A comparative study of conventional ligation and self-ligation bracket systems

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The increased use of self-ligating bracket systems frequently raises the question of how they compare with conventional ligation systems. An in vitro and clinical investigation was undertaken to evaluate and compare these distinctly different groups, by using five different brackets. The Activa ("A" Company, Johnson & Johnson, San Diego, Calif.), Edgelok (Ormco, Glendora, Calif.), and SPEED (Strite Industries Ltd., Cambridge, Ontario) self-ligating bracket systems displayed a significantly lower level of frictional resistance, dramatically less chairtime for arch wire removal and insertion, and promoted improved infection control, when compared with polyurethane elastomeric and stainless steel tie wire ligation for ceramic and metal twin brackets. (Am J Orthod Dentofac Orthop 1994;106:472-80.)

A review of the orthodontic literature from the last few years reveals a proliferation of publications evaluating the role of friction in the orthodontic system. However, many of these publications concentrate on how a particular facet, such as bracket width, wire material, and bracket material, impacts, either individually or in combination, on the level of friction produced in the system. Some of the more recent articles have highlighted the increasing use of self-ligating bracket systems and the role they may play in affecting the level of friction in the system. With the introduction of the Edgewise bracket (Ormco, Glendora, Calif.) in 1972, the SPEED system (Strite Industries Ltd., Cambridge, Ontario) in 1980, and the Activa bracket ("A" Company, Johnson & Johnson, San Diego, Calif.) in 1986, several independent claims have been made that share a common theme. All three inventors report a significant reduction in the level of friction, in addition to shorter treatment time and chairtime, when compared with conventional bracket systems. The fact that similar advantages were noted 47 years earlier with the use of the first Edgewise self-ligating bracket, the Russell Lock, lends a certain degree of credence to these current observations. To assess the authenticity of these claims and to examine the more recent bracket systems, a study was designed to evaluate and compare the three different self-ligating bracket appliances with conventional elastomeric and stainless steel ligation systems.

This article will examine these two contrasting groups of bracket systems from both an in vitro aspect, as well as by clinical measurements and subjective observations.

The in vitro portion of the study was designed to examine the static resistance and dynamic frictional resistance for sliding mechanics both between and within each of the two different groups. Since elastomeric power modules are often used as an alternative means of space closure to either closing-loop arch wires or intraoral elastics, the effect of their use on frictional resistance was also investigated.

As more orthodontic offices up-date or expand existing sterilization techniques to meet current requirements, a greater demand is placed on the doctor-staff time to maintain the same level of efficiency in patient care. To assist in balancing this new equilibrium the significant decreased time factor associated with the use of self-ligating brackets may be one of the greatest hidden virtues of the ligatureless system. To evaluate this claim, the clinical portion was designed to observe the time taken to remove and replace the ligating mechanism for the conventional bracket systems and to open and close the clips of the self-ligating bracket systems.

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Fig. 1. Scanning electron micrograph of five types of brackets used in study.

Table 1. Types of brackets and various methods of ligation evaluated

<table>
<thead>
<tr>
<th>Group</th>
<th>Bracket</th>
<th>Ligation</th>
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<tbody>
<tr>
<td>I</td>
<td>Standard metal twin</td>
<td>0.012-inch GAC steel tie</td>
</tr>
<tr>
<td>II</td>
<td>Standard metal twin</td>
<td>Polyurethane elastomeric module</td>
</tr>
<tr>
<td>III</td>
<td>Activa</td>
<td>Lever arm</td>
</tr>
<tr>
<td>IV</td>
<td>SPEED</td>
<td>Spring clip</td>
</tr>
<tr>
<td>V</td>
<td>Ceramic series 2000*</td>
<td>0.012-inch GAC steel tie</td>
</tr>
<tr>
<td>VI</td>
<td>Ceramic series 2000*</td>
<td>Polyurethane elastomeric module</td>
</tr>
<tr>
<td>VII</td>
<td>Edgelok</td>
<td>Sliding cap</td>
</tr>
</tbody>
</table>

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MATERIAL AND METHOD

The samples for the initial portion of the investigation consisted of five different types of 0.022 x 0.028-inch [0.55 x 0.71 mm] brackets (Fig. 1) divided into seven groups depending on the type of ligation system used (Table 1). Each bracket was mounted on an acrylic cylinder and an 0.018-inch [0.45 mm] arch wire (GAC International, Inc., Central Islip, N.Y.) was ligated into each bracket slot, either with 0.012-inch [0.30 mm] stain-
bracket. In the Edgelok appliance a labially positioned the spring clip in the SPEED bracket imparts a dynamic with the Edgelok bracket, a tube or rectangular slot is through the influence of this spring clip on the arch wire. planes permits precise control of tooth movement, to deliver continuous force vectors in all three spatial self-ligation from all others. The ability of the spring clip aspect to this system that differentiates this form of created thereby permitting complete freedom of move- ment of the arch wire. However, the inherent flexibility of the arch wire slot until it abuts against a smaller fixed cap, the lock stop, creating a rectangular slot or tube. The latch clip is capable to rotate freely around the horizontal axis of the arch wire slot, and the clip was closed to secure the wire with the bracket clips in the open position. An 0.018-inch O.018-inch steel wire with different types of ligating systems. TMT, Standard twin ligated with metal tie; TET, standard twin ligated with polyurethane elastomeric tie; SPD, SPEED self-ligating bracket; ACT, Activa self-ligating bracket; CMT, ceramic bracket ligated with metal tie; CRT, ceramic bracket ligated with polyurethane elastomeric tie; EDL, Edgelok self-ligating bracket.

Fig. 2. Graph indicating mean static resistance produced by sliding 0.018-inch steel wire with different types of ligating systems. TMT, Standard twin ligated with metal tie; TET, standard twin ligated with polyurethane elastomeric tie; SPD, SPEED self-ligating bracket; ACT, Activa self-ligating bracket; CMT, ceramic bracket ligated with metal tie; CRT, ceramic bracket ligated with polyurethane elastomeric tie; EDL, Edgelok self-ligating bracket.

less steel ties (GAC) with a tie force of approximately 150 gm, or with 0.40 mm (0.106 inch) polyurethane elastomeric ties (Las-Tie Carousel Elasto-Ring, GAC) or self-ligation. A new bracket and arch wire were used for each test to avoid creating any changes in the surface topography of the arch wire or the bracket slot, which may cause a greater level of frictional resistance to be recorded.

The mode of self-ligation varied for each ligatureless bracket. In the Edgelok appliance a labially positioned cap, the sliding lock, is slid horizontally across the top of the arch wire slot until it abuts against a smaller fixed cap, the lock stop, creating a rectangular slot or tube. The Activa appliance possesses a self-ligating latch clip, which resembles a bib with curled arms. The latch clip is able to rotate freely around the horizontal axis of the bracket and closes in a gingival direction to form a solid outer labial wall for retaining the arch wire. The Edgelok appliance a labially positioned the spring clip in the open position, and a much lighter gingivally directed force against the curved occlusal surface to reseat it. In the slot-closed position, the lingually inclined labial arm of the spring clip retains the arch wire by forming the fourth and outer wall of the arch wire slot.

Each bracket group consisted of twelve samples and the frictional force for each group was evaluated with a Universal Instron testing instrument (Instron Corp., Canton, Mass.) with each arch wire being moved through a distance of 1.0 inch [25.4 mm] at a crosshead speed of 0.001 inch [0.0254 mm] per minute, using a full scale load of 1 pound [454.5 gm]. Two different measurements were then retrieved and analyzed for each sample: The maximum force needed to initiate movement of the wire, which was considered as the force needed to overcome static resistance, and the maximum load through the tracking distance of 1.0 inch, which was interpreted as the dynamic resistance.

This Instron test was initially carried out with an artificial salivary medium (Saliva substitute, Roxan Labs, Columbus, Ohio) for each bracket system. However, this artificial saliva produced higher frictional resistance possibly because of the rapid rate of desiccation with the cellulose content adhering to the arch wire. It was therefore decided to examine the various bracket systems using a normal saline solution. The data collected were analyzed through the Anova Analysis using the Systat program.

The second portion of the investigation was designed to evaluate the influence of the elastomeric power module (GAC Energy Chainette) on the translatory movement of teeth.

The elastomeric power module was placed on each of 12 samples of the Activa, Edgelok, and SPEED brackets with the bracket clips in the open position. An 0.018-inch [0.45 mm] stainless steel wire was engaged into the bracket slot, and the clip was closed to secure the wire into the bracket. The samples were subjected to the Instron testing machine as previously described in the first phase of the study. The results obtained were subjected to the t test.

The final phase of the study involved a comparative clinical evaluation of the time required to remove and replace the mode of ligation in either the maxillary or mandibular arch from the right second premolar to the left second premolar, in 20 separate arches. The time recorded was solely related to the removal or replacement of the ligature tie and did not involve manipulation of the arch wire.

RESULTS

The results of the static resistance, as shown graphically in Fig. 2, demonstrate no statistical difference, p < 0.05, in the force values to initiate wire movement for the Activa, Edgelok, SPEED,
Table II. Mean of the time taken in seconds to remove ligation / open bracket and replace ligation / close bracket

<table>
<thead>
<tr>
<th>Type of bracket and ligation</th>
<th>Time taken to remove tie / open bracket</th>
<th>Time taken to replace tie / close bracket</th>
</tr>
</thead>
<tbody>
<tr>
<td>Twin with metal tie</td>
<td>180</td>
<td>300</td>
</tr>
<tr>
<td>Twin with rubber tie</td>
<td>60</td>
<td>80</td>
</tr>
<tr>
<td>SPEED</td>
<td>30</td>
<td>11</td>
</tr>
<tr>
<td>Activa</td>
<td>45</td>
<td>60</td>
</tr>
<tr>
<td>Edgelok</td>
<td>52</td>
<td>40</td>
</tr>
</tbody>
</table>

and twin bracket with metal tie. However, the variability in the force values was higher for the twin bracket with metal tie.

For measurements of dynamic frictional resistance (Fig. 3), the twin metal bracket with the elastomeric tie and the ceramic brackets with either the metal tie or the elastomeric tie all proved to be statistically different from the other four groups (I, III, IV, VII) at $p < 0.05$. The ceramic bracket with the elastomeric tie (group VI) offered the most resistance to movement with a mean value of 10.84 ounces (308.15 gm).

The use of the elastomeric power module revealed a higher level of mean frictional resistance of 3.07 ounces (87.26 gm) with the SPEED bracket system (Fig. 4) when compared with either the Activa bracket system, which had a mean value of 12.64 ounces (35.91 gm) or the Edgelok bracket system, with a mean value of 1.42 ounces (40.40 gm).

The time involved to open the self-ligated brackets in groups III, IV, and VII (Table II and Fig. 5), Table II illustrated a significant decrease in time when compared with either of the other two forms of conventional ligation methods, groups I and V or groups II and VI. This time difference was even more evident when the time for closing any of the self-ligating bracket systems was compared with that for replacing the stainless steel ligature tie or the elastomeric mode of ligation (Fig. 5, Table II).

DISCUSSION

The ceramic brackets, as a group, offered more resistance to movement, with group VI displaying
the greatest value. This finding, which is in agreement with that of Pratten et al., Kusy and Whitley, and Tanne et al., could possibly be related to the roughness of the bracket slot (Fig. 6), in addition to the mechanical binding between the elastomeric tie and the ceramic bracket surface.

The frictional resistance associated with the use of elastomeric ties in groups II and VI was higher than when steel ties were used with the same bracket system, groups I and V, Fig. 3. In previous studies, elastomeric ties have also demonstrated higher frictional resistance when compared with other modes of ligation and in particular with self-ligation. This, combined with the rapid rate of decay for these elastomeric ties and their predilection for harboring large quantities of plaque and the resultant decalcification, suggests that there is little merit in their use, especially in translatory movement and sliding mechanics.

In observing the inconsistency in force values associated with the twin bracket and metal ties (group I), one could postulate that this fluctuation could be attributed either to the binding effect of the steel tie or to the intimate relationship of the cut end of the tie wire where it was tucked under or over the main arch wire.

Perhaps the most noticeable features of Figs. 2 and 3 were the dramatically low levels of mean resistance as exhibited by the Activa, Edgelok, and SPEED self-ligating systems when measured against either the elastomeric or steel tie ligation groups. All three of the self-ligating systems revealed a remarkably similar range of measurements from lowest value to highest value and a statistically insignificant difference in their respective mean force values. This no doubt is readily explained by the lack of any tight contact as exhibited by a steel tie or elastomeric tie around the arch wire. Furthermore, the outer labial wall in all three self-ligating brackets would, in the closed position, tend to create a tunnel, or tube, in which to house the arch wire (Fig. 7).

These differences of arch wire entrapment in the self-ligating group necessitate critical evaluation before constructing the experimental model. Both the horizontal labial wall of Edgelok and the concave fourth wall of Activa are inflexible, solid arms that create a hollow rectangular tube permitting free uninhibited movement of the arch wire. However, in the SPEED bracket the outer labial wall is formed by the linguually inclined, resilient spring clip that undergoes constant positional change to effect rotational, tip, and torque control. If in the experimental design the flexible spring clip is subjected to a constant force in any one of these spatial planes during movement of the arch wire through the arch wire slot, as in the study by Bednar et al., then the spring clip will be maintained continuously in a displaced condition while the arch wire is pulled past it. Consequently, the experimental model would tend not to represent an accurate design for the SPEED bracket system and would produce results with a higher level of friction. Therefore, to compare each system equally in
Fig. 7. Scanning electron micrograph of sagittal view of self-ligating brackets indicating individual ligation methods holding 0.018-inch arch wire in position.

this study, the arch wire was moved parallel to the arch wire slot for each bracket. Regrettably, this portion of the study, as with all in vitro studies, is really a comparative study and in no way is capable of simulating clinical conditions with all the attended variables.

From the scanning electron microscopic views of the Activa, SPEED, and Edgelok brackets, with the elastomeric power module in place under the arch wire (Fig. 8), it would appear that the anatomic design of each bracket could have created the noticeable difference in the levels of mean resistance produced by each system. With the Activa bracket, each elastomeric power module can readily be looped behind the lever arm ensuring a distant location from the arch wire. The same configuration is evident for the elastomeric power module and the Edgelok bracket. Unless the elastomeric power module is engaged between the base of the SPEED bracket body and the spring clip, both incisally and gingivally, then the opportunity for extended contact between the arch wire and the elastomeric power module is dramatically increased. This problem is exacerbated if the elastomeric power module is placed after the seating of the arch wire and closure of the spring clip, as is routinely performed by clinicians for convenience (Fig. 9). This technique negates the advantage of the low frictional resistance offered by the SPEED bracket. However, the advent of the recently designed SPEED bracket with a mushroom hook (Fig. 10) permits the gingival positioning of the elastomeric power module and, hence, the chances of frictional drag between the arch wire and the elastomeric power module become nonexistent. This portion of the study did not investigate the frictional resistance involved with the use of elastomeric power modules over twin metal brackets because the initial pilot study demonstrated that the force values were very similar to that of the twin brackets with elastomeric modules. The alternative technique of employing elastomeric power modules over brackets tied with metal ligatures also revealed similar force values as that of wire restrained solely with elastomeric modules over the twin brackets.

Significantly less chairtime was required for arch wire removal and insertion when any of the Activa, Edgelok, or SPEED bracket systems (groups III, IV and VII) were employed, (Fig. 5, Table II). Opening of either the sliding cap of Edgelok or the spring clip of the SPEED bracket showed a greater variability than with the lever-pull action of the Activa bracket. This could be ex-
Fig. 8. Sagittal view of scanning electron micrograph of three self-ligating brackets with elastomeric power module placed under 0.018-inch steel wire. Note the lack of contact of the wire with the power module in the Activa bracket.

Fig. 9. Sagittal view of the scanning electron micrograph indicating a SPEED bracket with elastomeric power module placed over arch wire after clip closure.

plained by the difference in the structural design of each bracket body in addition to the material composition of both the highly resilient SPEED spring clip and the retaining mechanism for the sliding cap of Edgelok, as opposed to the nonresilient lever arm of the Activa bracket (Fig. 1). Closing the self-ligating component of each bracket system was equally easy. Clinically, it was of interest to note the absence of accidental soft tissue laceration or impingement from tie wire ends. The smooth round shape of each self-ligating systems further added to tissue comfort.

CONCLUSION

By using bracket systems that are self-ligating tends to address two important concerns of ortho-
dentists today. A decrease in frictional resistance, both static and dynamic, has to benefit the hard and soft tissues, whereas a decrease in the time of arch wire removal and insertion addresses both ergonomic and economic considerations. The self-ligating bracket systems are advantageous in that they do not promote poor oral hygiene, as with elastomeric ties, and eliminate any chance of soft tissue laceration to both the patient and the orthodontist from the use of stainless steel tie wires. Besides enhancing public relations between the orthodontist and the patient with respect to both patient care and infection control in the oral cavity, a self-ligating system is also appreciated by the support staff, both at the chairside and in sterilization. It is not unrealistic to expect that one day self-ligating bracket systems will become the bracket system of choice.

We acknowledge the contribution made, in the clinical portion of this investigation, by Dr. Jim Wildman for his invaluable expertise with the use of the Edgelok bracket. In addition, we thank Dr. David Edgar and Dr. Thurle Hice for detailed answers concerning the development and use of the Edgelok bracket and also Dr. Erwin Pletcher for information on his design and observations of the Activa straight-wire appliance. We also thank Mrs. Janice Lipshy for her help in the preparation of this manuscript.

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AAO MEETING CALENDAR

1995—San Francisco, Calif., May 13 to 18, Moscone Convention Center
(International Orthodontic Congress)

1996—Denver, Colo., May 11 to 15, Colorado Convention Center

1997—Philadelphia, Pa., May 3 to 7, Philadelphia Convention Center

1998—Dallas, Texas, May 16 to 20, Dallas Convention Center

1999—San Diego, Calif., May 15 to 19, San Diego Convention Center

2000—Chicago, Ill., April 29 to May 3, McCormick Place Convention Center