2C2 | 164.80 | 170.00 | 16.66 |
| A1B2C3 | 539.40 | 520.00 | 31.73 | A2B2C3 | 245.00 | 240.00 | 22.07 |
| A1B3C1 | 197.00 | 192.00 | 23.80 | A2B3C1 | 72.80 | 65.00 | 31.25 |
| A1B3C2 | 398.60 | 385.00 | 36.77 | A2B3C2 | 144.80 | 150.00 | 30.34 |
| A1B3C3 | 538.40 | 558.00 | 55.98 | A2B3C3 | 220.40 | 220.00 | 31.48 |
| A1B4C1 | 197.00 | 205.00 | 14.40 | A2B4C1 | 89.60 | 75.00 | 31.08 |
| A1B4C2 | 384.40 | 362.00 | 37.51 | A2B4C2 | 171.00 | 162.00 | 23.65 |
| A1B4C3 | 554.20 | 542.00 | 50.27 | A2B4C3 | 246.60 | 242.00 | 13.22 |
| A1B5C1 | 165.20 | 168.00 | 36.16 | A2B5C1 | 82.00 | 75.00 | 22.80 |
| A1B5C2 | 342.60 | 355.00 | 74.28 | A2B5C2 | 159.40 | 160.00 | 20.58 |
| A1B5C3 | 530.40 | 542.00 | 49.42 | A2B5C3 | 232.00 | 237.00 | 23.16 |
| A1B6C1 | 188.20 | 198.00 | 23.17 | A2B6C1 | 93.40 | 87.00 | 20.12 |
| A1B6C2 | 403.40 | 412.00 | 41.44 | A2B6C2 | 174.80 | 167.00 | 21.58 |
| A1B6C3 | 583.40 | 590.00 | 50.89 | A2B6C3 | 250.00 | 240.00 | 25.73 |

Table 1 shows the mean value of the force created by the stainless steel and TMA segmental T-loop retraction spring with different gables and activation distances. Based on the table, it is discovered that on stainless steel segmental T-loop, the least amount of force created is 93 gF, created by gable 0°–0° and activated by the distance of 1 mm, and the most amount of force is 583 gF, created by gable 30°–15° and activated by the distance of 3 mm. On the TMA segmental T-loop, the least amount of force created is 52.40 gF, created by gable 0°–0° and activated by the distance of 1 mm, and the most amount of force is 250.00 gF, created by gable 30°–15° and activated by the distance of 3 mm.
Based on the analysis from ANOVA from SPPS ver.19 with experiment design 2x3x6 with 5 replications, it is discovered that all treatment – whether it is wire material, gable, retraction distance, material’s interaction with gable and retraction distance – gave the most significant effect towards the created force (p-value <0.05), shown with different letterings.

Table 2. Amount of force based on the material: Stainless Steel (SS) and TMA (Titanium Molybdenum Alloy)\(^a\).

| Material | Force (gF) | Mean | Median | SD  | Minimum | Maximum | Posthoc Test* |
|----------|------------|------|--------|-----|---------|---------|---------------|
| SS       | 343.00     | 352.50 | 160.86 | 70.00 | 622.00  |         | a             |
| TMA      | 151.50     | 151.00 | 68.39  | 33.00 | 287.00  |         | b             |

\(^a\) SS = Stainless steel, TMA = Titanium Molybdenum Alloy, SD = Standard Deviation, *S-N-K and Tukey test.

Table 2 shows that based on the factor of material, which are SS and TMA, it is discovered that the force created by SS is greater than TMA. The force created significantly differs on the 5% level by using the posthoc Student Newman Keuls and Tukey test.

Table 3. Amount of force based on the interaction between the material and angle (AB)\(^a\).

| AB      | Force (gF) | Mean | Median | SD  | Minimum | Maximum | posthoc test* |
|---------|------------|------|--------|-----|---------|---------|---------------|
| A1B1    | 214.67     | 203.00 | 108.63 | 70.00 | 393.00  |         | c             |
| A1B2    | 349.07     | 347.00 | 165.85 | 127.00 | 580.00  |         | d             |
| A1B3    | 378.00     | 385.00 | 149.95 | 177.00 | 603.00  |         | e             |
| A1B4    | 378.53     | 362.00 | 154.87 | 175.00 | 620.00  |         | e             |
| A1B5    | 346.07     | 355.00 | 162.70 | 105.00 | 580.00  |         | d             |
| A1B6    | 391.67     | 412.00 | 171.31 | 150.00 | 622.00  |         | e             |
| A2B1    | 98.53      | 90.00 | 43.19  | 33.00 | 172.00  |         | a             |
| A2B2    | 164.87     | 170.00 | 70.10  | 60.00 | 270.00  |         | b             |
| A2B3    | 146.00     | 150.00 | 68.67  | 37.00 | 265.00  |         | b             |
| A2B4    | 169.07     | 162.00 | 69.93  | 73.00 | 270.00  |         | b             |
| A2B5    | 157.80     | 160.00 | 66.65  | 65.00 | 263.00  |         | b             |
| A2B6    | 172.73     | 167.00 | 69.42  | 75.00 | 287.00  |         | b             |

\(^a\) A1=SS, A2=TMA, B1-B6= gable 0°–0°; 0°–45°; 45°–0°; 22.5°–22.5°; 15°–30°; 30°–15°, SS = Stainless steel, TMA = Titanium Molybdenum Alloy, SD = Standard Deviation.

Table 3 shows that based on the interaction between wire material (A) and gable angle (B), the force created is greater along with the addition of gable angle on the same material. On SS segmental T-loop, the measurements are significantly greater on the 5% level by using the posthoc Student Newman Keuls and Tukey test – the same goes to the TMA segmental T-loop 0°–0° compared to other gables. However, in the group of TMA T-loops with asymmetric α and β gables with α + β = 45° (0°–45°; 45°–0°; 22.5°–22.5°; 15°–30°; 30°–15°), the results show no significant difference.
Table 4. Amount of force based on the interaction between the material and retraction distance (AC)*.

| AC     | Mean (gF) | Median (gF) | SD (gF) | Minimum (gF) | Maximum (gF) | posthoc test* |
|--------|-----------|-------------|---------|--------------|--------------|---------------|
| A1C1   | 165.67    | 177.50      | 43.14   | 70.00        | 235.00       | b             |
| A1C2   | 348.67    | 361.00      | 78.98   | 175.00       | 455.00       | d             |
| A1C3   | 514.67    | 531.00      | 90.89   | 292.00       | 622.00       | e             |
| A2C1   | 79.17     | 75.00       | 26.14   | 33.00        | 145.00       | a             |
| A2C2   | 151.47    | 160.00      | 34.06   | 82.00        | 213.00       | b             |
| A2C3   | 223.87    | 236.00      | 49.08   | 135.00       | 287.00       | c             |

* A1=SS, A2=TMA; C1-C3= retraction distance 1, 2, dan 3 mm; SS = Stainless steel; TMA = Titanium Molybdenum Aloy; SD = Standard Deviation; *S-N-K and Tukey test.

Table 4 shows that based on the interaction of the material (A) and the retraction distance (C), it is discovered that the force created becomes greater the further the retraction distance is for the same wire material. The force created significantly differ on the 5% level using the posthoc Student Newman Keuls and Tukey test.

Table 5. Amount of force based on the interaction between gable (B) and retraction distance (C)*.

| BC Interaction | Mean (gF) | Med (gF) | SD (gF) | Min (gF) | Max (gF) | Posthoc test* |
|----------------|-----------|----------|---------|----------|----------|---------------|
| B1C1           | 72.80     | 70.00    | 27.50   | 33.00    | 115.00   | a             |
| B1C2           | 151.30    | 142.50   | 63.52   | 82.00    | 238.00   | b             |
| B1C3           | 245.70    | 232.00   | 105.12  | 13500    | 393.00   | c             |
| B2C1           | 119.10    | 117.00   | 42.24   | 60.00    | 185.00   | b             |
| B2C2           | 259.60    | 248.50   | 103.62  | 143.00   | 395.00   | c,d           |
| B2C3           | 392.20    | 390.00   | 157.29  | 218.00   | 580.00   | e             |
| B3C1           | 134.90    | 149.50   | 70.50   | 37.00    | 235.00   | b             |
| B3C2           | 271.70    | 271.00   | 137.49  | 105.00   | 455.00   | c,d           |
| B3C3           | 379.40    | 363.50   | 172.98  | 187.00   | 603.00   | e             |
| B4C1           | 143.30    | 160.00   | 61.04   | 73.00    | 210.00   | b             |
| B4C2           | 277.70    | 281.50   | 116.29  | 155.00   | 430.00   | c,d           |
| B4C3           | 400.40    | 387.50   | 165.78  | 238.00   | 620.00   | e             |
| B5C1           | 123.60    | 112.50   | 52.30   | 65.00    | 198.00   | b             |
| B5C2           | 251.00    | 201.00   | 109.38  | 132.00   | 398.00   | c,d           |
| B5C3           | 381.20    | 361.50   | 161.43  | 200.00   | 580.00   | e             |
| B6C1           | 140.80    | 138.50   | 53.99   | 7500    | 205.00   | b             |
| B6C2           | 289.10    | 272.50   | 124.44  | 157.00   | 447.00   | d             |
| B6C3           | 416.70    | 392.00   | 179.78  | 223.00   | 622.00   | e             |

* B1-B6= gable 0°–0°; 0°–45°; 45°–0°; 22.5°–22.5°; 15°–30°; 30°–15°, C1-C3= retraction distance 1, 2, dan 3 mm; SD = Standard Deviation; *S-N-K and Tukey test.

Table 5 shows that based on the interaction between the gable angle (B) and the retraction distance (C), it is discovered that the force created becomes greater the further the retraction distance is for the same gable angle, as well as the angle of the gable. The force created significantly differ on the 5% level by using the posthoc Student Newman Keuls and Tukey test, with the exception of the group with asymmetric α and β gables (but α + β =45o) which show no significant difference.
4. Discussion

As much as 60 SS and TMA Segmental T-loop retraction springs with diameter of 0.016 x 0.022 inches with different anterior (α) and posterior (β) gable angles of 0°–0°; 0°–45°; 45°–0°; 22.5°–22.5°; 15°–30°; 30°–15° are retracted within a distance that represents the common clinical activation distance, which are 1, 2, and 3 mm. The research was conducted in-vitro in a laboratory to measure the amount of force created in unit of gF.

Table 1 shows the mean value of the force created by the stainless steel and TMA segmental T-loop retraction spring with different gables and activation distances. Based on the table, it is discovered that on stainless steel segmental T-loop, the least amount of force created is 93 gF, created by gable 0°–0° and activated by the distance of 1 mm, and the most amount of force is 583 gF, created by gable 30°–15° and activated by the distance of 3 mm. On the TMA segmental T-loop, the least amount of force created is 52.40 gF, created by gable 0°–0° and activated by the distance of 1 mm, and the most amount of force is 250.00 gF, created by gable 30°–15° and activated by the distance of 3 mm.

The force differences created by the TMA T-loop spring with gables of 0°-45°; 45°–0°; 22.5°–22.5°; 15°–30°; 30°–15° on each retraction distance are not significant; this shows that the angle difference of gable α and β does not affect the force created, as long as α + β are the same (45°). The results are different when using stainless steel T-loops – despite gable angle α + β = 45°, the force created have significant differences. This is caused by the stainless steel wire’s lower formability property compared to TMA wire 8, so that the wire is damaged when bent to a significantly large angle and affects the force created [10].

This research takes thought, planning, and a complicated preparation in order to imitate the real situation. However, because the observation is only done two-dimensionally, what actually happen inside the mouth cannot be simulated completely on the contraption designed for the in-vitro laboratory research. As stated by Chen [12], Gajda [13], and Katona [14], due to the multiple three-dimensional systems applied to the tool, there should be an adjustment on the material choice and T-loop configuration on the use of T-loop spring for anterior teeth retraction in clinics.

5. Conclusion

The conclusion of this research is that there is significant difference on the force created by the SS segmental T-loop sized 0.016 x 0.022 inches compared to the ones made of TMA with various gable angles and activation distance, where the force created by the SS segmental T-loop is significantly larger compared to TMA. Stainless steel segmental T-loop springs with gable angle α and β produce different force, while TMA T-loops create the same amount of force, as long as α + β is the same. The force created by SS segmental T-Loop with the same gable angles and retraction distance is twice the force compared to the TMA – this should be a concern for orthodontic practitioners when determining the retraction distance during tooth retraction.

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