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Frictional Resistance of Two Types of Esthetic Self-Ligating Brackets

H. A. Kamil (DDS, MS)[*1], Sh. Sh. Taha (DDS, MS)[1]

1.Department of Orthodontics, College of Dentistry, University of Baghdad, Baghdad, Iraq.

[*]Corresponding Author: H. A. Kamil (DDS, MS)
Address: Department of Orthodontics, College of Dentistry, University of Baghdad, Baghdad, Iraq.
Tel: +964 (772) 1014811. **E-mail:** heba.Ali1203a@codental.uobaghdad.edu.iq

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ABSTRACT

Background and Objective: Friction between the archwire and bracket is the main problem during tooth movement. Self-ligating bracket systems have become common in recent years. The aim of this study was to investigate and compare the effect of active and passive esthetic self-ligating brackets on static frictional force with different orthodontic archwires under wet conditions.

Methods: This in vitro study included 180 ceramic self-ligating brackets, 90 passive brackets (Damon Clear), and 90 active brackets (Empower Clear), which were tested for frictional resistance using three different types of 0.018-inch archwires, namely copper NiTi archwires and two esthetic archwires (Epoxy- and rhodium-coated NiTi archwires). According to the types of brackets and archwires, six groups of ten were defined. An experimental model with three non-leveled brackets in wet condition using artificial saliva was adopted. The friction test was conducted by Instron Tinius Olsen testing device. The test was performed at a room temperature ranging from 24-25°C.

Findings: Empower clear with Cu NiTi archwire showed the highest mean value of static frictional force with the mean value of (327.85±53.43) and Damon clear with epoxy coated NiTi archwire showed the lowest mean value (58.06±10.87). There were significant differences in the static frictional forces generated in both bracket systems when coupled with the Epoxy wires ($p=0.000$) and when coupled with the CuNiTi and Rhodium archwires ($p=0.001$).

Conclusion: The result of this study showed that the Damon Clear brackets produce lower frictional forces than Empower Clear brackets and Epoxy-coated NiTi archwires can produce lower static frictional force compared to Rhodium-coated NiTi and CuNiTi archwires.

Keywords: *Friction, Coated Archwire, Ceramic Bracket, Self-Litigating Bracket.*

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Introduction

Straight wire appliances succeed when the archwire slides through the brackets and tubes during leveling and alignment, closure of extraction space, and retraction of canine (1). However, the main problem is the friction produced by these movements (2). Static friction and kinetic friction are the two types of friction. Static friction is the force required to move a tooth, and it is always more than kinetic friction since it keeps a body moving (3).

The need for esthetic orthodontic devices has significantly grown in recent years. Therefore, researchers work hard to create orthodontic devices that are both aesthetically pleasing and have acceptable clinical performance (4, 6). Using aesthetic archwires with esthetic brackets typically results in excellent esthetics in labial appliances (7). Ceramic brackets have higher frictional resistance than the metal ones (8, 9). Various self-ligating bracket systems (SLB) have been developed to reduce unwanted frictional forces between archwires and bracket slots. SLB reduces static friction and eliminates the use of ligature wires or elastomeric module contacts, reducing static frictional forces (10, 11). These brackets have active or passive ligation mechanisms for full bracket engagement. As there is less friction between the archwire and the bracket, teeth could move faster (12). The passive self-ligating brackets, like Damon brackets, have a rigid, moveable part to enclose the archwire with one of two bracket gate designs: a rigid slide gate or a gate with an integral labial "C" clip (13). The active self-ligating brackets have an elastic portion that holds the archwire in place. This flexible segment presses the archwire into the slot and can store and then release energy through elastic deformation (14).

Interactive self-ligation techniques (pactive) have both passive and active characteristics; the Pactive brackets produced significantly higher friction, which can be attributed to their flexible clip as opposed to the sliding clip design of Damon brackets, while the clip of the Pactive system acts passively with the smaller round archwire, and with larger rectangular wire, the clip deflected labially, resulting in higher friction (15).

Esthetic archwires are composite or metallic archwires covered in polymers such as Epoxy, Teflon, Rhodium, and silver polymer (16). Epoxy-coated archwires provide the least surface roughness for patients' esthetics during fixed appliance therapy (17). Rhodium enhances aesthetics when used as a coating material for standard orthodontic arch wires because of its silvery-white glossy look and friction-reducing properties (18), and shows non-significant color change after immersion in Biofresh mouthwash (19). Cu improves alloy shape memory and reduces NiTi archwire limitations. Cu in a NiTi archwire increases unloading stress and decreases loading stress, improving tooth movement during orthodontic therapy (20).

Thus, this article aims to assess static frictional force in esthetic self-ligating brackets with different orthodontic wires under wet conditions during the leveling and aligning stage.

Methods

This in vitro experimental study was approved in the ethics Committee of the College of Dentistry, University of Baghdad with the code No. 800423. The sample size was calculated at n=10 in each subgroup, by statistical package G power (3.1.9.4), assuming a=0.05, B=0.2, and a power of 0.8, at a confidence level 95%. Two types of ceramic self-ligating brackets of upper right premolar with a slot size 0.022 were used. Those included 90 Damon clear brackets with standard torque prescription (Ormco, Orange, CA, USA) and 90 active Empower clear brackets with MBT prescription (American Orthodontics, Sheboygan, Wisconsin, USA), using three different archwire types in 0.018 inch. The friction test was conducted using the straight ends of the archwires as follows: CuNiTi archwires (Ormco Corporation, Orange, CA, USA), Epoxy coated

NiTi archwires (Tooth Tone® arches, Ortho Technology, USA), and Rhodium-coated NiTi archwires (Orthometric, Brazil) (20 pieces of each type were used). Three brackets from each system were fixed on a plastic block cut by a CNC laser machine using a cyanoacrylate adhesive (Soma Kimya Co., Turkey). Each block had three squares; the middle one was (1) mm higher than the other squares; the inter bracket distance, measured from the center of brackets, was (11 mm) to simulate an unaligned portion of the dental arch. To avoid torque and tipping (factors affecting friction force), a straight stainless-steel wire jig of 0.021x0.025″ inch was utilized (as shown in Figure 1) to position the brackets on the plastic blocks (21).

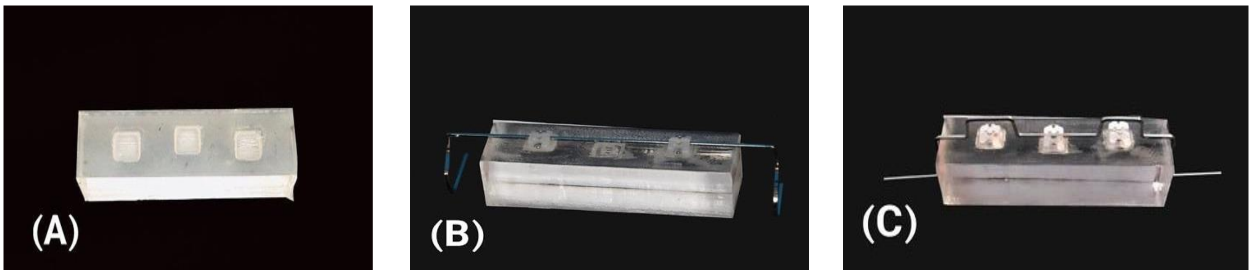

Figure 1. A: a plastic block with three squares, B: align the two peripheral brackets with a 0.021x0.025 inch stainless steel jig, C: aligning the central bracket with a jig of 0.021x0.025 inch stainless steel

Samples were then divided into 6 groups:
Group 1: Damon Clear bracket-CuNiti wires, Group 2: Damon Clear bracket-Rhodium coated NiTi wires, Group 3: Damon Clear bracket-Epoxy coated NiTi wires, Group 4: Empower Clear bracket--CuNiti wires, Group 5: Empower Clear bracket-Rhodium coated NiTi wires and Group 6: Empower Clear bracket-Epoxy coated NiTi wires.

The static frictional force of the samples was assessed using the computerized Instron H50KT Tinius Olsen testing machine; the load cell of the machine was 10 Newton (N), which was used to measure static frictional force in wet condition using artificial saliva prepared by a modified Carter's solution with a PH value 6.75±0.15 (22).

A model is held by a machine's lower part (the fixed part), while the upper part (the load cell) is clamped to the free end of the wire (23). After data entry, each wire was pulled vertically at a distance of 5 mm with an average rate of 5 mm per minute until a 5 mm length of wire was completely pulled through the bracket (24). Meanwhile, artificial saliva was dripped over the bracket/wire combination during the friction test using a plastic syringe. For standardization, only 3 mL/min of artificial saliva was dripped during each test (Figure 2) (25).

Figure 2. A friction test using the Instron machine, with artificial saliva dripping from a plastic syringe during the test

Frictional forces were displayed on the computer screen of the testing machine (QMat 4.53 T series software, England), whereas a maximum force represented static friction. The following equation converts newtons to grams for all forces generated in newtons:

$$\textbf{Friction in gram (g.)} = [\textbf{friction in (N)} \div 9.8] \times 1000$$

Finally, the data were analyzed using one-way ANOVA, Tukey's post hoc and independent T-test, using SSPS, and $p \leq 0.05$ was considered significant.

Results

Descriptive statistics of static frictional force, measured in grams (g), of each subgroup are shown in Table 1. Empower clear with Cu NiTi archwire showed the highest mean static frictional force (327.85±53.43) and Damon clear with epoxy coated NiTi archwire showed the lowest mean value (58.06±10.87). The results showed a highly significant difference between the wires coupled with Empower Clear and Damon clear brackets (p=0.000). In order to verify the difference between wires, post-hoc Tukey's test was used. There was no significant difference between CuNiTi archwire and rhodium coated NiTi archwire in both types of brackets; Damon clear (p=0.942) and Empower clear (p=0.259). A highly significant.difference was between the epoxy-coated NiTi archwire and CuNiTi archwires and between epoxy-coated NiTi archwire and rhodium coated NiTi archwire in both types of brackets (p=0.000). Independent t-test was used for the comparison between Damon clear and Empower clear brackets (Table 2). The test showed a statistically highly significant difference between the mean values of the static frictional forces of the two bracket types when coupled with the Epoxy wires (p=0.000) and when coupled with the CuNiTi and Rhodium archwires (p=0.001).

Table 1. Descriptive statistic and ANOVA test to compare the wires coupled with Damon Clear and Empower Clear brackets

Bracket	Wire	No	Mean±SD	SE	F	p-value
Damon Clear	Epoxy	10	58.06±10.87	3.44	123.689	0.000
	CuNiTi	10	241.10±39.61	12.53		
	Rhodium	10	236.73±30.96	9.79		
Empower Clear	Epoxy	10	175.81±18.98	6.00	40.776	0.000
	CuNiTi	10	327.85±53.43	16.90		
	Rhodium	10	299.08±39.81	12.59		

Table 2. The independent samples t-test for comparison between two brackets

Wires	Brackets	Mean	Mean Difference	T	p-value	S.D
Epoxy	Damon clear	58.06	-117.756	-17.029	0.000	10.87
	Empower clear	175.81				18.98
CuNiTi	Damon clear	241.10	-86.751	-4.125	0.001	39.61
	Empower clear	327.85				53.43
Rhodium	Damon clear	236.73	-62.346	-3.909	0.001	30.96
	Empower clear	299.08				39.81

Discussion

The results of the present study showed that the Epoxy archwire has lower friction than other wires, with a highly significant difference compared to Rhodium-coated NiTi and CuNiTi archwires. This could be attributed to a good adhesion and a wide range of physical properties, including chemical resistance and dimensional stability, which may contribute to the lowest friction with Epoxy resin. This agrees with a study by Al-Ghroosh et al. (26). On the other hand, after decreasing the total dimension of the Epoxy archwire, the Epoxy coating applied a thin layer to the archwire. The dimension of the wire and the thickness of the coating had a direct effect on the frictional forces (27).

This study demonstrated no significant difference between Rhodium-coated NiTi and CuNiTi wire. This finding agreed with the findings reported by Acev et al. (28) who stated that rhodium coating makes the alloy harder and possesses greater surface roughness, contributing to increased frictional resistance. It was suggested that the frictional behavior of archwires was positively correlated with their surface roughness; that is, greater surface roughness will generate higher frictional force (29, 30).

The elasticity of the CuNiTi archwire has a rougher and more irregular surface due to the pressure created by the clip of the self-ligating brackets, which may increase the wire's surface area in contact with the inside of the slot. Following this, the frictional force would increase, and these results agreed with previous studies (31, 32).

In the comparison between the two bracket types, the present study showed a statistically significant difference in the generation of friction between the brackets. The active bracket produced significantly higher friction, which can be attributed to its flexible clip, which is deflected labially and produces an active seating force on the archwire, yielding more resistance to sliding when compared to the passive bracket, which produced no active seating force. This finding is consistent with the findings of Zreaqat and Hassan (33). Some studies revealed no significant difference between passive and active self-ligating brackets in certain circumstances. In one study, this was observed when a tipping force was applied to the system (34). In other studies, there were no changes between the active and passive brackets when a moment was applied (35, 36); the moment increased from 2000 to 4000 mg. The difference between the two types of ligation disappeared, which can be attributed to the rigidity of the passive ligation which increases the friction under deflection time (35). Another reason is the slot dimension, which has a wider slot mesiodistally and may increase the surface area where the bracket and archwire are in contact, hence increasing friction; this conclusion was confirmed by Pacheco et al. (37). The influence of bracket width on frictional force generation between the archwire and the bracket slot is still being debated in orthodontics, with some researchers, such as Pacheco et al. (37) and Yang et al. (38), supporting this study finding that bracket width is directly proportional to frictional force generation. Other researchers, such as Tidy (39) and El-Bialy et al. (40), found that friction with wider orthodontic brackets is lower than with narrower brackets due to reduced tipping with the wider brackets, which results in less resistance to sliding and binding of the archwire.

According to the results of this study, it was concluded that the Damon Clear bracket can produce significantly lower static frictional force than the Empower Clear bracket. Epoxy-coated NiTi archwires can produce less significant static frictional force than Rhodium-coated NiTi and CuNiTi archwires. There is no.statistical.difference between the Rhodium-coated NiTi archwire and CuNiTi. The best bracket/archwire combination that produces the least friction during the leveling and alignment stage comprises the Damon Clear bracket and epoxy-coated NiTi archwire.

Conflicts of Interest: There is no conflict of interest.

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