Evaluation of the Friction of Self-Ligating and Conventional Bracket Systems

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ABSTRACT

Objectives: This *in vitro* study evaluated the friction (F) generated by aligned stainless steel (SS) conventional brackets, self-ligating Damon MX© brackets (SDS Ormco, Glendora, California, USA), Time3© brackets (American Orthodontics, Sheboygan, Wisconsin, USA), Vision LP© brackets (American Orthodontics), and low-friction Slide© ligatures (Leone, Firenze, Italy) coupled with various SS, nickel-titanium (NiTi), and beta-titanium (TMA) archwires.

Methods: All brackets had a 0.022-inch slot, and the orthodontic archwires were 0.014-inch, 0.016-inch, 0.014×0.025-inch, 0.018×0.025-inch, and 0.019×0.025-inch NiTi; 0.017×0.025-inch TMA; and 0.019×0.025-inch SS. Each bracket-archwire combination was tested 10 times. In the test, 10 brackets of the same group were mounted in alignment on a metal bar. The archwires moved through all the 10 brackets at a crosshead speed of 0.5 mm/min (each run lasted approximately 5 min). The differences among 5 groups of brackets were analyzed through the Kruskal-Wallis test, and a Mann-Whitney test was calculated as post hoc analysis. The P value was set at 0.05.

Results: Coupled with 0.014-inch NiTi and 0.016-inch NiTi, Victory Series© brackets generated the greatest F, while Damon MX© and Vision LP© brackets generated the lowest ($P<.05$); no significant differences were observed between Time3© brackets and Slide© ligatures. Coupled with all the rectangular archwires, Victory Series© brackets, Slide© ligatures, and Vision LP© self-ligating brackets generated significantly lower F than did Time3© and Damon MX© self-ligating brackets ($P<.05$).

Conclusions: These findings suggest that self-ligating brackets are a family of brackets that, *in vitro*, can generate different levels of F when coupled with thin or thick, rectangular, or round archwires. Clinical conclusions based on our results are not possible due to the limitations of the experimental conditions. (Eur J Dent 2011;5:310-317)

Key words: Friction; Orthodontic brackets; Ligation.

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INTRODUCTION

In orthodontics, several studies have showed that bracket and wire materials, sections, surface conditions, type and force of ligation, use of self-ligating brackets, saliva, and other oral functions influence friction (F) at the archwire-slot interface.[1-10]

Self-ligating bracket[11-12] is a family of ligatureless brackets characterized by a metal device to close off the edgewise slot[2] that demonstrates a significant decrease in F compared to conventional brackets.[7,10,13-18]

Recently, new low-friction systems and self-ligating brackets were introduced in trading, with differentiated performances according to their manufacturers.

Among them, for example, there are low-friction ligatures (Slide©; Leone, Firenze, Italy), which are similar to conventional elastic ligatures, but have an anterior part that is more rigid and similar to the cap of self-ligating brackets; they are recommended when low F is desired, but they can be replaced when more F is needed. Then, there are also the recently introduced Vision LP© brackets (American Orthodontics, Sheboygan, Wisconsin, USA), which seem to generate low F even when thick rectangular archwires are employed. On the contrary, there are other recently introduced brackets, called Time3© brackets (American Orthodontics), which guarantee high F with thick rectangular archwires in order to better control dental torque.

According to the proper manufacturers, each of these brackets has different clinical indications and can be helpful in various situations in which different levels of F are needed. However, the literature lacks comparisons about F generated by the brackets. Thus, the aim of this *in vitro* study is to compare the F generated by these recently introduced self-ligating brackets, low-friction ligatures, and conventional stainless steel (SS) brackets.

The null hypothesis for this investigation was that there are no significant differences among the various self-ligating brackets and between the low-friction system and traditional system, in terms of F generated, when these brackets are coupled with the same type of archwire.

MATERIALS AND METHODS

Mechanical testing

In this investigation, we included passive, interactive, and conventional brackets, according to the classification introduced in literature by Voudouris.[19]

The brackets tested were:

(1) Damon MX© brackets (SDS Ormco, Glendora, California, USA) (passive),

(2) Time3© brackets (American Orthodontics) (interactive),

(3) Victory Series© brackets (3M Unitek, Monrovia, California, USA) ligated with Ligature Ringlet© elastic modules (RMO, Denver, Colorado, USA) (traditional),

(4) Victory Series© brackets (3M Unitek) ligated with Slide© low-friction ligatures (Leone) (conventional), and

(5) Vision LP© brackets (American Orthodontics) (passive).

The testing model (fabricated by Myrmex Laboratory, Foggia, Italy) was described in a previous investigation.[9] It was composed of a metal bar, approximately 10 cm long, 3.5 cm wide, and 1 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, Mr. Ugo Comparelli. Ten brackets of the same group were mounted in alignment on the metal bar using a cyanoacrylate adhesive (Loctite 416; Loctite Corp., Rocky Hill, Connecticut, USA). The number of procedures was calculated using a test for the calculation of sample numerosity on the basis of α value fixed at 0.05, considering the minimum detectable difference and the number of groups.

Alignment of the brackets was obtained through preliminary insertion of a 0.021×0.028-inch SS archwire into the slots of the brackets, without ligation. However, as minor misalignments of the brackets or non-linearity of the wire could not be controlled to estimate the extent to which the F could be attributed to misalignment rather than ligation, a preliminary confirmatory check was performed by measuring F for each bracket-archwire combination with only the terminal brackets ligated.

The models with only the terminal brackets ligated were compared with each other, and then, with the models with all the brackets ligated. The comparison among models with only the terminal brackets ligated is useful because if the comparison was among different types of brackets (with the same slot size) coupled with the same archwire but without any ligation except for the terminal brackets (ligated in order to obtain only the stabilization of the archwire along the slots), no differences would be observed among the brackets in terms of F, except if the brackets (of 1 type, with respect to another) were positioned in misalignments. In this case, the expectation is that the 10 misaligned brackets could generate a higher F with respect to the 10 brackets positioned in alignment.

In total, 25 testing models were constructed, *i.e.*, 5 models for each group of brackets (Victory Series©, Time3©, Damon MX©, Slide© ligatures, and Vision LP©). For each group, a single model was used 10 times to test the same bracket-archwire combination with all the brackets ligated and 10 times to test the same bracket-archwire combination with only the terminal brackets ligated.

The archwires tested were 0.014-inch, 0.016-inch, 0.014×0.025-inch, 0.018×0.025-inch, and 0.019×0.025-inch nickel-titanium (NiTi); 0.017×0.025-inch beta-titanium (TMA); and 0.019×0.025-inch SS (Table 1).

For each testing procedure, a new archwire was employed. The F values were evaluated for each archwire 10 times. The tests were run in dry state at an ambient temperature of 34°C maintained through the use of an air conditioner. For frictional evaluation, a mechanical testing machine (Model Lloyd 30K; Lloyd Instruments Ltd., Segensworth, UK) with a 10-lb tension load cell, set at a range of 1 lb and calibrated from 0 to 1000 g, was employed. The archwires moved through all the 10 brackets at a crosshead speed of 0.5 mm/min (each run lasted approximately 5 min). F was calculated as the mean of all the values recorded as the wire was drawn through the brackets. F was calculated in centiNewtons (cNs). A randomized sequence for each type of archwire was performed. The load cell registered the force levels needed to move the wire along the 10 aligned brackets, and these levels were transmitted to a computer.

Statistical analysis

Descriptive statistics were calculated for each bracket-archwire combination. Due to skewed data, nonparametric tests were used to investigate statistically significant differences in F among the groups. The data were analyzed as differences in F observed in the groups of archwires among the 5 groups of brackets with all the brackets ligated through the Kruskal-Wallis test; if the results of the Kruskal-Wallis test were significant, a Mann-Whitney test was performed as post hoc analysis to evaluate the significance of the differences among the groups.

In order to estimate the extent to which F could be attributed to the misalignment of brackets rather than to the type of ligation, a statistical comparison (Kruskal-Wallis test) was also performed on all the groups of brackets with only the terminal brackets ligated.

Finally, a Mann-Whitney test was performed on the data for all ligated brackets and the data for those with only the terminal brackets ligated; comparisons were made for each bracket-archwire combination in order to verify the effect of ligation on F. For each statistical test, the statistical significance was set at α=0.05.

RESULTS

For majority of the bracket-archwire combinations, F values obtained with all the 10 brackets ligated were significantly higher than those obtained with only the terminal brackets ligated; no significant differences were observed in only 4 cases, *i.e.*, when the Damon MX© brackets and Vision LP© brackets were engaged with round archwires (Table 2).

The F recorded with all the brackets ligated and their significant differences are shown in Table 2 and Figure 1. Coupled with round archwires, Damon MX© and Vision LP© brackets generated

Table 1. Self-ligating, conventional brackets and archwires used in the study.

Self ligating and conventional brackets[a]	Archwire[b] nominal dimensions and alloy
	0.014 NiTi-A[c d]
Damon MX, SDS Ormco	0.016 NiTi-A[c d]
Time3, American Orthodontics	0.014 x 0.025 NiTi-A[c d]
Victory, 3M Unitek with elastic ligatures	0.018 x 0.025 NiTi-A[c d]
Victory, 3M Unitek with slide ligatures (Leone)	0.017 x 0.025 TMA[e]
Vision LP, American Orthodontics	0.019 x 0.025 NiTi-A[c d]
	0.019 x 0.025 Stainless Steel[e]

[a] Bracket had nominal slot dimension of 0.022 inch.
[b] Archwires obtained directly from the manufacturers.
[c] Nickel-titanium in the austenitic phase.
[d] RMO, Denver, Colorado, USA.
[e] Dentaurum, Pforzheim, Germany.

significantly lower F than Victory Series©, Time3©, and Slide© ligatures brackets (P<.05). Victory Series© brackets generated significantly higher F than the other groups (P<.05). Coupled with rectangular archwires, Victory Series©, Slide© ligatures, and Vision LP© self-ligating brackets generated significantly lower F than Time3© and Damon MX© brackets (P<.05).

DISCUSSION

In this investigation, we made a comparison of the effects of different self-ligating and con-

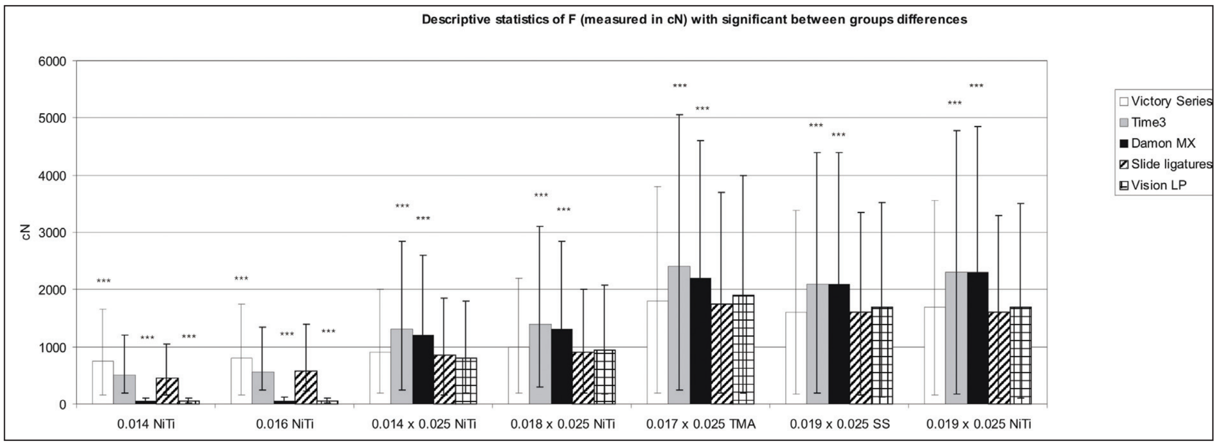

Figure 1 Descriptive statistics of force. * indicates statistically significant differences among the 5 groups (P<.05).

Table 2. Friction recorded for each bracket-archwire combination, with 10 brackets ligated and with only terminal brackets ligated. The statistically significant differences were evaluated as intra-group differences and among the five types of brackets for each archwire, when all the brackets were ligated and when only terminal brackets were ligated. The ** represents the significant inter-group differences. See the legends for details.

	Victory Series		Time3		Damon MX		Slide ligatures		Vision LP	
	10 brackets ligated		10 brackets ligated		10 brackets ligated		10 brackets ligated		10 brackets ligated	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
0.014 NiTi	§ 751.4**	152.5	504	202.4	‡ 53**	12	452	150	‡ 51**	12
0.016 NiTi	§ 800,2**	151.4	554	253.6	‡ 48**	16.4	581	230	‡ 49.2**	11.7
0.014 x 0.025 NiTi	900.5	202.8	1320**	252.8	1204**	203.8	851	150	802.5	201.3
0.018 x 0.025 NiTi	1000.5	202.4.	1425**	308.2	1303**	251	900.3	200	947.8	179
0.017 x 0.025 TMA	1800.8	203.4	2415**	248.9	2198**	198.4	1754	200	1895	199
0.019 x 0.025 SS	1620	182.5	2108**	199.4	2097**	201	1603.6	150	1703	122.4
0.019 x 0.025 NiTi	1725	153.7	2303**	183.2	2297**	252.5	1598	100	1692	102
	Only terminal brackets ligated		Only terminal brackets ligated		Only terminal brackets ligated		Only terminal brackets ligated		Only terminal brackets ligated	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
0.014 NiTi	52	20	51.2	22	51 NS	11	52	21	52 NS	11.3
0.016 NiTi	54.4	23	53	23	52.4 NS	16	51	22	51 NS	10.4
0.014 x 0.025 NiTi	60.5	18	84	22.8	81.2	18	52.3	29	58	18.2
0.018 x 0.025 NiTi	78.4	33.5	123	33	101.3	19	79	18	82.4	21
0.017 x 0.025 TMA	218.4	52.6	203	58	302	49	197	52	97.3	28
0.019 x 0.025 SS	158.2	58.6	251	92	201	81.6	153	28.2	151.4	31
0.019 x 0.025 NiTi	220.4	93.7	254	77.8	302.1	122.3	198.2	79.3	198.2	38

** p<0.05

‡ When coupled with round archwires, Damon MX and Vision LP showed a significant lower F than Victory Serie, Time 3 and Slide Ligature

§ When coupled with round archwires, Victory Series showed a significant higher F than all the other groups

Φ When coupled with rectangular archwires, Time 3 and Damon MX showed a significant higher F than all the other groups

NS In the comparison between the same brackets in the two conditions (with all the brackets ligated and with only the terminal brackets ligated), Damon MX and Vision LP showed no significant difference between the two conditions, when coupled with round archwires.

ventional brackets on F, but we did not include a group ligated with SS ligature wire to avoid unexpected results associated to the force spent by the operator during ligation.

In addition, because of its design, this *in vitro* study cannot add data on the clinical indications of these brackets. However, the results will be useful to indicate the proper clinical study that must be conducted to obtain such data. Then, clinical conclusions are not possible due to the limitations of the experimental conditions, as, for example, it did not take into account the canine bracket tipping during retraction or the undesirable rotation during retraction.

As reported in Table 2, for majority of bracket-archwire combinations, the F values obtained with all 10 brackets ligated were significantly higher than those recorded with only the terminal brackets ligated (P<.05), confirming that ligation plays an important role in generating F. This is in accordance with previous literature.[14,20]

There were no significant differences in only 4 cases, *i.e.*, when Damon MX© and Vision LP© brackets were engaged with round archwires, probably due to the shapes of their rigid caps. As reported, the archwires were moved at a crosshead speed of 0.5 mm/min (each run lasted approximately 5 min) to avoid failure of the brackets from the metal bar. This low crosshead speed is generally lower than in other investigations, such as, for example, Khambay et al,[7] who used a crosshead speed of 5 mm/min (each test run lasted for 4 min) but included only 1 bracket in their model.

In this study, 3 different self-ligating brackets showed different trends when used with the various archwires (Table 2 and Figure 1). Coupled with round archwires (0.014-inch and 0.016-inch NiTi archwires), Time3© self-ligating brackets generated significantly higher F than the other 3 self-ligating brackets (Damon MX© and Vision LP© brackets), while no significant differences were observed between Slide© ligatures and Time3© brackets. On the contrary, Victory Series© generated significantly higher F than all the other groups (Table 2 and Figure 1). A consistent agreement was found among the reviewed studies that self-ligating brackets produce lower F compared to conventional brackets when coupled with small round archwires, as pointed by a recent systematic review.[21] The differences in F observed among the self-ligating brackets could be explained by the differences in the shapes of their little caps. Damon MX© and Vision LP© brackets show a little cap that keeps the bracket closed without pressing the archwire against the slot, while the Time3© bracket is characterized by a bell-shaped cap that can squeeze the archwire into the slot, probably increasing F at the archwire-slot interface.

As noted, Damon MX© and Vision LP© brackets showed a lower level of F with round archwires compared to the other groups, suggesting that among the archwire-bracket combinations considered, they could guarantee the lowest F during the alignment phase of orthodontic treatment.

In addition, it must be noted that when coupled with all the rectangular archwires, Damon MX© brackets showed significantly higher F than majority of the other brackets (Table 2 and Figure 1), except for Time3© brackets, for which no significant differences were observed between the 2 systems (Table 2 and Figure 1). This finding suggests that Damon MX© bracket results in low F only when engaged with round archwires but not with rectangular archwires, probably because of the shape of its sliding little cap, which when engaged with rectangular archwires, provides a large contact surface between the archwire and slot walls, thus increasing the level of F. Similarly, when coupled with rectangular archwires, Time3© bracket could probably allow for an increase in F because of its bell-shaped cap, which when closed, can compress the archwire against the slot walls.

Vision LP© brackets exhibited a different behavior with respect to the other 2 self-ligating brackets, showing a low F when matched with either round or rectangular archwires (Table 2 and Figure 1). Coupled with round archwires, Vision LP© brackets showed significantly lower F than Victory Series©, Slide© ligatures, and Time3© brackets, but no significant differences with Damon MX© brackets; as previously mentioned, this finding could be explained through the little cap of this bracket, which could prevent the compression of the archwire against the slot, thus reducing the F generated, as is also assumed for Damon MX© brackets. However, coupled with rectangular archwires, Vision LP© brackets showed significantly lower F than both, Damon MX© and Time3© brackets (Table 2 and Figure 1), probably because the particular design of closing mechanism of this bracket allows the little cap to slide along a rail to maintain space between the archwires and slot walls, thus reducing the F produced. In addition, the little cap of Vision LP© brackets is not exactly on a parallel plane to the base of the slot, but is lightly inclined to leave a small trilateral free space between the archwire and the little cap. Consequently, this little cap seems to allow for a decrease in F at the archwire-slot interface.

Taken together, these findings suggest the importance of the closing mechanism and cap design in determining the F generated at the bracket-archwire interface. Differences in the structural design and material composition of the bracket slot and cap can influence the level of F generated at the bracket-archwire interface when coupled with rectangular or round archwires.

We must state that the particular design of this study allowed a possible lack of alignment of the 10 brackets, which presents as a limitation of the study. In passive systems, such as Damon MX© and Vision LP© brackets, any rigid lack of alignment will lead to high levels of binding with rectangular wires, while in active systems and conventional ligated systems, the "give" in the ligation method will allow for a lack of alignment. In this regard, our findings are also a function of the experimental setup and do not actually reflect the situation in clinical use wherein the periodontal ligament provides "give." This clarification is fundamental as this concept limits the possibility of making any clinical extrapolation from this study. This point has enormous importance from a clinical point of view, because the clinician must know the different *in vitro* behaviors of the different self-ligating brackets.

From a clinical point of view, for example, the low F observed with Slide© ligatures or Vision LP© brackets, compared to Time3© and Damon MX© brackets when coupled with rectangular archwires (Table 2 and Figure 1), could be considered either as an advantage or a disadvantage in different situations; during anterior tooth retraction, low F is desired in the lateral segment of dental arches, while in the final phase of stabilization, high F is desired in all slots. For Slide© ligatures, however, the primary advantage seems to be that they can be used only when low F is necessary or *vice versa*.

From a clinical point of view, the observations in this study altogether indicate that the clinician must select the type of self-ligating system to be employed depending on the type of malocclusion to treat. With regard to the literature, our findings about Damon MX© and Time3© brackets are in accord with those of Khambay et al,7 who employed a model with only 1 Damon SL II© bracket and 1 conventional straight-wire bracket, and tested (for 10 times, in the presence of human saliva) various archwires with 4 types of elastomeric modules and preformed 0.09-inch SS ligatures. They found that the Damon SL II© (SDS Ormco, Glendora, California, USA) self-ligating bracket and unligated conventional SS bracket produced negligible F with any of the round wires tested, but coupled with 0.017×0.025-inch and 0.019×0.025-inch SS and 0.019×0.025-inch TMA archwires, the Damon SL II© bracket produced the highest F (as in this study), while the SS ligatures produced the lowest.

As recently reported in a systematic review, there is not enough evidence to claim that with large rectangular wires, in the presence of tipping and/or torque and in arches with considerable malocclusion, SL brackets produce lower F compared to conventional brackets.[21]

The primary finding of this study is that self-ligating brackets with different slot designs show different behaviors in terms of F generated at the bracket-archwire interface when coupled with rectangular or round archwires.

In this study, Slide© ligatures showed a similar behavior as the conventional ligatures when coupled with all the rectangular archwires (Table 2 and Figure 1). When coupled with round archwires, they showed significantly lower F than Victory Series© and significantly higher F than Damon MX© and Vision LP© brackets, but similar F as the Time3© brackets. When coupled with rectangular archwires, they showed significantly lower F than Damon MX© and Time3© brackets, but similar F as the Vision LP© brackets. This behavior is probably associated with their design; their elastic properties decrease when coupled with thicker archwires, resulting in low F. In contrast, self-ligating brackets have a built-in metal device (to close off the edgewise slot) that is rigid and rather stiff, compared to the soft and elastic surface of low-friction ligatures.

Our findings are not in agreement with the general statement that self-ligating brackets generate lower F than conventional SS brackets,[2,9,14-15,17-18,22] probably because a variety of different self-ligating brackets were tested, each with different mechanical characteristics:[19] passive or interactive slots. The differences among the passive and interactive SL brackets could be explained by the flexibility of the spring clip of active SL brackets that can actively engage the wire also in the presence of tipping.[21]

In addition, in this study, no significant differences were observed between the TMA, SS, and NiTi archwires in terms of F, although it was reported that TMA generates higher F than both SS and NiTi for all bracket-archwire combinations.[2,23-30] This variability may be due to the differences in the experimental setup, number of brackets, or bracket angulations.[31] Therefore, a direct comparison of various published studies on this topic is complex.

One limitation of this study is that it was carried out under ideal conditions, in a passive configuration with no misalignment of brackets, as shown by previous reports.[2,9,17,20,21,24-25,29-30]

CONCLUSIONS

Self-ligating brackets appear to be a family of very different brackets.

For majority of the bracket-archwire combinations, the F values obtained with all 10 brackets ligated were significantly higher than those obtained with only the terminal brackets ligated; no significant differences were observed in only 4 cases, *i.e.*, when Damon MX© and Vision LP© brackets were engaged with round archwires.

Coupled with round archwires, Damon MX© and Vision LP© brackets generated significantly lower F than Victory Series©, Time3©, and Slide© ligature brackets, while Victory Series© brackets generated significantly higher F than all the other groups. Coupled with rectangular archwires, Victory Series© brackets, Slide© ligatures, and Vision LP© self-ligating brackets generated significantly lower F than Time3© and Damon MX© brackets. However, as these findings do not actually reflect the situation in clinical use wherein the periodontal ligament provides "give," the possibility of making any clinical extrapolation from this study is limited.

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