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Frictional Resistance in Self-ligating Orthodontic Brackets and Conventionally Ligated Brackets (An In Vitro Study)

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الخلاصة

الأهداف: ان الهدف من اجراء هذه الدراسة هو مقارنة مقاومة الاحتكاك السكونية بين ثلاث انواع من الحاصرات(الحاصرات التقليدية، الحاصرات ذاتية الربط الفعالة و غير الفعالة) و كذلك مقارنة تأثير حجم السلك التقويمي على مقاومة الاحتكاك. **المواد و طرائق العمل**: عينة الدراسة تتكون من ثلاث انواع من الحاصرات حجم الاخدود لجميع الحاصرات كانت ٠,٠٢٢انج. هذه الحاصرات اختبرت مع ٠,٠٢٠، ٠,٠١٨x٠,٠٢٥ و ٠,٠١٩x٠,٠٢٥ انج من الاسلاك الفولاذية المقاومة للصدأ. نموذج الاختبار يتكون من ستة حاصرات تمثل المقطع الامامي من الفك السفلي.عشرة اختبارات قيست باستخدام جهاز اختبار الشد بواسطة سحب السلك التقويمي على طول الحاصرات. جميع القياسات أخذت في حالة جافة وتم تحديد مستوى العينة عند ٠,٠٥. **النتائج**: الحاصرات ذاتية الربط أنتجت قوة احتكاك سكونية أقل بالمقارنة مع الرباطات الالاستيكية للحاصرات التقليدية وبصورة معنوية. بالإضافة إلى أن تأثير حجم السلك التقويمي أظهر زيادة في قوى الاحتكاك كلما زاد حجم السلك التقويمي. **الأستنتاجات** :طريقة ربط الحاصرات يعتبر العامل الاساسي المسؤول عن مقاومة الأحتكاك لهذه الحاصرات.

ABSTRACT

Aims: This study was aimed to compare static frictional forces generated by 3 types of brackets (conventional, active self-ligating and passive self-ligating) combined with 3 different sizes of stainless steel wire. **Material and Methods**: The sample consisted of three types of brackets (Equilibrium 2, Empower, discovery sl) with a slot size 0.022 inch were coupled with 0.020, 0.018×0.025 and 0.019×0.025 inches stainless steel wires, The testing model consists of 6 brackets used to represent lower anterior teeth. Ten tests were carried out for each group of bracket-wire combination in dry state, frictional force were measured by tensile testing machine. A significant P value of 0.05 was predetermined. **Results:** self-ligating brackets produced significantly lower value ($P \leq 0.05$) of mean of static friction than elastomerically tied conventional bracket. The frictional force increased proportionally to the wire size. **Conclusions:** The method of ligation appears to be the primary variable responsible for the frictional resistance generated by these types of brackets.

Keywords: Frictional resistance, Self-ligating bracket, Conventional bracket, Archwires.

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INTRODUCTION

The introduction of the preadjusted edgewise system reduced substantially the need for wire bending, but relies on sliding mechanics to move teeth, especially during space closure, whenever sliding occurs, frictional resistance is encountered.[1]

Friction is a force that retards or resists the relative motion of two objects in contact. The static frictional force is the smallest force needed to start the motion of solid surfaces that were previously at rest with each other, whereas the kinetic frictional force is the force that resists the sliding motion of one solid objective over another at a constant speed.[2] Because tooth movement along an archwire is not continuous, but occurs in a series of very short steps, static friction is considered to have more importance because it needs to be overcome each time the tooth moves a little.[3]

Self–Ligating Brackets (SLBs) are ligatureless bracket systems that have a mechanical device built into the bracket to close off the slot. In recent years, various SLBs have been developed, those that have a spring clip that presses against the archwire ("active" SLBs), and those in which the self-ligating clip does not press against the wire ("passive" SLBs),[4] several previous studies demonstrated a significant decrease in friction for self-ligating brackets, compared to conventional stainless steel brackets. Such a reduction in friction can help shorten chair time and treatment.[5]

The purpose of this in vitro study was to compare static frictional forces generated by 3 types of brackets (elastomerically tied conventional bracket, active self-ligating and passive self-ligating brackets) in combination with 3 different wire sections (0.020, 0.018×0.025 and 0.019×0.025 inches) in dry state.

MATERIALS AND METHODS

Bracket systems and wires

An experimental model reproducing the anterior segment of the lower arch (from right canine to left canine) was used to assess the frictional forces produced by 3 types of stainless steel roth brackets: active self-ligating brackets (Empower, American orthodontics, Sheboygan, USA), passive self-ligating brackets (Discovery sl, Dentaurum company, Isprengen, Germany) and conventional brackets (Equilibrium 2, dentaurum company, Isprengen, Germany), all brackets were 0.022 inch slot and tested with three wire sections (Remanium, Dentaurum, Germany): 0.020, 0.018 x 0.025 and 0.019 x 0.025 inches. The conventional brackets were ligated with Conventional elastic ligatures (silver medium sized ligatures of 1.3mm inner diameter, Leone orthodontic products, Sesto Fiorentino, Firenze, Italy) in order to prevent individual differences in forces resulting from ligature wires. The total numbers of test samples were 90 specimens divided into three groups; each group contains 30 tests of ligation type-archwire combination.

Experimental set-up

The method used in this study quoted from a previous work on the friction measurement carried out by other researchers[6-9] by drawing a straight wire through a bracket or a group of brackets.

The testing model was composed of a metal ruler approximately 20cm long, 2.5cm wide. The brackets were ligated either by elastic ligatures or by a self-ligating mechanism on a section of 0.021x 0.025 inch stainless steel wire which was used to achieve good alignment of the brackets' slots before fixing them with an Epoxy steel glue on a metal ruler with inter bracket distance of 6 mm. (Figure 1) The model was made 9 times (3 models for each type of ligation). The wire (0.021x 0.025 inch) was removed after one day to be sure of complete setting of the glue.

Figure (1): Tensile testing machine.

The test wire was fixed into testing machine; the bottom end was attached to the lower crosshead moving downward while the metal ruler with bonded brackets attached to the upper end of testing unit crosshead. Care was taken to align the wire, so that the sample was parallel with the vertical framework of the machine (Figure 2).

All tests were conducted under dry condition at (20°± 2° C) using a tensile testing machine (ZWEGLE 140, Germany) with the crosshead moving downward at speed of 50 mm/minute. The forces produced by each wire-brackets-ligation method combination were tested 10 times with new wires and ligatures each time.

Figure (2): metal ruler with fixed brackets in a tensile testing machine.

Statistical Analysis

The statistics included, the descriptive (mean, standard deviation, minimum and maximum values), the analysis of variance (ANOVA) and Duncan's Multiple Range Test at $P \leq 0.05$ significance level.

RESULTS

Effect of archwire ligation method on friction

The descriptive statistics and the results of Duncan's Multiple Range Test for the static friction of different bracket types are demonstrated in Tables (1 and 2), passive self-ligating bracket has a significantly lower value ($P \leq 0.05$) of mean of static friction than other types of ligation when combined with different sizes of wire except with 0.020 inch which shows non-significant difference with active self-ligating brackets. Whereas the conventional bracket with conventional elastic ligature shows significantly the highest mean value of static friction than other types of ligation methods.

Table (1): Descriptive statistics of the static friction (gm) for different bracket types and stainless steel wires.

Bracket type	Wire size	No. of sample	Mean (gram)	Standard deviation	Minimum	Maximum
ASLB	0.020”	10	8.50	5.986	20	35
	0.018x0.025”	10	499..70	45.573	432	555
	0.019x0.025”	10	588.40	22.687	540	612
PSLB	0.020”	10	3.00	2.582	0	5
	0.018x0.025”	10	32.90	6.045	25	45
	0.019x0.025”	10	50.90	6.190	40	60
CB+CEL	0.020”	10	650.80	38.209	608	733
	0.018x0.025”	10	750.60	13.599	733	755
	0.019x0.025”	10	869.20	63.897	812	950

ASLB= Active Self-Ligating Brackets, PSLB= Passive Self Ligating brackets, CB+CEL= Conventional Brackets with Conventional Elastic Ligatures.

Table (2): Duncan's Test for Comparison of the effect of different ligation methods on static friction when combined with different sizes of stainless steel wire.

Wire size	Bracket type	No. of samples	Mean (gram)	Standard deviation	Standard error	Duncan's Group
0.020"	PSLB	10	3.00	2.582	0.816	A
	ASLB	10	8.50	5.986	1.893	A
	CB+CEL	10	650.80	38.209	12.083	B
Wire size	**Bracket type**	**No. of samples**	**Mean (gram)**	**Standard deviation**	**Standard error**	**Duncan's Group**
0.018x0.025"	PSLB	10	32.90	6.045	1.912	A
	ASLB	10	499..70	45.573	14.411	B
	CB+CEL	10	750.60	13.599	4.300	C
Wire size	**Bracket type**	**No. of samples**	**Mean (gram)**	**Standard deviation**	**Standard error**	**Duncan's Group**
0.019x0.025"	PSLB	10	50.90	6.190	1.958	A
	ASLB	10	588.40	22.687	7.174	B
	CB+CEL	10	869.20	63.897	20.206	C

ASLB=Active Self-Ligating Brackets, PSLB=Passive Self-Ligating brackets, CB+CEL= Conventional Brackets with Conventional Elastic Ligatures, Different letters mean significant difference.

Effect of wire size on friction

The descriptive statistics and the results of Duncan's Multiple Range Test for the effect of wire size on static friction when combined with different bracket types are demonstrated in Tables (1 and 3), which show that 0.020 inch stainless steel wire has a significantly lower value ($P \leq 0.05$) of mean of static friction than 0.018x0.025 inch stainless steel wires which in turn has a significantly lower value ($P \leq 0.05$) of mean of static friction than 0.019x0.025 inch. For all the groups tested static friction increases with increasing the wire size.

Table (3): Duncan's Test for Comparison of the effect of different wire sizes on static friction when combined with passive self-ligating brackets.

Ligation method	Wire size	No. of Samples	Mean (gram)	Standard deviation	Standard error	Duncan's Group
ASLB	0.020"	10	25.50	5.986	1.893	A
	0.018x0.025"	10	499..70	45.573	14.411	B
	0.019x0.025"	10	588.40	22.687	7.174	C
Ligation method	**Wire size**	**No. of Samples**	**Mean (gram)**	**Standard deviation**	**Standard error**	**Duncan's Group**
PSLB	0.020"	10	3.00	2.582	O.816	A
	0.018x0.025"	10	32.90	6.045	1.912	B
	0.019x0.025"	10	50.90	6.190	1.958	C
Ligation method	**Wire size**	**No. of Samples**	**Mean (gram)**	**Standad deviation**	**Standard error**	**Duncan's Group**
CB+CEL	0.020"	10	650.80	38.209	12.083	A
	0.018x0.025"	10	750.60	13.599	4.300	B
	0.019x0.025"	10	869.20	63.897	20.206	C

ASLB= Active Self-Ligating Brackets, PSLB= Passive Self-Ligating brackets, CB+CEL= Conventional Brackets with Conventional Elastic Ligatures, Different letters mean significant difference.

DISCUSSION

The results of the present investigation indicated that self-ligating brackets (both active and passive type) produced significantly lower frictional forces than conventional bracket ligated by conventional elastic ligature. These results fully agree with those of most previous studies.(9-11) This is because of the absence of the ligation force from the elastic ligatures when the slide restrained the archwire.(12)

In the present investigation passive self-ligating brackets produced significantly lower frictional force than active self-ligating brackets when coupled with rectangular wires. This finding is in agreement with previous research that compared the frictional properties of active and passive self-ligating brackets (13-15). This is probably due to the design of the active self-ligating brackets which incorporates a spring clip that can press against the arch wire.

While the passive type possess a passive cap which converts the bracket slot in to a tube and thus places no active force on the arch wire once the teeth have been leveled and aligned.(16) On the other hand no significant difference was found between the frictional force of both active and passive self-ligating brackets when coupled with round wire, this agrees with.(9,17) This is due to the fact that round wires equal or less than 0.020" inches in diameter sit passively in the slot, with no force being delivered from the clip. Any wire with a bucco-lingual dimension larger than 0.020" inches will receive a greater amount of force from the actively displaced clip, thereby delivering greater rotational control and, in the case of a rectangular wire, greater torque control.(13)

An evaluation of the effects of wire size on brackets-wire friction demonstrated mostly a significant increase in friction as the wire size increased. These results came in coordination with previous studies carried out by(18-21) this is due to the fact that increasing thickness of the wire produces greater frictional force values, and that rectangular wire generally shows higher values than the round wires, because there is a larger contact area between slot and wire surfaces.(22, 23)

CONCLUSIONS

This study demonstrated that self-ligating brackets generated significantly lower static frictional forces than conventional brackets ligated with conventional elastic ligatures. Active and passive self-ligating brackets produced negligible friction when coupled with round wires but in the case of rectangular wires the passive self-ligating was significantly better than any of the other brackets and should be preferred if sliding mechanics is the technique of choice.

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