Original Article

Friction of Conventional and Self-Ligating Brackets Using a 10 Bracket Model

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Abstract: The friction generated by various bracket-archwire combinations previously has been studied using in vitro testing models that included only one or three brackets. This study was performed using a specially designed apparatus that included 10 aligned brackets to compare the frictional resistance generated by conventional stainless steel brackets, self-ligating Damon SL II brackets and Time Plus brackets coupled with stainless steel, nickel-titanium and beta-titanium archwires. All brackets had a 0.022-inch slot, and five different sizes of orthodontic wire alloys used. Each bracket-archwire combination was tested 10 times, and each test was performed with a new bracket-wire sample. Time Plus self-ligating brackets generated significantly lower friction than both the Damon SL II self-ligating brackets and Victory brackets. However, the analysis of the various bracket-archwire combinations showed that Damon SL II brackets generated significantly lower friction than the other brackets when tested with round wires and significantly higher friction than Time Plus when tested with rectangular archwires. Beta-titanium archwires generated higher frictional resistances than the other archwires. All brackets showed higher frictional forces as the wire size increased. These findings suggest that the use of an in vitro testing model that includes 10 brackets can give additional interesting information about the frictional force of the various bracket-archwires combinations to the clinician and the research worker. (*Angle Orthod* 2005;75:1041–1045.)

Key Words: Frictional resistance; Conventional brackets; Self-ligating brackets; Archwires

INTRODUCTION

Friction is the resistance to motion when an object moves tangential against another.[1,2] In orthodontics, many studies have used experimental testing models that included only one or three brackets to evaluate the factors that influence frictional resistance between the brackets and the archwire.[2–6] These studies showed that the more important factors involved in the determination of the frictional level were bracket and wire materials, surface conditions of archwires and bracket slot, wire section, torque at the wire-bracket interface, type and force of ligation, use of self-ligating brackets, interbracket distance, saliva, and influence of oral functions.[2–6] Consequently, because these factors could influence friction, they are critically important when considering the clinical application of sliding mechanics. Such a reduction in friction can help shorten overall treatment time, especially in extraction patients where tooth translation is achieved by sliding mechanics.[2]

However, low friction also may be desired during the orthodontic phase of alignment, when all the teeth move at the same time and the wire slides through 10 brackets and two tubes. However, to date, no studies have evaluated the total friction produced by various bracket-archwires combinations in a testing model that includes 10 brackets simulating the alignment phase.

Self-ligating brackets, introduced in the mid-1930s,[7–9] are ligature-less bracket systems that have a mechanical device built into the bracket to close off the edgewise slot.[2] They are generally smoother for the patients because of the absence of wire ligature[10] and also do not require as much chair time.[11] Several studies have

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demonstrated a significant decrease in friction with self-ligating brackets, as compared with conventional bracket designs.[12–17]

The purpose of this study was to compare the frictional forces generated by three types of brackets (conventional stainless steel brackets and two types of stainless steel self-ligating brackets), using an especially custom-designed apparatus that included 10 brackets. In this investigation, we compared self-ligating brackets and conventional brackets because the study of the mechanical properties of self-ligating brackets is increasingly of interest. As Schumacher et al[7] stated, friction is determined mostly by the nature of the ligation.

MATERIAL AND METHODS

Mechanical tests

The testing model (manufactured by Myrmex Laboratory, Foggia, Italy) was composed of a metal bar, approximately 10 cm long, 3.5 cm wide, and one cm thick. On one of the larger surfaces of this metal bar, 10 brackets (to represent the upper right to the upper left second bicuspid) were bonded by the same technician, Ugo Comparelli. All 10 brackets were mounted in alignment with the others using a cyanoacrylate adhesive (Loctite 416, Loctite Corp, Rocky Hill, Conn). The model was made 30 times, using each of the three types of brackets, Damon SL II (SDS, Ormco, Glendora, Calif), Victory (Victory Series, 3M Unitek, Monrovia, Calif), and Time Plus (American Orthodontics, Sheboygan, Wis) 10 times (Figure 1). Each model was inspected for general appropriateness by the senior author (Dr D'Attillo) before it was selected for frictional evaluations.

Conventional brackets were ligated with elastic modules (Ligature Ringlet, RMO, Denver, Colo). One minute was allotted for ligation of elastic modules, followed by a three-minute waiting period to allow a reproducible amount of stress relaxation to occur.

Three types of archwires, nickel-titanium (NiTi, SDS, Ormco), stainless steel (SS) and beta-titanium (TMA) of three different sizes of cross sections (0.016, 0.017 $\times$ 0.025, and 0.019 $\times$ 0.025 inch) were selected as representative of the wires used in various stages of orthodontic treatment. All wires were tested with the self-ligating and conventional brackets. For every testing procedure, a new archwire was used.

The drawing force (P) value was evaluated 10 times for each archwire for. A total of 300 testing procedures were performed in this investigation. The tests were run in the dry state at an ambient temperature of 34°C.

For frictional evaluations, a mechanical testing machine (Model Lloyd 30K, Lloyd Instruments Ltd, Segensworth, UK) with a 10-lb tension load cell, set on a range of 1 lb, and calibrated from 0 to 1000 g was used (Figure 1). The archwires were gripped by crimping brass fittings onto the distal ends. It allowed sliding of the wire along the 10 brackets and recording of the frictional forces. A randomized sequence for each type of archwire was performed.

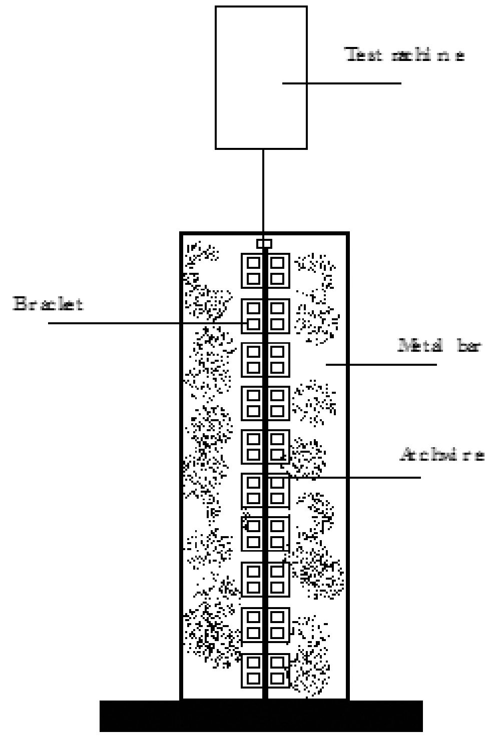

FIGURE 1. Testing model and mechanical testing machine.

The archwires were moved through all 10 brackets with a crosshead speed of 0.5 mm/min. Once archwire movement began, each run was approximately five minutes (two mm). Load values (P) were calculated in centinewtons (cN). After each test, the testing machine was stopped, the bracket-and-wire assembly removed, and a new assembly placed. This was done for 10 nonrepeated evaluations for each bracket-wire combination. The load cell registered the force levels needed to move the wire along the 10 aligned brackets, and the levels were transmitted to a computer.

Statistical analysis

Descriptive statistics, including the mean, standard deviation, minimum and maximum values were calculated for each bracket-archwire combination. For statistical analyses, a Kruskal-Wallis test was used to study the effects of all the various bracket-archwire combinations. For the post hoc test, a Mann-Whitney *U*-test was used, and the Bonferroni adjustment was applied.

To understand better the main effects of bracket type, wire alloy, and cross-sectional size on the fric-

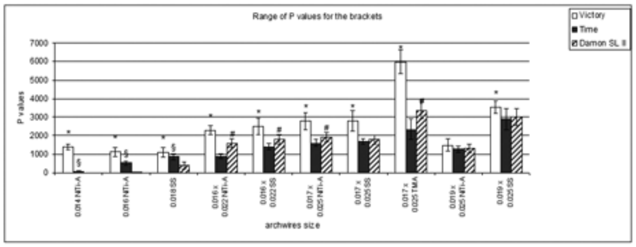

FIGURE 2. Means and standard deviations of *P* values for the various brackets-archwire combinations. The sign * indicates a significant higher *P* value of Victory brackets, compared with both Time and Damon SL II brackets; the sign § indicates a significant higher *P* value of Time brackets compared with Damon SL II brackets; the sign # indicates a significant higher *P* value of Damon SL II brackets compared with Time brackets.

TABLE 1. List of Self-ligating Brackets, Conventional Bracket, and Archwires

Self-ligating and Conventional Brackets[a]	Archwire[b] Nominal Dimension (mil) and Alloy
Damon SL II, SDS Ormco	0.014'' NiTi-A[cd]
Time, American Orthodontics	0.016'' NiTi-A[cd]
Victory, 3M Unitek	0.018'' Stainless Steel[e]
	0.016 × 0.022'' NiTi-A[cd]
	0.016 × 0.022'' Stainless Steel[e]
	0.017 × 0.025'' NiTi-A[cd]
	0.017 × 0.025'' Stainless Steel[e]
	0.017 × 0.025'' TMA[e]
	0.019 × 0.025'' NiTi-A[cd]
	0.019 × 0.025'' Stainless Steel[e]

[a] Bracket slot had nominal slot dimension of 22 mil.
[b] Investigators obtained archwires directly from the manufacturers.
[c] Nickel-titanium in the austenitic phase.
[d] RMO, Denver, Colo.
[e] Dentaurum, Pfarzheim, Germany.

tional resistance, the same tests were used among the three types of brackets using the various archwire sizes and various archwire alloys. According to this aim, three other statistical analyses were performed. Not significant values were defined as $P > .05$.

RESULTS

The descriptive statistics of frictional force (P) for each bracket-archwire combination are shown in Figure 2. The descriptive statistics that considered the main effects of bracket, archwire section, and archwire alloy are shown in Table 1.

The Kruskal-Wallis test showed a significant bracket effect ($P < .001$) (Table 2). Post hoc pairwise comparisons showed that the Time Plus brackets produced significantly lower frictional forces than the conventional stainless steel and Damon SL II brackets ($P < .05$) (Table 1). However, the differences between the two types of self-ligating brackets included: (1) when Damon SL II was coupled with 0.014 inch NiTi, 0.016 inch NiTi, and 0.018 inch SS, a significantly lower frictional force was recorded as compared with Time Plus brackets and the Victory brackets; (2) when Damon SL II was coupled with 0.016 × 0.022 inch NiTi, 0.016 × 0.022 inch SS, 0.017 × 0.025 inch NiTi, 0.017 × 0.025 inch SS, and 0.017 × 0.025 inch TMA, as compared with the Time Plus bracket with a statistically significant difference for 0.016 × 0.022 inch NiTi, 0.016 × 0.022 inch SS, 0.017 × 0.025 inch NiTi, and 0.017 × 0.025 TMA higher frictional forces were recorded (Figure 2).

TABLE 2. Descriptive Statistics (cN) with Significant Differences Evaluated Basing on Bracket Type, Wire Alloy and Wire Section

Variables	Mean	SD	Minimum	Maximum
Bracket				
Victory	2120.19*	±950	900	6100
Time	1483.4	±600	80	3800
Damon SL II	1777	±550	0	3700
Wire alloy				
NiTi-A	1220.126	±580	0	3250
SS	1983.75	±450	350	3700
TMA	3899.6*	±890	2100	6100
Wire size				
0.014''	493.3	±250	0	1600
0.016''	553.96	±340	15	1350
0.018''	786.3	±320	350	1200
0.016'' × 0.022''	1750*	±650	850	1950
0.017'' × 0.025''	2699.88*	±720	1300	6100
0.019'' × 0.025''	2251*	±560	900	3700

The Kruskal-Wallis test showed a significant alloy effect ($P < .001$) (Table 2). Post hoc pairwise comparisons showed that TMA wires produced significantly higher frictional force with all bracket types than did SS and NiTi (Table 1). No significant differences were found between NiTi and SS archwires in frictional force (Table 1). The frictional force observed by using Victory brackets and 0.017 × 0.025 inch TMA was the higher frictional force found in the present investigation (mean, 5979 ± 650 cN; range, 5100–6100 cN) and significantly higher than that for the Time Plus bracket and Damon SL II brackets (Figure 2). Between the two self-ligating brackets, Damon SL II generated a significant higher frictional force than Time Plus, when tested with 0.017 × 0.025 inch TMA (Figure 2).

A significant wire section effect ($P < .001$) was shown by Kruskal-Wallis test. Post hoc pairwise comparisons revealed that rectangular archwire produced significantly higher frictional forces with all bracket types than did the round archwire ($P < .05$). No statistically significant differences were found among the three different rectangular archwire (Table 2).

DISCUSSION

The proper force magnitude during orthodontic treatment will result in optimal tissue response and rapid tooth movement.[2] During mechanotherapy involving movement of the wire along the brackets, friction at the bracket-archwire interface might prevent attaining optimal force levels in the supporting tissues.[2] Therefore, an understanding of the forces required to overcome friction is important so that the appropriate magnitude of force can be used to produce optimal biologic tooth movement.[2] To elucidate the nature of friction between wire and bracket, several variables such as bracket material, wire alloy, and wire section should be studied.[2]

The results presented in this study showed that Time Plus brackets produced significantly lower frictional resistance than conventional stainless steel and Damon SL II self-ligating brackets. Our findings agree with those of previous studies that found that stainless steel self-ligating brackets generated lower frictional resistance than did conventional stainless steel brackets.[2,10,13,14,16–18]

However, in this study, we also observed a significant difference in frictional levels between Time Plus brackets and Damon SL II brackets (Table 1). This difference could be explained by the difference in structural design of each bracket body, in addition to the material composition of the bracket slot and cap.[10] However, it must be noted that Damon SL II brackets showed significantly lower frictional force than Time Plus brackets when tested with 0.014 inch NiTi, 0.016 inch NiTi, and 0.018 inch SS. On the other hand, when they were tested with 0.016 $\times$ 0.022 inch NiTi, 0.016 $\times$ 0.022 inch SS, 0.017 $\times$ 0.025 inch NiTi, and 0.017 $\times$ 0.025 inch TMA, they generated a significantly higher frictional force.

This study also showed that the wire alloy has a significant influence on friction. The TMA generated higher friction than both SS and NiTi for all bracket-archwire combinations. These findings confirm those reported in previous studies.[2,19–26] The adherence of the archwire material to the material of the slot during the experimental procedure could be a possible explanation.[2,27] However, no significant differences were found between NiTi archwire and SS archwire. This agrees with the findings of Loftus et al[19] and Cacciafesta et al.[2] However, previous studies, which compared the frictional force generated by SS and NiTi, found higher frictional forces with SS.[20] This variability is probably associated to differences in experimental settings, different number of brackets, or different angulation between bracket and wire, which in many studies is not zero.[28] Therefore, a direct comparison of the various published studies on this topic is complex.

Each of the two alloys showed higher frictional force values as the wire size increased (Table 2). Similar findings have been reported in many studies.*

This study was carried out under ideal conditions, in a passive frictional configuration, equivalent to that shown in previous reports.† Frictional investigations in an active configuration (with different bracket angulations) are still in progress. It will be useful in the future to compare those findings with those achieved in the passive state.

CONCLUSIONS

The findings of this investigation agree with those of other investigations, which used testing models with one or three brackets, suggesting that the two types of in vitro testing models are equally valid.

Time Plus self-ligating brackets (that have a spring clip that presses against the archwire) generated significantly lower friction than both Damon SL II self-ligating brackets. In these latter two brackets, the self-ligating clip does not press against the wire.

Conventional stainless steel brackets showed no significant differences between themselves.

The Damon SL II brackets generated significantly lower friction when coupled with round wires and significantly higher friction when coupled with rectangular archwires when compared with the other two types of brackets.

Beta-titanium archwires had higher frictional resistance than did stainless steel and nickel-titanium archwires. No significant differences were found between stainless steel and nickel-titanium archwires.

All brackets showed higher frictional forces as the wire size increased.

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