SHORT COMMUNICATION

Forces released during sliding mechanics with passive self-ligating brackets or nonconventional elastomeric ligatures

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Introduction: The aim of this study was to evaluate the frictional forces generated by 4 types of passive stainless steel self-ligating brackets (SLBs) and by nonconventional elastomeric ligatures (NCEL) and conventional elastomeric ligatures (CEL) during sliding mechanics. Methods: An experimental model consisting of 5 aligned stainless steel 0.022-in brackets was used to assess frictional forces produced by the SLBs, NCEL, and CEL with a 0.019 × 0.025-in stainless steel wire. Results: Significantly smaller static and kinetic forces were generated by the SLBs and NCEL (<2 g) compared with the CEL (>500 g). No significant differences were found within the different types of SLBs, or between these and the NCEL. Conclusions: SLBs and NCEL are valid alternatives for low friction during sliding mechanics. (Am J Orthod Dentofacial Orthop 2008;133:87-90)

Friction is determined mainly by the nature of ligation.1 In an in-vivo study, Iwasaki et al2 confirmed that, during sliding mechanics, 30% to 50% of the total friction force generated by a premolar bracket traveling along a .019 × .025-in stainless steel archwire is due to the friction of the ligation. Various methods, therefore, have been proposed to reduce the friction of ligation, such as loosely tied stainless steel ligatures,3 self-ligating brackets (SLBs),4-7 and unconventional ligation systems.8-10 Stainless steel ligatures produce variable ligation forces and are time-consuming to place.2

SLBs are ligatureless bracket systems that have a mechanical device built into the bracket to close off the slot. From the patient’s perspective, SLBs are generally smoother, more comfortable, and easier to clean because of the absence of wire ligature; reduced chair time is another significant advantage.11 In recent years, various SLBs have been developed: those that have a spring clip that presses against the archwire (“active” or “interactive” SLBs), such as SPEED (Strite Industries, Cambridge, Ontario, Canada), In-Ovation (GAC International, Bohemia, NY), Quick (Forestodont USA, St Louis, Mo), and Time2 brackets (American Orthodontics, Sheboygan, Wis); and those in which the self-ligating clip does not press against the wire (“passive” SLBs), such as Damon (SDS Ormco, Orange, Calif), SmartClip, (3M Unitek, Monrovia, Calif), Carrier (Ortho Organizers, Carlsbad, Calif), and Opal (Ultradent Products, South Jordan, Utah). Passive SLBs have shown consistently less friction during sliding mechanics than active SLBs, with the exception of undersized round archwires.4,5,7 Significant reduction in friction has been reported also for nonconventional elastomeric ligatures (NCEL) (Slide; Leone Orthodontic Products, Sesto Fiorentino, Italy) on conventional brackets when compared with conventional elastomeric ligatures (CEL).10

The aim of this study was to evaluate the frictional forces generated by 4 types of passive stainless steel SLBs and by NCEL when compared with CEL during sliding mechanics.

MATERIAL AND METHODS

An experimental model reproducing the right buccal segment of the maxillary arch was used to assess the frictional forces produced by 4 types of passive SLBs (Damon 3 MX, SDS Ormco; SmartClip, 3M Unitek; Carriere, Ortho Organizers; and Opal-M, Ultradent Products), by NCEL (Slide; Leone Orthodontic Products) on conventional stainless steel brackets (STEP brackets; Leone Orthodontic Products), and by CEL (silver mini modules; Leone Orthodontic Products) on
the same type of conventional stainless steel brackets. The buccal segment model consisted of 5 brackets for the second premolar, the first premolar, the canine, the lateral incisor, and the central incisor. A section of 0.0215 × 0.028-in stainless steel wire was used to align the brackets before fixing them with cyanoacrylate glue onto an acrylic block (Fig. A). The interbracket distance was set at 8.5 mm.

An 18-cm-long 0.019 × 0.025-in stainless steel wire was tested. The wire was secured into the brackets by using the self-ligating systems, the NCEL, or the CEL. The frictional forces generated by the 0.019 × 0.025-in stainless steel wire with the 2 types of ligation systems were recorded by sliding the wire into the aligned brackets. The friction generated by the testing unit consisting of wire, brackets, and ligation systems was measured under dry conditions and at room temperature (20°C ± 2°C) with a testing machine (model 4301; Instron, Canton, Mass) with a load cell of 10 N (Fig. B). The testing machine had been calibrated by the Instron Calibration Laboratory in terms of crosshead displacement/speed and load cell. The test wire was inserted into the testing unit, and its bottom end was clamped by a vise and mounted on the machine’s crosshead. The elastomeric ligatures were placed immediately before each test run to avoid ligature force decay. Frictional forces produced were tested 30 times with new wires on each occasion.

A total of 180 tests (30 tests for each of the 6 types of ligation systems) were carried out. Static and kinetic friction forces were recorded while 15 mm of wire were drawn through the brackets at a speed of 15 mm per minute. Static friction was defined as the force needed to start the wire moving through the bracket assembly. This force was measured as the maximal initial rise on the machine’s chart trace. Recommendations for usage with the testing machine strongly suggested that, in tests measuring kinetic friction, this must be evaluated as an average of the frictional forces appraised at subsequent time periods during displacement. For the purpose of this study, measurements of kinetic friction were performed at 2, 5, and 10 mm of displacement and then averaged.

**Statistical analysis**

Descriptive statistics, including means, medians, standard deviations, and minimum and maximum values were calculated for the static and kinetic frictional forces produced by the various ligation systems with the 0.019 × 0.025-in stainless steel wire. Because normal distribution of the data was not found (Shapiro-Wilks test), the comparisons between the ligation systems were carried out with analysis of variance (ANOVA) on ranks with the Tukey post-hoc test (P < .05) (SigmaStat 3.1; Systat Software, Point Richmond, Calif).

**RESULTS**

The descriptive statistics and the comparisons of static and kinetic frictional forces for the ligation systems are shown in Tables I and II. The statistical tests showed significantly smaller static and kinetic forces generated by the SLBs and the NCEL when compared with the CEL. No significant differences were found among the different SLBs, or between these and the NCEL.

The average amount of both static and kinetic friction was minimal (<2 g) in the SLB and NCEL groups with aligned brackets with 0.019 × 0.025-in stainless steel wire, whereas it was greater than 500 g with CEL.
DISCUSSION

Clinical evidence of the beneficial effects of low-friction archwire ligatures on the biomechanical characteristics of orthodontic treatment can be derived from either passive SLBs or NCEL on conventional brackets, in which the archwire is not compressed into the slot by a ligation structure. Our aim in this study was to compare the friction generated by these innovative ligation systems (SLBs and NCEL) with the friction produced by CEL. The research was tailored to test the friction during the fundamental therapeutic phase of sliding mechanics on aligned brackets with a rectangular archwire. We used a device specifically designed and manufactured to simulate the clinical conditions of a dental arch section to study static and kinetic attritions.

Both the SLBs and the NCEL showed levels of friction that were significantly lower than those produced by CEL during sliding mechanics with a 0.019 x 0.025-in rectangular wire. The amounts of static and kinetic frictional forces exerted by the SLBs and the NCEL were minimal (<2 g) when compared with the CEL, that exhibited more than 500 g of force on average for both frictional force types. The significant differences between SLBs and NCEL vs CEL are similar to those reported by Pizzoni et al and Thomas et al. However, both studies used a single-bracket experimental model, whereas we attempted to reproduce the clinical condition of 5 aligned brackets in a dental arch segment.

The data concerning the elastomeric ligatures, however, should be considered with caution. Each test with the machine was performed with new elastomeric ligatures. We made no attempt to evaluate the effects of time and oral environment on the amount of force released with different types of elastomeric ligatures. Frictional resistance is reduced after presoaking elastomeric modules in saliva for 1 week.

This investigation demonstrated clearly that minimal amounts of friction are generated with 4 types of passive SLBs that are commercially available. The literature reports values of frictional forces for active SLBs that are 5 times greater than passive SLBs. Based on the results of this study, NCEL also produce significantly lower levels of frictional forces than CEL, so that NCEL might be a valid alternative to passive SLBs during sliding mechanics.

CONCLUSIONS

In this study, we found that both passive SLBs and NCEL produce significantly smaller frictional forces (<2 g) than CEL (>500 g).

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REFERENCES