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RESEARCH ARTICLE

FRICTIONAL RESISTANCE EVALUATION IN CONTEMPORARY LIGATION SYSTEMS: AN INVITRO STUDY

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ABSTRACT

Objectives: This study was to evaluate the frictional resistance produced by various contemporary ligation systems in comparison with passive self-ligation system
Materials and methods: The study was done using 0.019 X0.025″ Stainless steel wire of 7cm length with 0.022" MBT pre adjusted edgewise maxillary 1st premolar brackets and 3 different types of ligation-0.009” stainless steel ligatures, Superslick ligatures, Slide ligaturescompared to Smart Clip 3 passive self-ligating brackets. The study was conducted in dry and wet conditions at 7 and 21 days intervals. A customized testing jig with bracket, wire and ligature assembly was fabricated and mounted parallel to the vertical framework of universal testing machine. The mechanical testing was done with a load cell of 10 N at a crosshead speed of 5mm/min. 10 samples for each group were tested. Inter and intra group comparison was done using t Test and analysis of variance Test (F Test) with SPSS version 22 software.
Results: SmartClip 3 showed statistically significantly low staticand dynamic friction compared to others in dry and wet condition at 7 days interval. There exists a significant difference in friction between the super slick and slide ligature in the 21 days wet condition. Superslick ligature showed rapid decrease in friction in wet condition compared to dry condition. However, SmartClip showed least dynamic friction in 21 days in wet condition.
Conclusion: This study concluded that SmartClip self-ligating brackets produced least friction both in dry and wet condition. Frictional resistance reduced considerably when placed in wet condition for 21 days compared to that in dry condition in all the evaluated samples. Thus proving that self-ligating appliance are very effective in enhancing tooth movement during all stages of treatment and thus reducing treatment time

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INTRODUCTION

In contemporary preadjusted edgewise appliance sliding or friction mechanics is a common method of tooth movement. Here the individual teeth, guided by their brackets slide along the archwire or archwire carrying the entire anterior teeth segment may slide through the posterior brackets and molar tubes to achieve the desired result. This is called friction mechanics because of the frictional force generated at the interface between the brackets and the archwire. More the frictional force more is the force needed to slide the teeth along the archwire causing greater strain on the teeth and the anchorage. Friction is defined as ‘‘the force tangential to the common boundary of two bodies in contact that resists the motion of one relative to the other”. The amount of friction is proportional to the force with which the two surfaces are pressed together and dependent on the nature of the surfaces in contact. The area of contact is influenced by the roughness and force with which the surfaces are pressed against each other (Dowling, 1998).The friction encountered during tooth movement can be divided into static friction and dynamic friction. Static friction is defined as the force required to initiate tooth movement. Static friction is opposed to any application of force, and its magnitude is that to prevent movement between two surfaces, up to the point when it is overcome and movement begins. Here the force applied is not sufficient to move the object. Whereas dynamic friction is the force that resists motion. Dynamic friction is opposed to the direction of movement of the object and occurs when the

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bodies are in motion (Frank, 1980).A number of studies have identified the principal factors that may influence orthodontic frictional resistance: relative bracket-wire clearances (Andreasen, 1970), archwire size (Frank, 1980; Huffman, 1983), archwire section (round vs rectangular wires) (Drescher, 1986 and Peterson, 1982), torque at the bracket-wire interface[7], surface conditions of the archwires and bracket slot (Kusy, 1988), bracket and archwire materials (Bednar, 1919 and Kusy, 2001) bracket slot width (Peterson *et al*., 1982), brackettype (conventional vs self-ligating brackets) (Bednar, 1991; Berger, 1990 and Taylor, 1999), type and force of archwire ligation (Dowling, 1985; Bednar, 1991). Various factors interfere in friction, but alterations to the elastomeric ligatures deserve attention as they play an important role with regard to friction between the bracket and wire during orthodontic mechanics. A reduction in friction between the bracket and orthodontic wire may be obtained with the use of lubricated elastomeric ligatures, or with alterations in their composition. Recently, a ligature with polymer coating was launched on the market: The Superslick ligature (TP Orthodontics, LaPorte, Ind., USA), with the purpose of reducing friction, in comparison with conventional ligatures. According to the manufacturer, this ligature is covered with a polymer coating, allowing greater sliding of the wire over this material (Flávia Ramos, 2013). An innovative ligature manufactured with a special polyurethane mix by injection molding (Slide, Leone Orthodontic Products, Sesto Fiorentino, Firenze, Italy) was introduced. This ‘‘nonconventional’’ elastomeric ligature is used on conventional brackets to produce low levels of frictional resistance in treatment mechanics with the preadjusted appliance. Once the ligature is applied on the bracket, the interaction between the ligature and the slot forms a ‘‘tube like’’ structure, which allows the archwire to slide freely and to produce its effects more readily on the dentoalveolar component (Tiziano Baccetti, 2006).

Since the 1980s, self-ligating brackets have become increasingly popular. These types of brackets are characterized by the presence of a fourth mobile wall that converts the slot into a tube. Self-ligating brackets are claimed to reduce friction levels in a considerable way because they simply allow the wire to move freely into the bracket slot. Several studies have demonstrated a significant decrease in friction by using these types of brackets with a reduction in the time necessary for single tooth movements (Gandini, 2008). This study proposes to evaluate the frictional resistance between the archwire and orthodontic brackets using three different ligation technique, when compared to a passive self-ligation system in dry and wet condition over a fixed time interval to simulate the clinical situation. This study also evaluates whether the nonconventional newer ligation techniquesmay represent a valid alternative to passive self-ligating brackets for low-friction biomechanics and faster treatment outcome.

Aim

This study was to compare the frictional resistance between the archwire and orthodontic bracket with three different ligation techniques and passive self-ligation system in dry and wet condition.

MATERIALS AND METHODS

A straight length 0.019X0.025″ Stainless steel arch wire segment (Captain ortho, India) of 7cm length was used with 0.022" preadjusted edgewise premolar brackets MBT Prescription (American Orthodontics) and 3 different types of ligatures namely stainless steel ligatures 0.009" (Leone Orthodontic Products, Italy), Super Slick elastomeric ligatures (TP Orthodontics, LaPorte, Ind. USA), Slide elastomeric ligatures(Leone Orthodontic Products, Italy)and a passive self-ligating premolar bracket (0.022" slot) (SmartClip 3,3M Unitek, Calif. USA). The study was conducted in dry and wet conditions at 7 and 21 days intervals in artificial saliva.

For the study in dry condition the sample were divided into 4 groups

Group A- Bracket wire combination with stainless steel ligatures
Group B- Bracket wire combination with Super Slick ligature
Group C- Bracket wire combination with Slide ligatures
Group D- Passive Self ligating bracket- SmartClip 3 with wire

For study in wet condition the samples were divided into 6 groups

Group A1- Bracket wire combination with stainless steel ligatures in wet condition for 7 days.
Group D1- Self ligating bracket- SmartClip 3with wire in wet condition for 7 days.
Group B1- Bracket wire combination with Super Slick elastomeric ligature placed in wet condition for 7days
Group B2- Bracket wire combination with Super Slick elastomeric ligature placed in wet condition for 21days
Group C1- Bracket wire combination with Slide elastomeric ligatures placed in wet condition for 7 days
Group C2- Bracket wire combination with Slide elastomeric ligatures placed in wet condition for 21 days

A customized testing jig (Fig. 1) was made to hold the bracket, wire and ligature assembly parallel to the vertical framework of universal testing machine (INSTRON-3345) during mechanical test with a load cell of 10N at a crosshead speed of 5mm/min. (Fig. 2) 10 samples for each group were evaluated.

Statistical Analysis

Statistical analysis was done using SPSS version 22 systems. The analysis employed to statistically evaluate the results were t Test and analysis of variance Test (F Test).

RESULTS

SmartClip bracket produced significantly less static (39.0 +/- 1.563) and dynamic (11.30+/- 1.337) friction at $P<0.05$ compared to other ligation techniques in dry condition (Table 1/ graph 1 & 2). When the static and dynamic friction between the specimens in the artificial saliva for 7 days were compared, SmartClip produced significantly less friction ($P<0.05$) 31.09+/- 1.418 and 4.50+/-0.527 respectively (Table 2/ graph 3 & 4). There exists a significant difference ($P<0.05$) in friction between the Super Slick (static friction: 96.30+/- 1.829 and dynamic friction: 72.80+/- 2.30) compared to Slide ligature (static friction: 47.60+/- 0.0966 and dynamic friction: 18.80+/- 1.398) at the 21 days wet condition (Table 3/ graph 5 & 6).

Table 1. Static and dynamic friction of group a, b, c and d under dry condition

	Stainless steel Static	Stainless steel Dynamic	Super slick static	Super slick dynamic	Slide ligature static	Slide ligature dynamic	Smart clip static	Smart clip dynamic
Friction	169.00	155.20	170.60	140.80	64.30	32.40	39.00	11.30
Std. Deviation	1.333	1.398	2.633	1.033	2.584	1.578	1.563	1.337

Table 2. Static and dynamic friction of group a1, b1, c1 and d1 under 7 days wet condition

	Stainless steel Static	Stainless steel Dynamic	Superslick Static	Super slick dynamic	Slide ligature static	Slide ligature dynamic	Smart clip static	Smart clip dynamic
Friction	165.50	153.10	110.40	84.20	52.50	36.20	31.30	4.50
Std. Deviation	2.593	0.876	2.413	0.789	1.434	1.033	1.418	0.527

Table 3. Static and dynamic friction of group b2 and c2 under 21 days wet condition

	Super slick static	Super slick dynamic	Slide ligature static	Slide ligature dynamic
Friction	96.30	72.80	47.60	18.80
Std. Deviation	1.829	2.300	0.966	1.398

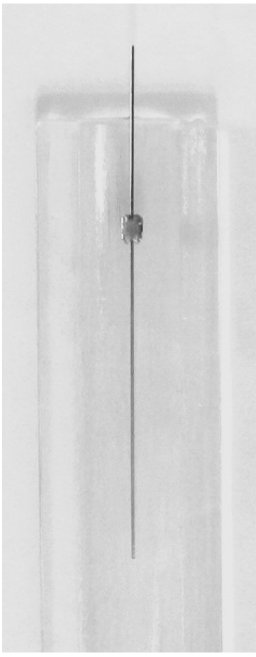


Figure 1. Customized Testing Jig

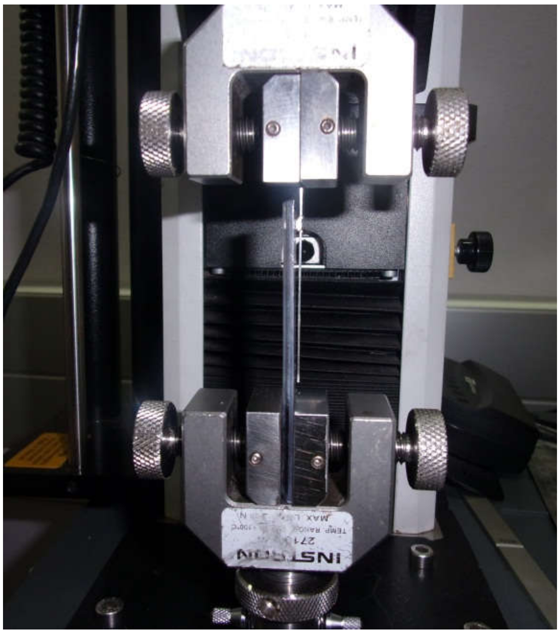
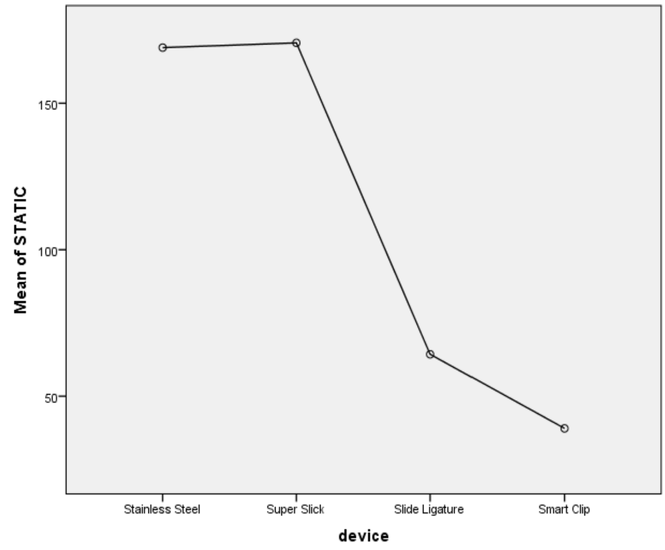


Figure 2. Customised Jig attached to Instron Machine

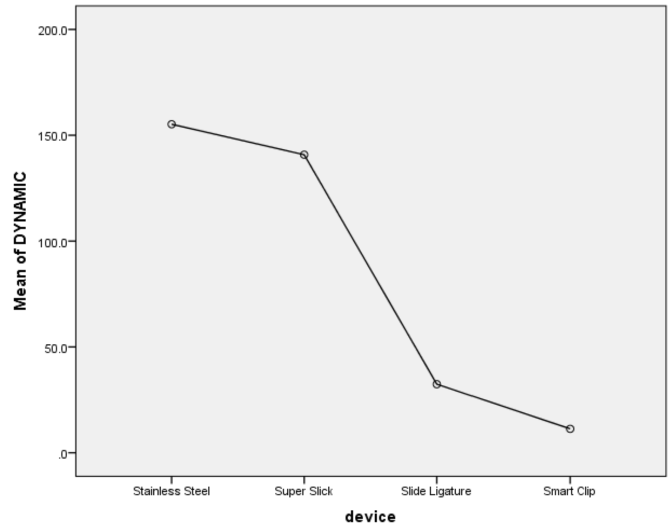
The SmartClip3 appliance showed least frictional resistance in both dry and wet conditions. Superslick ligature showed drastic reduction in friction in wet condition (static friction: 96.30+/- 1.829 and dynamic friction: 72.80+/- 2.30) compared to dry state (static friction: 170.60+/- 2.633 and dynamic friction: 140.80+/- 1.033) (Table 1 & 3/ graph 7 & 8). Slide ligature produced comparable low frictional resistance in wet condition (Table 2 & 3/ Graph 9 & 10)

DISCUSSION

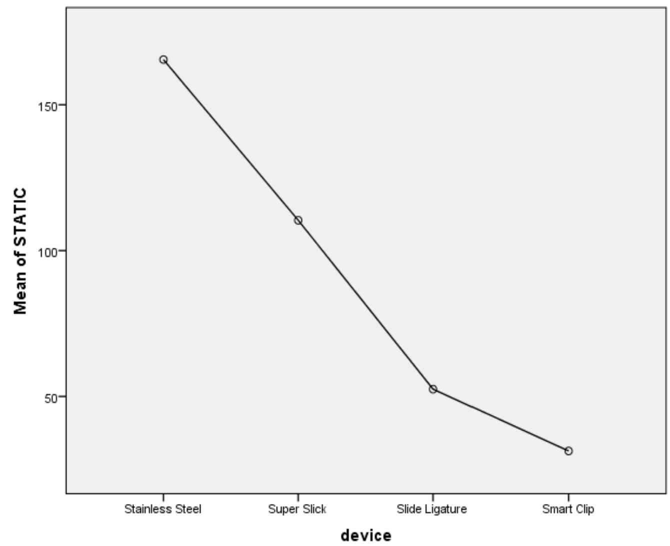
The amount of friction is proportional to the force with which the two surfaces are pressed together and dependent on the nature of the surfaces in contact'' (composition of the material, surface roughness, etc.). The force applied, therefore, has to overcome friction to achieve the desired orthodontic movement. The dissipation of the orthodontic force as resistance to sliding may vary between 12% and 60% or it may lead to a stop in tooth movement (Kusy, 1997). A number of factors have been implicated in influencing frictional forces during orthodontic tooth movement. The effects of archwire material, dimensions, and bracket material have been investigated. The method of archwire ligation would appear to be an important determinant in the generation of friction, yet relatively few studies have looked at this interaction. In the present study, standard edgewise maxillary premolar metal brackets of slot 0.022" X 0.028"and SmartClip self-ligating brackets were used. In this study various ligatures were compared to find out which ligation produce least friction in both dry and wet conditions. Both the static and dynamic friction of various ligations used were also compared. It is important to study the friction generated by elastomeric ligatures available in the market which makes orthodontic treatment efficient, fast and inexpensive. According to Leander and Kumar (2011), elastomeric ligature is the most commonly used method for uniting the wire to the bracket, as ligatures are comfortable for the patient, offer fewer risks of causing damage to the mucosa, have better acceptance due to the possibility of choosing colors and increase motivation with regard to the treatment. Here in this study two types of elastomeric ligatures were compared to stainless steel ligature and concluded that stainless steel ligatures produced more friction than elastomeric ligatures used in the study. A reduction in friction between the bracket and orthodontic wire may be obtained with the use of lubricated elastomeric ligatures, or with alterations in their composition.



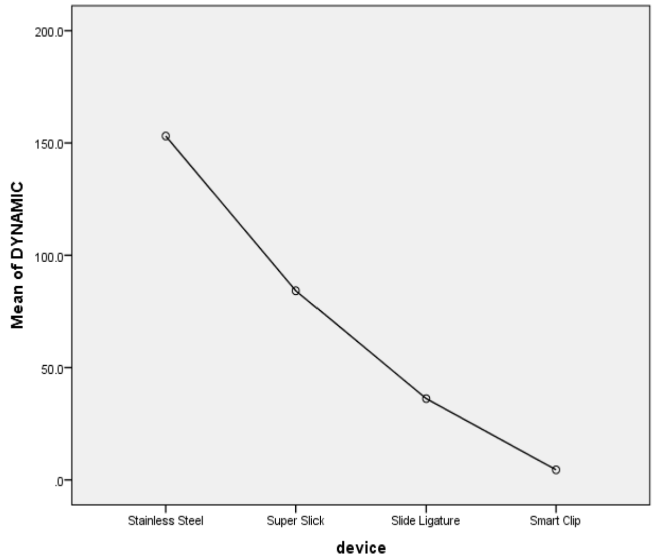
Graph 1. The mean plot of static friction determined when stainless steel ligatures, Slide ligatures, SuperSlick ligatures and Smart clip brackets used under dry condition



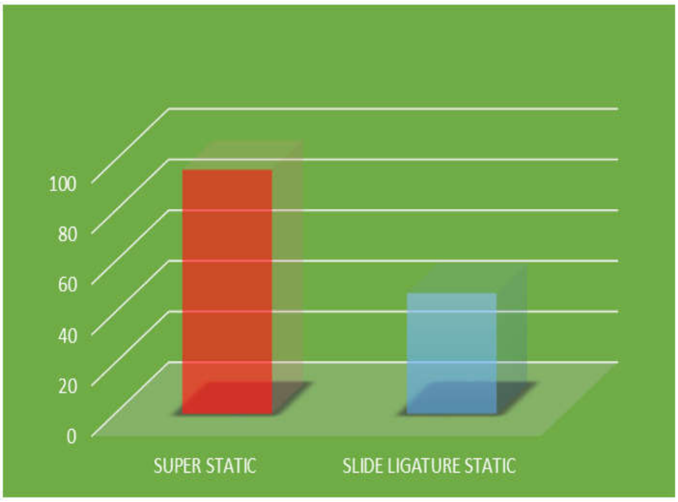
Graph 2. The mean plot of dynamic friction determined when stainless steel ligatures, Slide ligatures, SuperSlick ligatures and Smart clip brackets used under dry condition



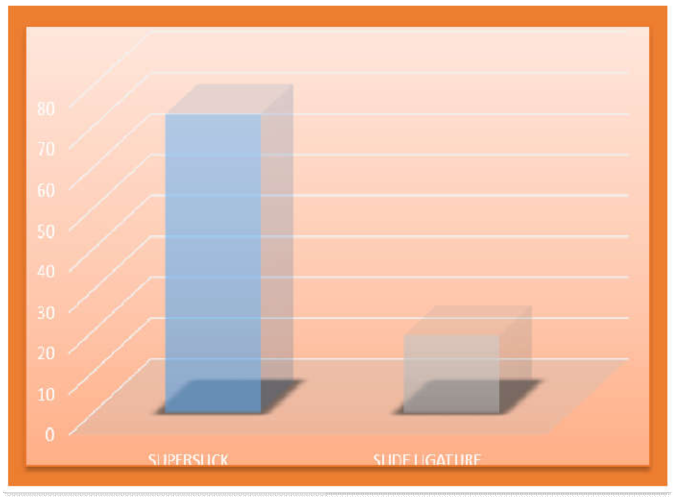
Graph 3. The mean plot of static friction determined when stainless steel ligatures, Slide ligatures, SuperSlick ligatures and Smart clip brackets placed under wet condition for 7 days



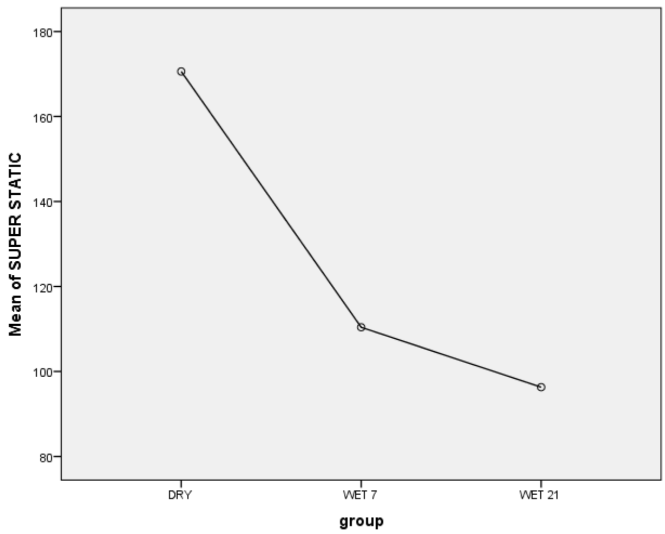
Graph 4. The mean plot of dynamic friction determined when stainless steel ligatures, Slide ligatures, SuperSlick ligatures and Smart clip brackets placed under wet condition for 7 days



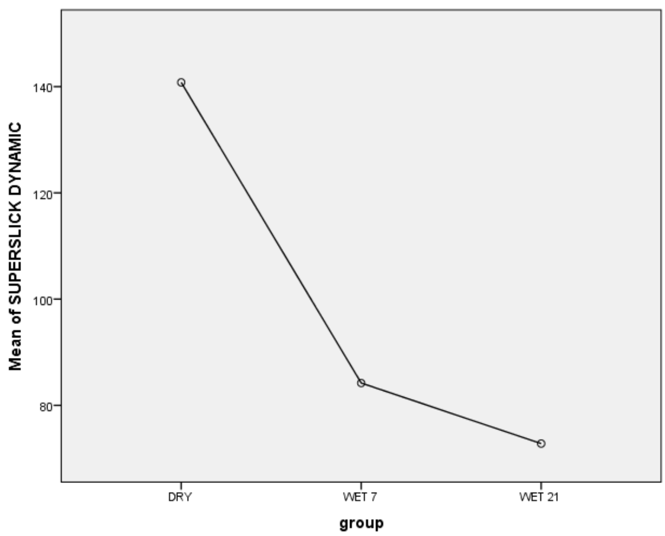
Graph 5. The static friction of Super Slick and Slide ligature placed in wet condition for 21 days



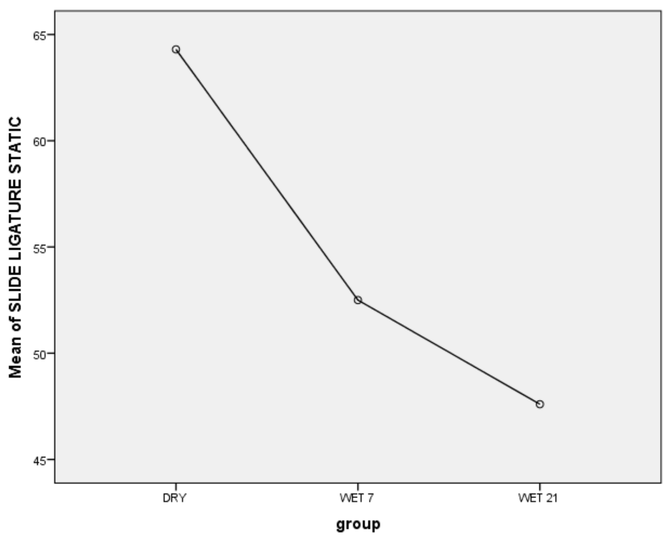
Graph 6. The dynamic friction of Super Slick and Slide ligature placed in wet condition for 21 days



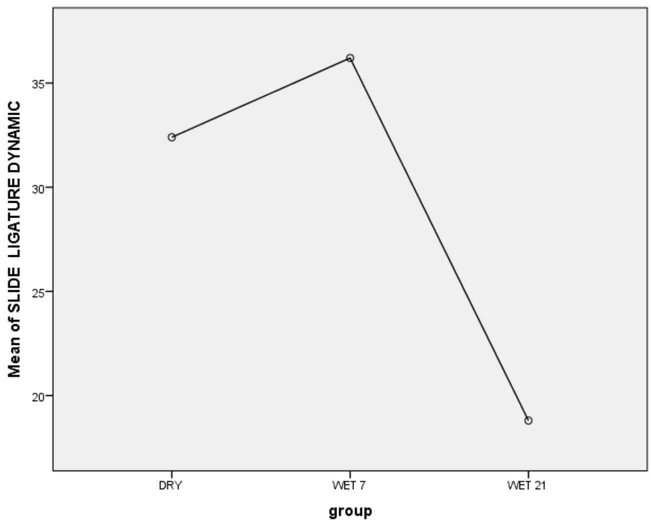
Graph 7. The mean plot of static friction determined when Superslick ligature placed under dry (B), wet condition for 7 days (B1) and wet condition for 21 days (B2)



Graph 8. The mean plot of dynamic friction determined when Superslick ligature placed under dry (B), wet condition for 7 days (B1) and wet condition for 21 days (B2)



Graph 9. The mean plot of static friction determined when Slide ligature placed under dry (C), wet condition for 7 days (C1) and wet condition for 21 days (C2)



Graph 10. The mean plot of dynamic friction determined when Slide ligature placed under dry (C), wet condition for 7 days (C1) and wet condition for 21 days (C2)

Recently, a ligature with polymer coating was launched on the market: Super Slick (TP Orthodontics, La Porte, IN, USA), with the purpose of reducing friction, in comparison with conventional ligatures. According to the manufacturer, this ligature is covered with a polymer coating, allowing greater sliding of the wire over this material. In this study Superslick ligature produced least friction when compared to stainless steel in wet condition only. In dry condition stainless steel ligatures and Superslick ligature produced almost same friction.0.019 X 0.025" archwire was chosen in conjunction with a 0.022-in bracket slot in various studies because this gives good overbite and torque control while allowing free sliding in the buccal segments. In this study 0.019 X 0.025" rectangular stainless steel wire was used. It is known that the frictional force tends to increase with rectangular cross-section wires in comparison with round wires. Cacciafesta *et al*. (2004), reported that higher frictional force was present with an increase in orthodontic archwire thickness. In this study tight stainless steel ligation was used and it was seen that in dry and wet condition the friction was more when compared to other ligatures used. Gandini *et al*. (Gandini, 2008) mentioned that the metal ligature produces less frictional force in comparison with that of elastomeric ligatures; however, friction depends on the tying force between the metal ligature and orthodontic archwire, which was different from elastomeric ligatures. In order to reduce the friction caused between the bracket/ orthodontic archwire/ligature interface, self-ligating bracket systems have been introduced in the market. Here passive self-ligating brackets were used and found that the friction in dry and wet condition differs. Compared to other ligatures used self-ligating brackets produced least friction. These results fully agree with those of previous studies that found that passive self-ligating brackets generated smaller frictional forces than conventional ligatures on conventional brackets (Gandini, 2008). Recently, an innovative unconventional elastomeric ligature, manufactured with a special polyurethane mix by injection molding (Slide), was introduced. Once the ligature is applied on the bracket it simulates the labial cover of a passive self-ligating bracket, thus transforming the slot into a tube that allows the archwire to slide freely (Tiziano Baccetti and Lorenzo Franchi, 2006). The results of the present study confirm previous findings by Baccetti and Franchi (2006), who reported significantly lower levels of friction for conventional brackets with unconventional elastomeric ligature compared with conventional bracket with conventional elastomeric ligature during sliding mechanics with 0.014 super elastic NiTi wire and 0.019 X 0.025 SS wire. In summary, the present study demonstrated that SmartClip self-ligating brackets produced least static and dynamic friction both in dry and wet condition. The frictional resistance reduced significantly when placed in wet condition compared to dry condition in all the studied samples.

Conclusion

This study concluded that

- SmartClip self-ligating brackets produced least friction both in dry and wet condition.
- Slide ligature produced relatively less friction compared to Super Slick ligature and stainless steel ligature both in dry and wet condition.
- Super Slick ligature produced higher frictional resistance in dry condition similar to stainless steel ligature but drastically reduced when exposed to wet condition over 7 days and 21 days.
- Frictional resistance reduced considerably when placed in wet condition for 21 days compared to that in dry condition in all the evaluated samples.

But all the limitations that involve in invitro studies should be taken into consideration. The intraoral conditions like oral temperature, intraoral bacteria, enzymes etc. influence the materials used. These were not considered in this study.

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