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FEATURES SECTION

Current Products and Practices

Self-ligating brackets: where are we now?

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Abstract

The current situation regarding self-ligating brackets is reviewed. Recent developments, clinical advantages, and remaining imperfections are described. The question of active versus passive ligation is scrutinized. The evidence regarding treatment efficiency is reviewed. Suggested clinical tips and changes of treatment mechanics are summarized and illustrated.

Self-ligating brackets have reached a stage of design and production control, where the advantages are significantly greater than the remaining imperfections.

Index words: Clinical tips, self-ligation, treatment effectiveness.

Introduction and history

Self-ligating brackets have an inbuilt metal labial face, which can be opened and closed. Brackets of this type have existed for a surprisingly long time in orthodontics— the Russell Lock edgewise attachment being described by Stolzenberg[1] in 1935. Many designs have been patented, although only a minority have become commercially available. The author has used several types from the list in Table 1[2–4] and has also used self-ligating Begg brackets. New designs have continued to appear, the Time bracket becoming available in 1994, the Damon SL bracket in 1996[5,6] and the TwinLock bracket in 1998, being three designs from that decade. This continued activity is in spite of the fact that self-ligating brackets have, until recently, never attracted more than a small percentage of bracket sales. The latest and most significant developments have been the Damon2 and In-Ovation brackets in 2000. These brackets exhibit major advances in robustness and ease of use, have rapidly grown in popularity and merit a scrutiny of the current situation in this class of bracket.

Properties of an ideal ligation system

The concept that brackets are ligated via tie-wings is so prevalent that it is worthwhile considering 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. 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 high friction when desired;
- permit easy attachment of elastic chain;
- assist good oral hygiene;
- be comfortable for the patient.

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, whilst elastomeric ligatures are inferior, especially if left for too long without being renewed. The force decay of elastomerics has been well documented.[7]

Table 1 Examples of self-ligating bracket designs

Bracket	Year
Russell Lock	1935
Ormco Edgelock	1972
Forestadent Mobil-Lock	1980
Orec SPEED	1980
‘A’ Company Activa	1986
Adenta Time	1994
Ormco TwinLock	1998
Ormco/‘A’ Co Damon 2	2000
GAC In-Ovation	2000
GAC In-Ovation R	2002
Adenta Evolution LT	2002

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Full bracket engagement

It is a large 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. Elastomerics 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. Twin brackets with the ability to 'figure of 8' the elastomerics are a significant help in this respect, but certainly not a complete answer.

Quick and easy to use

This is a major weak point of wire ligatures and the principal reason for the enormous decline in their use. Maijer and Smith,[8] and Shivapuja and Berger[9] have shown that wire ligation is very slow compared to elastomerics. 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 largest and very understandable reason why so few wire ligatures are now used.

Low friction

Wire ligatures are better than elastomerics; producing 30–50 per cent of the elastomeric friction forces in one representative study,[9] but the forces still reach undesirable levels relative to those that are ideal for tooth movement. Also, the force normal to the archwire produced by a wire ligature is probably very variable. This force has also been shown to be more variable for elastomeric ligatures than for passive self-ligation.[10]

High friction

It is also helpful under some circumstances if the ligation system can 'lock' a tooth to the wire to prevent unwanted movement of that tooth along the wire. When initially placed, an elastomeric in a 'figure of 8' configuration increases the friction by a factor of 70–220 per cent compared to the 'O' configuration[11] and this partially meets this requirement.

Easy attachment of elastic chain

Some self-ligating brackets have dispensed with tie-wings. This makes attachment of elastic chain and if desired, elastomeric ligatures, inconvenient or impossible. The recently developed self-ligating brackets all have tie-wings.

Assistance to good oral hygiene

Elastomerics accumulate plaque more than tie-wires do and fluoride-releasing elastomerics have yet to reach reliably robust performance levels by way of compensation. The ends of wire ligatures are, however, an additional obstacle to oral hygiene.

Comfortable for the patient

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

Summary: what is wrong with conventional ligation?

- Failure to provide and to maintain full archwire engagement.
- High friction.
- For elastomerics, the force (and therefore tooth control) decays and they are sometimes lost.
- Potential impediment to oral hygiene.
- Wire ligation is very slow.

Wire ties are secure, robust, enable full, partial or distant ligation, and have lower friction than elastomerics. Their largest drawback is the time required for ligation. Elastomerics are quick, but less good in every other respect. Neither method is ideal or nearly as good as a molar tube assembly, which is universally adopted as the 'ligation' of choice on posterior teeth. It is easy to find examples of the deficiencies of conventional ligation, but clinicians have become accustomed to tolerating these shortcomings.

Advantages of self-ligating brackets

These advantages apply in principle to all self-ligating brackets, although the different makes vary in their ability to deliver these advantages consistently in practice:

- more certain full archwire engagement;
- low friction between bracket and archwire;
- less chairside assistance;
- faster archwire removal and ligation.

Secure, full archwire engagement

Full engagement is a feature of self-ligation because a clip/slide is either fully shut or it is not. Unintentional partial engagement is not possible. There is no problem of decay of the ligature as with elastic ligatures. However, security of ligation will depend on the clip/slide being robust and not inadvertently opening. Until very recently, this requirement for security of performance was not fully met by self-ligation designs. Secure, full archwire engagement maximizes the potential long range of action of modern low modulus wires and minimizes the need to regain control of teeth where full engagement is lost during treatment.

Low friction

Very low friction with self-ligating brackets has been clearly demonstrated and quantified in work by various authors,[9,11–13] for both Activa and Speed brackets, and Edgelok. Voudouris[14] has reported greatly reduced friction with Sigma and Interactwin prototypes and with Damon brackets. The friction is dramatically lower than for elastomeric rings with conventional brackets and seems to be an inherent characteristic of self-ligating brackets. Thomas *et al.*[15] confirmed extremely low friction with Damon brackets compared to both conventional pre-adjusted and also Tip-Edge brackets. Kapur[16] found dramatically lower friction with both stainless steel and nickel-titanium wires for Damon brackets compared to conventional brackets. With NiTi wires, the friction per bracket was 41 g with MiniTwin and conventional ligation and 15 g with Damon brackets; whilst with stainless steel wires, these values were 61 and only 3.6 g, respectively. Pizzoni *et al.*[17] have reported that Damon brackets showed lower friction than Speed which in turn had less friction than conventional brackets stating that: 'In the case of rectangular wires, the Damon bracket was significantly better than any of the other brackets and should be preferred if sliding mechanics is the technique of choice'. Meling *et al.*[18] examining the effect of friction on wire stiffness concluded that each elastomeric placed in an 'O' configuration produces an average of 50 g of frictional force.

Friction in vivo and with active wires

It is, however, difficult to be certain how accurately any laboratory simulation of friction reproduces the true *in vivo* situation. A study by Loftus *et al.*[19] found that in an experiment with a simulated periodontal ligament, and with slight tip and rotation of the brackets, the friction with Damon SL was not significantly less than with conventionally ligated brackets. Read-Ward *et al.*[20] reported that the reduction in friction with self-ligation is much less when the wire is active, but this study also showed the considerable methodological problems in measuring friction with active wires, the standard deviation of repeated measurements being very high. Other authors[12] found friction with self-ligating brackets to still be substantially lower even at high values of active torque. A recent paper on this topic, by Thorstenson and Kusy,[21] examined the effects of varying active tip (angulation) on the resistance to sliding. They found that angulation beyond the angle at which the archwire first contacts the diagonally opposite corners of the bracket slot causes a similar rise in the resistance to sliding of both self-ligated (Damon SL) and conventional brackets. However, at all degrees of tip, the Damon brackets produced significantly less resistance to sliding. At a realistic angulation of 6 degrees for an 0.018 × 0.025-inch stainless steel wire, this difference (60 cN) is probably of clinical significance (Table 2).

Friction in vivo: occlusal and masticatory forces

A further factor has been investigated in studies,[22,23] which found that various vibrations and displacements of a test jig (to mimic intra-oral masticatory forces) can substantially reduce the friction with conventional ligation. This is a valid line of enquiry and an interesting finding, but the question then arises as to how accurately these laboratory studies mimic intra-oral masticatory 'jiggling' forces. The full interpretation of laboratory friction studies is clearly difficult and the *in vivo* situation will show substantial variation. Studies involving tooth displacements, such as rotation or lingual displacement, which create more labial pressure from elastomeric ligatures, would usefully simulate another *in vivo* factor. Nevertheless, the balance of the current evidence from

Table 2 Resistance to sliding (RS) for different bracket angulations with a 0.018/0/025-inch archwire.[21]

Angulation (°)	Damon SL (RS force, cN)	Conventional bracket (RS force, cN)
0	0	34
3.5	0	55
6.0	80	140

studies and from clinical experience is that self-ligation provides very significant reduction in friction in all dimensions of tooth movement. The clinical significance of this factor in isolation is hard to estimate and it is more appropriate to consider the combined features of low friction and secure archwire engagement.

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 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 inter-maxillary traction. These ligation methods simultaneously increase friction as they attempt to retain full archwire engagement. With tie-wing brackets an improvement in one respect is usually at the cost of deterioration in the other. 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 beneficial feature of such brackets. This combination enables a tooth to slide 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.

Anchorage consequences of low friction and secure full archwire engagement

This combination of properties can conserve anchorage for three reasons:

- With low 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,[24] it does support the idea that lower forces per unit root area lead to more anchorage.
- Lower net forces deflect archwires less and, therefore, facilitate release of binding forces between wire and bracket, enhancing sliding of brackets along a wire.
- 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, e.g. loss of rotational control. Following such separate canine retraction, the low friction of self-ligating brackets then permits the sensible use of sliding mechanics to retract incisors, even though there will now be a minimum of three brackets distal to the remaining space through which archwire sliding must occur.

Alignment of severely irregular teeth

The other situation in which the combination of low friction and secure full engagement is particularly useful, is in the alignment of very irregular teeth and the resolution of severe rotations, where the capacity of the wire to slide through the brackets of the rotated and adjacent teeth significantly facilitates alignment. This relationship between friction and derotation has been described and quantified by Koenig and Burstone,[25] and the potential adverse forces shown to be very large. Low friction, therefore, permits rapid alignment and more certain space closure, whilst the secure bracket engagement permits full engagement with severely displaced teeth and full control, whilst sliding teeth along an archwire. Modern, low modulus wires substantially enhance our ability to harness these benefits.

Less chairside assistance and faster ligation/archwire removal

The original motive when developing the earlier self-ligating brackets was to speed the process of ligation. For example a paper by Maijer and Smith[8] demonstrated a four-fold reduction in ligation time with Speed brackets compared to wire ligation of conventional brackets. Shivapuja and Berger[9] have shown similar results but also that the speed advantages compared to elastomeric ligation are less dramatic (approximately 1 minute per set of archwires). Voudouris[14] has also reported a fourfold reduction in archwire removal/ligation time with prototype Interactwin brackets which lead to the commercially available In-Ovation brackets. A study by Harradine[26] found statistically significant, but clinically very modest savings in ligation/re-ligation time with Damon SL—an average of 24 seconds per archwire removal and replacement. It should, however, be remembered that archwire 'ligation' using self-ligating brackets does not require a chairside assistant to speed the process, since self-ligating brackets require no passing of elastomeric or wire ligatures to the operator during ligation. Although the evidence suggests that this is the least significant advantage of self-ligation, it is still perhaps worthwhile.

'A' Company Damon SL brackets

These self-ligating brackets (Figure 1) became available in 1996. They had a slide, which moved vertically on the labial surface of an otherwise fairly conventional twin tie-wing bracket. The slide clicked into a positive open or shut position and opened in a downwards direction in both jaws to give a full view of the slot. 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 major step forward, but suffered two irritating problems—the slides sometimes opened inadvertently and they were prone to breakage. The study by Harradine[26] quantified these problems. In 25 consecutive cases in treatment for more than one year, 31 slides broke and 11 inadvertently opened between visits. This compared with 15 broken and lost elastomeric ligatures in 25 consecutive cases treated for at least a year with conventional brackets. Slide breakage was due to work hardening of the slide corners. The loss of slide was sometimes due to breakage at the slide angles caused by work hardening, but was also due to the overall length of the slide and the play in the slide/bracket contact. This permitted over-opening of the slide, which could pass beyond the stop provided by the underlying U-shaped wire.

Damon 2 brackets

These imperfections led to the development of Damon 2 brackets (Figure 2), which retain the same vertical slide action and U-shaped spring to control opening and closing, but place the slide within the shelter of the tie-wings. Combined with the metal injection moulding manufacture, which permits closer tolerances, these developments have almost completely eliminated inadvertent slide opening or slide breakage. Although special and excellent slide-opening tools are provided with these brackets, they can—after some practice—be easily opened and closed with conventional light-wire pliers in combination with the Cool-Tool archwire-seating implement. A side effect of this design change has been to reduce the overall size of the bracket to very compact dimensions. This reduced size is an advantage. The larger inter-bracket span produces lower forces, but the secure full engagement retains much better control than for a conventional bracket of the same width. There remains scope for further improvement. The lingual crown torque in the lower second premolars, although recently reduced by 5 degrees, makes slide opening with conventional pliers (though not with Kasso D2 pliers) more awkward on this tooth. Also, whilst the slide closure is very secure, the close fit causes the force required for closure to vary. The recent introduction of metal injection moulded slides has delivered a more consistent closure force and further refinements that address this issue are reportedly in hand. These continuing developments illustrate the significant technical demands of manufacturing an ideal self-ligating bracket. One unique and useful feature of the slides on Damon brackets is that they open inferiorly in both arches in order to give an unobstructed view of the slot.

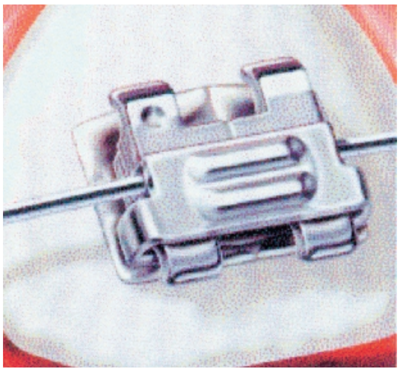

Fig. 1 The Damon SL bracket.

GAC In-Ovation brackets

These are very similar to the SPEED bracket in conception and design, but are of a twin configuration (Figure 3). They are a good, robust design, and no breakage of the clips has been personally experienced or reported. Some relatively minor disadvantages in bracket

Fig. 2 Damon 2 bracket.

handling are apparent. First, some brackets are hard to open. This is unpredictable, but more common in the lower arch where the gingival end of the spring clip is difficult to visualize. Excess composite to the gingival of lower brackets can be hard to see and may hinder opening. Secondly, these brackets are extremely easy to close inadvertently before the archwire is in position and the downwards direction of closure makes this more likely in the lower arch. Thirdly, the security of closure of the flexible clip can be overcome by some rectangular nickel-titanium wires, which can cause spontaneous opening of the clip. Lastly, it is possible—as with the Damon2 bracket slides—to incompletely open the clip and discover the need for the final fraction of opening through difficulty with removing a thicker archwire. These minor reservations may well be reduced by further bracket development.

In 2002, smaller brackets for the anterior teeth became available—In-Ovation R (Reduced). This narrower width is very welcome in terms of greater inter-bracket span. In-Ovation brackets have an active clip and this is discussed in the next section. Figure 3 shows the invasion of the slot by the clip and the consequent differential height of the gingival and occlusal bracket walls, the former being considerably less than the nominal slot depth. This feature is considered in more detail below, in relation to torque.

Active clip or passive slide?

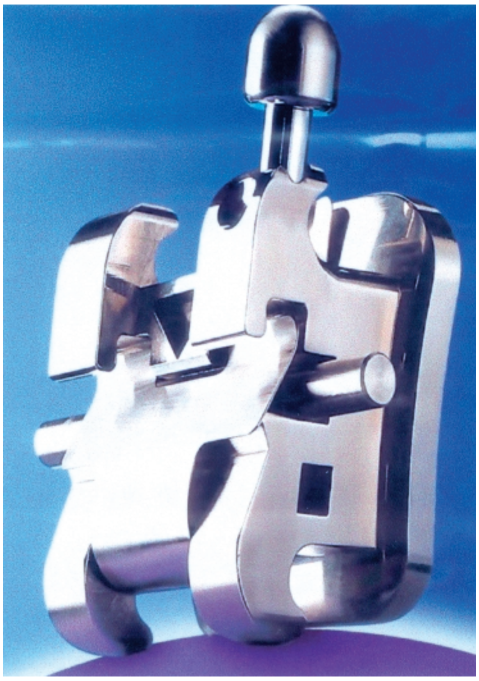

Fig. 3 The GAC In-Ovation bracket.

This is an issue that has attracted heated debate.[27] It is therefore worth detailed consideration. Speed and In-Ovation brackets both have a sliding spring clip, which encroaches on the slot from the labial aspect, potentially placing an active force on the archwire. Time brackets have a similar clip, but for closure it rotates round a tie-wing, rather than slides into place. These three brackets all have potentially active clips. In contrast, Damon2 (and the previous Damon SL and TwinLock brackets) have a slide that opens and closes vertically, and creates a passive labial surface to the slot with no intention or ability to invade the slot, and store force by deflection of a metal clip.

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 labio-lingual action increased and, therefore, produce more alignment than would a passive slide with the same wire. This needs more detailed consideration. It is perhaps helpful to think of the situation with three different wire sizes.

With thin aligning wires smaller then 0.018 inch diameter. The potentially active clip will be passive and irrelevant, unless the tooth (or part of the tooth if it is rotated) is sufficiently lingually placed in relation to a neighbouring tooth that the wire touches the active spring clip. In that situation, a higher total force will usually be applied to the tooth in comparison to a passive clip. Even if there is no significant clip deflection, there is still a force on the wire which would not exist with a passive clip because the active clip effectively reduces the slot depth from 0.027 inch (the depth of a Damon2 slot) to approximately 0.018 inch, either immediately—if the clip is not deflected—or as the wire becomes passive if it is initially deflected. This additional force is unlikely to be detrimental with modern low modulus wires but should be borne in mind, since several studies,[28,29] have shown that only large deflections are likely to enable a super-elastic wire to show a plateau of force for a range of deflection. For teeth that are initially positioned lingual to their neighbours, the active clip can bring that tooth more labially (up to a maximum of $0.027 - 0.018 = 0.009$ inch) with a given wire. These figures are slightly complicated by the fact that the active clip does not reduce the slot depth to the same extent over the whole height of the slot—the clips on Speed, Time, and In-Ovation brackets impinge into the slot more at the gingival end than at the occlusal. Also, the slope of the clips varies with brackets from different manufacturers. The slopes of the clips and the consequent asymmetries of the bracket slots are illustrated and quantified by Thorstenson and Kusy.[30] This asymmetry would make a difference with small diameter wires depending on the relative vertical positions of neighbouring teeth. The effect of having an active clip at this early stage of treatment can be thought of as having a potentially shallower bracket slot. This will frequently produce higher forces with a given wire, but a potential maximum extra 0.009 inch of labial movement of some teeth for a given small diameter wire. This figure is approximate for the reasons given above.

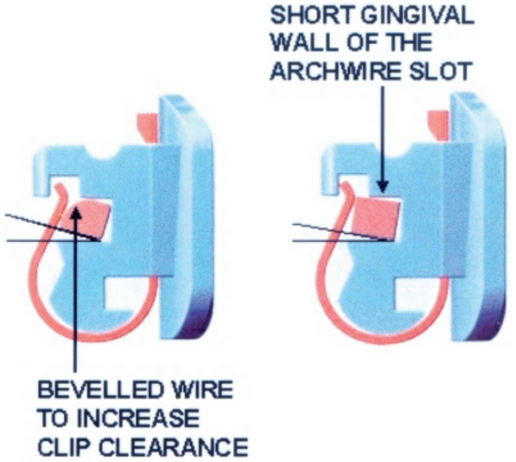

Fig. 4 Diagram of a SPEED bracket with conventional and bevelled rectangular wires, both showing the reduced gingival slot wall depth and consequent reduction in torquing ability in one direction. Selective use of significantly higher palatal root torque values would be sensible in upper incisor brackets.

For wires >0.018 inch diameter. An active clip will place a continuous lingual force on the wire even when the wire has gone passive. On teeth that are whole or in part lingual to a neighbouring tooth, the active clip will again bring the tooth (or part of the tooth if rotated) slightly more labial than would have been the case with a passive clip at 0.027-inch slot depth. The maximum difference will be the difference between the labio-lingual dimension of the wire and 0.027 inch. For a typical 0.016 × 0.022-inch intermediate wire, this would give a maximum difference of 0.005 inch. 0.016 × 0.025-inch nickel titanium wires are recommended as the intermediate aligning wire for Damon2 and this wire reduces this potential difference to 0.002 inch. Lingually-placed teeth would have a slightly higher initial force with an active clip and wires of this intermediate size. With an active clip, an active force will remain on the wire, even when it is passive.

With thick rectangular wires. An active clip will probably make a labio-lingual difference in tooth position of 0.002 inch or less, which is very small and unlikely to be of clinical significance. The suggestion that continued lingually-directed force on the wire from an active clip (or from a conventional ligature) will cause additional torque from an undersized wire is interesting and probably reflects a degree of misunderstanding about the generation of torque in an edgewise slot. Figure 4 shows that whatever the orientation or shape of the rectangular wire, the clip places a diagonally directed lingual force on the wire, which does not contribute to any third order interaction between the wire corners and the walls of the bracket slot, which is the origin of torquing force. In fact, the need for an active clip to invade the slot reduces the available depth of one side of the slot and this means the rectangular wire is not fully engaged. This increases the 'slop' between the rectangular wire and the slot, and also reduces the moment arm of the torquing mechanism. These factors probably explain the reported additional difficulty in finishing cases with some examples of this bracket type. Errors in torque can appear as errors in height or as labio-lingual contact point errors. Speed brackets have recently addressed this problem on upper incisors by extending the gingival walls of the slot either side of the clip as 'torquing rails'. This should indeed restore the torquing effectiveness, but at the cost of a reduced mesio-distal width of the clip and therefore reduced rotational control in a bracket that is already narrow. Another possible and sensible response to this problem is to place higher torque values in the direction of the inefficiency in torquing—the problem only existing in one direction for a given bracket. This would need to be selectively applied to prevent certain teeth being over-torqued in the opposite direction.

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 a clinically useful extent. However, with modern low modulus wires it should be possible to insert thicker wires into a bracket with a passive clip and arrive at the working archwire size after the same number of visits, i.e. to store all the force in the wire, rather than dividing it between wire and clip. Once in the thick working archwire, the potential disadvantages of an active clip are increased friction and reduced torquing capacity in one direction. To put the friction levels in context, these higher friction forces are still much lower than those found with elastomeric ligatures on a conventional tie-wing bracket. All other factors being equal, higher friction is a disadvantage, but it is hard to assess the loss of clinical performance that arises from this level of increased friction. 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.

Conclusion

The question of active clip or passive slide may not be the most fundamental aspect of self-ligation. Although the different effects can be elucidated, it is hard to weigh the extent to which the differences between active and passive affect clinical performance. However, it is hoped that this section usefully informs a consideration of the claims made in this context.

Clinical tips when using self-ligating brackets

These tips apply in varying degrees to all self-ligating brackets.

Aids to archwire engagement with self-ligating brackets

With self-ligating brackets, it is much more important to fully engage the wire *before* clip closure, rather than attempt to close the clip and simultaneously engage the wire. If the wire is passive labio-lingually, this consideration does not apply. However, if archwire engagement and clip/slide closure is difficult for a particular tooth, several practical tools and techniques are worth knowing.

- The wire can be held into the slot base with a variety of tools. Simple tools, such as an amalgam plugger, ligature tucker, or Mitchell's trimmer, may suffice. However, these only push on one side of the bracket and may fail to fully engage the wire across the whole width of the slot. The Cool Tool is a specific tool, which is rather akin to a torquing key. Dwight Damon has developed this instrument for engagement of wires, via balanced pressure on both sides of the bracket. GAC has more recently developed the R tool, which resembles a double ligature tucker and works in the same way. These specific tools work very well and can reassure the clinician that slide closure is not being attempted over an incompletely seated wire. They can also assist cheek/lip retraction during slide closure and such a tool is firmly recommended as a routine part of slide closure on teeth where the wire requires lingual pressure for full engagement. With thermally active wires, it is potentially easier to insert a wire in some awkward teeth if the Cool Tool is kept in the freezer (as its name suggests).
- Whereas engagement of an irregular tooth with an elastomeric ligature can involve considerable pulling on the tooth, with a self-ligating bracket, a pushing force is required. Reduction of a pulling force on the tooth when placing an elastomeric is difficult, but it is easy to reduce the net push on the tooth when engaging a wire in a self-ligating bracket—use a labio-lingual 'squeeze technique'. As you push from the labial (e.g. with a Cool Tool), also push the tooth from the lingual/palatal with a thumb of the same hand. The net force on the tooth is greatly reduced and the wire is fully engaged more easily and comfortably.
- If the tooth is very rotated and one end of the slot is too close to the adjacent tooth for an instrument to be used to seat the wire, dental floss or a ligature wire looped over the archwire can be used to fully engage the wire on that side
- Another useful manoeuvre on a very rotated or displaced tooth with any self-ligating bracket, is to first close the clip or slide, and then thread the aligning wire through the closed bracket before engaging the other brackets, i.e. to first convert it to a 'molar' tube!
- Once the wire is fully engaged, In-Ovation brackets and Speed brackets can be closed with a finger. Damon2

brackets can be closed with ordinary light-wire or bird beak pliers.

Opening clips/slides

- In-Ovation brackets are opened by pushing in an occlusal direction on the tail of the clip behind the bracket. An important point is to avoid getting composite resin near this tail during bracket placement. Such excess adhesive can hinder or prevent clip opening. This problem is more difficult and more important to avoid in the lower arch, where the tail is not visible from the operator's position.
- Time and Speed brackets are opened with a probe or other fairly sharp instrument, such as a Mitchells trimmer using the hole in the clip. Speed brackets can also be opened in the same way as In-Ovation.
- Damon2 brackets can be opened with ordinary pliers. Specific Damon pliers, which resemble modified distal end cutters, are slightly easier to use. Both these types of plier work better if there is a slight downward rotation to the opening movement.
- Very specific and extremely effective pliers for Damon2 brackets are manufactured by Plydentco and called Kasso D2 pliers. These pliers are personally recommended for all first-time users since they make all slides very easy to open. Importantly, no downward rotation is required when using these pliers.

Prevention of wire pokes

Low friction increases wire displacement. Ironically, the problems of wire displacement resulting from low friction are perhaps the most convincing and immediate clinical evidence that the low friction found in laboratory studies is readily apparent *in vivo.* Even with very irregular teeth, the very low friction with self-ligating brackets enables aligning archwires to slip through the brackets and an archwire end to protrude. This is clearly a potential nuisance. Steps to prevent this can include:

- Using tie-backs with flexible wires over extraction sites to lessen the effects of occlusal forces on unprotected spans of wire.
- Thorough turning in the ends of flexible archwires. An interesting innovation in this respect is the Bendistal plier described by Khouri[31]. This is designed to place an effective distal end bend in a super-elastic wire without the need for over-bending which can be difficult and uncomfortable and also risks the loss of a bonded molar tube.
- Selective locking of individual brackets to the archwire with elastomerics can be helpful in those designs which have a full conventional tie-wing assembly
- Small V-shaped notches in the midline of flexible wires can also limit the scope for wire swivelling. These are commercially available or can be bent into nickel-titanium wires with triple beak pliers. Pre-notched wires are usually more expensive. Sometimes in the lower arch the notches are too large for the available inter-bracket span. Also, some notches can creep into the adjacent bracket and cause irregularity of that tooth. For these reasons, this particular method is not personally recommended.
- Small sections of stainless steel tube can be crimped onto the archwire. This is quick, easy, versatile and recommended. 0.5 mm tubing (approx. 0.020 inch internal diameter) is a good size for smaller diameter wires. With larger wires, 0.7-mm tubing is required, but a crimp-on hook may be a better option since it is harder to crimp tubing securely onto the flat surface of a rectangular wire.
- The neatest solution is probably the crimp-on split tube available from manufactures such as Unitek and Speed. These can be squeezed onto almost all wires, require no fabrication, are unobtrusive and effective. The cost is a factor.
- It is recommended that the stop is not placed on a significantly active part of the archwire. This would diminish the range of action of the wire where it is most needed.

Changing treatment mechanics

It is useful to briefly list some of the ways that treatment can be changed to take advantage of the combination of low friction and full, secure bracket engagement.

More traction on lighter wires. The increased effectiveness of light forces and the decreased loss of control combine to enable more mesio-distal tooth movement to be sensible on lighter, more flexible wires (Figure 5). Compressed coil springs to move teeth apart can appropriately be placed from the first visit in many instances.

Longer appointment intervals. The ability to ensure full and secure wire engagement of modern, low modulus wires makes an extension of the interval between appointments a logical step. Eight- to ten-week intervals are usually appropriate (Figure 6).

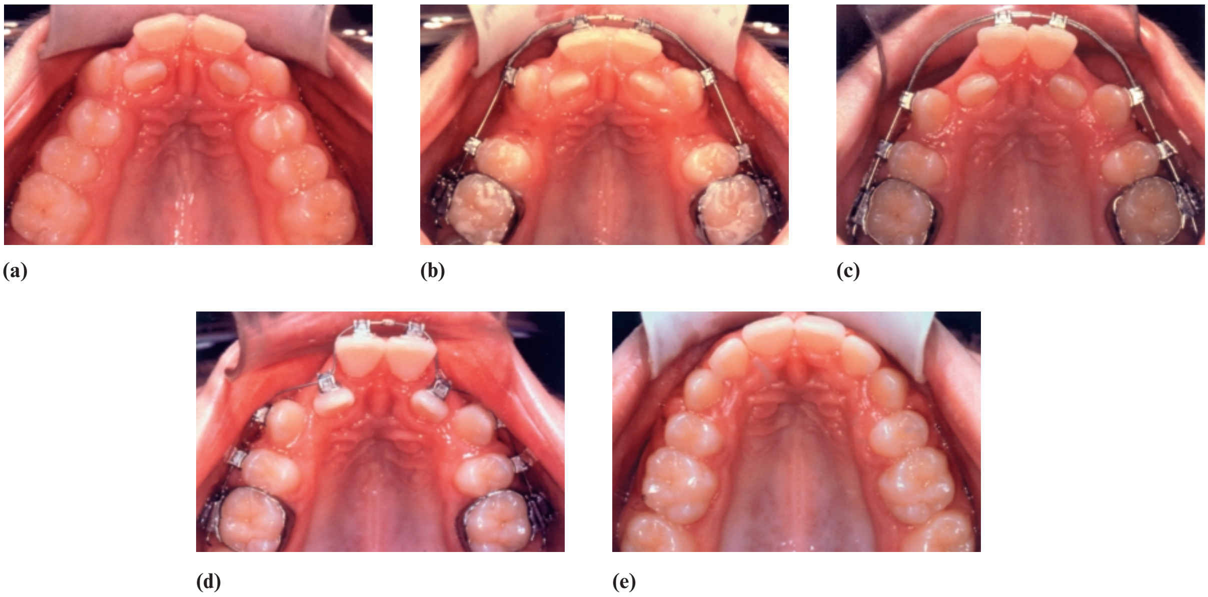

Fig. 5 (a) A case requiring substantial canine retraction. (b) Canine retraction from the first visit on 0.014-inch nickel titanium wire. (c) Next appointment after 10 weeks. Good canine rotational control. (d) Next appointment. 0.014-inch nickel titanium wire. (e) At appliance removal.

Fig. 6 (a) Marked rotation of previously palatal UL3. 0.012-inch nickel titanium wire to accommodate small interbracket distance. (b) Next appointment after 11 weeks. Change to 0.018-inch nickel titanium. (c) Placement of 0.016/0.025-inch nickel titanium after 7 weeks at next visit.

Separate movement of individual teeth. The control of rotation during traction on an individual tooth makes this option much more attractive when required. This can conserve anchorage in a variety of situations without a penalty in loss of tooth control or disproportionate lengthening of the treatment.

Parallel processing. These mechanical features make it sensible in some malocclusions to separately retract canines to a Class I relationship, whilst reducing the overbite. By the time the overbite reduction permits upper incisor retraction, the canines are already Class I, but in good rotational control and the case is further advanced with anchorage conserved.

Squeezing teeth into alignment. Crowded teeth align more rapidly. If the clinician wishes to align crowded teeth without making space with extractions, these brackets facilitate the alignment (Figure 7).

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, which 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,[8,9] this would provide an offsetting saving.

A study of treatment efficiency by Harradine[26] found the following:

- a very modest average time saving from a reduction in archwire placement/removal of 24 seconds per arch;

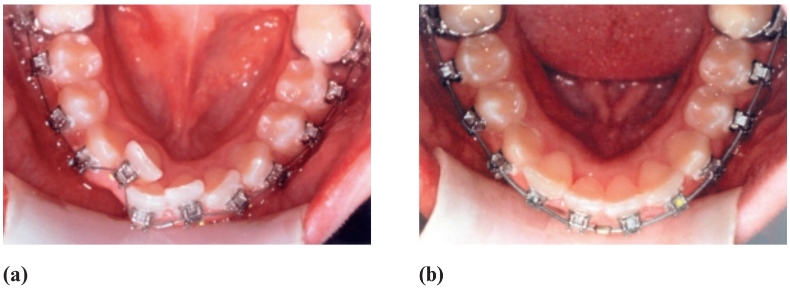
(a) (b)

Fig. 7 (a) 0.012-inch nickel titanium wire in acrowded arch with no extractions. (b) Placement of 0.016/0.025-inch at third visit. Slight rotational activations. Low friction and full engagement has permitted good alignment.

- a mean reduction of four months in treatment time (from 23.5 to 19.4 months)
- a mean reduction of four visits during active treatment (from 16 to 12).
- the same average reduction in PAR scores for matched cases

This finding of a mean reduction of four months in treatment time was also reported by Dr Robert Fry in a presentation at the AAO 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 to his other office where he had, for the time being, stayed with conventional ligation. A study by Eberting *et al*.[32] of intra-practitioner 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 to conventional ligation. The final average ABO occlusal regularity score was slightly better for the Damon cases. 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 and this is an appropriate area for further studies.

Conclusions

Currently available self-ligating brackets offer the very valuable combination of extremely low friction and secure full bracket engagement and, at last, they deliver most of the potential advantages of this type of bracket. These developments offer the possibility of a significant reduction in average treatment times and also in anchorage requirements, particularly in cases requiring large tooth movements. Whilst further refinements are desirable and further studies essential, current brackets are able to deliver measurable benefit with good robustness and ease of use.

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