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Evaluation of friction produced by self-ligating, conventional and Barbosa Versatile brackets

Avaliação do atrito produzido por bráquetes autoligados, convencionais e Barbosa Versátil

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Resumo

Introdução: O bráquete Barbosa Versátil apresenta um desenho que pode promover menor resistência friccional e maior deslize. No entanto, nenhum estudo *in vitro* avaliou seu mecanismo de deslize e resistência ao atrito, mesmo quando comparado com outros bráquetes autoligados ou convencionais. **Objetivo:** Comparar a resistência ao atrito entre bráquetes autoligados (EasyClip/ Aditek, Damon MX/ Ormco e In Ovation R/ GAC), convencionais (Balance Roth/ GAC, and Roth Monobloco/ Morelli) e o bráquete Barbosa Versátil (Barbosa Versatile/ GAC) com diferentes angulações e fios. **Material e método:** Os bráquetes foram avaliados com fios de aço inox 0.014”, 0.018”, 0.019”×0.025” e 0.021”×0.025”, com angulações de 0, 5, 10, 15 e 20 graus. Amarrias foram realizadas com ligaduras elastoméricas para os bráquetes convencionais e para o Barbosa Versátil, enquanto que se utilizou o sistema de fechamento próprio para os bráquetes autoligados. A máquina de teste universal foi utilizada para as avaliações de resistência ao atrito entre os bráquetes e fios. **Resultado:** ANOVA em esquema fatorial 4 × 5 × 6 (bráquetes × angulação × fios) e o teste de Tukey mostraram que houve diferenças significativas para todos os fatores e interações (p<0,0001). Houve menor resistência ao atrito para o bráquete Barbosa Versátil e maior para os bráquetes Roth Monobloco e Balance. **Conclusão:** Menor resistência ao atrito foi obtida com o bráquete Barbosa Versátil e com os autoligados em comparação com os bráquetes convencionais. O aumento do diâmetro dos fios aumenta a resistência ao atrito. Menores angulações promovem menor resistência ao atrito.

Descritores: Fricção; fios ortodônticos; bráquetes ortodônticos.

Abstract

Introduction: The Barbosa Versatile bracket design may provide lower frictional force and greater sliding. However, no in vitro studies have shown its sliding mechanisms and frictional resistance, particularly in comparison with other self-ligating or conventional brackets. **Objective:** To compare the frictional resistance among self-ligating brackets (EasyClip/ Aditek, Damon MX/ Ormco and In Ovation R/ GAC); conventional brackets (Balance Roth/ GAC, and Roth Monobloc/ Morelli); and Barbosa Versatile bracket (Barbosa Versatile/ GAC) with different angles and arch wires. **Material and method:** Brackets were tested with the 0.014”, 0.018”, 0.019”×0.025” and 0.021”×0.025” stainless steel wires, with 0, 5, 10, 15 and 20 degree angulations. Tying was performed with elastomeric ligature for conventional and Barbosa Versatile brackets, or with a built-in clip system of the self-ligating brackets. A universal testing machine was used to obtain sliding strength and friction value readouts between brackets and wires. **Result:** Three-way factorial ANOVA 4×5×6 (brackets × angulation × wire) and Tukey tests showed statistically significant differences for all factors and all interactions (p<0.0001). Static frictional resistance showed a lower rate for Barbosa Versatile bracket and higher rates for Roth Monobloc and Balance brackets. **Conclusion:** The lowest frictional resistance was obtained with the Barbosa Versatile bracket and self-ligating brackets in comparison with the conventional type. Increasing the diameter of the wires increased the frictional resistance. Smaller angles produced less frictional resistance.

Descriptors: Friction; orthodontic wires; orthodontic brackets.

INTRODUCTION

With the frequent use of sliding mechanics in Orthodontics, friction control has become a major concern for successful treatment[1-4]. The use of forces below values required for tooth movement prolongs treatment time. Whereas, using force above the limit in an attempt to compensate the friction, causes discomfort to the patient and greater loss of anchorage[4]. Because of this resistance to movement, it is known that the force effectively applied to the teeth during treatment must overcome friction and will depend on the skill of the clinician, who should monitor the mechanical forces that stimulate biological responses in the periodontium[5,6].

Among the factors influencing frictional resistance are: the type of bracket and tying; angle; dimensions of the wires and the folds of the first, second and third order. In addition, the roughness, hardness and thickness of the wires influence the intensity of friction, being more evident in wires with lower hardness and greater flexibility[2,7]. There is increasing resistance to sliding as the angles increase[7-13]. Considering the types of brackets, the self-ligating system has lower frictional forces compared with conventional types[9,10,12-18]. The Barbosa Versatile (BV) bracket[19] design may provide lower frictional force, greater sliding, and require less anchorage. Although it is not a self-ligating bracket, it has a slot with a concavity at the bottom to create only two points of contact instead of a contact surface. It also has three tie-wings, for both cervical and incisal slots. This allows for various forms of tying, including passive tying when the central wings are used, because the depth of the slot is 0.30" and allows the tie to touch the bracket structure without pressing the wire to the bottom of the slot. Given these characteristics, this bracket seems to present lower frictional resistance when compared with conventional and self-ligating brackets. However, no *in vitro* study has shown its sliding mechanics and frictional resistance. Thus, the aim of this *in vitro* study was to compare the static frictional resistance among three types of self-ligating brackets and three conventional brackets with different angles and wires. The null hypothesis tested was that there would be no differences in frictional resistance between self-ligating and conventional brackets with different angles and wires.

MATERIAL AND METHOD

The experimental units consisted of self-ligating brackets (In-Ovation R, Damon MX, and EasyClip), conventional brackets (Balance Roth, and Roth Monobloc), and the BV bracket (Figure 1 and Table 1) with different diameters of round and rectangular wires subjected to static frictional resistance at different angles (n=5) (Table 1).

A polytetrafluoroethylene device (PTFE) with a groove was developed, and fast-drying adhesive was used on one end of the bracket to be tested (Superglue, Henkel Ltda., Itapevi, Brazil). This device was a PTFE steel guide developed especially for the experiment. At one end it had a longitudinal opening with rectangular features to allow sliding and reduce undesirable angulation of the bracket. This device together with the fixed bracket was attached to the universal testing machine in a range of angles (Figure 2). It was possible to align the bracket with the orthodontic wire, and promote the different angulations to be tested in this experiment. The wire was cut to a length of 20cm; was fitted into the upper arm of the universal testing machine, and passed through the slot of each bracket being tested. The entire bracket/wire set was tied with elastomeric ligatures on conventional brackets; and the clip itself for closing self-ligating brackets. For the BV bracket, elastomeric

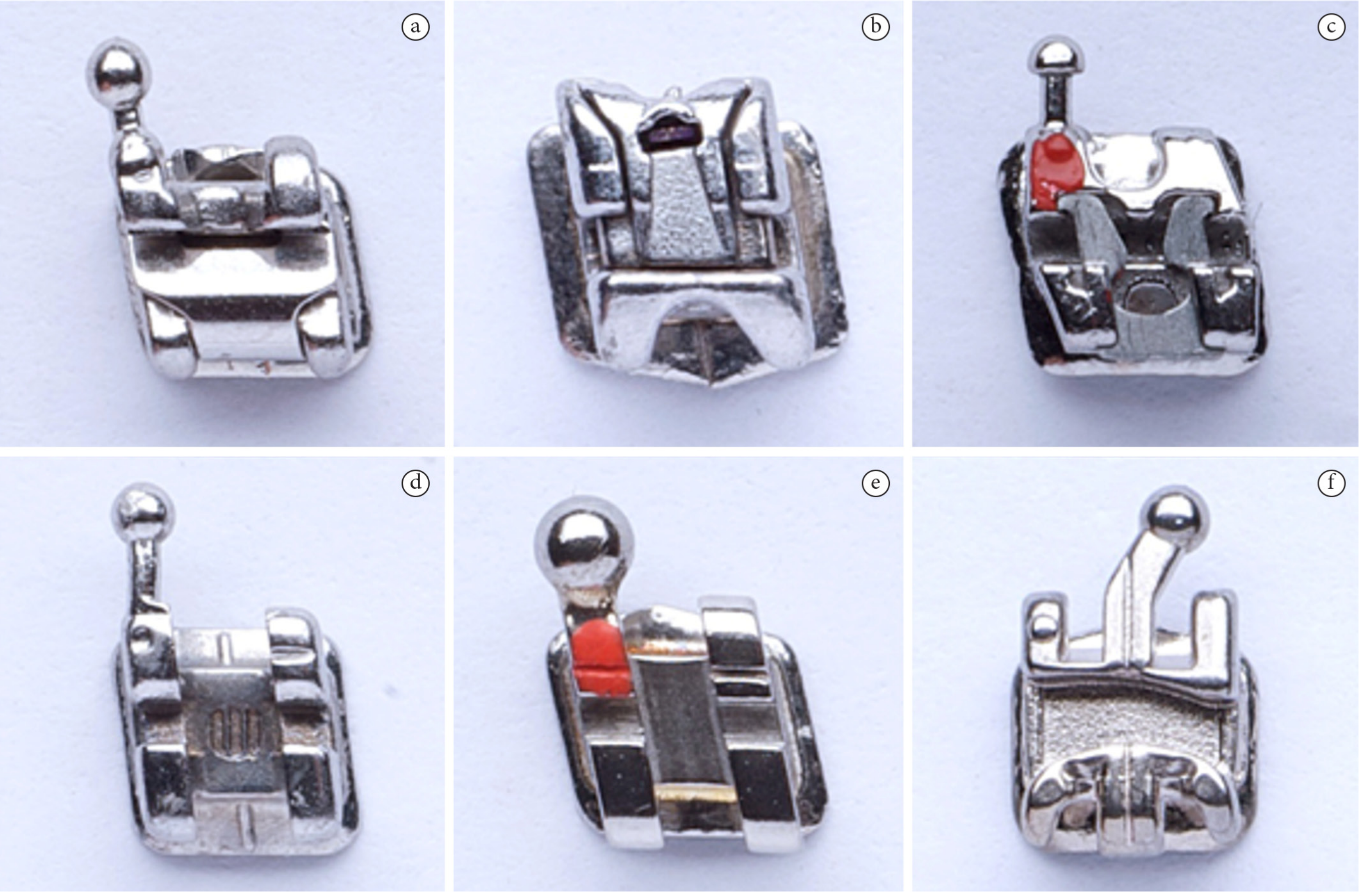

Figure 1. Brackets used in the experiment: (a) In-Ovation R; (b) Damon MX; (c) EasyClip; (d) Balance Roth; (e) Morelli Roth Monoblock; (f) Barbosa Versatile bracket.

Table 1. Materials used in the experiment, characteristics and their manufacturers

Materials/ Abbreviation	Characteristics	Manufacturer (city, state, country; site)
EasyClip (ref. 14.02.113T)/ EC	Self-ligating; maxillary right canine; torque: 0; angulation: 5	Aditek (Cravinhos, São Paulo, Brazil; www.aditek.com.br)
Damon MX (ref. 494-4480)/ DA	Self-ligating; maxillary right canine; torque: 0; angulation: 6	Ormco (Glendora, California, United States of America; www.ormco.com)
In-Ovation R (ref. KIT89-055-24)/ IO	Self-ligating; maxillary right canine; torque: -2; angulation: 13	Dentsply GAC (Bohemia, New York, United States of America; http://www.gacintl.com)
Balance Roth (ref. 31-332-15)/ BR	Conventional; maxillary right canine; torque: -2; angulation: 13	
Barbosa Versatile bracket (ref. 31-132-15)/ BV	Conventional; maxillary right canine; slot with free torque and angulation	
Roth Monobloc Morelli (ref. 10-15-901)/ RM	Conventional; maxillary right canine; torque: 0; angulation: 0	Morelli (Sorocaba, São Paulo, Brazil; www.morelli.com.br)
Ligature (ref. 59-600-14)	Elastomeric ligature	GAC (Bohemia, New York, United States of America; http://www.gacintl.com)
Stainless steel wire (ref. 03-014-58)	0.014”	
Stainless steel wire (ref. 03-018-58)	0.018”	
Stainless steel wire (ref. 03-925-58)	019 × .025	
Stainless steel wire (ref. 03-125-58)	021 × .025	

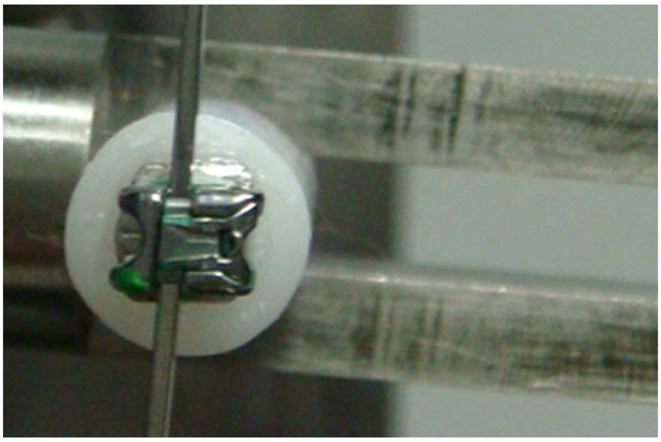

Figure 2. Bracket fixed onto the PTFE device and attached to the universal testing machine (Emic) and submitted to different ranges of angulations.

ligature ties were used through the central wings. Thus, the ligature touched only the bracket structure without putting pressure on the wire, featuring a passive binding and acting as a pipe.

The tests were performed with all wires and brackets. For each bracket/wire set, all angulations were tested and repeated five times. At each repetition, the elastomeric ligature was removed and replaced by another one in the case of conventional brackets. For each repetition with self-ligating brackets, the clip was opened; the wire was removed from the slot, and then replaced again before closing the clip. Upon completion of the tests, the wire was removed from the bracket slot and the change to the next angulation was made by rotating the steel guide coupled to the bracket at its extremity. It was guided by a steel wire thread, welded at the other end of the guide, which was measured using a scale adjusted between the fixing device and the guide.

Twenty combinations were obtained for each angle × bracket × wire set. The universal testing machine (EMIC DL 10000, São José dos Pinhais, Brazil) was programmed to move at a speed of 3mm per minute by traction force that moved by pulling the wire, causing it to slide along the bracket slots. This movement simulated the distal movement of a canine tooth in a pre-aligned arc.

The frictional force generated during movement of the wire was determined using a load cell of 20N attached to the universal testing machine. The frictional resistance (in gf) was recorded on a computer.

The exploratory statistical analysis of the data indicated a logarithmic transformation to meet the assumptions of analysis of variance (ANOVA). After processing, the data were submitted to a three-way factorial ANOVA 4×5×6 design (brackets × angulation × wire) (bracket × wire × angle) and Tukey tests. Analyses were performed with the statistical program SAS with a level of significance of 5% (SAS Institute Inc., Release 9.1, 2003).

RESULT

The results were statistically significant for all factors and all interactions among them ($p<0.0001$). The unfolding of the triple interaction resulted in Tables 2 and 3. BR bracket, with a 0-degree angle to the 0.14” and 0.18” wires showed no statistically significant differences. Variations were found between these wires and 0.019” and 0.021”, with higher values of friction for 0.021”×0.025”. The same occurred when tested at 5 degrees. A significant difference was

Table 2. Mean (SD) maximum force (gf) of friction as a function of the bracket and wire

Brackets	Angulation	Wire			
		0.014	**0.018**	**0.019**	**0.021**
BR	0	46.3(2.5)Cb	51.0(4.6)Cd	83.9(5.5)Bd	106.4(6.0)Ae
	5	54.1(4.3)Cb	52.3(1.0)Cd	103.3(9.4)Bc	166.6(6.7)Ad
	10	48.9(3.9)Db	69.0(2.9)Cc	153.7(6.6)Bb	242.9(19.7)Ac
	15	81.1(6.5)Ca	93.7(3.0)Cb	174.8(6.7)Ba	364.7(18.0)Ab
	20	82.9(3.2)Da	119.8(4.4)Ca	193.3(10.7)Ba	398.5(18.6)Aa
DA	0	0.5(0.2)Be	0.8(0.0)Be	1.0(0.0)Be	61.2(2.5)Ae
	5	6.2(0.5)Dd	29.1(2.1)Cd	181.7(6.0)Ad	75.8(3.0)Bd
	10	18.9(1.0)Dc	70.4(5.9)Cc	327.5(1.9)Ac	175.7(6.9)Bc
	15	28.9(0.7)Db	121.8(9.1)Cb	420.4(24.6)Ab	374.4(18.5)Bb
	20	40.5(3.7)Ca	175.7(7.4)Ba	595.9(6.2)Aa	631.6(54.7)Aa
EC	0	0.5(0.1)Bc	0.8(0.0)ABd	1.1(0.1)ABe	2.5(0.6)Ae
	5	1.1(0.1)Cbc	2.8(0.4)Ccd	29.4(2.8)Bd	46.4(2.1)Ad
	10	1.3(0.0)Dbc	5.6(0.8)Cc	72.3(2.2)Bc	110.6(2.4)Ac
	15	2.4(0.2)Db	10.7(0.5)Cb	134.0(4.9)Bb	187.7(4.7)Ab
	20	20.1(2.4)Da	35.4(1.8)Ca	168.4(5.6)Ba	261.7(7.1)Aa
IO	0	0.7(0.0)Cc	0.7(0.0)Ce	10.3(0.3)Bc	37.4(2.6)Ad
	5	1.5(0.1)Cbc	6.8(0.6)Bd	11.0(0.3)Bc	94.9(4.9)Ac
	10	3.0(0.4)Db	21.9(1.0)Cc	68.8(1.6)Bb	155.3(8.0)Ab
	15	3.9(0.2)Cab	65.8(4.6)Bb	79.1(5.6)Bb	220.1(6.7)Aa
	20	6.5(0.8)Da	101.3(4.2)Ca	124.5(10.6)Ba	241.6(25.9)Aa
RM	0	49.7(1.5)Cc	62.1(1.3)Bd	73.3(2.1)Be	92.0(3.7)Ae
	5	54.1(1.8)Dc	68.2(4.2)Cd	92.2(6.1)Bd	209.6(10.6)Ad
	10	70.3(2.8)Db	101.9(3.8)Cc	154.6(9.9)Bc	337.0(10.8)Ac
	15	73.7(3.1)Db	148.2(5.1)Cb	219.0(19.6)Bb	474.1(36.0)Aa
	20	89.9(1.6)Da	226.5(8.3)Ca	318.8(19.5)Ba	397.7(21.7)Ab
BV	0	0.4(0.0)Ba	0.7(0.0)Bb	1.3(0.0)Bd	6.4(0.5)Ac
	5	0.3(0.0)Ba	0.6(0.0)Bb	5.7(0.3)Ac	3.0(0.2)Ac
	10	0.4(0.0)Ba	0.6(0.0)Bb	6.4(0.2)Ac	3.4(0.2)Ac
	15	0.5(0.0)Ba	0.5(0.0)Bb	45.1(1.6)Ab	56.1(2.8)Ab
	20	0.5(0.0)Da	3.9(0.4)Ca	101.1(4.5)Ba	287.2(18.6)Aa

Means followed by different capital letters horizontally and lowercase letters vertically comparing the wire of each type of bracket differed between them by the Tukey test ($P<0.05$).

observed for the 10, 15 and 20-degree angles with higher friction values among the greatest wire thicknesses.

Except for the RM bracket, there was statistically significant difference for all the wires and all angulations. In general, BR and RM brackets showed higher friction values with no differences among the different wire dimensions and angulations. DA and IO showed an intermediate position, while the BV bracket and EC showed lower friction values for the larger wires at different angulations.

DISCUSSION

Many studies have shown that lower angulations showed less resistance to sliding when compared with higher angulations[7,8,12,13]. These findings support the present study results that showed statistically significant differences for all the wires and at all angles studied for all brackets, except for RM. Thus, the null hypothesis of this study was rejected.

Table 3. Mean (SD) maximum force (gf) of friction as a function of the bracket and wire

Angulation	Brackets	Wire			
		0.014	0.018	0.019	0.021
0	BR	46.3(2.5)a	51.0(4.6)a	83.9(5.5)a	106.4(6.0)a
	DA	0.5(0.2)b	0.8(0.0)b	1.0(0.0)c	61.2(2.5)b
	EC	0.5(0.1)b	0.8(0.0)b	1.1(0.1)c	2.5(0.6)e
	IO	0.7(0.0)b	0.7(0.0)b	10.3(0.3)b	37.4(2.6)c
	RM	49.7(1.5)a	62.1(1.3)a	73.3(2.1)a	92.0(3.7)a
	BV	0.4(0.0)b	0.7(0.0)b	1.3(0.0)c	6.4(0.5)d
5	BR	54.1(4.3)a	52.3(1.0)b	103.3(9.4)b	166.6(6.7)b
	DA	6.2(0.5)b	29.1(2.1)c	181.7(6.0)a	75.8(3.0)d
	EC	1.1(0.1)c	2.8(0.4)e	29.4(2.8)d	46.4(2.1)e
	IO	1.5(0.1)c	6.8(0.6)d	11.0(0.3)e	94.9(4.9)c
	RM	54.1(1.8)a	68.2(4.2)a	92.2(6.1)c	209.6(10.6)a
	BV	0.3(0.0)c	0.6(0.0)f	5.7(0.3)f	3.0(0.2)f
10	BR	48.9(3.9)b	69.0(2.9)b	153.7(6.6)b	242.9(19.7)b
	DA	18.9(1.0)c	70.4(5.9)b	327.5(1.9)a	175.7(6.9)c
	EC	1.3(0.0)de	5.6(0.8)d	72.3(2.2)c	110.6(2.4)c
	IO	3.0(0.4)d	21.9(1.0)c	68.8(1.6)c	155.3(8.0)d
	RM	70.3(2.8)a	101.9(3.8)a	154.6(9.9)b	337.0(10.8)a
	BV	0.4(0.0)e	0.6(0.0)e	6.4(0.2)d	3.4(0.2)e
15	BR	81.1(6.5)a	93.7(3.0)c	174.8(6.7)c	364.7(18.0)b
	DA	28.9(0.7)b	121.8(9.1)b	420.4(24.6)a	374.4(18.5)b
	EC	2.4(0.2)c	10.7(0.5)e	134.0(4.9)d	187.7(4.7)d
	IO	3.9(0.2)c	65.8(4.6)d	79.1(5.6)e	220.1(6.7)c
	RM	73.7(3.1)a	148.2(5.1)a	219.0(19.6)b	474.1(36.0)a
	BV	0.5(0.0)d	0.5(0.0)f	45.1(1.6)f	56.1(2.8)e
20	BR	82.9(3.2)a	119.8(4.4)c	193.3(10.7)c	398.5(18.6)b
	DA	40.5(3.7)b	175.7(7.4)b	595.9(6.2)a	631.6(54.7)a
	EC	20.1(2.4)c	35.4(1.8)e	168.4(5.6)d	261.7(7.1)c
	IO	6.5(0.8)d	101.3(4.2)d	124.5(10.6)e	241.6(25.9)cd
	RM	89.9(1.6)a	226.5(8.3)a	318.8(19.5)b	397.7(21.7)b
	BV	0.5(0.0)e	3.9(0.4)f	101.1(4.5)f	287.2(18.6)d

Means followed by different letters vertically comparing the type of bracket at each wire differed among them by the Tukey test (P<0.05).

Lower frictional resistance values were found for the BV bracket and for self-ligating brackets. Despite being a conventional bracket, the BV bracket provided low friction in its slot and passive binding[19], obtaining the lowest friction values of all the brackets tested for the largest wire thickness. These results may be related to this bracket design with freedom provided by the slot, allowing various angulations between bracket and wire with low friction. Lower frictional resistance was also observed with the increase in slot size[20].

Self-ligating brackets presented a lower friction rate compared with conventional brackets, as the fixing device differed between them, since the type of ligation interferes with the frictional force. It allows for passive trapping of the wire (except in the interactive brackets with larger diameter wires) without the involvement of any outside connecting agent and allows the use of lighter forces due to reduced friction, which helps to preserve the anchorage[3,9,10,14,17,18,21].

With respect to canine retraction in cases of premolar extractions, Loh[22] described a short-term case that corroborated the findings of Barbosa[19] when using the BV bracket. It appears that the use of light forces were able to quickly move the canines distally during leveling and alignment without having exerted the same power of retraction. Studies have shown that ceramic brackets showed the highest amount of friction, followed by conventional metal braces, both active self-ligating and self-ligating with variable tying methods[23,24]. This study simulated a situation of canine retraction, demonstrating that the self-ligating brackets exerted a lower friction rate compared with the conventional types, except for the BV bracket, when using the passive type of tying. Furthermore, the BV bracket tended to tip the canine while the other brackets tended to move the tooth bodily. A root angulation correction will be needed after retraction by the use of an uprighting spring inside the bracket tube. It is essential to consider that during canine retraction, the lower the rate of friction, the lower will be the requirement of the anchorage elements. When the frictional resistance was compared between self-ligating brackets using beta-titanium and stainless steel wires in round and rectangular configurations, the round wire produced less friction than the strength of rectangular wires, and the beta-titanium wires showed markedly more friction than the steel wires[14]. It has also been demonstrated that increasing the angle produced a greater amount of friction, and self-ligating brackets showed less friction than conventional types. The present study showed similar results, as the round wires exerted less friction compared with rectangular wires. As regards the Damon bracket, the authors considered that compared with the conventional brackets evaluated, the frictional resistance values were higher, especially for higher angulations and rectangular wires. However, compared with the conventional bracket Monobloc Roth, the frictional resistance values were frequently even lower. This could be attributed to the different designs of the slots and the clip closing systems that - according to the types and angles of the wires - promoted the differences in the friction values observed.

Larger angulations increased the frictional resistance and the self-ligating brackets showed less friction than the conventional types, despite the BV bracket having a lower frictional force among all brackets studied, as the binding system is passive and it provides some looseness between the wire and the inner surfaces of the bracket. This is probably caused by the fact that when a tooth is slanted, there are two points of contact in extreme regions of the bracket. When thin round wires with 0-degrees of angulation were used, there was a gap between the bracket and wire, and the sliding resistance was low and even insignificant, especially with the BV bracket. When rectangular wires and increased angulations were used, the looseness between the bracket and wire disappeared and the sliding resistance increased in all types of brackets analyzed. The more rigid the wire, the higher the resistance to sliding becomes. The present study confirmed these findings, since there was greater frictional force on increasing the size of the wires, with exception of the situation without angulation, and of the BV bracket that presented less frictional resistance in all situations and angles of the wires tested.

Simulation of the passive binding system was used for the BV bracket, when a conventional elastomeric ligature was tied to the central wing of the bracket, considering that this type generated higher frictional force than the metal types[5,25]. Moreover, a reduction in friction values may occur due to time and presence of heat and humidity in oral cavity[26].

Based on these results, the authors recommend that when making the choice of the bracket to be used in treatment, planning of the case and the biomechanical needs should be taken into account the to achieve the best result, both esthetically and functionally. Professionals should be warned that when using mechanical systems that generate frictional force, the levels of force should be increased to overcome it in order to resolve slow tooth movement. This leads to overload of the anchorage units, with consequent greater loss of anchorage. BV bracket showed the lowest amount of friction, presented less friction at all angles and thicker rectangular wires, and provided more freedom for movement. In addition, it may decrease the amount of anchorage loss, making biomechanical planning more predictable. In all situations, the smaller angles and round wires generated less friction. The final position of the canines with individualized angulations that provide functional occlusion with a guide for canines, may be facilitated by the slot design with the low friction provided by the BV bracket.

CONCLUSION

The lowest frictional resistance was obtained with the BV bracket and self-ligating brackets that produced less friction than the conventional types. Increasing the diameter of the wires increased the static frictional resistance. Smaller angles produced less frictional resistance.

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CONFLICTS OF INTERESTS

The authors declare no conflicts of interest.

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