Influence of the cross-section of orthodontic wires on the surface friction of self-ligating brackets

Roberta Buzzoni*, Carlos N. Elias**, Daniel J. Fernandes***, José Augusto M. Miguel****

Abstract

Objectives: The purpose of this study was to assess the surface friction produced between self-ligating stainless steel brackets equipped with a resilient closure system and round and rectangular orthodontic wires made from the same material. **Methods:** Thirty maxillary canine brackets were divided into six groups comprising Smartclip and In-Ovation R self-ligating brackets, and conventional Gemini brackets tied with elastomeric ligatures. This investigation tested the hypothesis that self-ligating brackets are susceptible to increases in friction that are commensurate with increases and changes in the cross-section of orthodontic wires. Traction tests were performed with the aid of thirty segments of 0.020-in and 0.019 x 0.025-in stainless steel wires in an EMIC DL 10000 testing machine with a 2N load cell. Each set of bracket/wire generated four samples, totaling 120 readings. Comparisons between means were performed using analysis of variance (one way ANOVA) corrected with the Bonferroni coefficient. **Results and Conclusion:** The self-ligating brackets exhibited lower friction than conventional brackets tied with elastomeric ligatures. The Smartclip group was the most effective in controlling friction ($p<0.01$). The hypothesis under test was confirmed to the extent that the traction performed with rectangular 0.019 x 0.025-in cross-section wires resulted in higher friction forces than those observed in the 0.020-in round wire groups ($p<0.01$). The Smartclip system was more effective even when the traction produced by rectangular wires was compared with the In-Ovation R brackets combined with round wires ($p<0.01$).

Keywords: Brackets. Orthodontic wires. Stainless steel. Friction.

INTRODUCTION

The increasingly frequent use of sliding mechanics underscores the importance of controlling friction when performing orthodontic movement.[10] Friction can be defined as a force that opposes or slows down the movement of two bodies in contact.[5,8,10] Before orthodontic movement can be produced it is necessary that the force delivered exceed the frictional resultant present in the bracket/wire interface.

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However, when high friction rates are observed in this situation, force can be reduced to as low as 60%[11] of its original intensity, which may clinically cause a delay in biological response.[8,10]

A wide range of variables can modulate the amount of friction generated, among which are type of material, size and shape of brackets[4,10] and orthodontic wires,[1,4,10] and types of ligation used at the bracket/wire interface.[1,15] Wire thickness has a direct relationship with friction forces while rectangular archwires feature higher friction than their round counterparts.[9] Regarding ligation type, self-ligating brackets are reported in the literature as appliances that allow friction control of the orthodontic archwires engaged in their slots[15] (Fig 1).

Self-ligating systems are divided into two categories according to how the mechanical ligation method operates. Action can be either active or passive.[4,15] Passive systems have a sliding clip that entraps the archwire inside the bracket slot without applying any pressure.[15] Active models exert a continuous pressure on the archwire,[4] enabling faster alignment with greater speed and torque control.[15] In some models, pressure becomes more intense as archwire size is increased,[9] which may also result in the incorporation of higher frictional forces. This investigation tested the hypothesis that self-ligating brackets are susceptible to increases in friction that are commensurate with increases and changes in the cross-section of orthodontic wires used in traction. The aim of this study was to assess the surface friction produced by self-ligating stainless steel brackets equipped with a resilient closure system and compare the friction generated during traction of round and rectangular orthodontic wires made from the same material using round and rectangular cross-section wires.

MATERIAL AND METHODS

For this study, 30 maxillary canine brackets were divided into six distinct groups each with five brackets. The groups were composed of SmartClip (3M/Unitek, CA, USA) and In-Ovation R (GAC, NY, USA)

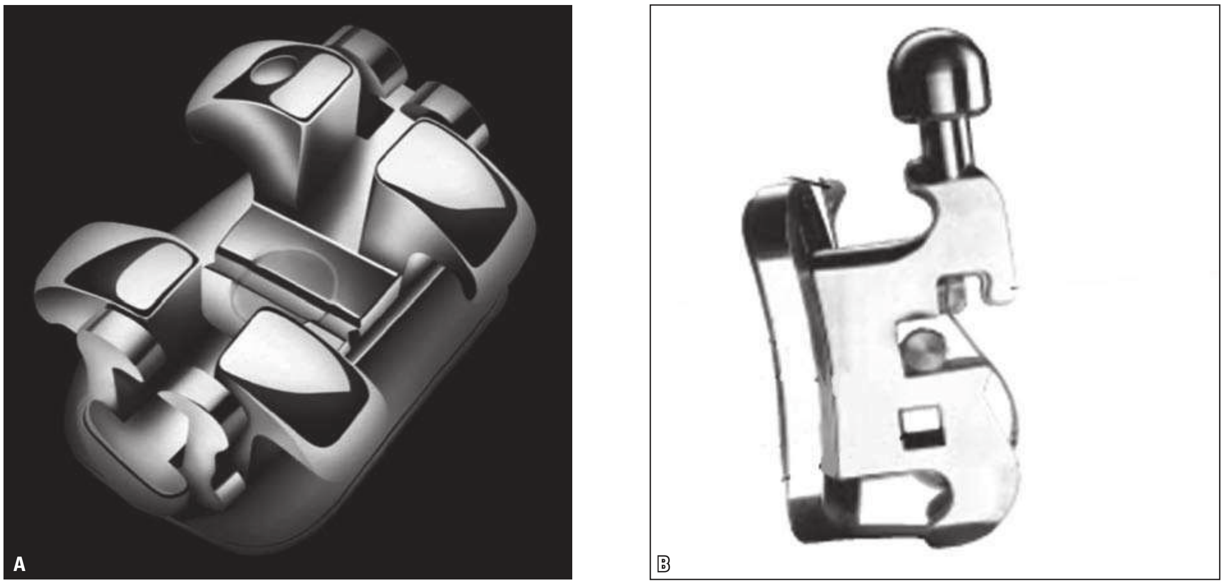

FIGURE 1 - Self-ligating brackets with resilient self-ligating system. **A**) Front view of SmartClip system (3M/Unitek) with anterior clip. **B**) Side view of the In-Ovation R brackets (GAC), with anterior resilient cap. Note round wire entrapped inside bracket slot.

self-ligating brackets, and conventional Gemini (3M/Unitek, CA, USA) brackets tied with gray elastomeric ligatures (TP Orthodontics, IN, USA) (Table 1). Five segments of round 0.020-in orthodontic wires and five segments of rectangular 0.019 x 0.025-in (TP Orthodontics, IN, USA) wires measuring 8.0 cm were used in each of the three types of brackets evaluated (Table 1). The surface friction generated by traction of the steel wires inside the bracket slots was evaluated according to four consecutive readings of each bracket/orthodontic wire pair. Twenty readings were conducted of each group in a total of 120 readings.

The bracket/wire models were tested for surface friction in an EMIC DL 10000 (EMIC, PR, Brazil) testing machine with a load cell of 2.0 kilograms (kg) of force (Fig 2). To perform the tests and compensation of different angulations (tips) built into the pre-adjusted brackets, metal cylinders were especially developed with compensatory tips so that all the wires were placed in parallel relationship with the bracket slots. These stainless steel cylinders were connected to the testing machine and the brackets bonded with the aid of Super Bonder instant adhesive (Loccite, SP, Brazil). The bracket bases were first filled with Transbond XT (3M/Unitek, CA, USA)

TABLE 1 - Description of groups, number of brackets, pre-angulations and pre-torques relating to prescriptions, and angulations used in the bracket traction tests.

Groups	Brackets	Number of brackets	Pre-angulations	Pre-torques	Cross-section
1	SmartClip	5	+8°	0°	0.020-in
2	In-Ovation R	5	-2°	13°	0.020-in
3	Gemini	5	+8°	0°	0.020-in
4	SmartClip	5	+8°	0°	0.019 x 0.025-in
5	In-Ovation R	5	-2°	13°	0.019 x 0.025-in
6	Gemini	5	+8°	0°	0.019 x 0.025-in

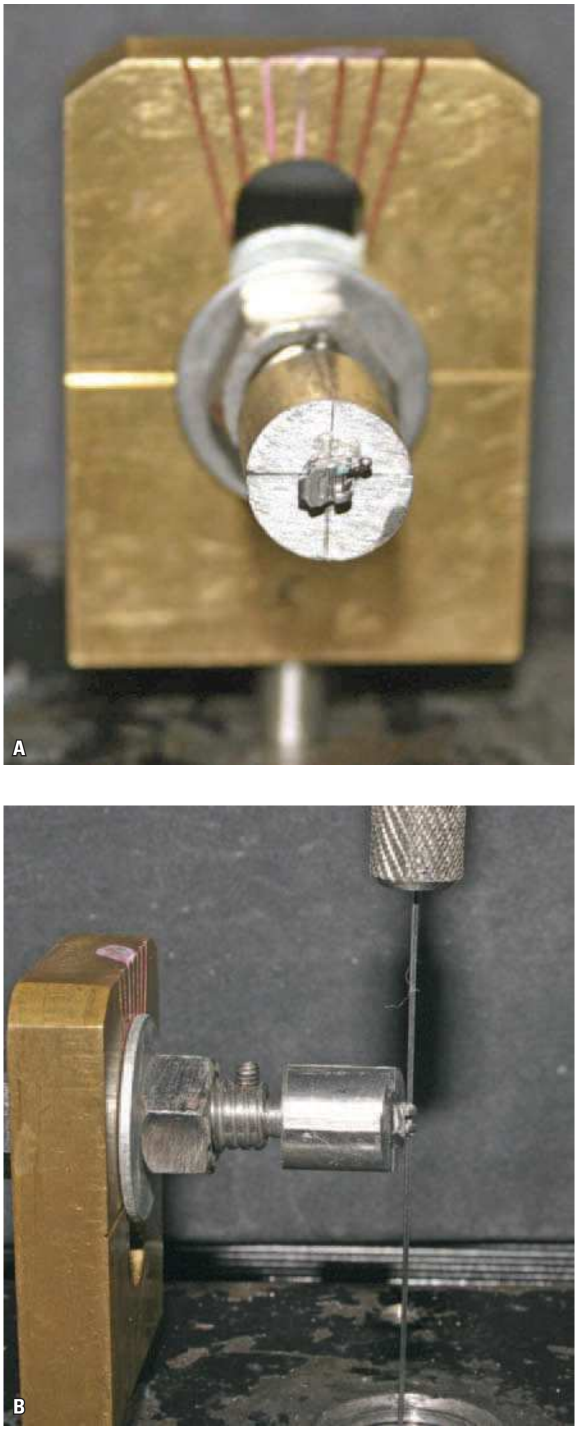

FIGURE 2 - **A**) Front view of self-ligating bracket bonded to metal cylinder with compensatory angulation to ensure traction is performed with no pre-angulation or torque. Total absence of angulation (tip) can be confirmed by the vertical alignment of the markings on the metal cylinder and copper colored part seen in the background. **B**) Side view of the same bracket described during traction of stainless steel 0.019 x 0.025-in cross-section wire.

light cure resin in order to determine the area for bonding (Fig 3).

Ligation of orthodontic wires to the Gemini brackets was performed using elastomeric ligatures (TP Orthodontics, IN, USA), which were replaced at each trial. The orthodontic wires were pulled at a speed of 5 mm/min at a distance of 3.5 mm (Fig 2). Maximum force (gF) values were recorded by computer program Tesc, version 3.04 (EMIC, PR, Brazil).

The results were summarized as means and standard deviations. Comparisons between means were performed using analysis of variance (one way ANOVA) corrected with the Bonferroni coefficient.

RESULTS

Comparison between surface friction force means in grams-force (gF) under traction with 0.020-in and 0.019 x 0.025-in stainless steel wire is shown in Table 2. The values found show lower mean friction in the self-ligating groups compared with conventional brackets tied with elastomeric ligatures. The most effective friction control was afforded by the groups with SmartClip self-ligating brackets, regardless of the wire cross-section under traction ($p<0.01$). Increases and changes in the cross-section of wires, from round to rectangular, caused friction to increase in all groups tested ($p<0.01$).

Distribution of values was analyzed using the Shapiro-Wilk normality test ($p<0.05$) and presented in a box-plot graph (Fig 4). The resulting pattern showed normal distribution for all groups except for SmartClip brackets combined with 0.020-in archwires.

Analysis of variance (ANOVA) values revealed associations between frictional forces and self-ligating systems. The p value ($p<0.01$) found with the Bonferroni multiple comparisons test indicated statistical differences between groups (Table 2).

DISCUSSION

In this study, twenty specimens from each group were obtained through surface tensile tests. Each bracket provided four consecutive friction readings representative of the traction of each archwire type in the slot, totaling twenty measurements for each group. This methodology was employed with the purpose of simulating the clinical conditions involved in

FIGURE 3 - Gemini bracket bases filled with resin for subsequent bonding to surface of metal cylinders. Observe the flattening of the bases accomplished with Transbond XT light cure resin. This procedure was used prior to bonding all brackets under test.

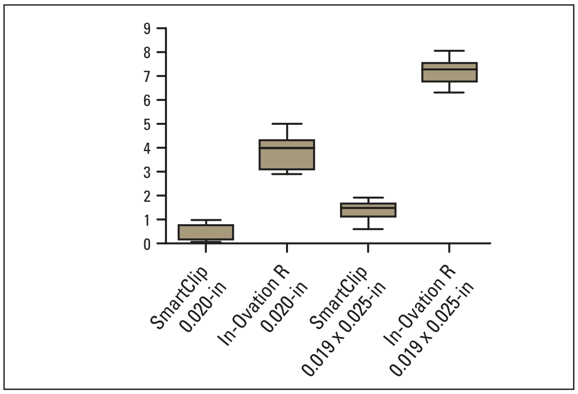

FIGURE 4 - Distribution of friction values in gram-force (gF) for self-ligating brackets and stainless steel wires of 0.020-in and 0.019 x 0.025-in cross-sections.

TABLE 2 - Surface friction in Gram-force (gF) produced by self-ligating brackets using stainless steel wire with 0.020-in and 0.019 x 0.025-in cross-sections.

Self-ligating Group	Cross-section	Mean (gF)	Standard Deviation	Sample (n)
SmartClip	0.020-in	0.470^{a}	0.3525	20
In-Ovation R	0.020-in	3.864^{b}	0.6952	20
SmartClip	0.019 x 0.025-in	1.467^{c}	0.3468	20
In-Ovation R	0.019 x 0.025-in	7.182^{d}	0.5290	20

Note: Conventional Gemini brackets combined with 0.020-in wires. Mean (gF) = 114.4 conventional Gemini brackets combined with 0.019 x 0.025-in wires. Mean (gF) = 147.48.
ANOVA ($p<0.01$) - different letters imply different means by the Bonferroni multiple comparisons test ($p<0.01$).

sliding repeatedly — be it the bracket sliding on the wire or vice versa — according to the time period established in the treatment goals. The results showed reduced standard deviations, which would make redundant repetitions with the same brackets. Although some authors argue that the bracket/wire surface is susceptible to wear,[6,7] the authors believe that, in this test, wear occurs significantly only in materials with a high coefficient of friction such as crystalline matrix or polycarbonate. This methodology is similar to research conducted by Voudoris[15] in which only eight brackets in each group were subjected to sliding, totaling twenty four samples for each type of bracket.

Only maxillary canine brackets were evaluated. This choice is justified by the fact that, clinically, canine teeth are often involved in sliding mechanics, especially in cases that require premolar extraction. The same brackets were selected in studies conducted by Berger[2] and Brown et al.[3] However, the bases of these brackets were found to be too concave, hindering the bonding procedure. To ensure proper bonding, the bracket bases had to be filled flush with light cure resin. Voudouris[15] also used the same resin filling technique in his study and noted no variation in friction values.

Each manufacturer developed their own self-ligating model with individual angulations and torques. It has been argued that there is a direct relationship between angulation (tip), active torques and increased surface friction.[9] Metal cylinders were fabricated with the purpose of standardizing the various prescriptions in bonding the brackets subjected to traction. A compensatory angulation was pre-adjusted in the bonding surface so as to neutralize the original bracket tip, ensuring parallelism between slot and wire. This standardization system is consistent with the methodology developed by Sims et al,[11] who also used a piece of metal support for compensatory bonding. Some authors have used different methods to standardize the pre-existing angulations.[3,15]

An important factor influencing the magnitude of friction is how the bracket and orthodontic wire are ligated.[11] The conventional brackets were ligated with the aid of elastomeric ligatures in order to standardize the force delivered to entrap the orthodontic wire inside the bracket slot. Voudouris[15] reported that the loss of elasticity experienced by the material is subjective and directly proportional to the length of time it remains stretched, and such loss could exert significant influence on the surface friction. For this reason, the ligatures were replaced at each test.

Piozzoni, Ravnholt and Melsen[9] argued that thicker wires produce higher friction values and, in general, rectangular archwires generate more friction than round archwires due to a broader contact area with the brackets under traction. Others believe that the most important variable is the extent to which bracket slots are filled by the archwires.[3,11] In this research, after comparing different stainless alloy wires, it was found that increases in friction are directly proportional to increases in the cross-section of the archwires, regardless of the bracket model evaluated. This was shown to have a statistically significant correlation.

Self-ligating brackets with a resilient closure system feature a self-closing anterior cap that entraps — by pressure — the orthodontic wires inside the bracket slots.[9] It is believed that the permanent contact between the self-ligating cap and the wire contribute to increasing the friction generated in sliding.[14] This interaction was evidenced in this study, where the friction generated by rectangular wires was found to be higher than that of round wires. A possible explanation could be that rectangular wires contact the self-closing cap on its 0.025-in face, while round wires contact only the 0.020-in face. As the bracket slot is filled by the wire, the resilient cap exerts more pressure on the wires, consequently increasing the friction resultant on the brackets that experience traction.

The results of this study showed that In-Ovation R brackets yielded friction means above those observed in the SmartClip appliance when 0.020-in and 0.019 x 0.025-in cross-section wires were used. The group comprising SmartClip brackets was statistically more effective in controlling friction even when the traction of rectangular wires was compared with the test involving In-Ovation R brackets in combination with round wires. The mean friction values produced by conventional Gemini brackets indicate that the self-ligating groups were more effective in controlling surface friction. This finding is in agreement with several previous studies.[1,2,10,11] The aim of this study was to assess the behavior of self-ligating brackets with resilient ligation systems in combination with orthodontic wires of different cross-sections. The mean values found for the conventional Gemini system served only as reference and were therefore not treated statistically.

CONCLUSIONS

The SmartClip self-ligating bracket system allowed better control of friction forces regardless of the type of orthodontic wire used for traction. Rectangular 0.019 x 0.025-in wires produced a greater amount of friction than round 0.020-in wires made from the same stainless alloy. This finding supports the hypothesis of this investigation as regards the self-ligating brackets tested. The group comprised of SmartClip brackets was more effective even when the traction of rectangular wires was compared with the test involving In-Ovation R brackets in combination with round wires.

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