The History and Development of Self-Ligating Brackets

Nigel Harradine

Self-ligating brackets do not require an elastic or wire ligature, but have an inbuilt mechanism that can be opened and closed to secure the archwire. In the overwhelming majority of designs, this mechanism is a metal face to the bracket slot that is opened and closed with an instrument or fingertip. Brackets of this type have existed for a surprisingly long time in orthodontics—the Russell Lock edgewise attachment being described by Stolzenberg in 1935. Many designs have been patented, although only a minority have become commercially available. In addition, there are lingual self-ligation brackets, and in general terms, the same challenges and potential differences apply on the lingual surface. Specific comparison of some types of lingual self-ligating brackets can be found in the article by Silvia Geron in this issue. New designs have continued to appear, the Time bracket (Adenta GmbH, Glching, Germany) becoming available in 1994, the Damon SL bracket ("A" Company, San Diego, CA) in 1996,5,6 and the TwinLock bracket (Ormco Corp., Orange, CA) in 1998, being three designs from that decade. Since the turn of the century, the pace of development has greatly accelerated with the launch of at least 13 new brackets and rapidly increasing sales for such brackets. This article aims to outline the history and development of this type of bracket and to put the current situation in context. The generic advantages claimed for these brackets will be described. In addition, the problems encountered with various bracket types will be discussed to provide a summary of why, despite these claimed advantages, self-ligation has for so long and until so recently been a small part of orthodontics. (Semin Orthod 2008;14:5-18.) © 2008 Elsevier Inc. All rights reserved.

It is more than 70 years since Stolzenberg1 described a self-ligating edgewise bracket and the recent proliferation of bracket types represents a minority of the types that have been patented since that time.2-4 Table 1 is not exhaustive, but contains a majority of the bracket types that have been available for clinical use. Several types appeared in the 1980s, the Damon SL5,6 was a significant introduction in the 1990s and the more recent proliferation of bracket types is apparent in this table. A core intention throughout this article is to clarify which assertions about these brackets are based on reasonably firm evidence, which seem probable in the light of rather incomplete evidence, and which ideas are currently hypotheses in need of formal investigation. It is fair to say that, as with several popular orthodontic products such as preadjusted brackets and superelastic wires, the clinical popularity of self-ligating systems has run ahead of the evidence to firmly support all the proposed advantages.

Properties of an Ideal Ligation System

The concept that brackets are ligated via tie wings is so prevalent that it is worthwhile consid-
ering a list of ideal properties of any ligation system. This exercise puts in perspective any assessment of the benefits and difficulties with current self-ligating systems. In this authors view, ligation should:

- Be secure and robust,
- Ensure full bracket engagement of the archwire,
- Exhibit low friction between bracket and archwire,
- Be quick and easy to use,
- Permit easy attachment of elastic chain,
- Assist good oral hygiene, and
- Be comfortable for the patient.

Before looking at self-ligating brackets in relation to this list, it is instructive to consider the performance of conventional wire and elastomeric ligatures in relation to these requirements.

### Secure Robust Ligation

It is highly desirable that once ligated, the system is very resistant to inadvertent loss of ligation. Wire ligatures are good in this respect, whereas elastomeric ligatures are much less so, especially if left for too long without being renewed. The force decay of elastomers has been well documented.7

### Full Bracket Engagement

It is a great advantage if the archwire can be fully engaged in the bracket slot and maintained there with certainty. Wire ligatures do not stretch to an extent that engagement once achieved at ligation is subsequently lost, so they can meet this requirement. Elastomers are worse since they may frequently exert insufficient force to fully engage even a flexible wire and the subsequent degradation of their elastic performance may cause a significant loss of full engagement as the elastomeric stretches (Fig 1). Twin brackets with the ability to “figure 8” the elastomers are a significant help in this respect but certainly not a complete answer.

### Low Friction

Wire ligatures produce substantially lower friction forces than elastomers.8 However, the forces generated by wire ligation still reach high and very variable levels9 relative to those force levels that are thought to be optimal for tooth movement. It is perhaps helpful at this point to summarize why low friction levels are considered to enhance orthodontic tooth movement. Most tooth movements with most mechanical procedures involve relative movement between the archwire and bracket. These movements include leveling, buccolingual alignment, rotation, correction of angulation, opening of space, and any space closure with sliding mechanics. Friction between the bracket and the archwire is a force that must be overcome before the intended tooth-moving forces can have their effect and this relative movement between the bracket and the archwire can occur. Frictional forces arising from the method of

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**Table 1. Self-Ligating Bracket Types**

<table>
<thead>
<tr>
<th>Bracket</th>
<th>Year</th>
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<tbody>
<tr>
<td>Russell Lock</td>
<td>1935</td>
</tr>
<tr>
<td>Ormco Edgelok</td>
<td>1972</td>
</tr>
<tr>
<td>Forestadent Mobil-Lock</td>
<td>1980</td>
</tr>
<tr>
<td>Forestadent Begg</td>
<td>1980</td>
</tr>
<tr>
<td>Strite Industries SPEED</td>
<td>1980</td>
</tr>
<tr>
<td>&quot;A&quot; Company Activa</td>
<td>1986</td>
</tr>
<tr>
<td>Adenta Time</td>
<td>1996</td>
</tr>
<tr>
<td>&quot;A&quot; Company Damon SL</td>
<td>1996</td>
</tr>
<tr>
<td>Ormco/&quot;A&quot; Co. Damon 1</td>
<td>1998</td>
</tr>
<tr>
<td>Ormco/&quot;A&quot; Co. Damon 2</td>
<td>2000</td>
</tr>
<tr>
<td>GAC In-Ovation</td>
<td>2000</td>
</tr>
<tr>
<td>Gestenco Oyster</td>
<td>2001</td>
</tr>
<tr>
<td>GAC In-Ovation R</td>
<td>2002</td>
</tr>
<tr>
<td>Adenta Evolution LT</td>
<td>2002</td>
</tr>
<tr>
<td>Ultradent OPAL</td>
<td>2004</td>
</tr>
<tr>
<td>Ormco Damon 3</td>
<td>2004</td>
</tr>
<tr>
<td>3 M Unitek SmartClip</td>
<td>2004</td>
</tr>
<tr>
<td>Ormco Damon 3 MX</td>
<td>2005</td>
</tr>
<tr>
<td>Ultradent OPAL metal</td>
<td>2006</td>
</tr>
<tr>
<td>Forestadent Quick</td>
<td>2006</td>
</tr>
<tr>
<td>Lancer Praxis Glide</td>
<td>2006</td>
</tr>
<tr>
<td>Class 1/Ortho Organisers Carrière LX</td>
<td>2006</td>
</tr>
</tbody>
</table>
ligation are an additional resistance to this relative movement. Correspondingly higher forces must therefore be applied and this has two related potential effects that inhibit tooth movement. First, the net effective force is much more difficult to assess and is more likely to be undesirably higher than force levels best suited to create the optimal biologic response. Second, the binding forces are higher both between bracket and wire and also at the contacts between irregular adjacent teeth. These binding forces also inhibit the required relative movement. Certain tooth movements, such as space closure with closing loops placed in the space, expansion of a well-aligned arch, and torque (inclination) changes are not facilitated by a low-friction method of archwire ligation.

**Quick and Easy to Use**

This is a significant disadvantage of wire ligatures and the principal reason for the decline in their use. Maijer and Smith\(^{10}\) and Shivapuja and Berger\(^{8}\) have shown that the process of wire ligation is very slow compared with elastomeric ligature. In the latter study, the use of wire ligatures added almost 12 minutes to the time needed to remove and replace two archwires. This is the major reason for the decreased use of wire ligation.

**Easy Attachment of Elastic Chain**

Conventional brackets have tie wings, which are very convenient for the attachment of elastic chain. Some self-ligating brackets have dispensed with tie wings. This is less convenient for attachment of elastic chain.

**Maintenance of Optimal Oral Hygiene**

It is a prevailing view that elastomers accumulate plaque more than do wire ligatures and there is some evidence to support this.\(^{11}\) There is also some evidence that the use of wire ligatures reduces bleeding on probing of the gingival crevice when compared with elastomeric ligatures.\(^{12}\) However, a scanning electron microscopy study\(^{13}\) found no difference in bacterial morphotypes when using elastomers or steel ligatures. The latter area requires further investigation; however, current evidence suggests that a reduction in the bacterial challenge through an absence of elastomeric ligation is a reasonable hypothesis.

**Comfortable for the Patient**

Elastomers are good in this respect, but wire ligatures require careful tucking in of the ends to avoid soft tissue trauma and even then can occasionally be displaced between appointments and cause patient discomfort.

**Summary: Frequently Proposed Limitations of Conventional Ligation**

- Failure to provide and to maintain full archwire engagement results in poor control of tooth movement.
- Frictional values are increased.
- For elastomers, the force decays and therefore tooth control is not optimal.
- Both wire and elastomeric ligatures sometimes become displaced.
- Oral hygiene is potentially impeded.
- Wire ligation is a time-consuming clinical procedure.

Examples of the deficiencies of conventional archwire ligation are common, but clinicians have become accustomed to tolerating these deficiencies. Self-ligation offers the opportunity for significant improvements relative to all of these factors.

**Proposed Core Advantages of Self-Ligating Brackets**

- More certain full archwire engagement,
- Low friction between the bracket and the archwire,
- Less chairside assistance needed, and
- Faster archwire removal and ligation.

These core advantages are now all well documented and additional evidence is appearing with increased frequency. Individually and in combination, each advantage has potential clinical benefit. As will become evident later in this article, and in other articles in this issue, there are other proposed advantages, such as more rapid treatment, which can at the present time only be described as probably true or conjecture. There are still further proposed advantages, which at this time can be best described as
very interesting hypotheses. These have arisen from clinical observation and are in the early stages of more formal investigation.

The proposed four core advantages listed previously apply in principle to all self-ligating brackets although the different types of bracket may vary in their ability to deliver these advantages consistently in clinical practice. These advantages have been previously discussed\textsuperscript{14} and are described and supported in other articles in this issue in relation to individual bracket types. It is helpful, however, to summarize some of the proposed advantages for the unique combination of low friction and good control, which these brackets can provide.

Secure Archwire Engagement and Low Friction as a Combination

Other bracket types—most notably Begg brackets—have achieved low friction by virtue of an extremely loose fit between a round archwire and a very narrow bracket, but this is at the cost of making full control of tooth position correspondingly more difficult. Some brackets with an edgewise slot have incorporated shoulders to distance the elastomeric from the archwire and thus reduce friction, but this type of design also produces reduced friction at the expense of reduced control. A deformable elastomeric ring cannot provide and sustain sufficient force to maintain the archwire fully in the slot without actively pressing on the archwire to an extent that significantly increases friction. Comparison with a molar tube is helpful in this context, since such an attachment is in essence a self-ligating bracket with the clip permanently closed. Once a convertible molar tube is converted to a bracket by removal of the slot cap or straps, an elastomeric or even a wire ligature can prove very ineffective at preventing rotation of the tooth if it is moved along the wire or used as a source of intermaxillary traction. With tie wing brackets, an improvement in control is usually at the cost of an increase in friction, especially with elastomerics ligatures. This point has been well illustrated by Matasa.\textsuperscript{15} The combination of very low friction and very secure full archwire engagement in an edgewise-type slot is currently only possible with self-ligating brackets (or with molar tubes) and is likely to be the most advantageous feature of such brackets. It has therefore been proposed\textsuperscript{14} that this combination enables a tooth to slide easily along an archwire with lower and more predictable net forces and yet under complete control, with almost none of the undesirable rotation of the tooth resulting from a deformable mode of ligation such as an elastomeric.

Possible Anchorage Consequences of the Combination of Low Friction and Secure Full Archwire Engagement

Tooth movement has been shown to be only partially related to the level of force applied,\textsuperscript{16} although in that study in beagle dogs, the lower force per unit root area in the anchorage unit did result in much lower rates of movement over the wide range of forces they used. In clinical investigations, the study by Rajcich and Sadowsky\textsuperscript{17} demonstrated extremely good anchorage preservation where retraction of canine teeth was pitted against an anchorage unit of the rest of the arch. This study using conventional brackets supports the clinical application of the differential force theory. More widespread use of this anchorage-preserving effect is inhibited by the tendency with conventional ligation for individual teeth to rotate relative to the archwire and then require realignment. A thesis by Srinivas\textsuperscript{18} contains a well-conducted split-mouth study of canine retraction using sliding mechanics on 0.018”/025” wire. One upper canine had a Damon SL bracket and the contralateral canine a conventional bracket. Canine retraction was more rapid, to a clinically and statistically significant extent (0.24 mm per month), on the side with Damon SL brackets. This shortened the average time for canine retraction of 3 mm from 16 weeks to 12 weeks. In addition, the anchorage loss was reduced by 0.3 mm on the Damon SL side. Furthermore, canine rotation averaged 8° on the Damon side and 12° on the conventional bracket side. These studies support the hypothesis that the combination of low friction and good rotational control exhibited by self-ligating brackets may also conserve anchorage by facilitating better use of the differential force theory as will be outlined herein.

With lower friction, the net tooth-moving forces are more predictably low and the reciprocal forces correspondingly smaller. Although the evidence shows that the relationship between
force level and tooth movement is complex, it does support the idea that within the range of forces advocated for orthodontic tooth movement, lower forces per unit root area lead to more anchorage. The force used by Srinivas was 150 gms, which is at the lower end of the range originally suggested by Reitan as suitable to induce an optimal histological response when bodily retracting an upper canine (150-250 gms) and therefore much lower than the recommended effective force for bodily movement when spread over the much larger root surface area of the other teeth on that side of the arch. Individual teeth—for example, canines—can be retracted separately along an archwire and thus potentially reduce the overall anchorage demands by reduction of the root area of teeth to be moved at any one time, but with none of the potential disadvantages of other methods of separate canine retraction, for example, loss of rotational control. Following such separate canine retraction, the low friction of self-ligating brackets then facilitates sliding mechanics to retract incisors even though there will now be a minimum of three brackets distal to the remaining space through which the archwire must slide. These considerations apply equally to preservation of anterior anchorage in hypodontia cases.

Alignment of Severely Irregular Teeth

A combination of low friction and secure full engagement is particularly useful in the alignment of very irregular teeth and the resolution of severe rotations, where the capacity of the wire to release from binding and slide through the brackets of the rotated and adjacent teeth would be expected to significantly facilitate alignment. This relationship between friction and derotation has been described and quantified by Koenig and Burstone and the potential adverse forces shown to be very large. This is described and discussed in the article by Mavreas in this issue of Seminars in Orthodontics. Low friction therefore permits rapid alignment and more certain space closure, whereas the secure bracket engagement permits full engagement with severely displaced teeth and full control while sliding teeth along an archwire. It is this feature that greatly facilitates the alignment of crowded teeth, which have to push each other along the archwire to gain alignment.

Factors That Have Hindered the Adoption of Self-Ligation

The four core advantages listed previously are increasingly supported by greater clinical experience and by formal investigations. In addition, there are studies that provide some support for a resulting increase in clinical effectiveness. It is therefore helpful to describe some of the factors that have, until recently, hindered the more widespread use of self-ligating brackets. The factors have varied with different bracket designs and can be illustrated by examples from Table 1. With the exception of Edgelok, the author of this article has used all the examples used for illustration herein.

Edgelok brackets. Edgelok brackets (Ormco Corp., 1717 W. Collins Ave., Orange, CA 92867; Fig 2) were the first self-ligating bracket to be produced in significant quantities. Disadvantages included inadequate rotational control, bulkiness, and some inconvenience with opening and closing the slide.

SPEED brackets. The well-known SPEED brackets (Strite Industries Ltd., 298 Shepherd Avenue, Cambridge, Ontario, N3C 1V1 Canada; Fig 3) have remained in successful production since 1980. This testifies to the inherent soundness of many of the original design features. Early brackets were handicapped by clips, which could too easily be displaced or distorted. These drawbacks have since been successfully addressed, but combined
with the inherent unfamiliarity for clinicians of a bracket with no tie wings, these aspects probably hindered the wider popularity of SPEED in previous years.

**Mobil-Lock brackets.** Mobil-Lock brackets (Forestadent Bernhard Foerster GmbH, Westliche 151 75173 Pforzheim, Germany; Fig 4) had a rotating cam, which was turned with a “screwdriver,” thus covering part of the labial surface of the slot. The wire could be tightly or loosely engaged by the degree of rotation of the cam. These brackets were well engineered by the standards of the day, but a major limitation was the narrowness of the resulting labial face of the slot. This gave very poor rotational control to the extent that upper incisor brackets were given twin cams to increase the effective bracket width. Another problem was the difficulty of access to open and close premolar brackets with the straight screwdriver.

**Activa brackets.** Activa brackets (“A” Company, San Diego, CA; Fig 5) had a rotating slide, which therefore gave a concave inner radius to the labial surface of the slot. This increased the effective slot depth with small diameter wires, diminishing labiolingual alignment with such wires. The slide was retained on the mesial and distal ends of the slot and this made for a wider than average bracket, which reduced the inter-

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**Figure 3.** SPEED bracket. More details are in the article by Berger in this issue. (Color version of figure is available online.)

**Figure 4.** Mobil-Lock bracket. (Color version of figure is available online.)

**Figure 5.** Activa bracket. (Color version of figure is available online.)

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bracket span with the consequent disadvantages. A potential advantage of self-ligation is that the good archwire control permits use of narrower brackets and thus greater interbracket span and hence lower forces and a longer range of action with any given archwire during the alignment phase. The absence of tie wings was a nuisance when placing elastomeric chain and the unfamiliar shape of the early bonding base made bracket positioning more difficult. Finally, a combination of the design features substantially reduced bond strength. Despite these substan-
tial drawbacks, cases could be successfully treated that demonstrated the now familiar advantages of self-ligation, but the deficiencies of the design ensured that they were only adopted by a minority of enthusiasts.

**Time2 bracket.** The Time2 bracket (Adenta GmbH; Fig 6) has some enthusiastic users. It superficially resembles a SPEED bracket, but unlike the SPEED clip that has a vertical movement, the Time clip rotates into position around the gingival tie wing and rotates toward the occlusal rather than the gingival wall of the slot. Early versions suffered from displacement of the clips, and important but subtle changes in clip design were needed to sufficiently reduce this tendency and ensure its continued availability and success. Early production examples of many self-ligating designs have needed significant modification. The negative effect of such initial problems with self-ligating brackets has sometimes hindered subsequent popularity even when the problems have been very largely overcome.

**Damon SL brackets.** Damon SL brackets (“A” Company, San Diego, CA; Fig 7) also became available in the mid 1990s and had a slide that wrapped around the labial face of the bracket. A tiny U-shaped wire spring lay under the slide and clicked into the two labial “bulges” on the slide to provide positive open and shut positions. These brackets were a definite step forward, but suffered two significant problems—the slides...
sometimes opened inadvertently and they were prone to breakage. The study by Harradine quantified these problems. In 25 consecutive cases in treatment for more than 1 year, 31 slides broke and 11 inadvertently opened between visits. This compared with 15 broken and lost elastomeric ligatures in 25 consecutively treated cases with conventional brackets, so the difference in ligation fragility was not enormous, but when a clinician has paid extra for a novel bracket design and the main design feature is not highly robust and is susceptible to inexpert handling from inexperienced operators, it has a definite negative effect on widespread adoption of that bracket. Nevertheless, these brackets generated a substantial increase in the appreciation of the potential of self-ligation.

**Damon 2 brackets.** Damon 2 brackets (Ormco Corp.; Fig 8) were introduced to address the imperfections of Damon SL. They retained the same vertical slide action and U-shaped spring to control opening and closing, but placed the slide within the shelter of the tie wings. Combined with the introduction of metal injection molding manufacture, which permits closer tolerances, these developments almost completely eliminated inadvertent slide opening or slide breakage and led to a further acceleration in the use of self-ligation. However, the brackets were not immediately and consistently very easy to open and this aspect of functionality is important to the new user.

**Damon 3 and Damon 3 MX brackets.** Damon 3 and Damon 3 MX brackets (Ormco Corp.; Fig 9A and 9B) have a different location and action of the retaining spring, and this has produced a very easy and secure mechanism for opening and closing. In addition, Damon 3 brackets are semiesthetic. However, early production Damon 3 brackets suffered three significant problems: a high rate of bond failure, separation of metal from reinforced resin components, and fractured tie wings. These three problems all re-
received rapid and effective investigation and correction, but illustrate that it continues to be a significant challenge for manufacturers to extrapolate from the experience with prototype brackets in the hands of skilled enthusiasts to subsequent full-scale production and the use by relative novices. It is interesting that such early difficulties did not prevent the enthusiastic adoption of these brackets. This was probably due to the greatly increased appreciation of what self-ligation could do and also to the greater willingness of manufacturers to invest in finding solutions. The recently launched all-metal Damon D3 MX bracket (Fig 9b) has clearly benefited from manufacturing and clinical experience with previous Damon brackets.

**System R brackets.** System R brackets (GAC International Inc., 355 Knickerbocker Ave., Bohemia, NY 11716; Fig 10), originally called In-Ovation brackets, are very similar to the SPEED bracket in conception and design, but of a twin configuration with tie wings. In 2002, smaller brackets for the anterior teeth became available— In-Ovation R (Reduced, referring to the reduced bracket width) and this narrower width was effective in terms of greater interbracket span. The bracket subsequently became known as System R. They are a successful design, but some relatively minor disadvantages in bracket handling were initially apparent. Some brackets of this type are difficult to open and this is more common in the lower arch where the gingival end of the spring clip is difficult to visualize. Excess composite at the gingival aspect of brackets in the lower arch can be difficult to see and may also hinder opening. Similarly, lacebacks, underties, and elastomerics placed behind the archwire are competing for space with the bracket clip. Interestingly, both SPEED and System R and also the similar and recently released Quick brackets (Forestadent Bernhard Foerster GmbH; Fig 11) have addressed this difficulty by providing a labial hole or notch in the clip in which a probe or similar instrument can be inserted to open the bracket. The need to acquire the expertise of opening an unfamiliar bracket can dishearten the new user of self-ligating brackets and these more recent refinements of the method of opening are a definite advance in this respect. These refinements are also typical of the incremental improvement of self-ligating brackets, which can take place without being appreciated by clinicians who have experienced difficulties with earlier production examples.

**SmartClip bracket.** The SmartClip bracket (3M Unitek 3M Center, St. Paul, MN 55144-1000; Fig 12) retains the wire by two C-shaped spring clips on either side of the bracket slot. The instrument or finger pressure required to insert or remove an archwire is therefore not applied directly to the clip, but to the archwire, which in turn applies the force to deflect the clips and thus permits archwire insertion or removal. This mechanism therefore has to cope with providing easy insertion and removal through the jaws of the clips but must also prevent inadvertent loss of ligation for both small, flexible archwires and large, stiff archwires. The design has to find a difficult compromise between the best requirements for the wide range of orthodontic archwires. Other spring clips, such as on SPEED and System R brackets with their vertical action, have a rigid bracket component to assist the spring in resisting a loss of ligation. It became apparent with wider clinical use that the force required for insertion and removal of thick stainless steel wires from SmartClip brackets was uncomfortable.
ably high. A recent modification has addressed this difficulty by lowering the effective stiffness of the spring clips. These examples illustrate the difficulties that have been experienced by manufacturers aiming to meet the requirements of an ideal ligation system. The resulting imperfections in bracket design have undoubtedly slowed the adoption of self-ligation systems by clinicians. Current self-ligation designs have benefited greatly from previous clinical experience and from advances in the available production techniques such as metal-injection molding.

**Active Clip or Passive Slide**

This is an issue that has attracted heated debate and, as is seen in the subsequent articles in this issue, continues to be stressed by many producers and advocates of particular brackets as a major feature of importance. It is therefore worth a detailed consideration of the fundamental dimensions and issues.

Among the brackets in Table 1 that are currently available, SPEED, System R (In-Ovation), and Quick brackets have a sliding spring clip, which encroaches on the slot from the labial aspect, potentially placing an active force on the archwire. Time2 brackets have a very similar clip, but for closure it rotates around a tie wing rather than slides into place. These four brackets are all described as having potentially active clips. In contrast, Damon brackets have a slide that opens and closes vertically and creates a passive labial surface to the slot with no intention or ability to encroach on the slot and store force by deflection of a metal clip. SmartClip, Praxis Glide

**Figure 11.** Quick bracket. (Color version of figure is available online.)

**Figure 12.** SmartClip brackets. More details are in the article by Trevisi in this issue.
(Lancer, 253 Pawnee St., San Marcos, CA 92069; Fig 13) and Carrière LX brackets (Ortho Organisers, 1822 Aston Ave., Carlsbad, CA 92008-7306; Fig 14) are also passive systems.

The intended benefit of storing some of the force in the clip as well as in the wire is that in general terms a given wire will have its range of labiolingual action extended and produce more alignment than would a passive slide with the same dimension wire. This difference in labiolingual force delivery needs more detailed consideration. It is perhaps helpful to think of the situation with three different wire sizes.

• With thin aligning wires smaller than 0.018” diameter:
  The potentially active spring clip will be passive and its activity irrelevant unless the tooth (or part of the tooth if it is rotated) is sufficiently lingually placed in relation to a neighboring tooth that the wire touches the inner surface of the clip. In that situation, a higher force will be applied to the lingually placed tooth with an active clip than with a passive slide since the latter would be more labially placed relative to the base of the slot. An active clip effectively reduces the slot depth from 0.027” (the depth for example of a Damon slot) to approximately 0.018” either immediately—if the clip is not deflected—or as the wire goes passive if it was initially deflected. This additional force is unlikely to be detrimental with modern low modulus wires but should be borne in mind when choosing initial archwires. However, for such lingually placed teeth, the active clip can move the tooth more labially by a maximum of 0.027” – 0.018” = 0.009” with a given wire. These figures are slightly complicated by the fact that the active clip has a diagonal surface in relation to the slot walls and base, so the clip on these brackets impinges into the slot more at one slot wall than at the other. This geometry is well visualized in the illustrations in an article by Thorstenson and Kusy.21 The effect of having an active clip at this early stage of treatment can be thought of as equivalent to having a shallower bracket slot.

• For wires larger than 0.018” diameter:
  With these wires, an active clip will place a continuous lingually directed force on the
wire even when the wire has gone passive. On teeth that are in whole or in part lingual to a neighboring tooth, the active clip will again bring the tooth slightly more labial than would have been the case with a passive clip at 0.027" slot depth. The maximum difference in labial tooth movement will be the difference between the labiolingual dimension of the wire and 0.027". For a typical 0.016" × 0.022" intermediate wire, this would give a maximum difference of 0.005". 0.016" × 0.025" or 0.014" × 0.025" nickel titanium wires are recommended as the intermediate aligning wire for the passive Damon system and this wire reduces the potential difference to 0.002". Lingually placed teeth would have a slightly higher initial force with an active clip when using wires of this intermediate size.

- With thick rectangular wires:
  An active clip will make a labiolingual difference in tooth position of 0.002" or less, which is very small clinically. It has been suggested that continued lingually directed force on the wire from an active clip will cause additional torque from an undersized wire. This would be a useful action in such brackets, because it would overcome the diminished torquing ability in one direction, which inevitably results from the active clip needing to encroach into the slot. This encroachment diminishes the labiolingual slot depth on one side of the slot and therefore the generation of torque from the gingival and occlusal slot walls. The suggestion that the lingually directed force from an active clip can generate effective torque perhaps reflects a degree of misunderstanding or optimism about the generation of torque in an edgewise slot. The diagonally directed lingual force may not contribute to any effective third order interaction between the wire corners and the upper and lower walls of the bracket slot, which is the origin of torquing force. SPEED brackets have therefore more recently addressed this question on upper incisors by extending the gingival walls of the slot either side of the clip to the full slot depth as “torquing rails.” This should indeed restore the torquing effectiveness. Time2 brackets also have two torquing rails within the overall clip width. Similarly, System R (In-Ovation) brackets have a small central portion of the slot wall of some brackets that is full depth and therefore provides full torquing capacity on that section. It should be noted that while SPEED and System R brackets have a clip that impinges on the slot at the gingival slot wall, the reverse is the case for Time2 brackets, so a potential effect on torque in an upper incisor would be on palatal root torque with the former brackets and labial root torque with Time2. The article in this issue by John Valant on Time2 brackets reports dimensions that indicate that the slot encroachment is 0.002" greater on the Time2 brackets, so these issues have a little more complexity than may initially seem the case.

Overall Advantages or Disadvantages of an Active Clip

The actual clinical consequences of having a potentially active clip impinging into the slot are perhaps harder to assess than a first thought suggests. It is probable that with an active clip, initial alignment is more complete for a wire of given size to an extent that is potentially useful clinically. However, the increased clearance between a given wire and a passive slide will generate lower forces and may facilitate dissipation of binding forces and the ability of teeth to push each other aside as they align.

With modern low modulus wires it is possible to subsequently insert thicker wires into a bracket with a passive slide and arrive at the working archwire size after the same number of visits as with an active clip—for example, to store all the force in the wire rather than dividing it between wire and clip. The relative stiffness of archwires and the spring clip is not well documented. If it is assumed that the spring clip has the same stiffness as a thicker nickel titanium wire, then both mechanisms would produce the same labiolingual aligning force with wires of that size. In fact, the different active clips are made from a variety of alloys—nickel-titanium, stainless steel and Elgiloy Co-Cr-Fe-Ni alloy—which will have different moduli, so the clips will very probably have differing rigidities. If the clip is more rigid, then for a given irregularity that deflects an archwire, the wire will be deflected more and the clip deflected less and vice versa.

Once in the thick working archwire, the potential disadvantages of an active clip are increased friction and potentially reduced
torquing capacity in one direction with some brackets. To put the friction levels in context, these higher friction forces are still very much lower than those found with elastomeric ligatures on a conventional tie-wing bracket. All other factors being equal, higher friction is a disadvantage in many tooth movements, but it is hard to assess the effect on clinical performance which arises from this level of increased friction. The trend to having a full slot depth for part of the encroached slot wall with some active self-ligating brackets reduces any difference in potential torquing ability and control. Finally, there are the questions of robustness, security of ligation and ease of use. Is a clip that is designed to flex, more prone to breakage or permanent deformation or to inadvertent opening or closing? This question has not been formally investigated. Studies involving the use of different self-ligating brackets in the same patient or randomly assigned to different patients are needed to test such hypotheses. Although the different effects can be elucidated, it is hard to weigh the extent to which the differences between active and passive brackets affect clinical performance. However, it is hoped that this section of the article usefully informs a consideration of the claims made in this context in later articles in this issue.

Cost and Treatment Efficiency

Currently available self-ligating brackets are more expensive than most good quality tie wing brackets. A modest balancing factor is the cost of elastic ligatures that are, of course, not required. However, this significant extra cost must be measured against savings in time—an expensive commodity. If self-ligating brackets save any appreciable chairside time as some studies suggest, this would provide an offsetting saving.

A study of treatment efficiency by Harradine found the following:

- A very modest average time saving from a reduction in archwire placement/removal of 24 seconds per arch,
- A mean reduction of 4 months in active treatment time from 23.5 to 19.4 months,
- A mean reduction of four visits during active treatment from 16 to 12, and
- The same average reduction in Peer Assessment Rating scores for matched cases.

These cases were treated in the late 1990s with no change in extraction philosophy or treatment goals.

This finding of a mean reduction of 4 months in treatment time was also reported by Dr. Robert Fry in a presentation at the American Association of Orthodontists Annual Session in Toronto 2001. He had converted one of his two offices to Damon SL. The office management software subsequently revealed that his treatment times reduced by an average of 4 months compared with his other office where he had, for the time being, stayed with conventional ligation. A study by Eberting and coworkers of intrapractitioner differences in three practices found an average reduction in treatment time of 7 months (from 30 to 25) and seven visits (from 28 to 21) for Damon SL cases compared with conventional ligation.

In two of the three centers, the American Board of Orthodontists irregularity scores were more improved with the Damon SL brackets to a statistically significant extent. These three reports support a view of clinically significant improvements in treatment efficiency with passive self-ligating brackets. The more recent bracket types would be expected to show still better treatment efficiency because they are less prone to breakage or loss of the clips and slides, are easier to open and close, are frequently of more effective slot dimensions, and are used with greater understanding of the optimal archwire selection and appointment intervals. Further studies are in progress with a variety of bracket types and some of these that deal with the early alignment phase of treatment are already in press, so this is a rapidly moving field of enquiry.

Conclusions

Currently available self-ligating brackets offer the very valuable combination of extremely low friction and secure full bracket engagement and—at last—they are sufficiently robust and user-friendly to deliver most of the potential advantages of this type of bracket. The core advantages of self-ligation are now established and readily available. These developments offer the possibility of a significant reduction in average treatment times and maybe also in anchorage requirements,
particularly in cases requiring large tooth movements. Evidence of better treatment effectiveness exists but is incomplete. While further refinements are desirable and further studies essential, current brackets appear able to deliver measurable benefit with good robustness and ease of use.

References

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