Friction Determination between Passive and Interactive Self-Ligating Brackets

Yash Raj Bahadur, DK Agarwal, Ankur Gupta, Arihant Jain

ABSTRACT

Introduction: Self-ligating brackets are claimed to eliminate or minimize the force of ligation at the bracket-wire interface; therefore, it is imperative to evaluate the frictional features of self-ligating brackets with different archwires.

Materials and methods: This in vitro study compared the effects of 0.018" and 0.019" x 0.025" stainless steel wires and 0.019" x 0.025" teflon-coated stainless steel wire on frictional forces of 0.022" slots passive and interactive self-ligating brackets. Friction was evaluated in a passive configuration on a universal testing machine. The static and kinetic friction data were analyzed with Wilcoxon signed-rank test.

Results: The interactive self-ligating brackets generated more friction with every wire used. However, the 0.018" stainless steel wires generated no friction. Also, the teflon-coated wire generated lesser friction as compared to uncoated wire.

Conclusion: The passive self-ligating brackets have been found to produce lesser friction than the interactive self-ligating brackets.

Keywords: Self-ligating brackets, Archwires, Friction, Teflon-coated, Stainless steel.

INTRODUCTION

The concept of friction or tribology has an important role in day to day orthodontic practice. It is considered as the evil of all motions as far as orthodontics is concerned. Friction is defined as a force tangential to the common boundary of two bodies in contact that resists the motion or tendency to motion of one relative to the other. The efficiency of fixed appliance therapy depends on the fraction of force delivered with respect to the force applied; hence, high frictional forces due to the interaction between the bracket and the guiding archwire affect treatment outcomes and duration in a negative manner.

MATERIALS AND METHODS

A custom-made apparatus was constructed to record the resistance to movement of 8 mm long 0.018" stainless steel (3M Unitek), 0.019" x 0.025" stainless steel (3M Unitek) and 0.019" x 0.025" teflon-coated stainless steel (Spectra, GAC Dentsply) working archwires through test brackets. Two types of maxillary premolar brackets were used which were grouped as:

- Group 1: Interactive self-ligating ceramic bracket (In-Ovation C, GAC Dentsply).
- Group 2: Passive self-ligating ceramic bracket ( Damon Clear, Ormco).

Testing was done with a universal testing machine, Instron 3382 (USA) with a 100 N load cell and crosshead speed of 10 mm/min (Fig. 1). The readings were recorded on Instron Bluehill Software Ver. 2.21.

The brackets and archwire were cleaned with an alcohol wipe before performing the tests. Lower end of
that the bracket and archwire specimens could self-align during a 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 sample was arranged parallel to the vertical framework of the machine. The bracket was then pulled in a vertical direction by a loop of 0.018” stainless steel wire which was fixed at upper jaw of machine (Fig. 3). The force required for initiating and maintaining movement of the bracket over an 8 mm test distance was recorded. Each bracket and archwire were used for 10 tests and, after 10 tests, the sample was changed.  

The static frictional force was measured as the initial rise or peak force required to initiate movement of the wire through the bracket and then halved. The drawing force required to maintain movement beyond the point of initial displacement was averaged and then halved and recorded as the kinetic friction. Data were obtained at a rate of 5 readings per second.  

Statistical Analysis

Descriptive data that included mean and standard deviation were determined for all the groups separately and together, and were used for comparison between groups. The data obtained were analyzed using Microsoft Excel SPSS 10.0 version.

The comparison of data obtained for various bracket archwire groups was done by Wilcoxon signed-rank test to determine the effect of bracket type archwire combination in paired variables.

RESULTS

This was an \textit{in vitro} study done to compare the static and dynamic frictional forces among two types of brackets and archwires. The results obtained are shown in Tables 1 to 4.

DISCUSSION

Friction is a function of the relative roughness of two surfaces in contact. It is the force that resists the movement of one surface past another and acts in a direction opposite the direction of movement.  

The present day scenario in orthodontics emphasizes the esthetic properties of ceramic brackets. However, the increased frictional resistance generated by the ceramic brackets diminish their effectiveness in clinical use. Hence, the ceramic self-ligating brackets were introduced to combine the superior esthetics of ceramic brackets with the reduced friction of the self-ligating brackets.  

The 0.018” round and 0.019” × 0.025” rectangular wires are used in the present study to assess the effect of wires of different cross-sections and sizes on the
Table 1: Comparison of static and kinetic frictional forces in group 1

<table>
<thead>
<tr>
<th>Wire</th>
<th>Static Mean (gm)</th>
<th>Static SD (gm)</th>
<th>Kinetic Mean (gm)</th>
<th>Kinetic SD (gm)</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.018&quot;</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>0.019&quot; x 0.025&quot;</td>
<td>45.87</td>
<td>3.92</td>
<td>43.4</td>
<td>4.04</td>
<td>Z = -13.457, p = 0.00 HS</td>
</tr>
<tr>
<td>Teflon-coated</td>
<td>34.09</td>
<td>3.62</td>
<td>32.39</td>
<td>9.27</td>
<td>Z = -13.207, p = 0.00 HS</td>
</tr>
</tbody>
</table>

HS: Highly significant

Table 2: Comparison of static and kinetic frictional forces in group 2

<table>
<thead>
<tr>
<th>Wire</th>
<th>Static Mean (gm)</th>
<th>Static SD (gm)</th>
<th>Kinetic Mean (gm)</th>
<th>Kinetic SD (gm)</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.018</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>0.019&quot; x 0.025&quot;</td>
<td>5.9</td>
<td>2.24</td>
<td>3.59</td>
<td>2.38</td>
<td>Z = -4.573, p = 0.00 HS</td>
</tr>
<tr>
<td>Teflon-coated</td>
<td>5.31</td>
<td>2.19</td>
<td>3.35</td>
<td>2.1</td>
<td>Z = -4.372, p = 0.00 HS</td>
</tr>
</tbody>
</table>

HS: Highly significant

Table 3: Comparison of kinetic frictional force between the two groups

| Brackets | Archwires
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>0.018&quot; SS</td>
<td>0.019&quot; x 0.025&quot;</td>
<td>0.019&quot; x 0.025&quot;</td>
<td>uncoated SS</td>
<td>Teflon-coated SS</td>
</tr>
<tr>
<td>Mean (gm)</td>
<td>Mean (gm)</td>
<td>Mean (gm)</td>
<td>SD (gm)</td>
<td>SD (gm)</td>
</tr>
<tr>
<td>Group 1</td>
<td>43.4</td>
<td>4.04</td>
<td>32.39</td>
<td>9.27</td>
</tr>
<tr>
<td>Group 2</td>
<td>3.59</td>
<td>2.38</td>
<td>3.35</td>
<td>2.1</td>
</tr>
<tr>
<td>1 vs 2</td>
<td>Z = -1.021</td>
<td>Z = -3.745</td>
<td>p = 0.00 HS</td>
<td>p = 0.00 HS</td>
</tr>
</tbody>
</table>

HS: Highly significant

Table 4: Comparison of static frictional force between the two groups

| Brackets | Archwires
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
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</tr>
</thead>
<tbody>
<tr>
<td>0.018&quot; SS</td>
<td>0.019&quot; x 0.025&quot;</td>
<td>0.019&quot; x 0.025&quot;</td>
<td>uncoated SS</td>
<td>Teflon-coated SS</td>
</tr>
<tr>
<td>Mean (gm)</td>
<td>Mean (gm)</td>
<td>Mean (gm)</td>
<td>SD (gm)</td>
<td>SD (gm)</td>
</tr>
<tr>
<td>Group 1</td>
<td>45.87</td>
<td>3.92</td>
<td>34.09</td>
<td>3.62</td>
</tr>
<tr>
<td>Group 2</td>
<td>5.9</td>
<td>2.24</td>
<td>5.31</td>
<td>2.19</td>
</tr>
<tr>
<td>1 vs 2 (Wilcoxon signed-rank test)</td>
<td>Z = -10.973</td>
<td>Z = -9.137</td>
<td>p = 0.00 HS</td>
<td>p = 0.00 HS</td>
</tr>
</tbody>
</table>

HS: Highly significant

Frictional forces generated in different brackets. Teflon or polytetrafluoroethylene is a material characterized by a completely fluoridated chain. It is an anti-adherent and esthetic material that has excellent chemical inertia as well as good mechanical stability. Teflon coating of wire results in improved esthetics and frictional losses ranging from 22.2 to 6.1%.

In the present study, when group 1 was considered in relation to the various archwires, no frictional force was generated with the 0.018" SS wire. However, highly significant difference was seen when comparing the static and kinetic frictional forces generated with 0.019" x 0.025" teflon-coated and uncoated SS archwire. The maximum static and kinetic frictional force was observed with the uncoated stainless steel archwire. These results are in acceptance with studies conducted by Singh et al.\cite{12} Farronato et al.\cite{11} and Brauchli et al.\cite{13} who stated that passive and interactive self-ligating brackets do not show any clinically relevant resistance to sliding with round wires which considerably increases when rectangular wires are used (Graph 1).
Similarly, when group 2 was considered in relation to the various archwires, no frictional force was generated with the 0.018” SS wire and highly significant differences were seen when comparing the static and kinetic frictional forces generated with 0.019” × 0.025” teflon-coated and uncoated SS archwire with maximum frictional forces being generated with 0.019” × 0.025” uncoated SS wire. These results are in accordance with studies conducted by Singh et al,12 Farronato et al,11 Oliver et al10 and Brauchli et al13 who claimed that passive self-ligating brackets generate extremely low frictional resistance to sliding even with wires of large dimensions (0.019” × 0.025”) and when 0.018” wires were used, no clinically relevant frictional forces were observed (Graph 2).

When considering the 0.018” SS archwire, no frictional forces were generated with groups 1 and 2. Group 1 bracket behaved similarly to group 2 brackets with the small dimension wire. Our findings are in accordance with studies conducted by Singh et al12, Farronato et al11 and Brauchli et al13 who stated that the active and interactive self-ligating brackets do not demonstrate any frictional forces with 0.018” SS wires and their conventional counterparts generated considerable frictional forces (Graphs 3 and 4).

The group 2 demonstrated levels of friction that were considerably lower than that of the group 1 during sliding mechanics with the 0.019” × 0.025” rectangular wire. The static and kinetic frictional forces exerted by group 2 were minimal when compared with group 1. These results are in accordance with studies conducted by Singh et al,12 Kannan et al,14 Brauchli et al13 Oliver et al10 Cacciafesta et al5 and Stefanos et al8 who stated that interactive self-ligating brackets have higher static and kinetic frictional forces compared with passive self-ligating brackets when coupled with 0.019” × 0.025” SS wires (see Graphs 3 and 4).

When frictional forces were assessed during sliding mechanics with 0.019” × 0.025” teflon-coated SS wire, it was found that the group 2 demonstrated less frictional force than by the group 1. These findings are in conjunction with the findings reported by Farronato et al11 who reported that teflon-coated archwires produce lower frictional levels than their corresponding uncoated archwires (see Graphs 3 and 4).

The friction values, when using 0.019” × 0.025” SS archwires, were more for all the groups when compared to the values with 0.018” SS wires. This correlates with studies done by Singh et al12 and Tecco et al15 that all brackets show higher frictional forces as the wire size is increased (see Graphs 3 and 4).

Our study indicates that the friction generated by teflon-coated 0.019” × 0.025” SS archwire is lesser as compared to uncoated 0.019” × 0.025” SS archwire. This has also been reported by the study conducted by Farronato et al11 stating that teflon-coated archwires produce lower frictional levels than their corresponding uncoated archwires.

The present study showed that the static friction was higher as compared to the kinetic friction in all the brackets and archwire combinations. Highly significant differences were seen in the results of the present study when comparing the static and kinetic frictional force in the group 1 and group 2. This is in accordance with studies conducted by Stefanos et al8 Krishnan et al,16 Cacciafesta et al5 Downing et al17 and Kusy et al18 who stated that the static friction will always be more than the kinetic friction irrespective of the bracket or archwire combination used (see Graphs 1 and 2).

CONCLUSION

It was concluded from the present study:
1. No friction is generated when 0.018” SS wires are used with self-ligating ceramic brackets. However, frictional
force increases when 0.019” × 0.025” wire is used, irrespective of the bracket type being used.
2. The passive self-ligating ceramic brackets produce lesser friction as compared to the interactive self-ligating brackets.
3. Teflon-coated SS wires produce less friction as compared to its uncoated counterpart.
4. The static friction is always more as compared to the kinetic friction for all the bracket types tested.
5. The interactive self-ligating brackets comply with the manufacturer claims of behaving as passive self-ligating brackets when smaller dimension archwires are used and as active self-ligating bracket when larger archwires used.

REFERENCES