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Comparative Evaluation of Frictional Forces of Different Bracket Systems and Ligations

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Abstract

Introduction: Friction is considered to have a greater importance in orthodontics because it needs to be overcome each time the tooth moves a little as it may reduces the amount of desired orthodontic movement. Number of factors that may influence orthodontic friction are type and force of arch wire ligation, relative bracket arch wire clearances, arch wire size , arch wire cross section , torque at the bracket wire interface, surface conditions of the arch wire and bracket slot , bracket and arch wire materials , bracket-slot width , bracket type.

Aim & Objective: The Aim of this study is to evaluate and compare the frictional forces generated by various ligation methods during sliding mechanics.

Materials and methods

Group I: This group consists of metal brackets ligated using: Ligature ties

Group 2: This group consists of metal brackets ligated using: Elastomeric modules.

Group 3: This group consists of metal brackets ligated using: Slide low friction ligatures.

The metal brackets used, were manufactured by three different companies:

- American Orthodontics
- 3M
- Ormco

No prestretching of the ligatures was done. One minute was allotted for ligation of elastic ligatures, followed by a three-minute waiting period to allow a reproducible amount of stress relaxation to occur.

Frictional force was measured using Instron universal testing machine.

Result: The order of the friction generated in the three ligation methods are as follows:

Metal ligature ties > Conventional Elastomeric modules > Slide nonconventional elastomeric ligatures.

Conclusion: In the age of low friction systems, even though slide ligature modules offer a promising solution to provide ligature with reduced friction during orthodontic treatment with better control of tooth position compared to conventional modules.

Introduction

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 magnitude of the frictional force is proportional to the normal force that pushes the two surfaces together'. Sliding between bracket and wire in the oral cavity occurs at a low velocity as a sequence of short steps rather than as a continuous motion.[2] In orthodontics, a tooth undergoing a sliding movement along an arch wire goes through many tipping and up righting cycles, moving in small increments. Therefore, orthodontic space closure depends more on static friction than on kinetic friction. Static friction is considered to have a greater importance in orthodontics.

Kusy and Whitley[4] divided resistance to sliding into three components: (1) Friction, static or kinetic (FR), due to contact of the wire with bracket surfaces; (2) binding (BI), created when the tooth tips or the wire flexes, (3) notching, when permanent deformation of the wire occurs at the wire- bracket corner interface.

The success of orthodontic tooth movement with pre adjusted appliances depends to a large extent on the ability of the orthodontic arch wire to slide through brackets and tubes4. The major disadvantage with the use of sliding mechanics is the friction that is generated between the bracket and the arch wire during orthodontic movement.

The nature of friction in orthodontics is multifactorial, derived from a multitude of mechanical factors such as arch wire material, cross-section shape and size, surface texture, stiffness, ligation of arch wire to bracket, bracket material, slot width and depth, bracket design, and biological factors such as saliva, plaque, acquired pellicle, and corrosion and other factors such as relative bracket arch wire clearances, torque at the bracket wire interface, surface conditions of the arch wire, type and force of arch wire ligation[3]. Among the numerous factors affecting friction between the bracket-arch wire interface, the method of ligation is one of the most important. A number of ways have been proposed to study this friction, including self-ligating brackets and more recently Slide low friction ligatures.

Aim and Objective

The Aim of this study is to evaluate and compare the frictional forces generated by various ligation methods during sliding mechanics. To evaluate the frictional forces generated by Slide low-friction ligatures .To evaluate the frictional forces generated by conventional ligation methods. To compare the frictional forces of Slide low-friction ligature's to that of conventional ligation.

Materials and Method

This study was conducted in the Department of Orthodontics and Dentofacial Orthopedics, Ahmedabad Dental College & Hospital, Ahmedabad with the aim to evaluate and compare the frictional forces generated by various ligation methods during sliding mechanics.

The material used for the study are Conventional MBT Metal brackets (American Orthodontics, 3M, Ormco) slot size 0.022” x 0.028”, Slide low friction ligatures, Elastomeric Modules, Ligature ties, 19 x 25 Stainless Steel wire (G&H).

Inclusion Criteria

- Only 0.022 MBT metal bracket Prescription to be used.
- 19 x 25 Stainless Steel wires to be used.
- Pre formed Ligature ties to be used.
- Slide low friction ligatures and elastomeric modules to be used.

Exclusion Criteria

- Distorted wires will be excluded from the study.
- 0.018 MBT bracket is not to be used.
- Debonded brackets will not be used.
- Distorted Ligature ties will be excluded.
- Distorted Slide low friction ligatures and elastomeric modules will not be used

The following three types of Ligating methods were used in the study.

Group I: All three types of metal brackets ligated using: Ligature ties

Group 2: All three types of metal brackets ligated using: Elastomeric modules.

Group 3: All three types of metal brackets ligated using: Slide low friction ligatures.

No prestretching of the ligatures was done. One minute was allotted for ligation of elastic ligatures, followed by a three-minute waiting period to allow a reproducible amount of stress relaxation to occur.

Frictional force was measured using Instron universal testing machine (Model 4501, Instron USA,

Norwood, MA, USA). The upper vice of the instron machine held the wooden fixture in place and the lower vice of the machine engaged one end of the vertically oriented arch wire, which was inserted in the bracket slots, and it pulled the arch wire downwards (Fig 1). The arch wires were moved through all ten brackets at a crosshead speed of 0.5 mm per minute. Once arch wire movement began, each run lasted for approximately 5 minutes. The load cell registered the force levels needed to move the wire along the ten aligned brackets, and the values were transmitted to a computer.

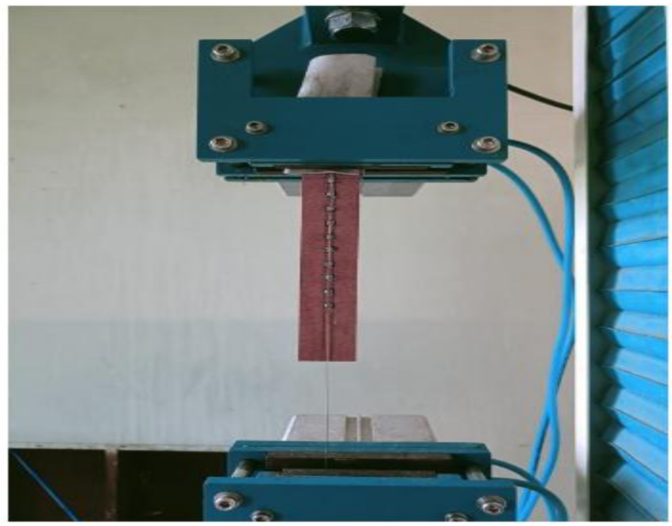


Figure 1: The fixture and the wire placed in the upper and lower vice of the machine

Load values were calculated in Newtons (N) and converted to grams (gm). The data was analyzed to determine which ligation methods and brackets yielded the least resistance to sliding. All the data was collected by the computer connected to the Instron machine. The data was grouped, appropriate titles and trial numbers were placed. The mean values were compared by one-way ANOVA. Multiple range tests by Tukey-Kramer honest significant difference (HSD) procedures were employed to identify the significant groups, if p-value in one-way ANOVA is significant by using statistical software. In the present study, p-value of <0.006 was considered as the level of significance.

Statistical Analysis and Results

Descriptive statistics and the statistical comparisons between the forces released by the different wire / bracket/ligature combinations are reported in the following tables and graphs:

Table 1: One way ANOVA – Friction results of the experimental groups demonstrating mean and standard deviation with minimum and maximum values.

Descriptives								
FRICTION								
	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
LIGATURE	30	1192.51	157.99	28.85	800.03	1584.98	1101.29	1374.94
MODULE	30	501.21	228.49	41.72	-66.39	1068.82	259.59	713.80
SLIDE	30	404.39	223.08	40.73	-149.76	958.55	202.22	643.71

Graph 1: Comparison of friction of Ligature, Module and Slide ligatures.

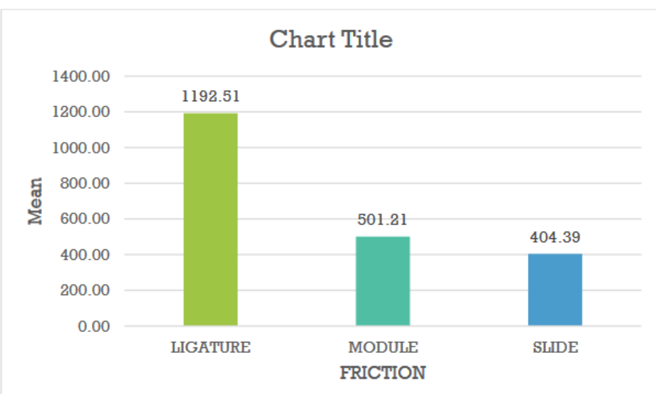
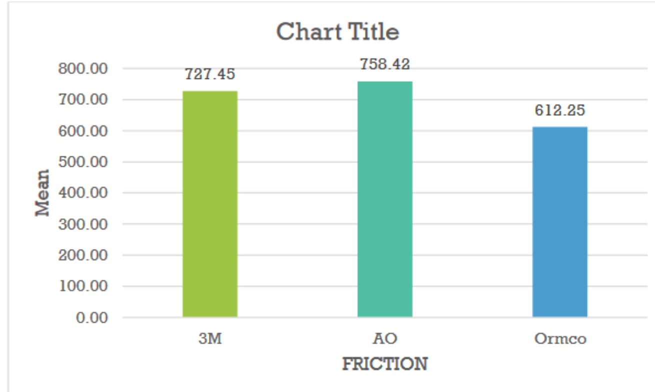


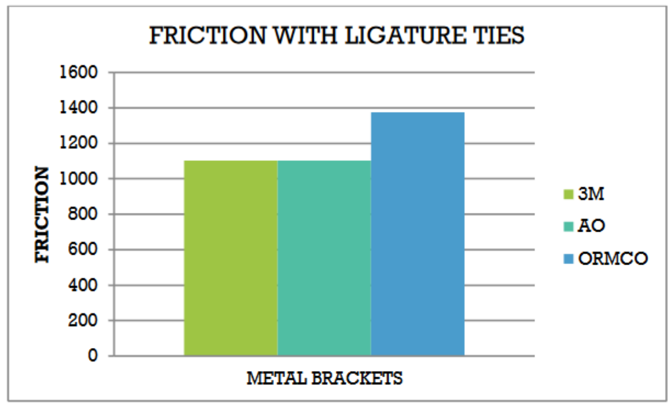
Table 2: One-way ANOVA – Friction results of the experimental groups demonstrating mean and standard deviation with minimum and maximum values.

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
3M	10	727.45	367.21	116.12	-184.75	1639.65	367.25	1101.29
AO	10	758.42	302.31	95.60	7.44	1509.39	530.25	1101.29
Ormco	10	612.25	661.13	209.07	-1030.09	2254.59	202.22	1374.94

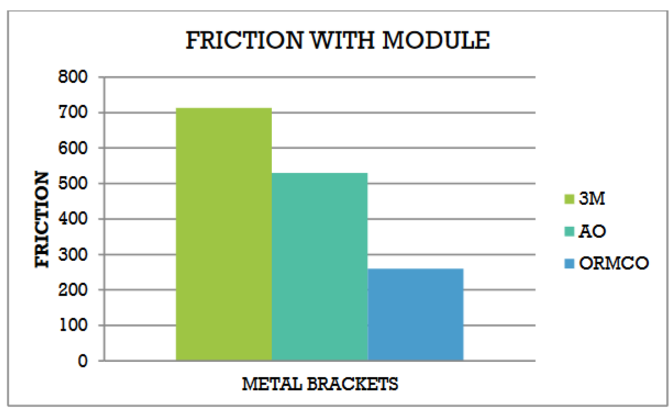
Graph 2: Comparison of friction in conventional metal brackets of various brands



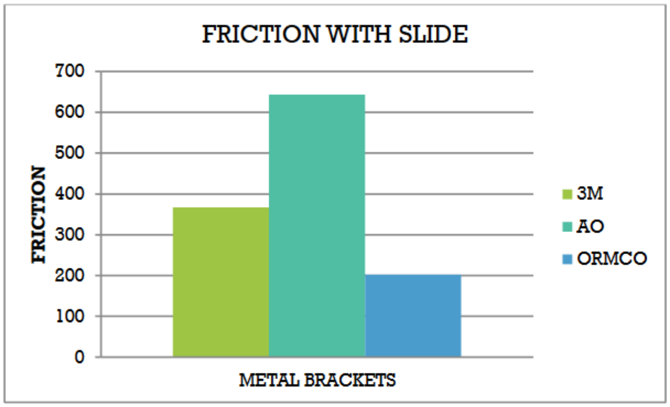
Graph 3: Comparison of friction in conventional metal brackets with ligature ties



Graph 4: Comparison of friction in conventional metal brackets with modules



Graph 5: Comparison of friction in conventional metal brackets with slide



Discussion

Force magnitude during orthodontic treatment will result in optimal tissue response and rapid tooth movement. During mechanotherapy involving movement of the wire along the brackets, friction at the bracket–arch wire interface might prevent optimal force levels in the supporting tissues.

An understanding of the forces required to overcome friction is important so that the appropriate magnitude of force can be used to produce optimal biological tooth movement. Friction reduces the efficiency of fixed appliances so that more force is required to achieve the desired result. However, low forces are considered desirable to conserve anchorage; they keep reciprocal forces low and facilitate release of binding forces between arch wires and brackets, facilitating sliding mechanics. In addition, low forces might increase patient comfort and reduce the risk of root resorption36. A combination of mechanical and chemical factors determines friction at the arch wire-bracket-ligature interface.

Optimal tooth movement with a fixed appliance requires the use of optimal forces that have to initially overcome the frictional resistance that is present between the wire, bracket and means of ligation. So the force applied is increased in order to compensate this resistance. From a clinical perspective, the aim is to keep the frictional forces as low as possible. Previous investigations have focused on the effect of changes in wire type or wire dimension as a means of reducing friction[35].

Resistance to sliding is the sum of classical frictional resistance and elastic binding, which increases linearly with increasing bracket/arch wire angulation, whereas the frictional resistance associated with the ligation force remains constant[37]. The relative magnitude of elastic binding and friction of ligation might thus vary according to the clinical situation, and components that predominate in the early stages of treatment might give way to others later[38].These factors are important when considering the clinical application of sliding mechanics, as they could influence friction. Reduction in friction can help shorten overall treatment time, especially in patients undergoing extractions where tooth translation is achieved by sliding mechanics.

Ligatures significantly exert friction by pressing the wire against the bracket. Frictional resistance at the binding unit caused by ligation has received limited attention in the literature. It has been proved in previous studies that elastic ligatures significantly contribute to friction compared to stainless steel ligatures and exert 50 gms to 150 gms of force at the time of seating[39]. Various methods have been used to reduce the friction of ligation, such as stainless steel ligatures [40], self ligating brackets[37], nonconventional ligation systems, self-ligating brackets have been designed with select accessories like clips or lock gates, which keep the arch wire in the slot, unlike conventional ligation, which is conducted with elastomeric or metallic ligatures. Stainless steel ligatures produce variable ligation forces and are time consuming to place. Some self-ligating bracket systems can lead to reduced treatment times and low frictional resistance as measured in the laboratory[37], but they are more costly.

Quest for finding various modalities to reduce friction at bracket archwire interface has brought in a different type of elastomeric ligatures namely Slide ligatures (Leone, Sesto Fiorentino). Slide ligatures (Leone, Sesto Fiorentino) introduced in 2005,are novel ligatures made of a special polyurethane mix contrived by the injection moulding technique with the claims of lowering the levels of friction during treatment mechanics using with pre-adjusted edgewise appliances . Designed to be used with conventional brackets, these special elastomeric ligatures are another resource geared at reducing classical friction. Their innovative design retains the orthodontic archwire without pressing it against the bottom of the slot. Upon insertion, the central body rests on the buccal surface of the bracket while the extensions are positioned under the tie-wings (fig 2).

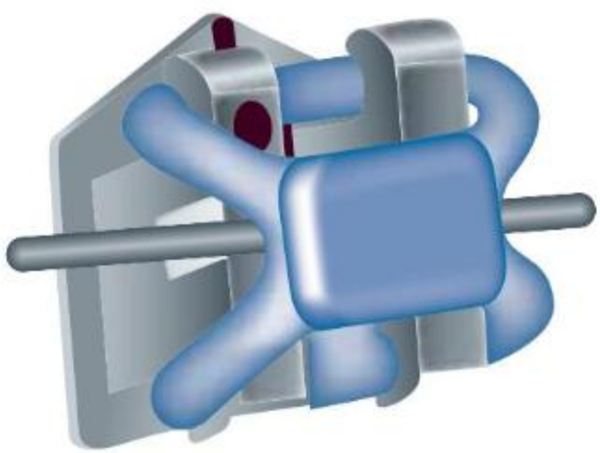


Figure 2: Slide ligatures: Frontal view. (Source: Catalog Leone Ortodonzia)

Figure 3: Slide ligatures: Side view. (Source: Catalog Leone Ortodonzia)

Previous in-vitro studies and a few clinical studies have shown that nonconventional elastomeric ligatures can reduce frictional resistance compared with conventional ligatures during initial leveling and aligning phase of orthodontic treatment [41,42]. According to the manufacturer. It can be applied in the same way as classical elastic ligatures and, once on the bracket, it self ligates on the slot leaving the wire free to slide and to act on the dentoalveolar structures. The ligature forms the fourth wall of the slot with its incisal and occlusal edge resting along the bucco-labial surface of the tie wings, permitting the bracket to slide over the arch wire while transmitting most of the tooth-moving forces to the surrounding dentoalveolar structures. Once applied on conventional brackets this ligature is completely passive, like the labial cover of passive Self-ligating brackets; thus, it guarantees the same freedom of sliding to the wire. Its particular form noticeably improves patient comfort during the first phases of treatment[44].

The purpose of this study was to compare the frictional forces generated by three methods of wire ligation by; elastomeric modules, conventional stainless steel ligatures, and Slide low-friction ligatures, using a especially custom-designed apparatus that included 10 brackets. The result obtained was incompliance with previous studies that indicated that the Slide low friction ligatures produce the least friction among the three and SS ligatures produced the most friction. Least friction was obtained in Slide ligation with Ormco brackets and highest friction in Ligature with Ormco brackets. The present experimental method gives a baseline to the clinician of the range of possible forces likely to be required to overcome friction in various arch wires/ bracket/ligating method combinations.

These results are supported in part by those of Kahlon et al[45] stated that both self-ligating brackets and the Leone slide ligature produced significantly less friction than conventional elastomeric modules. These fidings are similar to those found in the present study where the same bracket/ligation systems showed the same frictional force behaviour during the displacement of 0.019x0.025" steel arch wires. Clinical and experimental studies have shown better efficiency of nonconventional elastomeric ligatures in the alignment and levelling phase of orthodontic treatment[41,46,47].

On the basis of the results of the present study, the innovative elastomeric ligatures produce significantly lower levels of frictional forces than conventional elastomeric modules. The rate of canine retraction was more with Slide ligature module than with conventional module and super slick ligature in the given study period and method in previous studies. One of the most favourable features of the SLIDE nonconventional ligatures is the possibility of turning any type of existing conventional bracket system into a ''low-friction'' bracket system. Furthermore, these ligatures can be applied on specific groups of teeth where lower levels of friction are desired. Hence, in the age of low friction systems, slide ligature modules offer a promising solution to provide ligature with reduced friction during orthodontic treatment with better control of tooth position compared to conventional modules and metal ligature ties.

Conclusion

Friction restricts tooth movement and effort to reduce friction during orthodontic treatment is always explored. While ligation of arch wire to bracket is inevitable, the search to find better modes of ligation that would cause least friction and improve efficiency of tooth movements is on search. Nonconventional elastomeric modules have been introduced, with the claimed of causing least friction enabling more rapid alignment of teeth and faster space closure, while maintaining excellent control of tooth position including anchorage conservation. Since sufficient evidence to support their claim is lacking, this study was conducted to assess the efficiency of non-conventional ligature module as compared with the conventional ones.

In this in-vitro study, the friction generated in three different ligation methods that is metal ligatures, conventional elastomeric modules and SLIDE nonconventional elastomeric ligatures, was determined.

Within the limitations of an in-vitro study, the following conclusions are drawn:

- The friction generated by the slide nonconventional elastomeric ligatures was the least amongst all.
- The conventional elastomeric modules produced more friction when compared to Slide but less friction when compared with metal ligature ties.

- The metal ligature ties showed the highest friction amongst the three.
- The order of the friction generated in the three ligation methods are as follows :

Metal ligature ties > Conventional Elastomeric modules > Slid nonconventional elastomeric ligatures.

- The three different brands of conventional metal brackets that is American Orthodontics, Ormco and 3M did not show any significant difference in friction when compared with each other.

Also, the null hypothesis that there is no difference in frictional forces of Slide low friction ligatures and conventional ligating methods is rejected.

Hence, in the age of low friction systems, even though slide ligature modules offer a promising solution to provide ligature with reduced friction during orthodontic treatment with better control of tooth position compared to conventional modules. Still, further evidence based studies are essential, in order to evaluate definitively the clinical differences between non-conventional and conventional modules on orthodontic treatment.

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