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Evaluation of Effect of Air Abrasion on Friction and Surface Micromorphology of Passive Stainless Steel Self-Ligated Brackets: An *In Vitro* Study

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ABSTRACT

The friction that occur between arch wire and the brackets during arch wire sliding in fixed orthodontic appliance will affect negatively on the outcome of the orthodontic treatment in addition to the treatment time. The process of friction is a critical issue and should be understood properly by the orthodontist in order to provide the optimum treatment result in a short period of time. ***Aim:*** *The aim of our study was to compare the effect of calcium carbonate air abrasive on static friction and micromorphology of bracket slot surface for two different stainless steel self-ligated brackets.* ***Methods:*** *120 passive stainless steel self-ligated brackets from two different commercial brands where involved in the study (discovery® sl2.0, Dentaurum co. and Damon®, Ormco co.). The samples were divided randomly into 8 groups, and every group with 5 samples, the criteria for classification of these groups depend on bracket types and air abrasion periods. Round (18 inches) NITI arch wire was used to slide through 3 brackets with the middle one 1 mm higher than the others, the distance of sliding through the brackets was 10 mm, the machine used for measurement included the (instron) universal testing machine, the roughness of the bracket slot surface was analyzed be the machine of (scanning electron microscope).* ***Results:*** *The effect of air abrasive agent calcium carbonate on the both types of metal self-ligated brackets result in elevation the amount of static friction for (discovery® l2.0 by 35.157%, Damon® by 36.652%). Viewing the slot of the brackets under microscope by using (SEM) device reveal great modification in surface of the slot with uneven and rougher surface when compared to the brackets of control group that appear with polished and smooth surface.*

Keywords: Passive self-ligated brackets, Static friction, Calcium carbonate air abrasive polishing

INTRODUCTION

During orthodontic treatment, sliding of the arch wire through the slot of the brackets results in production of frictional forces at the bracket wire interface. These frictional forces obstruct the delivery of optimum orthodontic force for the supporting tissue to produce the desired tooth movement [1].

To produce efficient tooth movement with the appropriate level of orthodontic force, it is recommended that the force of friction should be minimum [2,3].

Researchers found that up to fifty per cent of orthodontic force required for movement of the tooth will be used to vanquish the friction. Moreover, the friction is affected by several factors including oral salivary fluid [4], the material used in arch wire fabrication and the dimension of orthodontic wire [5], the degree of angulation between arch wire and the orthodontic bracket [6], and finally the method used for arch wire ligation [7].

Several attempts have been accomplished to reduce the value of friction at the interface of the arch wire, the slot of the bracket and the ligature. One of these methods include using stainless steel ligatures tied loosely [8] or by using brackets with low friction like self-ligated brackets [9,10].

The idea of using self-ligated brackets begins in 1946 but it failed to gain success at that time because of many obstacles. Until 1980s, the use of self-ligated bracket became more widespread taking the advantage of using brackets without the need for using ligatures with low friction property and at the same time the gate of the brackets can be closed converting the slot into a tube [2].

MATERIALS AND METHODS

The Brackets

Total 120 metal self-ligated brackets taken from two types of companies, 60 brackets for each commercial brand (discovery® sl2, Dentaurum co. and Damon®, Ormco co.) The classification of the brackets included 8 groups with 5 specimens for each group; three non-leveled brackets on metal block represent each specimen. Eight groups categorized according to the type of self-ligated bracket type and to the period of time of air abrasion (0, 5, 10 and 20 seconds).

The Arch Wire

Around 5 cm cut from the end of round NITI orthodontic arch wire (a 0.018) inch from Dentaurum Company.

Fabrication of Test Specimens

Forty metal blocks with the dimension of 37 mm × 12 mm × 10 mm were used in the study. C.N.C laser cutting machine was used to fabricate plastic mold to work as a guide for accurate bracket placement on the metal block (Figure 1). After cutting with C.N.C laser machine, the outer border of plastic mold coincides with the border of the metal block. C.N.C laser machine made three squares in such a way that their dimensions coincide with the dimension of the self-ligated brackets inside the plastic mold so that the brackets precisely fit in these holes. The distance between the brackets was 11 mm with the central bracket 1 mm higher than the others (Figure 2) [11].

After close-fitting of the plastic mold on the metal block by light cure composite, bracket holder was used to hold the brackets for accurate placement inside the three holes in the plastic mold which stick to the metal block by cyanoacrylate adhesive. Few seconds later, the plastic mold was removed, and the brackets remain in the correct position on the metal block.

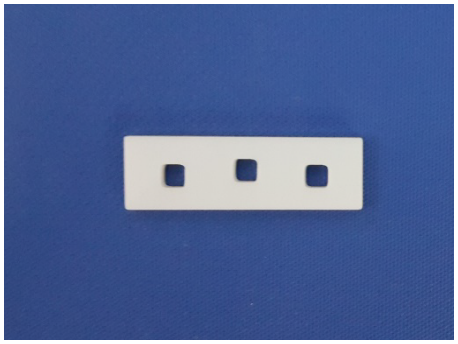

Figure 1 Mold fabricated by C.N.C laser cutting machine

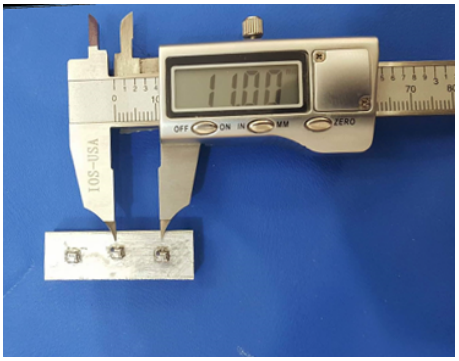

Figure 2 Brackets bonded to meal block after removal of plastic mold

Air Abrasion

The process of air abrasion was done with the use of holding device, the metal block was placed at the base of the holding device in a pre-marked position while a clamp was used to carry the hand piece of airflow abrasion with 2.3 bars of air pressure provided by the dental unit for the hand piece [12,13]. The nozzle of the hand piece was placed in perpendicular position to the bracket with a distance of 5 mm away from it [12]. After that the gate of the brackets opened and calcium carbonate air abrasive applied for (5, 10 or 20 seconds), a stopwatch timer was used for time monitoring.

Frictional Resistance Test

Instron universal testing machine was used to perform the frictional test. The lower end of the machine was used to grip the metal block with the adhered brackets and at the same time a clamp with 10N load cell at the upper end of the machine used to grip the nickel titanium arch wire. A computer was used to record the tensile force after sliding the arch wire for a distance of 10 mm with 1 minute for each 5 mm giving a total of 2 minute. The result displayed on a graph showing peak force variation and documented the tensile force created on every 0.01 mm distance of the tested wire for every traction test. The static friction obtained in newton represented the maximum frictional resistance force noted from the beginning of the movement.

Scanning Electron Microscopy

The micromorphology of bracket slot base for one sample of each group (with and without air abrasion) was captured and analyzed at magnification power of 2000x using scanning electron microscopy device (SEM).

RESULTS

The mean value for (discovery® sl2, Dentaurum co.) for the exposure times (0, 5, 10 and 20) was less than for (Damon®, Ormco co.). Moreover, comparing between the two companies (t-test) showed that there was high significant difference at the exposure times (0, 10 and 20) seconds except for (5 seconds) was non-significant difference as in Table 1.

Table 1 Effect of companies on the friction at each time of air abrasion

Time	Descriptive statistics				Comparison (df=8)	
	Dentaurum		Ormco			
	Mean	S.D.	Mean	S.D.	t-test	p-value
Control	1.444	0.037	1.501	0.008	-3.365	0.01
5 sec	1.62	0.025	1.611	0.015	0.701	0.503
10 sec	1.951	0.027	2.051	0.051	-3.863	0.005
20 sec	1.753	0.023	1.818	0.015	-5.21	0.001

One-way ANOVA test showed high significant difference for the four exposure times between and within the groups in each company as in Table 2 and Tukey's HSD test also showed that there was a high significant difference for the four exposure times as in Table 3 and Figure 3.

Table 2 One-way ANOVA test for the four exposure times

Companies	ANOVA	Sum of Squares	df	Mean Square	F-test	p-value
Dentaurum	Between Groups	0.689	3	0.23	283.915	0.00
	Within Groups	0.013	16	0.001		
	Total	0.702	19	-		
Ormco	Between Groups	0.882	3	0.294	380.307	0.00
	Within Groups	0.012	16	0.001		
	Total	0.895	19	-		

Table 3 Tukey's HSD test after ANOVA

Time		Dentaurum		Ormco	
		Mean difference	p-value	Mean difference	p-value
Control	5 sec	-0.176	0.00	-0.11	0.00
	10 sec	-0.508	0.00	-0.55	0.00
	20 sec	-0.309	0.00	-0.318	0.00
5 sec	10 sec	-0.331	0.00	-0.44	0.00
	20 sec	-0.133	0.00	-0.207	0.00
10 sec	20 sec	0.198	0.00	0.232	0.00

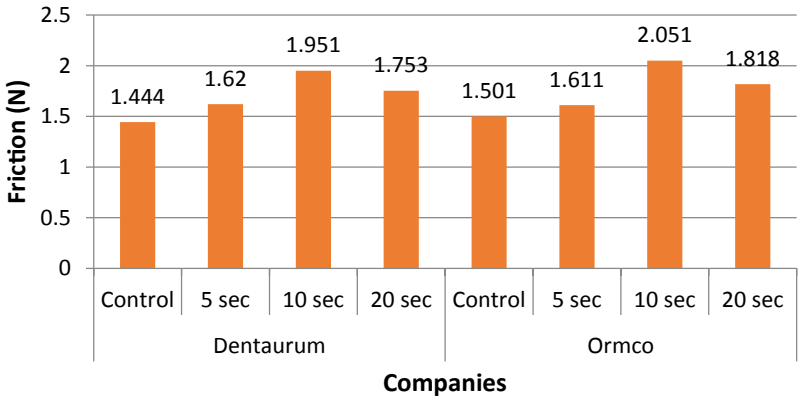

Figure 3 Friction resistance of the two types of companies

Scanning Electron Microscopy

SEM of the bracket slot of two companies at 2000x magnification show greater surface alteration due to removal of the polished glazed surface area leaving it rougher as in Figures 4 and 5.

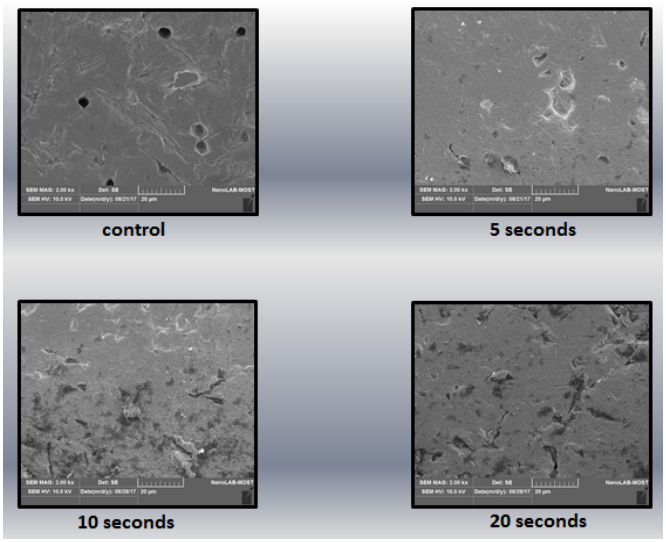

Figure 4 SEM for discovery® sl2. Dentaurum Company

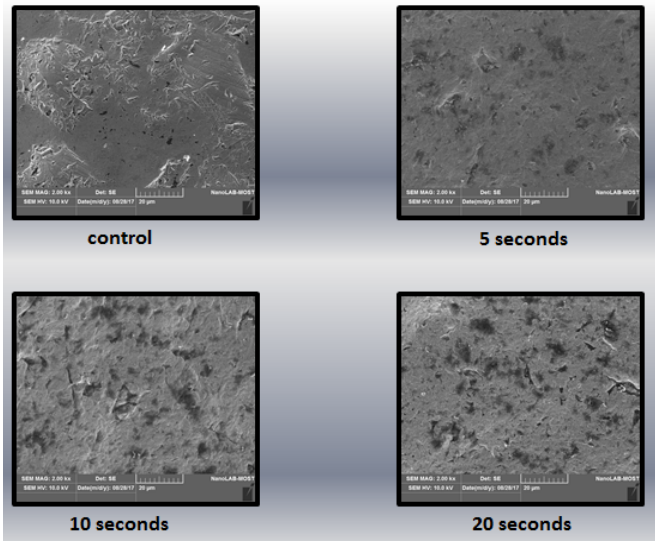

Figure 5 SEM for Damon® Ormco Company

DISCUSSION

The surface of the bracket slot base was examined by scanning electron microscope (SEM) after application of calcium carbonate air abrasive agent result in pronounced changes in the slot surface of the two bracket types (discovery® sl2.0, Dentaurum co. and Damon®, Ormco co.) when comparing between the control (no abrasion) and the abrasion times (5, 10, 20 seconds). The increase in surface roughness result from the removal of the polished glazed layer on the slot surface leaving it irregular, this finding agreed with Parmagnani and Basting [12] also there was increase surface roughness in their study on the other hand the result of or study differed from the finding of Wilmes, et al. [14] who noticed minor not significant changes in the base of the bracket slot, however in their study they left the arch wire in bracket slot during air abrasive polishing which may protect the slot surface from being exposed to air abrasive agent that result in these not significant changes.

In our study, the increase in surface roughness after the application of calcium carbonate air abrasive agent result in significant increase in friction in both types of self-ligated brackets (discovery® sl2.0, Dentaurum co.; and Damon®, Ormco co.). The findings of static frictional increase agreed with Filho, et al. [13] and Parmagnani and Basting [12] who used another type of air abrasive agent (sodium bicarbonate) and found an increase in static friction. Before air abrasion Dentaurum Company showed amount of friction less than Ormco Company. This difference may be attributed to Difference in manufacturing process for each company which result in differences in the polished layer of the slot that confirmed by scanning electron microscopy (SEM). Also, the morphology of the tested brackets differed in the two types of the self-ligated brackets that result in differences in bracket slot width which has direct effect on the inter-bracket distance this agreed with Kapila, et al. [5] and Whitley and Kusy [15] who found an inverse relationship between frictions and inter bracket distance for all arch wire alloys.

CONCLUSIONS

- Before air abrasion, Dentaurum brackets showed least static friction resistance than Ormco brackets.
- Calcium carbonate air abrasive polishing on the passive stainless-steel brackets caused significant increase in friction for Dentaurum by 35.157% and for Damon® Ormco by 36.652%.
- There was a significant increase in friction between the exposure times (5, 10 and 20 seconds) after air abrasive polishing on stainless steel brackets.
- Surface micromorphology for the base of self-ligated bracket slot showed great alteration after air abrasion due to the removal of the (polished glazed surface area), leaving it rougher which confirmed by scanning electron microscopy.

In conclusion, calcium carbonate air abrasive polishing should be used with caution on stainless steel brackets. It

is preferable to leave the arch wire in place during polishing or closure the gate of self-ligated brackets after the arch wire removal but abundant washing with water must be performed to remove the residue of calcium carbonate particles retained on the surface of the slot.

DECLARATIONS

Conflict of Interest

The authors and planners have disclosed no potential conflicts of interest, financial or otherwise.

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