Calibration of proclined force produced by rectangular TMA® bulbous loops with conventional round TMA® U loops

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Abstract

Objective: *To compare deactivation forces produced by various designs and sizes of advancing loops on round and rectangular wires at different deactivation ranges.*
Materials and Methods: *The tested archwires comprised of four groups. First group was 0.016" TMA® wire with U-shaped advancing loops (U). Other groups consisted of 0.016"×0.022" TMA® wire with three sizes of bulbous-shaped advancing loops (B 4x4, B 6x6, B 8x8). A universal testing machine applied deflections of 0.0 to 2.5 mm. During archwires were released from activated position at 2.5 mm to passive position, deactivation forces were measured at every 0.5 mm of deactivation range. Forces of deactivation were compared by Kruskal–Wallis one-way analysis of variance.*
Results: *Results showed no statistically significant differences (P>0.05) of deactivation forces between U at 2.5 mm, U at 2 mm, B4x4 at 0.5 mm, B6x6 at 1 mm and B8x8 at 1.5 mm deflection ranges.*
Conclusion: *This study revealed that U at 2.5 mm, U at 2 mm, B4x4 at 0.5 mm, B6x6 at 1 mm and B8x8 at 1.5 mm deflection ranges produced comparable light deactivation forces for maxillary incisors proclination.*
Keywords: *Incisors proclination; Light force; Orthodontic wires; Advancing loops; Titanium molybdenum alloy*

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Introduction

Patients with anterior crossbite can be corrected partly by proclination of maxillary incisors. By-products of this method are creating spaces for the eruption of canines and premolars, eliminating mandibular displacement[1] and traumatic occlusion.[2] The alternative early treatment of anterior crossbite in growing patients, all of whose permanent teeth have not yet completely erupted, is to use a removable appliance[3] or partial fixed appliance[4-6]. Partial fixed appliances may be more advantageous than removable appliances. They reduce the need for patient co-operation, increase the control of tooth movement and can move teeth in all three planes of space.[7] Many previous studies used 2x4 appliances (two-banded or bonded first molar tubes and preadjusted brackets on central and lateral incisors) for proclination of maxillary incisors.[1, 4-6] However, round wire was commonly used. This type of wire could not control torque thus maxillary incisors were proclined with uncontrolled tipping. After proclination, it was necessary to create labial root torque by using rectangular wire to obtain normal inclination.[6]

Previous studies did not mention about the magnitude of force for maxillary incisors proclination.[1, 6] However, force exceed optimal level can cause pain, bone dehiscence,[8] gingival recession[9] and root resorption.[10] Although the optimal force is capable of producing the maximal rate of tooth movement without tissue damage and with minimal patient discomfort[11], a recent study showed that lighter force could move teeth effectively. Light fixed technique was used to procline maxillary incisors with 89.6 g in patients with anterior crossbite by using 0.016" titanium molybdenum alloy (TMA®) round wire. Cone beam computed tomography was used in this study and found that a light force could procline maxillary incisors without alveolar bone changes and bony defects.[12] TMA® was used to procline maxillary incisors[12] because it has lower stiffness than stainless steel, thus it can produce a lighter force.[13] Moreover, it has excellent formability and low potential for hypersensitivity.[14, 15]

Uncontrolled tipping during maxillary incisors proclination using round wire might not be appropriate for patient who has normally inclined or proclined maxilllary incisors. Rectangular wire may be capable of controlling the inclination of maxillary incisors during proclination. However, to procline maxillary incisors with controlled tipping, the rectangular archwire should be lengthened to reduce the deactivation force.**[16]** One method of lengthening wire is increasing the length of loops by modifying the shape from U to bulbous to reduce the load/deflection rate and to produce a predetermined force system.[17] Moreover, loops can reduce wire stiffness and strength, increase the working range of activation and provide a lighter and continuous force.[17-19]

The purposes of this study were therefore to examine appropriate designs and sizes of advancing loops on round and rectangular wires, which produce appropriate light deactivation forces for maxillary incisor proclination.

Material and Methods

Four groups of archwires with advancing loops were tested. Each group consisted of five archwires. The first group was 0.016" TMA® wire (Ormco Corporation) with U-shaped advancing loops 3 mm in height and width (U). The other groups consisted of 0.016"×0.022" TMA® wire (Ormco Corporation) with bulbous-shaped advancing loops 4x4, 6x6 and 8x8 mm in height and width (B 4x4, B 6x6, B 8x8, respectively). The distance between the anterior and posterior legs of the loops was 3, 4 and 5 mm, respectively. The length between the posterior leg of the right and left loops of all archwires was 94 mm, determined by the mean values (94±3.5) of the arch length of 50 children with mixed dentition, who had no space loss from early loss of deciduous teeth. These children were selected at random from 8- to 10-year-old patients. All archwires were bent by one orthodontist **(Fig. 1)**.

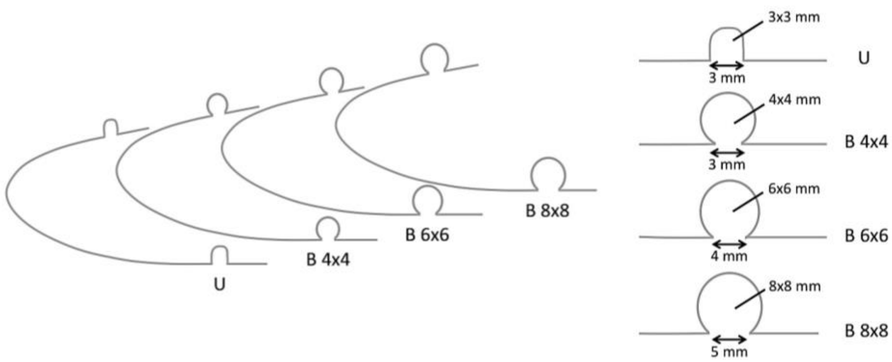

Fig. 1: Four types of tested archwires.

The deflection test was fabricated to allow one-point contact deflection by inserting the tested wire into 0.022"x0.028" standard molar buccal tubes (Ormco), which were bonded onto the first molars in a typodont. Advancing loops were pushed against the mesial side of the buccal tubes. The anterior segment of the archwire was co-ligated at four points to an acrylic pad with ligature wires to represent the position of the four maxillary incisor brackets and the dental arch curve of the maxillary incisors **(Fig. 2)**. The size of the acrylic pad was 20 mm in height, 30 mm in width and 3 mm in thickness and four holes were created for tying ligature wires. Then, a universal testing machine (Lloyd instruments, LRX-Plus, AMETEK Lloyd Instrument Ltd., Hamphshire, UK), which was regularly calibrated, was used by movement of a cylindrical metal head with a 10 kg load cell and a crosshead speed of 5 mm/min. The cylindrical metal head was used to push the archwire lingually **(Fig. 3).** While the archwires were released from the activated position at 2.5 mm to the passive position, the deactivation force was measured at every 0.5 mm of the deactivation range to obtain the load-deflection characteristics of the appliance. From this force test, activation-deactivation graphs were plotted showing the deactivation forces in the sagittal plane for maxillary incisor proclination in different deflection ranges **(Fig. 4)**. The force was measured 3 times per wire and the tested wire was removed and the new wire was replaced in buccal tubes on the first molars in the typodont to ensure that the wire did not deform before testing. The mean values of 3 measurements/wire obtained from the deactivation forces at 0.5, 1, 1.5, 2 and 2.5 mm deflection in the sagittal plane were presented and used for statistical comparison.

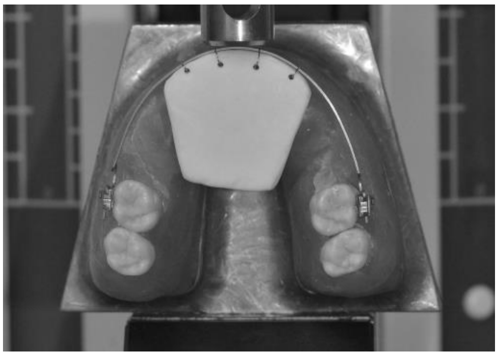

Fig. 2: Archwire was co-ligated at 4 points to the acrylic pad.

Fig. 3: Universal testing machine.

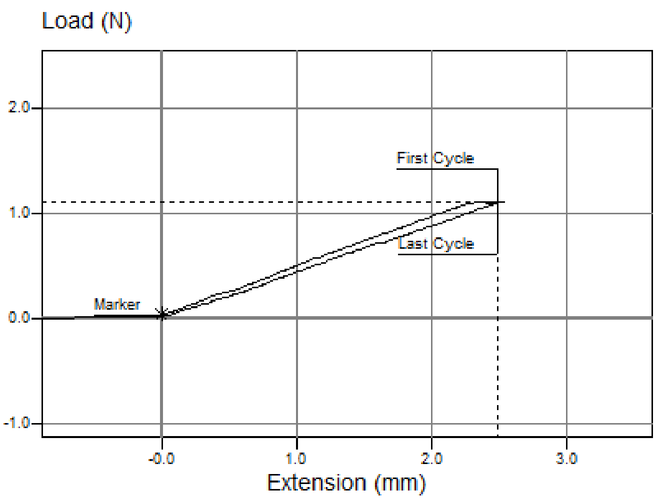

Fig. 4: Activation-deactivation graph.

To test measurement reliability, two archwires per group were randomly chosen and tested for the deactivation force. Both archwires were retested twice at 4-week intervals. The deactivation forces from both archwires were compared using a paired T-test. The results showed no statistically significant differences (P>0.05).

The deactivation forces were obtained from the mean values of 3 measurements/wire at 0.5, 1.0, 1.5, 2.0 and 2.5 mm deflection ranges from the deactivation graphs. Kruskal–Wallis one-way analysis of variance was used to test the deactivation force magnitude between U, B 4x4, B 6x6 and B 8x8 and the deactivation force within groups at different activation ranges. After that, Tukey's test was used to identify the pair showing the difference. The acceptable alpha level for significance was $p < 0.05$.

Results

Means and standard deviations of the deactivation forces of the wires measured at 0.5, 1.0, 1.5, 2.0 and 2.5 mm are listed in Table 1 and are shown graphically in Figure 5.

Since round wire has been commonly used to procline maxillary incisors[1, 4-6], U at 2.5 mm deflection range was selected as a standard group. Moreover, it provided deactivation force at 81.87±9.23 g, which was within light force (77.8-101.4 g) and capable for maxillary incisors proclination.[12] Deactivation force produced by U at 2.5 mm deflection range showed no statistically significant differences compared with U at 2.0 mm deflection range, B 4x4 at 0.5 mm deflection range, B 6x6 at 1.0 mm deflection range and B 8x8 at 1.5 mm deflection ra

nge.

Table 1: Mean values and standard deviation (SD) of deactivation forces at 0.5, 1.0, 1.5, 2.0 and 2.5 mm deflection in the sagittal plane on various types and configurations of archwires

Group of tested archwire	Deflection range (mm) 0.5 Mean	0.5 SD	1.0 Mean	1.0 SD	1.5 Mean	1.5 SD	2.0 Mean	2.0 SD	2.5 Mean	2.5 SD	P-value ⓐ
0.016" TMA wire® with U loops (U)	29.80	2.57	46.27	3.71	62.20	5.12	74.13**	7.60	81.87*	9.23	0.000
0.016"x0.022" TMA wire® with 8x8 mm bulbous loops (B8x8)	28.80	3.55	52.53	5.72	75.33**	5.96	97.13	5.33	110.53	5.03	0.000
0.016"x0.022" TMA wire® with 6x6 mm bulbous loops (B6x6)	42.60	8.49	71.73**	6.30	103.07	8.48	129.00	16.04	143.53	19.39	0.000
0.016"x0.022" TMA wire® with 4x4 mm bulbous loops (B4x4)	66.47**	11.34	119.60	16.38	152.80	15.82	174.47	15.01	188.67	16.41	0.000

NS, P >.05

ⓐ P-value of within-group comparison according to Kruskal–Wallis one-way analysis of variance tests

* Shows mean deactivation force of control group

** Shows mean deactivation force of group that has no statistically significant differences compared with deactivation force of control group (P>0.05)

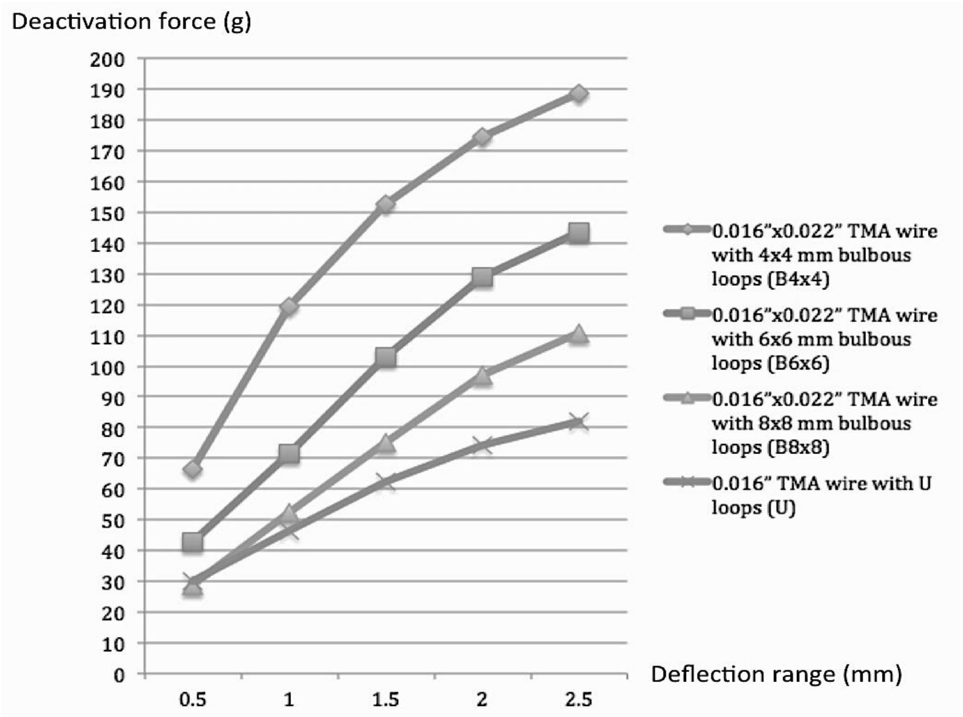

Fig. 5: Load-deflection curves of TMA® archwires during deactivation.

Discussion

The present study compared deactivation forces produced by round and rectangular wires with various designs and sizes of advancing loops at different deactivation ranges and found that 3 groups of rectangular wires produced greater force than round wire at the same deactivation range. At different deactivation ranges, rectangular wires with larger size of loops could produce comparable light forces to round wire with smaller loops.

The load-deflection curve

patterns during deactivation produced by four groups of tested wires were different. U had the flattest curve whereas B4x4, B6x6 and B8x8 had steeper curves. The steepness of the curve produced by rectangular wires was related to the size of bulbous loops. The smaller the loop, the steeper the curve produced. Since the size of the loop affected the length of the wire, B4x4 was the shortest wire compared with B6x6 and B8x8 and thus it had the highest amount of stiffness and provided the heaviest force.

In this study, the deactivation force within groups obtained from different deflection ranges had statistically significant differences ($P<0.05$). This could indicate that although TMA® wire has a lower stiffness than stainless steel[13] and loops can reduce wire stiffness and strength, increase the working range of activation and provide a lighter force,[17-19] every small range (0.5 mm) of activation can produce a significantly different force for proclination of maxillary incisors.

In comparison with a previous study, different materials and methods of measurement may affect the amount of deactivation force.

Previous study tested the deactivation force of 0.017"x0.025" TMA® wire. The brackets were used to support a 14 mm wire span between the brackets. It was found that TMA® provided a 61 g deactivation force at a 1 mm deflection range[20], whereas the present study tested the deactivation force on a 94 mm length of 0.016"x0.022" TMA® archwires and found that at a 1 mm deflection range, they provided 52.53, 71.73 and 119.60 g from 8x8, 6x6 and 4x4 mm bulbous loops, respectively. Although this study had a longer inter-bracket wire span combined with loops forming and a smaller wire size, it did not increase the flexibility of wires and neither produce a lighter deactivation force as expected. However, wire was ligated with elastomeric ligature in previous study[20], therefore they could not ligate tested wires tightly and the rigidity and force may decrease during measurement. In this study, however, an acrylic pad was used to fix the wire in a curve form. This may increase the rigidity of the wire leading to a high amount of deactivation force. In addition, previous study[20] applied perpendicular force to the wire whereas this study applied parallel force along the wire.

The temperature and characteristics of beta-titanium wire during the experiment have not been discussed. Some previous studies[16, 21] tested the stiffness and torque of beta-titanium at 37 ^{o} whereas some studies,[20, 22] including this study, did the experiment at room temperature. However, beta-titanium wire was developed by Burstone and Goldberg[23] by adding molybdenum with pure titanium to stabilize the beta phase of the wire even at room temperature. Therefore, the test at either oral or room temperature may provide the same result. However, the ideal method is to test at oral temperature.

The design of an advancing loop for round TMA® wire was a U loop as recommended by previous studies.[6, 12] However, rectangular TMA® wire with U loops may produce a heavier force, and therefore bulbous loops were carried out. This kind of loop increased the length of the wire compared with U loops so it reduced stiffness and provided a comparable light force to round wire for maxillary incisor proclination. In addition, since bulbous loops are round in shape, less irritation during use can occur than with other types of loops such as T and L loops.

Beta-titanium wires were used in this study. This type of wire has been used in orthodontics because of its advantages, such as low elastic modulus, excellent formability and low potential for hypersensitivity.[14, 15] However, the downsides are its high surface roughness and susceptibility to fracture because of the addition of zirconium and zinc.[24-26, 15, 27] Although it has high friction, our test was not affected because loops and non-sliding mechanics were used. Moreover, it might provide better control of the position of the incisors during proclination because of the friction between the wire and the brackets. However, when this type of wire is used in clinics, it must borne in mind that it is fragile, especially for long-span use. Thus, more cooperation from patients is needed than when using stainless steel during eating.

TMA® was selected for the deflection test in this study, although there are many companies producing beta-titanium wires. Previous study evaluated the force-deflection behavior of 6 commercial beta-titanium wires (timolium (TIM), titanium molybdenum (ORG), beta titanium (BETA), resolve (RES), titanium molybdenum alloy (TMA) and TMA low friction (TMAL)) and found that significant differences in force were observed among wires.[20] Thus, when using other brands of beta-titanium wire, the size of loops will vary depending on the stiffness of the wire. However, the exact amount of the deactivation force and the size of the loops of each brand should be further investigated. Moreover, for clinical use, force measurement should be carried out before inserting the wire into the bracket slots every visit.

In this study, the length of the archwire was obtained from the mean of the arch length of 50 children with mixed dentition. However, in patients who have longer or shorter arch length, the length of the archwire must be adapted and a force measuring device should be used to ensure that a light force is obtained.

Although B 4x4 at a 0.5 mm deflection range could produce a comparable light force to U at a 2.5 mm deflection range, B 4x4 needed a short range of activation, thus it can provide a small distance of tooth movement. Although B 8x8 at a 1.5 mm deflection range could produce a light force with a suitable distance, it is inappropriate for patients with a shallow vestibule because of the large size of the loops.

Thus, appropriate advancing loops on round and rectangular archwires, which produce comparable light forces for maxillary incisor proclination with both uncontrolled and controlled tipping, are U at either 2.0 or 2.5 mm deflection ranges and B 6x6 at a 1.0 mm deflection range. Moreover, a small size of bracket slot is recommended in the case of using rectangular wire because little slot play will be presented and maxillary incisors will be proclined with controlled tipping effectively.

For further study, it would be an interesting test to investigate torque during proclination with this rectangular archwire in different-sized bracket slots. For clinical investigation, effectiveness of maxillary incisors advancement with round and rectangular archwires producing light force on alveolar bone response should be investigated.

Conclusion

This laboratory study showed no statistically significant differences in deactivation force between 0.016" TMA® with 3x3 mm U loops at a 2.5 mm deflection range, 0.016" TMA® with 3x3 mm U loops at a 2 mm deflection range and 0.016"x0.022" TMA® with 4x4, 6x6 and 8x8 mm bulbous loops at 0.5, 1 and 1.5 mm deflection ranges, respectively.

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การปรับเทียบปริมาณแรงจากลวดเหลี่ยมทีเอ็มเอลูปรูปบัลบัสและลวดกลมทีเอ็มเอลูปรูปยูในการเคลื่อนฟันไปทางด้านริมฝีปาก

ปริยากร ชัยมงคล อุดม ทองอุดมพร**

บทคัดย่อ

วัตถุประสงค์: เพื่อปรับเทียบแรงที่ใช้ในการเคลื่อนฟันที่ผลิตโดยลูปที่มีรูปร่างและขนาดที่ต่างกันในลวดกลมและลวดเหลี่ยมที่ระยะทางต่างๆ

วัสดุและวิธีการ: ลวดที่ใช้ในการทดสอบประกอบด้วยลวด 4 กลุ่ม โดยในกลุ่มแรกคือลวดทีเอ็มเอ ชนิดหน้าตัดกลมขนาดเส้นผ่าศูนย์กลาง 0.016 นิ้ว ที่มีลูปรูปยู กลุ่มที่ 2,3 และ 4 คือลวดทีเอ็มเอชนิดหน้าตัดเหลี่ยมขนาด 0.016"×0.022" นิ้ว ที่มีลูปรูปบัลบัสขนาด 4x4, 6x6, 8x8 มิลลิเมตรตามลำดับ เครื่องทดสอบยูนิเวอร์แซลถูกใช้ในการวัดแรง โดยเริ่มจากการให้แรงกดลวดจากระยะทาง 0 ถึง 2.5 มิลลิเมตร ระหว่างการปล่อยลวดมีการวัดแรงที่ทุกๆระยะ 0.5 มิลลิเมตร จนถึงระยะที่ลวดไม่ได้ถูกให้แรง หลังจากนั้น แรงที่วัดได้ถูกนำมาทดสอบด้วยสถิติทดสอบครัสกัล-วอลลีสที่ระดับนัยสำคัญ 0.05

ผลการศึกษา: จากผลการศึกษา พบว่าลวดกลมลูปรูปยูที่ระยะทาง 2.5 มิลลิเมตร, ลวดกลมลูปรูปยูที่ระยะทาง 2 มิลลิเมตร, ลวดเหลี่ยมลูปรูปบัลบัสขนาด 4x4 มิลลิเมตรที่ระยะทาง 0.5 มิลลิเมตร, ลวดเหลี่ยมลูปรูปบัลบัสขนาด 6x6 มิลลิเมตรที่ระยะทาง 1 มิลลิเมตร และ ลวดเหลี่ยมลูปรูปบัลบัสขนาด 8x8 มิลลิเมตรที่ระยะทาง 1.5 มิลลเมตร ให้แรงไม่แตกต่างกันอย่างมีนัยสำคัญ ($P>0.05$)

สรุป: ลวดกลมลูปรูปยูที่ระยะทาง 2.5 มิลลิเมตร, ลวดกลมลูปรูปยูที่ระยะทาง 2 มิลลิเมตร, ลวดเหลี่ยมลูปรูปบัลบัสขนาด 4x4 มิลลิเมตรที่ระยะทาง 0.5 มิลลิเมตร, ลวดเหลี่ยมลูปรูปบัลบัสขนาด 6x6 มิลลิเมตรที่ระยะทาง 1 มิลลิเมตร และ ลวดเหลี่ยมลูปรูปบัลบัสขนาด 8x8 มิลลิเมตรที่ระยะทาง 1.5 มิลลเมตร ให้ปริมาณแรงไม่แตกต่างกันในการเคลื่อนฟันตัดบนไปทางด้านริมฝีปาก

คำสำคัญ*: เคลื่อนฟันตัดไปทางด้านริมฝีปาก; แรงขนาดเบา; ลวดทางทันตกรรมจัดฟัน; แอดวานซิ่งลูป; ลวดไทเทเนียมโมลิบดีนัม*

ผู้รับผิดชอบบทความ

อุดม ทองอุดมพร

ภาควิชาทันตกรรมป้องกัน คณะทันตแพทยศาสตร์

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