The Effect of Various Ligation Methods on Friction in Sliding Mechanics

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ABSTRACT

Aim: To evaluate the effect of ligation method on friction and the efficacy of the new slick elastomeric modules (TP Orthodontics, USA) and slide elastomeric modules (Leone Orthodontics, Italy) which claim to reduce friction at the module/wire interface.

Materials and methods: Slick and slide modules were compared with regular modules, modules tied in figure of eight fashion, tight stainless steel ligatures, and loose stainless steel ligatures. Brackets used for the study were 0.022" × 0.028" maxillary first premolar twin brackets (MBT Prescription, Gemini series, 3M Unitek USA.) The effect of bracket width on friction produced with four different methods of ligation was also studied using 0.022" × 0.028" maxillary first premolar single width brackets (Alexander prescription, Leone Co. Italy).

Results: When considering tooth movement along a 0.019" × 0.025" in stainless steel archwire, Super slick module produce less friction when compared to regular module, module tied in ‘figure of 8’ pattern and tight SS ligation produced more friction when compared to loose SS ligation and slide module. Slide modules produce least friction when compared to other available methods of ligation. Modules tied in a ‘figure of 8’ pattern generate highest friction.

Conclusion: Slide modules produce least friction followed by loose SS ligation, slick modules, regular modules, tight SS ligation and highest friction was produced by regular modules tied in a ‘figure of 8’ pattern. Width of bracket had no influence on friction produced.

Keywords: Bracket archwire interface, Friction, Method of ligation.


INTRODUCTION

The word friction refers to the resistance to motion encountered when one solid body slides or tends to slide over another solid body. It may be described as force acting parallel to the direction of motion and opposing the motion. One of the most important factors which strongly determine the orthodontic tooth movement is friction between archwire and bracket. Friction is an important factor in all forms of sliding mechanics, such as space closure, canine retraction into an extraction site, and in leveling and alignment where the wire must slide through the brackets and tubes. Friction may exist in two forms as follows:

1. Static friction, which is the component of friction that has to be overcomed to initiate motion.
2. Dynamic friction, which is the component of frictional force that has to be overcomed to maintain motion. The static frictional force usually is somewhat higher than the dynamic frictional force.

The nature of friction in orthodontics is multifactorial, derived from both a multitude of mechanical and biological factors. Magnitude of friction depends on the amount of normal force pushing the two surfaces together which is decided by the method of ligation, the surface roughness and the nature of materials from which the surfaces are made.

The method of ligation is an important contributor to the frictional force generated at the bracket/archwire interface. Loosely tied stainless steel ligations are supposed to generate less friction. The new slick modules introduced by TP Orthodontics and slide modules introduced by Leone Orthodontics claim to reduce the friction when compared with the regular elastic modules. Self-ligating brackets have been reported to generate less friction than conventional brackets.

The effect of bracket width on friction has been controversial. Some studies have found that altering bracket width made no difference in friction. Whereas others have found that frictional resistance decreased as bracket width decreases. On the other hand, frictional resistance has also been reported to decrease with increase in bracket width.

Baker et al using an artificial saliva substitute, found a 15 to 19% reduction in friction. While some of the studies showed that the coefficient of friction in the wet state is increased. Saliva could have lubricous as well as adhesive behavior, depending on which archwire bracket combination was under consideration.

This study was undertaken to evaluate factors causing friction in sliding mechanics. The effect of different ligation methods and different widths of brackets on friction in presence of saliva were examined.
MATERIALS AND METHODS

A 0.019" × 0.025" straight length stainless steel archwire piece of 7 cm length was used as it is the recommended size for sliding mechanics with 0.022" slot preadjusted edgewise brackets.

A 0.018 inch round stainless steel wire loop was used to pull the bracket over the test distance of 10 mm.

Brackets used were 0.022" × 0.028" maxillary first premolar twin brackets (–7º torque and 0º tip, MBT Prescription, Gemini series, 3M Unitek USA) and 0.022" × 0.028” maxillary first premolar single width brackets (–6º torque and 0º tip, Alexander Prescription, Leone Co, Italy).

The following ligation materials were used (Fig. 1):
1. Tight stainless steel ligature–0.010 inch.
2. Loose stainless steel ligature–0.010 inch.
3. Regular elastic modules (Ormco, USA)
4. Super slick elastic modules (TP Orthodontics, USA).
5. ‘Figure of 8’ elastic module ligation (Ormco, USA)
6. Slide elastic modules (Leone Orthodontics, Italy).

A custom-made apparatus was constructed to hold the bracket-wire assembly parallel to the vertical framework of the universal strength testing machine. Artificial saliva that has been used by various authors to create wet conditions was used in this study to simulate the oral environment while performing the test.

Test Groups

The sample was divided into two Groups A and B. Group A was further divided into six subgroups which consisted of twin bracket along with six different ligation methods.

Group A – Twin Bracket 0.022" × 0.028" Slot

A1. Gemini brackets with tight stainless steel ligature tie
A2. Gemini brackets with loose stainless steel ligature tie
A3. Gemini bracket with regular modules tie
A4. Gemini bracket with super slick modules tie
A5. Gemini bracket with ‘figure of 8’ modules tie
A6. Gemini bracket with slide modules tie

Group B was also divided into four subgroups which consisted of single width brackets along with four different ligation methods.

Group B – Single Width Bracket 0.022" × 0.028 Slot

B1. Alexander brackets with tight stainless steel ligature tie
B2. Alexander brackets with loose stainless steel ligature tie
B3. Alexander bracket with regular modules tie
B4. Alexander bracket with super slick modules tie

Tests were performed on Instron machine (Fig. 2) with a crosshead speed of 20 mm/min over a 10 mm stretch of archwire. The lower end of each test unit was attached to a heavy base block on the lower crosshead of the testing machine. A 2 mm right-angle bend in the archwire allowed for freedom of rotational movement, this ensured that the bracket and wire specimens could self-align during test run, allowing tip and torque to be effectively eliminated as variables so that the effect of ligation method on friction could be studied in isolation.

The base block was positioned on the machine with a permanent guide mark to aid in alignment. The bracket was pulled in a vertical direction by a loop of 0.018 inch stainless steel wire which was fixed to the upper arm of machine. Ten readings were taken per subgroup.

The force required for initiating movement of the bracket over the wire was measured as static friction. This was represented on the graph as the first peak during the test run. The force required for maintaining the movement over the 10 mm stretch was recorded as kinetic friction. This was measured as the mean value on the graph from 1 to 10 mm distance during the test run. Initially, the means and standard deviations for all the values in each group were calculated (Fig. 3). Analysis of variance (ANOVA) was applied to
determine the variance in groups with different ligation methods. T-test was performed for locating any differences between the static and kinetic friction values within each group and for comparing the values between single width and twin brackets. For all the tests a p-value of 0.05 or less was considered for statistical significance.

**RESULTS**

Table 1 and Figure 3 show mean static and kinetic frictional force of twin bracket with various methods of ligation. It was observed that ‘figure of 8’ method of ligation produced highest values of static and kinetic friction followed by tight SS ligation, regular module, super slick module, loose SS ligation and the least friction was produced by slide module.

In Table 2 and Figure 3 mean static and kinetic frictional force of single width bracket with various methods of ligation is shown. It was observed that tight SS ligation produced highest values of static and kinetic friction followed by regular module, super slick module and the least friction was produced by loose SS method of ligation.

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Method of ligation</th>
<th>Type of friction</th>
<th>N</th>
<th>Mean (N) Std. dev. (N)</th>
</tr>
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<tbody>
<tr>
<td>1</td>
<td>Fig. of 8</td>
<td>Static</td>
<td>10</td>
<td>3.4220 0.5445</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Kinetic</td>
<td></td>
<td>2.4270 0.3819</td>
</tr>
<tr>
<td>2</td>
<td>Loose SS</td>
<td>Static</td>
<td>10</td>
<td>0.0660 0.0347</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Kinetic</td>
<td></td>
<td>0.0590 0.0223</td>
</tr>
<tr>
<td>3</td>
<td>Regular</td>
<td>Static</td>
<td>10</td>
<td>1.7890 0.1215</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Kinetic</td>
<td></td>
<td>1.1780 0.1054</td>
</tr>
<tr>
<td>4</td>
<td>Slick</td>
<td>Static</td>
<td>10</td>
<td>0.5230 0.1365</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Kinetic</td>
<td></td>
<td>0.5690 0.1189</td>
</tr>
<tr>
<td>5</td>
<td>Slide</td>
<td>Static</td>
<td>10</td>
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</tr>
<tr>
<td></td>
<td></td>
<td>Kinetic</td>
<td></td>
<td>0.0058 0.0108</td>
</tr>
<tr>
<td>6</td>
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<td>Static</td>
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<td></td>
<td></td>
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<td></td>
<td>60</td>
<td>1.3097 1.2739</td>
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<tr>
<td></td>
<td>Kinetic</td>
<td></td>
<td></td>
<td>1.0591 1.0005</td>
</tr>
</tbody>
</table>

The Table 3 shows that the static friction is significantly greater than the kinetic friction, the p-value for significance being 0.002.

The Table 4 is showing the mean values and standard deviations for static and kinetic friction produced with both single and twin brackets using four methods of ligation.

In Table 5 the comparison of width of the two brackets as a factor affecting friction using independent t-test is shown. It was found that the width of the bracket had no significant effect on friction produced whether static or kinetic. For static friction the p-value of significance was 0.983 and for kinetic friction the value was 0.493, both of them above the 95% confidence level showing no statistical significance.
DISCUSSION

One of the most important factors which strongly determine the orthodontic tooth movement is friction between archwire and bracket interface. Fixed appliances used for orthodontic tooth movement are always associated with generation of friction between the bracket-wire interface. It has been proven in previous studies that the material properties of the bracket, wire, ligature and the amount of force by which the archwire is pressed against the bracket play an important role in the amount of friction generated. Tooth movement can occur only when tooth moving forces adequately overcome the friction at the bracket-wire interface. For these reasons there is a continuous search for methods to reduce friction while tooth movement is taking place.

When ligating the archwire to the bracket; friction produced by different methods varies because of different material properties and differences in the amount of force pushing the archwire against the slot surface. The first law of friction states that the frictional force produced is directly proportional to the amount of ‘normal’ force which is the force produced by the ligation in the case of tooth movement.

Loose Stainless Steel Ligation

In the present study, it was observed that friction for loose stainless steel ligation was significantly lesser than regular modules. Hain et al.3 and Bednar et al.10 in their study found similar results with loose SS ligation and with regular modules. Taylor et al.11 and Kambay et al.12 also found loosely tied stainless steel ligatures to produce less friction when compared to alastik elastomeric ligatures. However, Frank et al.5 and Thorstenson13,14 found no significant difference between loose stainless steel and elastomeric ligation methods.

Tight Stainless Steel Ligation

Higher values of both static and kinetic friction for tight SS ligation were observed than for regular as well as loose SS ligation. Similar observations were also made by Iwasaki et al.10 and Taylor et al.11 in their studies where they found tight SS ligation to produce higher frictional values when compared with loose SS ligation and regular elastomeric ligatures.

‘Figure of 8’ Ligation

In the present study, highest friction with ‘figure of 8’ method of ligation was observed. Similar observations were made by Hain et al.3 who found that the regular module tied in a ‘figure of 8’ pattern produced highest friction. This can be explained on the basis of three point contact between module and archwire as well as increased stretching of module causing the normal force to increase, which in turn pushes the archwire more firmly against the bracket slot.

Super Slick Module

In the present study the ‘super slick’ modules showed lesser friction than tight stainless steel ligation, regular elastomeric ligatures tied normally and in ‘figure of 8’ pattern but produced more friction when compared to loose stainless steel ligation and slide modules. Hain et al.3 found the recent ‘super slick’ modules introduced by TP Orthodontics which produces less friction when compared to the regular counterparts. However, Griffith et al.15 compared ‘super slick’ modules with round and rectangular modules and found that slick modules produced frictional forces more than the regular round modules but less than the rectangular modules. In another study Kambay et al.12 found the friction to be greatest with slick modules when compared with loose stainless steel ligation and Alastik modules. The differences in values might be because of differences in test apparatus of these studies and because of different inner diameters of modules.

Reduction in friction caused by slick modules has been explained on the basis of a polymeric coating on the module surface, which upon interaction with saliva becomes slippery and reduces friction at the archwire-bracket interface.

Slide Module

The present study showed that the friction was significantly less with this method of ligation. Slide modules produced least amount of friction when compared to all other methods of ligation. The values obtained were negligible when compared to other ligation methods. Baccetti and Franchi16 also found that the slide ligatures produced significantly lower levels of friction when compared with conventional elastomeric modules. This can be explained on the basis of absence of normal force pushing the wire into the slot resulting in minimum friction at bracket-wire interface.

Width of Brackets

Contradictory findings have been reported regarding the effect of the bracket width on the frictional force.

Drescher et al.6 Tidy17 and Bednar et al.10 found in their studies that friction increases with decrease in bracket width. However, Kapila et al.18 and Frank et al.5 found increased friction with increase in bracket width. In the present study no
significant difference was observed in frictional values obtained between single width and twin brackets. This confirms that the width of bracket slot does not have any significant influence on the friction produced between bracket and archwire. Yamaguchi and Nanda in their study found that at low bracket-wire angulations narrow brackets produced lower friction than wide brackets but as the angulations increased narrow brackets produced higher friction than the wide brackets.

**Static and Kinetic Friction**

The present study showed static friction to be significantly greater than the kinetic friction. Cacciafesta et al, Taylor et al, Kapur et al also found similar results with the static friction force always higher than dynamic friction.

The results obtained in the present study showed that the slide modules introduced by Leone Orthodontics reduce friction significantly at the archwire-bracket interface. This could be very useful in the initial alignment and leveling stage of treatment when the clinician wants minimum friction and full engagement of archwire in the bracket slot is not required. The low friction slide modules can reduce the tissue damage, patient discomfort and treatment time considerably. However for rotation correction the slide module will not be effective as it does not apply any force on the archwire.

For full rotation correction and in the later stages of treatment when the clinician wants full engagement of archwire, module tied in a ‘figure of 8’ pattern or tight SS ligation can be used for proper tip and torque expression in a preadjusted edgewise appliance system.

**CONCLUSION**

When planning for orthodontic tooth movement clinician should select the proper combination of bracket and ligation method to reduce the friction and increase the efficiency of the appliance. Newly introduced slide modules produced least friction when compared to other available methods of ligation. Super slick module introduced by TP Orthodontics produce less friction when compared to regular module, regular module tied in ‘figure of 8’ pattern and tight SS ligation but more friction when compared to loose SS ligation and slide module. Modules tied in a ‘figure of 8’ pattern generated highest friction because of increased amount of normal force pushing the archwire against the bracket slot. ‘Figure of 8’ modules can be used in the final phase of treatment when full engagement of archwire in the bracket slot is necessary for proper tip and torque expression. Static frictional force was observed to be more than dynamic friction. It can be concluded that use of either single width or twin bracket will not make much of a difference in friction produced at the archwire-bracket interface, while performing sliding mechanics.

**REFERENCES**