A comparison of different ligation methods on friction

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Introduction: An elastomeric module with a polymeric coating has been developed to reduce the friction of sliding mechanics. This in-vitro study examined the stability of the coating and compared the frictional properties of coated modules with those of other common ligation methods. Methods: Six ligation methods (regular uncoated, slick [coated], conventional silver, easy-to-tie, silicone-impregnated, and standard silver modules) were used with standard stainless steel brackets and 0.019 × 0.025-in archwires, and resistance to movement was measured. Two self-ligating (Speed [Strite Industries, Cambridge, Ontario, Canada] and Damon 2 [Sybron Dental Specialties Ormco, Orange, Calif]) brackets were also tested. Results: The Damon 2 self-ligating brackets produced less friction than the other ligation methods, followed by the coated modules. There was no significant difference between the frictional resistance of brackets ligated with regular uncoated, silicone-impregnated, and easy-to-tie modules. Speed self-ligating brackets produced less friction than regular uncoated, conventional silver, and standard silver modules. The frictional properties of coated modules were not significantly affected by repeating the test 5 times or by storage in saliva for a week. Conclusions: Damon 2 brackets produced no recordable friction of ligation. Coated modules produced 50% less friction than all other ligation methods except Damon 2. The coating was resistant to the simulated effects of the oral environment. Different methods of human saliva application were found to affect the frictional properties of the coating. (Am J Orthod Dentofacial Orthop 2006;130:666-70)
Modules coated with covalently bonded Metafasix (Super-slick, TP Orthodontics, LaPorte, Ind) have been claimed to reduce the friction of ligation by 60% compared with uncoated modules with similar elastic properties from the same manufacturer, although others have reported that coated modules did not produce less friction than uncoated brands. These contradictory findings require further investigation. In addition, any improvement in the frictional properties would be of clinical benefit only if the coating remained functional in the oral environment. Coated archwires have not been shown to reduce friction, because the coating was penetrated in many specimens and therefore became ineffective.

Our aims in this study were to compare the frictional properties of some commercially available module systems and to investigate the durability of the slick coating on elastomeric modules.

**MATERIAL AND METHODS**

An apparatus was constructed to record the resistance to movement of a wire through different bracket systems. A universal testing machine (model 5544, Instron, High Wycombe, Bucks, United Kingdom) was used at a crosshead speed of 20 mm per minute over 8-mm lengths of archwire. The apparatus was set up to record the static frictional force required to initiate movement for each test specimen as recorded by the highest point reached on the testing machine’s trace.

Three types of maxillary premolar brackets were used, each incorporating −7° of torque: Victory Twin (3M Unitek, Monrovia, Calif), Speed (Strite Industries, Cambridge, Ontario, Canada), and Damon 2 (Sybron Dental SpecialtiesOrmco, Orange, Calif). Victory Twin is a standard stainless steel bracket; Speed and Damon 2 are self-ligating. Victory Twin and Speed have no angulations; the Damon 2 bracket incorporates 2° of angulation. These differences were compensated for by the design of the test jigs, allowing the bracket assemblies to self-align; this effectively eliminated built-in differences in tip and torque. Straight 7-cm lengths of 0.019 × 0.025-in stainless steel wire (3M Unitek) were used for all tests. The brackets and archwires were cleaned with alcohol wipes before the modules were tied with mosquito forceps.

Four tests were run to investigate the effects of different aspects of ligation on friction.

In the first test, the frictional properties of 8 different ligation methods were compared—6 different modules were used with Victory (V) brackets, and 2 brackets were self-ligating: Vreg, regular uncoated modules (TP Orthodontics); Vslick, coated Super-slick modules (TP Orthodontics); V3M, conventional silver modules (3M Unitek); Veasy3M, AlastiiK Easy-to-Tie modules (3M Unitek); Vsilicone, Sili-Ties silicone impregnated modules (GAC International, Islandia, NY); VAO, standard silver modules (American Orthodontics, Sheboygan, Wis); Speed active self-ligating brackets; and Damon 2 passive self-ligating brackets. These units were presoaked in human saliva for 60 minutes before testing.

In the second test, the effect of abrasion on module coating was investigated by repeating the 8-mm test runs 5 times for each of the 15 regular uncoated (Vregx5) and Super-slick (Vslickx5) specimens. The mean static frictional resistances of the first and fifth runs were compared. These specimens were also presoaked in human saliva for 60 minutes before testing, and, in addition, a drop of saliva was reapplied to the test brackets between each test.

In the third test, the effect of prolonged exposure to saliva was examined by storing regular uncoated and Super-slick module test units in saliva for a week at room temperature before measuring the frictional resistance. A drop of saliva was applied before each test.

In the final test, the effect of different methods of saliva application on the slick coating was assessed. For this test, Super-slick modules were not presoaked in saliva; instead, a drop of saliva was applied to the test unit immediately before each test.

Each test was carried out on 15 brackets, plus ligatures as appropriate. The repeatability of the method was found to be satisfactory in an earlier study. To assess consistent reproducibility of bracket-archwire alignment, the tests were repeated for the Damon 2 self-ligating brackets. There was no significant difference between the 2 groups of readings, and the consistently low frictional forces indicated that any variation between bracket slot and archwire alignment was effectively eliminated by the test jig.

The results were analyzed by using ANOVA in the Minitab (State College, Pa) statistical program. Post hoc Tukey pairwise comparison tests were performed to identify significant between-group differences. Intergroup comparisons for experiments 2-4 were carried out using t tests.

**RESULTS**

The ligation method produced highly significant differences in friction: F = 158.32 (P = .000) (Table I). Damon 2 self-ligating brackets produced no measurable friction. Vslick produced significantly less friction than all other ligation methods except Damon 2. There were no significant differences in the frictional properties of Vreg, Veasy3M, and Vsilicone. Speed produced significantly less friction than Vreg, VAO, and V3M. V3M...
produced the most friction, followed by VAO. The effects of specific ligation methods according to the Tukey cross tabulations are shown in Table II. Repeating the test run 5 times for Vslick did not affect friction: $F = 0.73$ ($P = 0.572$). No statistical differences were detected with $t$ tests when comparing the first (Vslick, 0.96 ± 0.22) and fifth (Vslickx5, 0.97 ± 0.27) test runs.

The effect of prolonged exposure to saliva was significant for regular uncoated modules but not for coated ones. Vreg showed a significant reduction in friction after a week according to $t$ tests (Vreg, 2.00 ± 0.39; Vreg1wk, 1.54 ± 0.30), but this was still at least 50% more friction than produced by coated modules, which were not affected by saliva exposure (Vslick, 0.96 ± 0.22; Vslickx1wk, 0.97 ± 0.23).

Presoaked coated modules produced significantly less friction than coated modules exposed only to a drop of saliva just before testing (Vslick, 0.96 ± 0.22; Vslickdrp, 1.71 ± 0.48).

**DISCUSSION**

Resistance to sliding is the sum of classical frictional resistance and elastic binding. Elastic binding increases linearly along with bracket/archwire angulation, whereas frictional resistance remains constant. The ligation method affects frictional resistance and is proportional to the force of ligation and the coefficient of friction of the contacting surfaces. Elastic binding, in contrast, is determined by complex interactions of variables such as archwire flexibility and bracket dimensions, which are not directly influenced by the ligation method, so that, when the archwire and bracket are aligned, the effect of different forms of ligation can be isolated more precisely.

The validity of laboratory friction studies conducted in the steady state has been questioned. For example, comparison of clinical and laboratory measurements has shown that less force was needed to initiate movement when test jigs were used to measure resistance to movement intraorally than in the laboratory. It was suggested that this was due to the effect of occlusal forces on tooth movement in the mouth. This view is supported by the observation that simulated occlusal forces can temporarily abolish friction for some bracket/archwire combinations. Larger archwires were, however, not ligated with elastic modules. The elastic nature of modules and the spring clip in a Speed bracket could be expected to maintain contact with the archwire during such disturbances so that the ligation force is unlikely to be reduced simultaneously at multiple interfaces, although areas of binding and notching might be relieved. Experimental evidence showed that intraoral vibrations from mastication do not eliminate the friction associated with sliding mechanics.

Clearly, the relative motion and the environment of the mouth cannot be duplicated exactly in the laboratory. However, rankings of frictional forces should still be proportionate for a given sample of contacting surfaces and conditions.

Our results with 0.019 × 0.025-in wires show that, when archwire/bracket alignment is carefully controlled, the friction generated at the module-wire-bracket interface is significantly affected by the ligation method (Table I).
The 0.019 \times 0.025\text{-in} archwire was chosen in conjunction with a 0.022\text{-in} bracket slot because this gives good overbite and torque control while allowing free sliding in the buccal segments.\textsuperscript{25}

The low frictional resistance of the slick coating that we found contrasts with the findings of both Khambay et al.\textsuperscript{18} and Griffiths et al.\textsuperscript{19} who reported that slick modules did not appear to offer reduced friction. However, comparison of the results of various studies is complicated by the different methods of lubrication. In 1 study, the test samples were not immersed in saliva; instead, saliva was dripped into the bracket/wire junction.\textsuperscript{18} In the other study, the specimens were immersed in water for 1 hour.\textsuperscript{19}

Frictional resistance increases by approximately 80\% if the coated modules are not presoaked in saliva. This is likely to account for some differences to the findings of Khambay et al.\textsuperscript{18} In addition, it can be seen from previous work carried out in the dry state and after soaking that the presence or absence of saliva has a proportionally greater effect on coated modules than on uncoated modules.\textsuperscript{16} Experiments conducted in saliva and water provided conflicting results,\textsuperscript{1} and the validity of frictional experiments with artificial saliva had been questioned.\textsuperscript{26}

Silicone-impregnated modules have been shown to reduce static frictional resistance by 23\% to 43\% compared with nonlubricated ligatures.\textsuperscript{27} Experiments were conducted in the dry state, and it is possible that the surface concentration of silicone remains higher in the dry state but is removed or softened by saliva in the wet state.

The Damon 2 bracket produced virtually no friction of ligation. This agrees with a previous study in which Damon brackets consistently produced low friction of ligation.\textsuperscript{10} In contrast, self-ligating brackets with active clips, such as Speed brackets, produce significant friction of ligation when the spring clip produces a normal force on larger diameter wires.\textsuperscript{12}

There was no statistically significant difference between Victory brackets ligated with either regular modules, Easy-To-Tie modules, or Sili-Ties silicone-impregnated modules. The standard modules from American Orthodontics and the conventional modules from 3M produced significantly more friction than the other methods of ligation.

Although the slick coating appeared resistant to the effects of abrasion and soaking in saliva, a dietary component or a combination of factors could still affect the integrity of the coating. However, in contrast to a coated archwire,\textsuperscript{28} coated modules will not be exposed to the forces of elastic binding and therefore might have a better chance of remaining intact during treatment.

Regular modules showed a significant decrease in frictional resistance after immersion in saliva for a week. This might be related to stress relaxation of the elastic in the presence of saliva,\textsuperscript{29} and it is possible that the slick coating protects the modules from this effect. Secure ligation could be compromised by the stress relaxation of regular modules. The absence of a seating force might increase slop in the system and reduce control of tooth movement.\textsuperscript{29} Although it can be seen that friction is reduced when there is no normal force of ligation (eg, Damon brackets), it is not known how the reduction in ligation or seating force might affect the expression of bracket prescription, particularly for torque control.

When considering the clinical implication of our results, it is important to remember that the effect of ligation on the total resistance to sliding decreases as bracket/archwire angulation increases.\textsuperscript{1,10} However, a low-friction ligation method contributes to appliance efficiency and might have clinically important advantages.\textsuperscript{9,17}

**CONCLUSIONS**

1. Damon 2 brackets produced significantly less friction than the other ligation systems when used with 0.019 \times 0.025\text{-in} archwires.
2. Slick modules with standard stainless steel brackets generated significantly less friction than the other types of modules or the Speed self-ligating bracket, when used with 0.019 \times 0.025\text{-in} archwires.
3. There was no significant difference in the frictional properties of regular uncoated, silicone-impregnated, and Easy-To-Tie modules.
4. The slick coating appeared to be resistant to abrasion in a simulated clinical setting.
5. Immersion in saliva had no detrimental effect on the coating. Frictional resistance was reduced after soaking uncoated modules in saliva for a week, but they still produced 50\% more friction than the slick modules.
6. Differences in the application of saliva to the test apparatus can have a significant effect on the performance of slick modules.

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**REFERENCES**