

## Evaluation of frictional forces generated by different brackets and orthodontic wires

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### ABSTRACT

**Background:** Sliding mechanics is widely used during orthodontic treatment. One of the disadvantages of this mechanics is the friction generated at the bracket/archwire interface, which may reduce the amount of desired orthodontic movement obtained. The aim of the present in vitro study was to evaluate and compare the static frictional forces produced by two passive self-ligating brackets stainless-steel and hybrid and two conventional brackets stainless-steel and monocystal ligated with stainless-steel ligature wire at two degrees of torque (zero and twenty) under dry condition.

**Materials and method:** One hundred and sixty brackets were used in this study divided into four groups each group consisted of forty brackets these are: Two self-ligating (stainless-steel and Hybrid) while the two conventional types are the (stainless-steel and monocystal). twenty of each group examined with 0.016"x0.022" archwire, ten at 0° torque and ten at 20° torque while the other twenty of each group examined with 0.019"x0.025", ten at 0° torque and ten at 20° torque.

**Results:** There was a significant different between all groups except in case when self-ligating brackets (both types) ligated to both wires at 0° torque there was no significant difference.

**Conclusions:** The self-ligating brackets produce significantly lower static friction than the conventional types at both degrees of torque. There was no significant different between both self-ligating brackets at 0° torque while at 20° torque the stainless-steel self-ligating produce lower static friction than the clear self-ligating type.

**Keywords:** static, friction, self-ligating, conventional, torque. (J Bagh Coll Dentistry 2013; 25(Special Issue 1):126-131).

### INTRODUCTION

The appearance of fixed orthodontic appliances has always been of particular concern in orthodontic treatment. In the 1970s, attempts to produce brackets from different aesthetic materials included the use of plastic brackets that were injection molded from the aromatic polymer polycarbonate. Problems reported included crazing and deformation as well as stains and odors<sup>1</sup>. Even alternative composite brackets made of chopped glass fibers did not change these problems; it was nearly ten years before ceramic brackets became available for orthodontic applications. The ceramic brackets available nowadays are made of alumina (Al<sub>2</sub>O<sub>3</sub>) either in polycrystalline or monocrystalline forms, the manufacturing process of monocrystalline brackets results in a purer structure, a smoother surface, and a considerably harder substance than the fabrication of polycrystalline brackets<sup>2</sup>.

The proper magnitude of force during orthodontic treatment will result in optimal tissue response and rapid tooth movement<sup>3</sup> therefore orthodontic movement should be impressed with low forces<sup>4</sup>, thus ensuring treatment efficiency in respect of biologic principles<sup>5</sup>.

During mechanotherapy involving movement of the bracket along the wire, friction at the bracket-archwire interface might prevent attaining optimal force levels in the supporting tissues<sup>3</sup>.

In orthodontics, a tooth subjected to sliding motion along the archwire is alternately inclined and uprighted, moving in small increments therefore, space closure depends more on static than kinetic friction<sup>6</sup>.

The search for a bracket system with a low frictional resistance resulted in the development of self-ligating brackets, although the first self-ligating bracket was the Russell lock<sup>7</sup>.

Manufacturers and orthodontists have shown renewed interest in the development of self-ligating brackets since the mid-1970s. Two different types of self-ligating brackets were produced: those with a spring clip that pressed actively against the archwire, called active self-ligating such as the Speed bracket, and passive self-ligating brackets, like Activa bracket whose self-ligating clip did not press against the wire<sup>2</sup>.

The attempt to combine the benefits of both types of brackets, an acceptable aesthetic appearance for the patient and low friction for adequate clinical performance, resulted in the development of self-ligating aesthetic brackets such as the Opal, a new glass filled nickel free polycrystalline self ligating aesthetic bracket<sup>2</sup>.

The present study has been performed, because there was no previous Iraqi study on aesthetic brackets whether conventional or self-ligating, at the same time there was no previous Iraqi study measured friction with torque.

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## MATERIALS AND METHODS

### The sample(brackets and tubes)

One hundred and sixty Upper right central incisor brackets divided into four groups were used in the present study, each group include forty brackets, all types are pre-adjusted Roth type (incorporating +12° torque and +5° angulation) and have 0.022" slot width (Orthoclassic Company, USA). These are:

1- self-ligating stainless-steel 2- self-ligating clear 3- conventional stainless-steel 4- conventional sapphire. One hundred and sixty buccal tubes edgewise type (Dentarium Company, Germany)

Two types of wires has been used in this study 0.016"x 0.022" and 0.019"x 0.025" stainless-steel archwires.

Friction generated by the experimental model consisting of one upper right central incisor bracket (which chosen according to<sup>8</sup>). Twenty brackets of each type were bonded with a composite to a plastic bars, each bar dimensions were 10x10x100 mm, each one had a line drawn parallel to its long axis to ensure the straightness of the bracket slot to the bar.

Two brackets of the same type fixed to the plastic bar one on each side by using a piece of 0.0215" x 0.025" straight stainless-steel archwire that bend into L-shape used to align the brackets this guide allowed the slot axis of the bracket to be perpendicular to the plastic bar, so the brackets fixed by using the L-shape wire had 0° torque and 0° tip, two brackets of the same type fixed to the plastic bar one on each side by using this wire (guide) (**figure 1**),

After the fixation of the brackets another piece of 0.0215" x 0.025" straight stainless—steel archwire used to fix the buccal tubes by inserting two tubes into this piece ,then the two ends of this tube ligated into the brackets at each side of the plastic bar to ensure the vertical parallelism of these tubes to the brackets and the bar, each tube fixed at a distance of ten millimeter from each bracket (**figure 2**).

Ten brackets of each group fixed in this way tested with 0.016"x 0.022" and the other ten tested with 0.019"x 0.025"archwires.

The other twenty brackets of each type bonded to the plastic bar by using another piece of 0.0215" x 0.025" straight stainless-steel archwire that bend into L-shape and the its vertical arm which was perpendicular to the bar bent to create a twenty degree angle with its horizontal arm, so the angle formed between the archwire and the bar became twenty degree(**figure 3**) ,then this archwire would be used to align the brackets on the plastic bar in this case the bracket slot would

be tilt exactly twenty degree to the plastic bar in antero-posterior direction (**figure 4**)which mean the bracket slot had a twenty degree torque in relation to the plastic bar,two brackets of the same type fixed to the plastic bar one on each side by using this wire (guide), then the two tubes fixed on the same bar, each one at a distance of ten millimeter away from each bracket on that bar as explained previously.

Ten brackets of each group fixed in this way tested with 0.016"x 0.022" and the other ten tested with 0.019"x 0.025"archwires. A new bracket and ten centimeter length archwire used for each test run to prevent any distortion of the bracket slot or archwire surface.

Each testing archwire bent into a key hole bend at one end that was attached to the to the assembly that was clamped by the load cell of Instron machine, and seated in the slot of one bracket and pass through one tube at one end of the bar after it was degreased with ethanol to remove oil and dust as factors can affecting frictional resistance<sup>9,10</sup> and ligated either with the ligature wire tightened first then untwisted 90° to become slackened and to allow the archwire to slide freely, and then cut the access leaving a small part of it for the conventional bracket<sup>11,12,13,14</sup>, and with the solid labial slider by rotating the slide downward with a special tool into the slot-open position , it then rotated upward with finger pressure to entrap the archwire in a passive configuration for the self-ligating bracket , after the looped end of the wire was attached to the assembly that was clamped by the load cell of Instron machine , the bottom of the plastic bar was clamped by the lower fixed crosshead of the Instron machine.

Friction generated by the experimental model consisting of one upper right central incisor bracket (which chosen according to<sup>8</sup>, the archwire and the ligation method was tested on the Instron H50KT Tinius Olsen testing machine with a load cell of 10 N<sup>8,15</sup> and speed of 6 mm/minute<sup>8</sup>.

This arrangement allowed the wire to move along the bracket and tube on one side of the plastic bar as an axial tensile force was applied by the Instron's load cell<sup>8</sup>. In the same time, a computer connected to the testing machine displayed a graph showing peak force variation and recording the frictional resistance force generated on every 0.01mm distance of the tested wire for everytraction test over a distance of 12 mm, the maximum frictional resistance force generated in Newton was noted at the beginning of the movement and then the graph was declined

slightly, the Newton then converted to grams by the following equation:

$$\text{Friction in gram} = [\text{Friction in (N)} \div 9.8] \times 1000$$

All measurements were performed under dry conditions at room temperature of  $25 \pm 2$  degrees centigrade<sup>8</sup>. A total of one hundred and sixty tests were carried out (10 tests for each group).

## RESULTS

The data collected from the present study had been analyzed and the descriptive statistics were performed for all the variables measured. These

statistics included mean, standard deviation, standard error, minimum, and maximum values, these values were displaced in **table (1)**.

As shown in **table (1)**, self-ligating stainless-steel brackets showed the lowest measurement level of static frictional force when coupled with both wires at both degrees of torque and there was a very high significant different between all bracket types this was followed by the self-ligating clear, convention-nal stainless-steel and then the conventional monocystal.

**Table 1: Descriptive statistic of different brackets on 0.016"×0.022" and 0.019"×0.025" S.S. wires**

Bracket Type	NO.	Wire size	Torque (°)	Min	Max	Mean	SD	SE
Self-ligating S. S.	10	0.016"×0.022"	0	1.42	1.776	1.64	0.13	0.055
	10	0.016"×0.022"	20	192.857	214.286	198.776	7.85	3.206
Self-ligating Clear	10	0.016"×0.022"	0	1.73	2.14	1.9	0.16	0.068
	10	0.016"×0.022"	20	240.81	266.32	251.87	9.9	4.042
Conventional S.S.	10	0.016"×0.022"	0	91.73	95.91	94.18	1.43	0.58
	10	0.016"×0.022"	20	317.3	330.61	323.29	4.34	1.77
Conventional Monocrystal	10	0.016"×0.022"	0	108.2	111.22	109.54	1.03	0.42
	10	0.016"×0.022"	20	325.51	355.10	341.66	11.38	4.649
Self-ligating S. S.	10	0.019"×0.025"	0	2.031	2.857	2.43	0.33	0.1364
	10	0.019"×0.025"	20	274.490	330.612	305.95	23.12	9.439
Self-ligating Clear	10	0.019"×0.025"	0	6.73	7.95	7.44	0.47	0.19
	10	0.019"×0.025"	20	328.57	408.16	373.63	28.28	11.54
Conventional S. S.	10	0.019"×0.025"	0	117.34	135.71	125.85	6.47	2.643
	10	0.019"×0.025"	20	407.14	467.34	438.027	25.87	10.56
conventional	10	0.019"×0.025"	0	151.02	178.57	166.15	9.38	3.831
Monocrystal	10	0.019"×0.025"	20	486.735	530.61	509.405	15.454	6.309

The measurements of friction were in grams, S.S. = stainless- steel.

A one way analysis of variance was carried out for comparison among brackets self-ligating stainless steel, self-ligating clear, conventional stainless steel and conventional monocystal, the tests showed very high significant differences in static frictional forces ( $p \leq 0.001$ )

The least significant difference (LSD) method, at a significance level of  $p < 0.05$ , was used with the purpose of identifying significant differences between the combinations used in the study.

There was a significant difference ( $p < 0.05$ ) between the static frictional means of the self ligating stainless steel brackets with other brackets, except for the self-ligating clear there was no significant difference ( $P > 0.05$ ) between these brackets when coupled with both wires at 0° torque, while in all other cases the self-ligating stainless-steel brackets produce the lowest static friction, then the self-ligating clear which was followed by the conventional stainless-steel and lastly the highest friction was recorded by the conventional monocystal in all types of combinations.

The 0.016" x 0.022" archwire also produce lower static friction than the 0.019" x 0.025" in all

types of bracket combinations. In the same time we can detect that when torque increase the static friction increased in all types of bracket wire combinations. All these results summarized in **figure (5)**.

## DISCUSSION

### The influence of different factors on friction

The readings obtained from the Instron testing machine for each combination represented the outcome of the interaction of the bracket, arch wire and ligature, which makes it difficult to identify the effect of each variable (bracket, arch wire and ligature) separately, therefore in this study we tried to evaluate the effect of each variable separately by making other variables constants. The results of the present study indicate that there were a significant different between the static friction of all combinations except in case of both self-ligating brackets when combined with both wire at 0° torque, on the bases of biomechanical principles, one explanation for this finding that there was no actual binding between the wire and the bracket slot in case of 0° torque.

### The influence of bracket geometry

The self-ligating brackets always produce lower static friction than the conventional counterpart did this is related to the fact that in the conventional type apply a force to the archwire pushing it against the depth of the slot, thus increasing friction.

This finding agree with many researches<sup>2,3, 16-19</sup>, but didn't agree with<sup>20,21</sup> this may be related to the type of the bracket which is active type in both studies. This also didn't agree with<sup>22-24</sup> this maybe because they made their tests on typodonts in the presence of rotation, angulation, and torque in the pretreatment typodont models which also increase frictional resistance; attributing to binding rather than classic friction.

### The influence of torque degree

According to the results gained from this study, the static friction is always increased for all bracket wire combination when torque increased from 0° to 20° angle, this is related to the fact that 20° angle torque exceed the third order angle clearance that lead to increase the binding between the wire and bracket slot. Reportedly, the third-order clearance for a fully drawn, 0.019"×0.025" wire in a 0.022" is close to 10 degree<sup>25</sup>.

This agree with<sup>17,26,27</sup>, however, the self-ligating brackets still have a significantly less frictional force than the conventional brackets in spite of increase in the torque, this finding agree with<sup>28</sup>, but this finding disagree with<sup>29</sup>, in their study they use active self-ligating brackets they found that with the increase of torque degree, the self-ligating brackets displayed the greatest increase in frictional resistance which is possibly a result of magnified normal forces from its active self-ligation and asymmetrical clip.

### The Influence of wire dimensions

The results of the present study revealed that, there was a wide range of variation in the mean values of static friction between the 16"x22" and 19"x25" wires when coupled with different brackets, self-ligating stainless-steel bracket has the lowest static friction followed by clear self-ligating bracket which was followed by conventional stainless-steel and lastly the highest friction was recorded by clear conventional bracket, but always the 16"x22" wire has lower friction than the 19"x25" wire when both coupled with the same bracket, the same ligature method and the same degree of torque, on the bases of this comparison we conclude that the friction will increase as the archwire increase this is in agree with<sup>18,30-32</sup>.

According to<sup>33</sup> the influence of the wire size on friction increases because thicker wires fulfill the bracket slot and the amount of force needed to cause orthodontic tooth movement is also increased.

Generally, friction appears to be more when wire diameter increase in all of the previous studies.

This didn't agree with<sup>2,34</sup>, which may be due to the experimental set-up of their study in which there was tipping that increase the binding between the wire and bracket.

In the present study the static friction increase with increasing the wire dimension, but there was only one exception, that there was no significant difference between the two wires when coupled with the self-ligating brackets (both types) when the torque was zero degree.

On the bases of biomechanical principles, the explanation for this finding is also related to the fact that there is no actual contact (binding) between these wires and the slot of the brackets, this is related to the fact that the bracket slot is bigger than both wires, so there was no binding between these wires and self-ligating brackets at zero degree torque.

### The influence of bracket material

In the present study, the aesthetic bracket had higher frictional force when compared with the stainless-steel bracket when used with the same wire at the same degree of torque. This finding agrees with the findings of many other researchers<sup>20,22,33-35</sup>.

The higher frictional resistance of ceramic brackets may be attributed in part to the rough surface texture of these brackets in contrast to the smooth surface of stainless steel brackets. Also the increased hardness of the ceramic aluminum oxide material as compared to metal brackets and wires may have contributed to such result.

There was only one exception for this comparison that in case of clear self-ligating brackets there was no significant difference from stainless-steel self-ligating in case of zero torque in both wires, this is related to the fact that there is no actual binding between these brackets and the wires.

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Figure 1: The alignment of the brackets at zero degree torque



Figure 2: The fixation of the tubes by composite

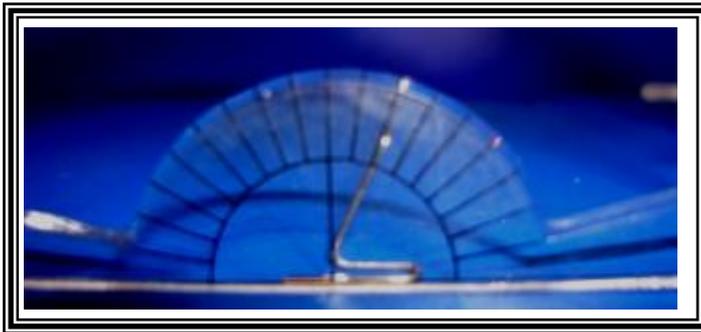


Figure 3: Measuring twenty degree



Figure 4: The alignment of the brackets at twenty degree torque

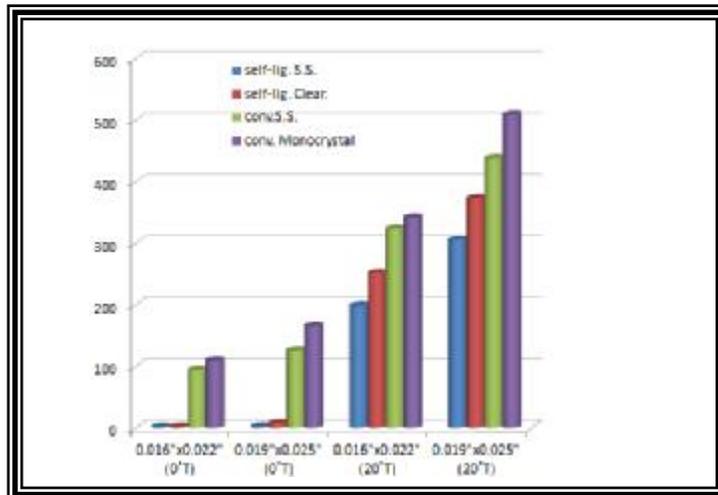


Figure 5: Static frictional force of different brackets and wires