EFFECT OF DIFFERENT LIGATION METHODS OF ORTHODONTIC BRACKETS ON FRICTIONAL RESISTANCE DURING SLIDING MECHANICS: IN-VITRO STUDY

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ABSTRACT:

Many factors can contribute to the frictional resistance of edgewise appliances including brackets, wire materials , cross-section and surface conditions of the archwires, torque at the wire-bracket interface, inter bracket distance, functions of the oral environment , type and force of ligation. The aim was to evaluate and compare the frictional resistance (static and dynamic) of different ligation methods during sliding mechanics. ***Methods:*** *Fifty canine brackets of three types; conventional (4 wings), Synergy (6 wings) and passive self ligating brackets system [SLBs]. Different ligation techniques (conventional elastomeric [CEL], unconventional elastomeric ligatures [UEL] and stainless steel ligatures [SS]) were used in a simulation for canine retraction in a curved path using 0.017X0.025" NiTi wire. Frictional resistance of the bracket/wire/ligation combinations was measured using experimental model mounted on a universal testing machine with 5KN load cell. Each sample was tested 10 consecutive times in dry state.* ***Results:*** *Large frictional forces were found for wires secured with SS ligatures and CEL in standard (4 wings) brackets. Conventional elastomeric ligatures tied on the*

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middle wings only of the Synergy (6 wings) brackets or the use of SLBs produced the lowest frictional forces. Unconventional elastomeric ligatures as well reduced frictional forces to a significant level in comparison with conventional brackets with SS or CEL. Conclusion: large variations in frictional forces were noticed when archwires were ligated in different bracket designs as well as when similar brackets and different ligation techniques were used. Unconventional elastomeric ligatures can be considered a valid alternative for low friction biomechanics.

Key words: *Self ligating brackets, elastomeric ligatures, static and dynamic frictional resistance, canine retraction, Unconventional elastomeric ligatures.*

INTRODUCTION

Friction acts at the surface between two bodies and happens when one body slides or tends to slide in contact with another body. This frictional force is always parallel to the surfaces that are in contact and its magnitude is dependent upon the amount of the normal (perpendicular) force (N) pushing the two surfaces together.[1] The later (N) acts perpendicular to the sliding direction and is applied in the case of archwires through the use of elastic modules or metal ligatures to tie them into the bracket slot[2]. Consistent with the first law of classical friction, the frictional resistance increases with an increase in the normal force provided by ligation [1].

Reduction of friction can mainly be achieved either by decreasing the friction coefficient of the bracket or wire materials or by decreasing the force of ligation (N) acting on the wire[3]. Consequently, in recent years, orthodontic manufacturing companies have offered new brackets and elastics intended to generate low frictional forces during sliding therapy. Self ligating brackets have become increasingly popular which are characterized by the presence of mobile fourth wall that converts the slot of the bracket in to a tube. Self ligating brackets are claimed to reduce friction in a considerable way as it allows the free movement of the arch wire[4,5,6]. Recently an innovative UEL (Slide ligatures)* had been introduced[7], it can be applied directly on conventional brackets as it is like a labial cover and is completely passive. Previous in-vitro studies[7,8] showed that this UEL can reduce frictional forces with respect to CEL and comparable to SLBs[9].

Materials and Methods:

In this study materials were selected from the recent generations of SLBs and conventional brackets as well as different and innovative means of ligation. Three types of low profile SS maxillary right canine brackets with hooks and 0.022X0.028" slot size were compared. The conventional Mini Master twin brackets** (-2 º torque and +10º angulations), combined with CEL were used as control, Synergy $f\chi$ Φ 6 wings (0º torque and +8º angulations) with CEL in the middle wings only (minimum ligation). Ten passive SLBs with hooks Vision LP ** (-2º torque and +9º angulations) were used with passive NiTi clip. Twenty five maxillary rectangular 0.017 X 0.025-inch NiTi arch wires** were used. Each wire was cut into two symmetrical halves using a wire cutter at the midline and each half was used separately. Different types of ligatures were compared; the SS ligatures*, small and transparent CEL** and UEL (fig.1) and the SLB system. The "Straight Shooter" a ligature gun† was used to apply the CEL to the brackets (fig.2).The ligatures were placed immediately before each test run to avoid ligature force decay[10]. The idea of testing frictional resistance was to simulate the distal driving of a canine bracket with arch wire guidance into a first-premolar-extraction site in a curved path which is more like what actually occurs clinically rather than the regular linear sliding motion[11]. An experimental acrylic resin model representing a replica of a half aligned maxillary arch was constructed (fig.3). A V-shape piece representing the first premolar tooth was removed from the acrylic resin block i.e. separating it into two pieces which were later connected by a ball joint with two roller bearings this joint allowed the movement in a curved path simulating the path of canine retraction. Brackets were bonded on the acrylic teeth (canine and second premolar) and a band on the first molar using cyanoacrylate adhesive. A section of 0.021X0.025" stainless steel

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archwire was used to align the brackets before fixing onto the canine acrylic block in the appropriate position. All materials were cleaned with 95% ethanol, as degreasing and to remove any dust, before testing and allowed to dry.

The resistance to sliding was recorded in the presence of different types of ligatures in dry state[12,13] using (LYOID)[*] niversal testing machine. In the movable upper jaw of the testing machine a metal rod was placed horizontally where the SS retracting wire was attached. That retracting wire was a readymade Kobayashi ligature[**] 0.014" with a loop to hold the hook of the canine bracket at one end and welded at the other end to join its terminals. While in the lower jaw a metal rod, with right angle placed in the acrylic model, was fixed. The drawing force (P) was digitally recorded as the bracket was translated (7mm) distance relative to the arch wire at a rate of (5mm/minute) [6]. Each of the five assemblies was repeated 10 times with new test bracket and wire[14]. The distal end of the wire was fixed to prevent sliding of the wire through the molar tube by ligating the wire firmly at the second premolar bracket and fixing a stopper, in the form of screw and sleeve mesial to the molar tube.

The data were tested with one way analysis of variance to compare the different ligation techniques in each of the bracket/wire/ligation combinations.

RESULTS

Statistical comparison of the recorded *static* and *kinetic frictional* forces of different bracket ligation combinations reported *no significant* difference between (**SL** & **SC** groups) and (**CC** & **CSS** groups) for both *static and kinetic* friction at 5% level of significance (table 2). Negligible fictional force values were recorded for the (**SL** & **SC** groups) (table 1). For (UEL) frictional force values were close to zero g with statistical *significance* difference between (**CU** & **CSS** groups) for both *static and kinetic* frictional resistance at 5% level of significance. Although **CU** group had no statistical significance with (**SL** &**SC** groups) for the *static* friction, while, it was significant for the *kinetic* friction at 0.1% level of confidence. On the other hand significant difference was found between

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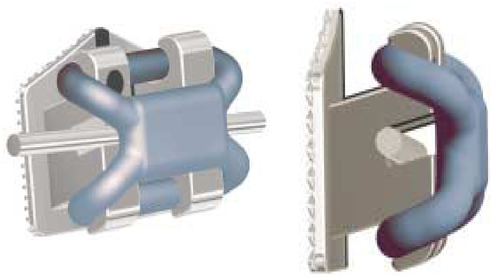
(**CU** & **CSS** groups) for both *static and kinetic* frictional resistance. High statistical significance was found between (**SC** & **CC** groups) for both *static and kinetic* frictional resistance with the **SC** group reporting the lowest mean frictional forces. Statistical significance was found between (**SL** & **CSS** group) for the *static* friction ($P \leq 0.01$) but highly significant ($P \leq 0.001$) for the *kinetic* friction.

DISCUSSION

The present study compared the effect of different ligation methods and various bracket designs on static and kinetic friction. The SLB, synergy brackets with CEL and UEL on conventional brackets produced significantly lower frictional forces compared with CEL on conventional brackets. The results of UEL agree with **Baccetti and Franchi** [9] and **Gandini** et al.,[15] Also, it simulated that for passive SLBs (Damon) as was reported by **Fortini** et al.,[16] and **Tecco** et al.,[17]. This could be explained by the fact that it is like a passive SLB, which allow the archwire to slide freely in the slot while transmitting its full force to the tooth.

The results of the SLBs are in full agreement with those of **Gandini** et al.,[16] **Tecco** et al.,[17] **Griffiths** et al.,[18] **Hain** et al.,[19] and **Franchi and Baccetti**[20] where the passive self ligating brackets generated smaller frictional forces than conventional ligatures on conventional brackets. This reduction of frictional forces could be attributed to the advantage gained from the movable fourth wall of the bracket to convert the slot into a tube.



45 degree view   Profile view

Fig (1): Unconventional elastomeric ligatures.

Fig (2): The ligature gun (Straight Shooter)

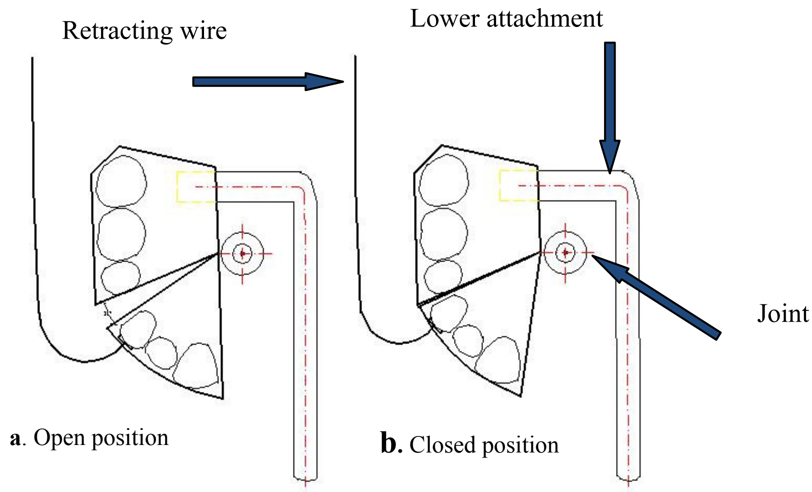


Fig (3): Diagrammatic representation of the experimental testing model. **a**. Model before testing with a space distal to the canine representing the extraction space of the first premolar. **b**. Model after testing with no space distal to the canine.

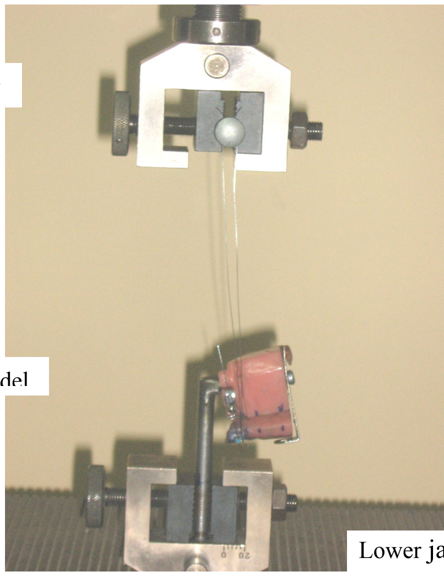


Fig (4): The upper and lower attachments in place connecting the model to the testing machine.

Table (1): Descriptive statistics of static and kinetic frictional forces (N) for the different groups with 0.017X0.025" Niti wire.

	KINETIC FRICTIONAL FORCES						STATIC FRICTIONAL FORCES				
Group	**N**	**Mean**	**S.D ±**	**Median**	**Min**	**Max**	**Mean**	**S.D ±**	**Median**	**Min**	**Max**
CC	10	0.228	0.112	0.222	0.063	0.466	0.286	0.11	0.246	0.137	0.558
CU	10	0.052	0.138	0.114	-0.235	0.312	0.131	0.1	0.127	0.010	0.32
CSS	10	0.237	0.129	0.216	0.023	0.427	0.253	0.125	0.238	0.028	0.48
SC	10	-0.075	0.044	-0.075	-0.170	-0.025	0.088	0.070	0.084	0.004	0.247
SL	10	-0.069	0.042	-0.065	-0.145	-0.010	0.125	0.106	0.115	0.012	0.244

CC = Conventional brackets & conventional ligature. CU= Conventional brackets & unconventional ligature.
CSS= Conventional brackets & stainless steel ligature. SC=Synergy brackets & conventional ligature.
SL= Self ligating bracket system. N= Number of samples in each group.
Min= Minimum value. Max. = Maximum value. S.D= Standard deviation.

Table (2): Comparison of ligation type on static and kinetic frictional resistance (N) (Kruskal-Wallis rank sum test).

	STATIC FRICTIONAL FORCES				**KINETIC FRICTIONAL FORCES**			
Groups	**CSS**	**SL**	**SC**	**CU**	**CSS**	**SL**	**SC**	**CU**
CC	NS	<0.01[b]	<0.001[a]	<0.001[a]	NS	<0.001[a]	<0.001[a]	<0.05[c]
CU	<0.05[c]	NS	NS		<0.05[c]	<0.01[b]	<0.01[b]	
SC	<0.01[b]	NS			<0.001[a]	NS		
SL	<0.01[b]				<0.001[a]			

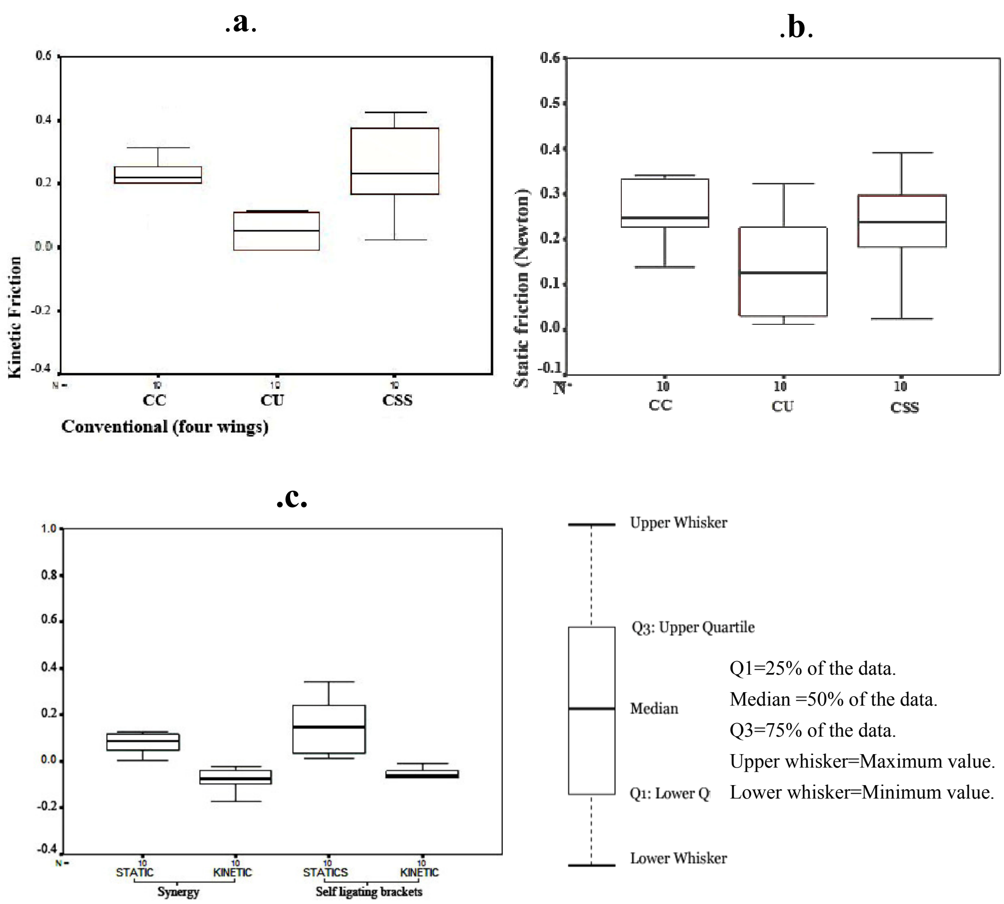
NS: no significant difference. [a] $P \leq 0.001$ [b] $P \leq 0.01$ [c] $P \leq 0.05$
CC = Conventional brackets & conventional ligature. CU= Conventional brackets & unconventional ligature.
CSS= Conventional brackets & stainless steel ligature. SC=Synergy brackets & conventional ligature.
SL= Self ligating bracket system.

There was no reduction in frictional forces with the loosely tied SS ligature with conventional brackets with great variability in frictional resistance as observed by increased range of dispersion in both the static and kinetic frictional forces with the maximum and minimum values away from the median value. This is in accordance with **Read-Ward** et al.,[21] where the stainless steel ligatures produced large variations, confirming the difficulty in standardizing ligation force and technique, which could be either more or less than the elastomeric ligation[22].

The synergy brackets, (6 wings) design, showed the lowest frictional forces among the other types of brackets investigated in this research with no significant difference found between the self ligating and the Synergy brackets (table 2).

This is in agreement with **Yeh** et al.,[10] **Ibrahim** et al.,[23] and **Raouf** [24] and could be attributed to its design feature modification with two wings ligation only (middle wings with elastic ligation) regardless of the archwire used. Also, **El-kadi and Ramadan**[25] found that friction free (Synergy) brackets with minimum ligation still had lower frictional force than the conventional ligation of standard edgewise brackets. On the other hand, **Abdel Menium**[26] found that elastomeric and stainless steel ligatures combined with the Synergy brackets exhibited higher frictional forces than the SLBs, but this could be attributed to the ligation of the 6 wings in their study (i.e. maximum ligation).

Figure (5): Box plot graph showing the distribution of the Static frictional forces for different bracket/ligation combinations: a. Kinetic frictional resistance of the (4wings) brackets. b. Static frictional resistance of the conventional (4 wings) brackets. c. Static and kinetic frictional resistance of the self ligating and Synergy (6 wings) brackets.



Generally lower frictional forces were encountered in our study with both the conventional and the SLBs compared with a previous study by **Hamede**[11] performed at dental materials laboratory, Ain Shams University, with the same testing machine and model to record frictional resistance in a curved path rather than the regular linear sliding motion. These differences in frictional forces between the two studies may be attributed to the modified method of traction; by moving the canine bracket distally utilizing its hook for attachment of the retracting wire (as a point of application of force) which simulates more what actually happens clinically; using a ball joint with two cylindrical roller bearings, added to that, the difference in the gauge and material of the wire.

CONCLUSIONS

Synergy brackets with minimum ligation with CEL, passive SLBs and UEL with CB are able to produce significantly lower frictional forces compared to CB with both the CEL and SS ligatures combined with 0.017X0.025" NiTi arch wire in a curved path and dry state. Unconventional elastomeric ligatures with CB represent valid alternative for low friction biomechanics.

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