Self-ligating brackets: Present and future

Daniel J. Rinchusea and Peter G. Milesb
Pittsburgh, Pa, and Caloundra, Australia

Recently, there has been a resurgence in the use of self-ligating (SL) brackets, which were introduced in the early 20th century. From a synthesis of both in-vitro and in-vivo evidence-based literature, we present general concepts, principles, and axioms. The references to “active” and “passive” SL brackets are explained and juxtaposed in relation to their perceived advantages and disadvantages. We also present new concepts in regard to the future of SL brackets: combination bracket system, hybrid system, and selective use of SL brackets. (Am J Orthod Dentofacial Orthop 2007;132:216-22)

Self-ligating (SL) brackets are not new to orthodontics; they are resurging from the early 20th century. In the mid 1930s, the Russell attachment was an attempt to enhance clinical efficiency by reducing ligation time. Some early SL brackets were the Ormco Edgelok (1972), Forestadent Mobil-Lock (1980), Orec SPEED (1980), and “A” Company Activa (1986). Currently, some popular SL brackets are Damon, Time, Speed, SmartClip, and In-Ovation R.

SL brackets can be dichotomized into those with a spring clip that can press against the archwire (active) and those with a passive system of ligation, in which the clip, ideally, does not press against the wire. However, the term “passive” is somewhat of a misnomer because it is passive only when teeth are ideally aligned in 3 dimensions (torque, angulation, and in-out), and an undersized wire would not touch the walls of the bracket slot. Examples of active brackets are In-Ovation “R” (GAC International, Bohemia, NY), SPEED (Strite Industries, Cambridge, Ontario, Canada), and Time (American Orthodontics, Sheboygan, Wis). Examples in the passive group are the Damon bracket (Ormco, Glendora, Calif) and the SmartClip bracket (3M Unitek, Monrovia, Calif). With the Damon bracket, the so-called “fourth wall” is comparable to a buccal tube.

It seems that SL brackets are not a fad but might be a viable alternative to conventional bracket systems. Dr Robert Keim, editor of the Journal of Clinical Orthodontics, stated that the future of orthodontics will focus on 3 areas: 3-dimensional (3D) imaging replacing 2-dimensional cephalometry, self-ligating brackets, and microimplants as endosseous anchorage (temporary anchorage device). However, Keim cautioned that we need sound scientific evidence before we accept manufacturers’ claims about SL brackets. Unfortunately, the evidence for most claims is lacking. For example, some of these claims are increased patient comfort, better oral hygiene, increased patient cooperation, less chair time, shorter treatment time, greater patient acceptance, and expansion because the appliance somehow “wakes up the tongue,” and so on.

The American Dental Association defined evidence-based dentistry (EBD) as “an approach to oral health care that requires the judicious integration of systematic assessments of clinically relevant scientific evidence, relating to the patient’s oral and medical condition and history, with the dentist’s clinical expertise and the patient’s treatment needs and preferences.” Ismail and Bader described a 3-tiered model of EBD. At the lowest level, model 1 is an experiential, biased model based on the opinions of a clinician or an educator. Model 2 is a combination of one’s experience in addition to a search for the best clinical and scientific studies. The limitation of model 2 is that, since all relevant research was not identified by an exhaustive and systematic review, biased conclusions can result. The highest level of evidence is a model 3—systematic review and evaluation of all evidence. Although EBD provides the least-biased and best-validated model, most questions in dentistry and orthodontics do not have answers provided by systematic reviews (model 3). Because there are no model 3 systematic reviews in regard to SL brackets, a limitation of this article could be a bias based on model 1 and model 2 information.

Many claims and vendor-sponsored presentations regarding SL brackets often have a scientific veneer, but they are mostly model 1 case presentations, with unsupported, verbal statements. One of the worst sources of information is case studies, including anec-
Systematic Review such as a Meta-analysis of available research
Randomized controlled clinical trials
Non-randomized controlled clinical trials
Cohort studies
Case-control studies
Crossover studies
Cross-sectional studies
In the absence of scientific evidence, the consensus of experts in the field
Case studies
Opinion (“I say it works so just believe me”)

**Fig 1.** Hierarchy of evidence, from best to worst.

dotes; most presenters on the lecture circuit show cases
that are not randomly selected or consecutively treated
(Fig 1). They are not randomly selected or consecu-
tively treated cases. Almost anyone can present se-
lected cases to prove a point; this is not evidence or
science but selective memory, wishful thinking, or
pseudo-science. Ordinary experiences alone can often
be unreliable (eg, we know the earth is round and
spinning, but our senses are not aware of it because we
cannot feel or see it). Intuition and common sense are
often in conflict with reality. Therefore, you might hear
an orthodontic practitioner say that “it works in my
hands, and I don’t see any of these problems.” Again,
without blinding and objective measurement, can we
rely on our senses?

**AXIOMS AND GENERALIZATIONS FROM THE SL
BRACKET LITERATURE**

The purpose of this section is to codify and synthesize
the literature about SL brackets so that general concepts,
principles, and axioms can be formulated. We will first
discuss in-vitro studies followed by in-vivo research.

Many factors have been identified by in-vitro studies
that influence frictional resistance in edgewise
appliances besides self-ligation. Some of these are wire
dimension (size), bracket width and slot, bracket com-
position, wire material, angulation, torque at the wire-
bracket interface, ligation forces, interbracket distance,
saliva, and other factors. Some of these factors
might be more important than whether SL brackets are
used. Therefore, when considering SL brackets and
evaluating research concerning them, these factors
should be scrutinized.

The validity of past studies on SL brackets is
questionable. First, most studies are in vitro. They
cannot simulate biologic responses, and the laboratory
setup might not represent the clinical situation. For
example, for canine retraction, the archwire is relatively
constrained at each end by the posterior and anterior
teeth but is often cantilevered in vitro. This relative
constraint affects the mechanical loading at the bracket-
archwire interface and thus the frictional resistance.
The ratio of the normal forces on an archwire con-
strained at both ends to that of a cantilevered archwire
can vary from 3:1 to over 9:1. Second, for the most
part, in-vitro studies are limited to fragmented or small
aspects of overall orthodontic treatment such as fric-
tional resistance with nickel-titanium wires relating to
initial alignment. Third, past studies are limited to the
investigation of .022-in slot brackets and not the .018-in
slot. Fourth, in-vitro vibration simulation of in-vivo
occlusal and masticatory forces can lack validity. Fifth,
in-vitro research involves rates of movement (0.5
mm per minute to 10 mm per minute); this is
21,700 to 435,000 times faster than occurs clinically
(1 mm per month = 2.3 × 10⁻⁵ mm per minute) and
cannot take into account tooth movement due to alve-
olar remodeling that can occur clinically before the
archwire slides through the bracket. Sixth, comparisons
of .022-in slot conventional brackets and passive slide
SL brackets (Damon, SmartClip) with SL brackets with
a spring clip (In-Ovation “R,” Time 2, Speed) are like
comparing apples to oranges. The .022-in slot SL
bracket with a spring clip is not a true .022 × .028-in
slot. The horizontal gingival wall is reduced (in the
In-Ovation “R,” it is .0195 in) and not .028 in, and
therefore the spring clip invades the bracket slot (Fig
2). Consequently, this reduces the dimensions and size
of the bracket slot.

Moreover, these in-vitro studies dealing with fric-

**Fig 2.** Specifications for .022-in slot In-Ovation “R”
bracket. Note short gingival horizontal wall (.0195 in)
compared with conventional occlusal horizontal wall (.0285 in).
tional resistance with nickel-titanium archwires simulating early stages of treatment seem somewhat superficial. The answers are axiomatic, and they can be logically deduced. That is, the larger the bracket slot and the smaller the wire, the less frictional resistance, less 3D control (ie, Damon bracket). Conversely, the smaller the bracket slot and the larger the wire, the more frictional resistance there is, and likewise more 3D control (ie, In-Ovation “R” bracket).

As a generalization, SL brackets show excellent performance in vitro with smaller wires that are used early in treatment. However, when larger wires are used such as .016 × .022 in and .019 × .025 in nickel-titanium in the austenitic phase, no differences were found between SL brackets and conventional brackets.11 In other words, SL brackets demonstrated low frictional resistance only up to certain size archwires in a .022-in slot.

In an in-vivo study, Miles14 compared the effectiveness in a .022-in slot of SmartClip brackets and conventional twin brackets, Victory MBT, for initial alignment of the mandibular arch. In this prospective study 58 patients were alternately assigned to a Smart-Clip or a conventional group. The irregularity index was used to determine differences, and measurements were taken before treatment, 10 weeks after initial archwire placement, and again at 20 weeks. The initial wire was a 0.014-in Damon copper-nickel-titanium wire (Ormco), and, at 10 weeks, the wire was changed to 0.016 × 0.025-in Damon copper-nickel-titanium wire. The results of this study demonstrated that, after the 20-week period, the SmartClip bracket was no more effective in reducing irregularity than a conventional twin bracket ligated with elastomeric modules or stainless steel ligatures with the 2 wires tested.

In an in-vivo study by Harradine2 comparing treatment efficiency with conventionally programmed brackets and the now superceded Damon SL brackets, the following results were reported. The consecutively treated Damon SL patients on average finished 4 months sooner and had 4 fewer appointments than patients with conventional brackets when treated to an equivalent level of occlusal regularity as measured by peer assessment rating (PAR) scores. The greater efficiency of the Damon SL compared with placing and removing elastic ligature ties with conventional brackets was modest and of little clinical relevance.

In a similar retrospective study, Eberting et al15 found an average reduction in treatment time of 6 months (from 31 to 25) and 7 visits (from 28 to 21) for Damon SL patients compared with conventional ligation patients. This indicates clinically significant improvements in treatment efficiency for passive SL brackets. However, those reduced treatment times are still longer than the pre-Damon treatment times reported by Harradine2 and greater than those reported in the literature with conventional brackets by Fink and Smith16 (23.1 months), and Skidmore et al17 (23.5 months).

Retrospective studies such as these are potentially biased despite apparent “matching” because many uncontrolled factors might affect the outcome. It is unclear what techniques were used or which variables were controlled and which were not. These include greater experience, modified appointment intervals, differing archwires, and altered wire sequences. Observer bias can affect the result if the practitioner is unknowingly doing a little more due to enthusiasm with the new appliance. These potentially confounding variables might have played a major role in reducing treatment time. For these reasons, prospective research with randomized or consecutive assignment is preferred.

As an aside, in the past, there was no real motivation for an orthodontist to finish patients expeditiously. We were traditionally taught that the average orthodontic treatment time took about 18 to 24 months, and patients’ monthly payments somewhat reflected this. If we finished too early, the patient might demand a refund. Accordingly, there was no incentive to finish treatment rapidly. But, with the promotion of faster treatment times with SL brackets, orthodontists have been challenged to look at faster treatment times, even with conventional brackets, from a positive dimension (marketing).

In a prospective in-vivo split-mouth study comparing Damon 2 with conventional brackets, Miles et al18 evaluated 58 consecutively treated patients over a 20-week period. The irregularity index was used to determine differences, and measurements were taken before treatment, 10 weeks after archwire placement, and again at 20 weeks. The initial wire was a 0.014-in Damon copper-nickel-titanium wire (Ormco), and, at 10 weeks, the wire was changed to a 0.016 × 0.025-in Damon copper-nickel-titanium wire. The following results were obtained: (1) conventional brackets achieved better irregularity index scores than the Damon 2 (although not clinically significant); (2) patients preferred the look of the conventional twin bracket over the Damon 2; (3) there were more bracket failures with the Damon 2; and (4) Damon 2 brackets were less painful initially, but they were substantially more painful when the second archwire was placed.

Some reasons Miles et al18 gave for different findings between their study and others (Harradine2 and Eberting
et al\textsuperscript{15} were the following: (1) reduction in treatment times by others might be due to a change to more efficient treatment systems other than SL brackets; (2) average patients might not respond differently to SL brackets but more severely crowded and extraction patients could; (3) as treatment times get shorter, perhaps any effect of SL bracket systems in reducing treatment times diminishes; and (4) there might be no real differences, and any time savings could be because of other factors such as altered mechanics and unintentional bias.

A possible confounding effect in the study of Miles et al\textsuperscript{18} might be the split-mouth design. Friction, a component of resistance to sliding (RS), on the conventional side might limit the alignment on the Damon side. The wire might not pass through the conventional side as well (greater friction as some in-vitro studies showed\textsuperscript{1,11} and therefore inhibit alignment on the Damon side, almost like a stop or a kink in an archwire that would inhibit sliding. Miles et al defended this, since the wire can still slide distally to the midline on the Damon side, and therefore it would not be expected to cancel out or reverse any possible effect. Most importantly, the Damon system itself advocates the use of midline or anterior archwire stops to prevent the wire from sliding to 1 side and skewing the archwire midline away from the dental midline.

Several investigators and many clinicians reported difficulties in finishing patients with self-ligating brackets.\textsuperscript{19} Particularly, torque and tip control can be compromised due to the greater play of the archwire in the slot of SL brackets.\textsuperscript{20,21} In the Damon system, a .022-in slot is advocated with finishing wires of .019 × .025-in stainless steel, or beta titanium. Creekmore and Kunik\textsuperscript{22} described the adverse effects of play. If an orthodontist uses a .019 × .025-in stainless steel finishing wire in a .022 × .028-in bracket slot, various permutations of torque outside the bracket prescription will result. Moreover, extrapolating from the data of Profit and Fields\textsuperscript{23} regarding comparable effective torque for undersized wires, a .019 × .025-in stainless steel wire in a .022-in slot bracket would actually deliver only 0.4° of effective torque for a bracket torque angle of 10°, 6.5° of torque for a 22° torque angle, and 20.4° of torque for a 30° torque angle. Hence, in addition to various permutations of torque values with play, undersized finishing wires deliver significantly lower torque values compared with the bracket prescription. This has contributed to a trend to increase torque values for many prescriptions, especially in the incisors.

Miles et al\textsuperscript{18} discussed the rotational play in the Damon 2 bracket because it essentially has a 0.028-in slot depth (0.0275 + 0.0010 in/−0.0000 in slot tolerance, data from ORMCO). For example, a 0.014-in wire in the passive Damon 2 bracket allows 8.5° of rotational play compared with a theoretically fully engaged conventional twin bracket. A 0.016 × 0.025-in archwire would be more active in the Damon 2 but still not fully engaged because of the 0.028-in slot depth, leaving 1.8° of rotational play.

Another principle to elucidate is that the ligation force is not transmitted to the tooth but is counteracted by the equal and opposite force of the SL bracket against the archwire (eg, when seated on a chair, if you place your arms under the chair and pull the chair up and yourself down into the chair; it neither lifts the chair off the ground nor places any extra force on the ground). A module exerting 50 g of force pulling the wire into the base of the slot is the load or normal force, so it is pertinent in friction when sliding but does not place a direct force on the tooth. The deflection of the archwire exerts the force on the tooth. Friction, which impedes sliding movements, is determined by multiplying the coefficient of friction of the materials in contact by the normal force, which is the force of ligation. Therefore, friction is directly proportional to the force of ligation.

The force applied to the tooth comes from the deflection of the archwire, so, if the module does not deflect the archwire, then it is passive, and no force is applied to the tooth (ligation force only comes in when sliding the wire along the bracket). This normal force is avoided by using a Damon or a SmartClip bracket or “passive” ligation only when the brackets and wire are ideally aligned (so no movement occurs). Any deflection of the archwire that engages the bracket due to rotation, tip, or torque creates a normal force and therefore classical friction. If this deflection is greater, eventually binding and notching occur; these cannot be avoided by any bracket design, SL or conventional.

**ACTIVE VS PASSIVE**

Although there is a conundrum concerning which SL bracket to use, the issue of active clip or passive slide/clip is and should be a major focus of the controversy. The Time, Speed, and In-Ovation brackets all have what is called a “spring clip.” Speed and In-Ovation brackets both have a similar sliding spring clip designs, which reduce the slot size in the horizontal dimension because the gingival wall is smaller than the normal-sized occlusal wall. For instance, in Figure 2, the In-Ovation “R” bracket slot (specifications are for the .022-in slot) has a short horizontal wall of .0195 in and a conventional horizontal wall of .0285 in. The Time 2 bracket has a similar clip, but, for opening and closing the movable part of the bracket, the facial portion must be torqued/rotated in a facial-lingual plane for opening with a specific tool, and the reverse for closure.

In a conventional .018-in slot bracket system, one
would need to place a full-sized .018 × .025-in stainless steel wire to have the potential for full 3D expression; whereas, with an “active” SL bracket, this may not be true. A smaller, undersized rectangular may produce enhanced 3D control compared to the same size wire in a conventional bracket system. 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 labial-lingual action increased and therefore produce more alignment than would a passive slide with the same wire.13

Unlike the spring clip, Damon SL brackets have a so-called “passive slide” that opens and closes vertically on the facial surface, whereas the SmartClip bracket has nickel-titanium spring clips mesial and distal to the tie wings to capture the wire. Therefore, the dimensions of the slot in a vertical and horizontal plane are conventional. The passive slide or clips might have an advantage for initial alignment. In in-vitro studies with severe malocclusions, the Damon SL bracket was shown to have greater reduction in RS compared with conventional and other SL brackets with small-sized wires.11 However, this increased ability of teeth to slide along an archwire comes at the cost of a reduced range of labial-lingual correction or rotational control for a given wire than with an active clip or conventional ligation.

Therefore, during orthodontic tooth movement, there are so-called “active and passive forces,” friction, force diminution, and so on. For instance, the In-Ovation “R” and Time SL systems claim to be interactive, but, as Figures 3 and 4 show, all bracket systems—conventional, and SL active and passive—are interactive to some degree, meaning that the wire probably touches some aspect of the bracket throughout treatment. As an aside, force diminution is the reduction in the force produced by an archwire, deflected in its elastic limits, as it returns to its original shape.22 A certain threshold of force is needed to move a tooth. If this threshold is not reached, the tooth will not move. Another expression of force diminution is that the force produced by an archwire, deflected to engage a malpositioned tooth, diminishes as the tooth moves until the minimum threshold of force is reached. In a clinical situation, a light archwire might not become straight because a physiologic threshold is not achieved. Then the clinician must place a heavier wire. Thorstenson and Kusy12 pointed out that RS occurs throughout orthodontic treatment:

Because RS affects all stages of treatment, the practitioner should revisit the treatment goals before selecting the appliance. Although a low value for RS might be desired during the early stages of treatment, a large value might be optimal for later stages. For a given plane in space, the amount of clearance (and, therefore, the angle through which clearance exists) will be inversely related to the amount of control that the orthodontist has over the root positions.12

DISCUSSION

For some orthodontists, it is not the absence or lack of evidence that make them cling to long-held, unsubstantiated beliefs and claims, but the suppression of this knowledge. Thus, a modus operandi would be that the predictability of treatment outcomes should be measured by science, and a conservative viewpoint would be safer. To this juncture, Cook and O’Connor24 stated: “Human knowledge is always frail and subject to revision. That should make us humble and exceedingly careful in claiming neither too much nor too little.”

In a survey in the Journal of Clinical Orthodontics, Sheridan25 found that, in regard to “filling the bracket slot,” some respondents indicated that they do not fill the slots and finished with a .019 × .025-in stainless steel wire in a .022 × .028-in slot. The reason some respondents gave for not fully filling the bracket slot was that it would magnify bracket placement errors. Therefore, if we assume that many orthodontists finish with undersized rectangular or square wires, then the SL brackets with the active spring clip might have an advantage. This assumes that the active spring clip positively and fully seats specific undersized rectangular wires.
However, Harradine\textsuperscript{13} argued that an active spring clip with slightly undersized rectangular wires actually places a diagonally directed lingual force on the wire. This will produce a slight additional labial movement of the tooth but will not be expected to generate the torquing force that is sometimes claimed (Fig 5). He further elaborated: “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. . . . Errors in torque can appear as errors in height or as labio-lingual contact errors.”\textsuperscript{13} The Speed system has a beveled archwire to ease wire engagement, and this rounding would be expected to further reduce the torquing moment.

**FUTURE SL BRACKET SYSTEMS**

As we ruminate on viable SL bracket designs, a possible ideal SL bracket could be a combination bracket with both a spring clip and a passive slide. It could also be tied conventionally. If low RS is desired, the passive slide could be used, but, if high RS is appropriate, then the active spring clip could be used. For instance, the passive slide to reduce frictional resistance could be used in the initial stages of treatment, and the spring clip later in treatment for 3D control. Therefore, this bracket system could take advantage of an active spring clip or a passive slide at the orthodontist’s discretion. Keeping with this idea, the orthodontist could determine the particular needs and vary the type of control for each tooth—spring clip or passive slide, or tied conventionally. It would be a twin bracket with wings that could be differentially tied with a chain elastic.

Another possibility could be a hybrid system in which various combinations of conventional brackets and ligation, SL spring clip, and SL passive slide brackets could be integrated into the patient’s treatment by using the same slot size for all teeth. For example, in the extraction space-closure method of Gianelly\textsuperscript{26}, with crimp-on hooks and molars, the anterior brackets could have conventional brackets and ligation or an SL active clip for 3D control, whereas the posterior teeth could have passive SL brackets to reduce friction for space closure by sliding.

From a survey, Sinclair\textsuperscript{27} reported that maintaining careful 3D control of the maxillary incisors is an important aspect of orthodontic treatment. Therefore, Gianelly’s bidimensional\textsuperscript{26} technique would offer excellent 3D control of the incisors. In this system, 2 bracket slot sizes are used simultaneously (the anterior brackets slots are smaller, .018-in slot, and the posterior brackets slots are larger, .022-in slot). Therefore, a pure bidimensional system with SL brackets could give even greater 3D control of the incisors (.018-in slot, possibly with an active clip bracket), and at the same time even greater reduction of friction in the posterior (.022-in slot, possibly with a passive slide bracket) for space closure by sliding and incisor alignment (the wire would pass through the posterior brackets more easily), albeit at the possible loss of some torque and tip control in the buccal segments.

The conventional bracket, spring clip, and passive slide scheme could be modified for extraction and nonextraction patients. Perhaps for certain nonextraction cases, all teeth could have brackets with a spring clip. Depending on the desired movement, SL brackets could be used selectively with conventional brackets. For example, SL brackets could be used only on teeth distal to extraction sites when closing spaces by sliding (Fig 6) or distal to open coil springs when opening space.

Another example of the selective use of SL brackets would be to have SL first molar brackets, or bands instead of a convertible buccal tube. A tedious task in orthodontics is, after bonding a bracket to a malaligned
Fig 7. In-Ovation “R” SL second premolar brackets bonded to mandibular first molars for easy, secure, and full engagement of archwire.

second molar, threading a wire through the first molar and then the second molar, or converting the first molar buccal tube and tying in the first molar with a steel or an elastic ligature. TheOrmco MX system and SmartClip have SL first molar brackets with a passive slide or clip. One author (D.J.R.) has been bracketing In-Ovation “R” SL second premolar brackets to first molars when malaligned second molars are bracketed (Fig 7). This has the advantage of simple, secure, and full archwire engagement. Therefore, SL first molar brackets, and bands might become the standard for conventional and SL systems.

Although SL brackets might have an impact on our profession, this should be tempered by remarks by Dr Peter Vig, who said that we should consider ourselves as craniofacial biologists. Too many orthodontists have a mechanistic view of orthodontics. In this regard, SL bracket systems are only a tool that we use today; therefore, they are just a component of orthodontics. Among other things, orthodontics deals with science/evidence, psychosocial issues, record taking, diagnoses, treatment, treatment outcomes, artistry, enhancements, and quality-of-life issues. In the future, we know for certain that there will be change. Therefore, we should be adaptable and prepared for knowledge to be undone, reworked, and revised.

REFERENCES
28. Vig P. Seminar, Department of Orthodontics, School of Dental Medicine, University of Pittsburgh; 1990.