Self-Ligating Brackets: An Overview

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1. Introduction

The specialty of orthodontics has continued to evolve since its advent in the early 20th century. Changes in treatment philosophy, mechanics, and appliances have helped shape our understanding of orthodontic tooth movement. In the 1890's, Edward H. Angle published his classification of malocclusion based on the occlusal relationships of the first molars. This was a major step toward the development of orthodontics because his classification defined normal occlusion. Angle then helped to pioneer the means to treat malocclusions by developing new orthodontic appliances. He believed that if all of the teeth were properly aligned, then no deviation from an ideal occlusion would exist. Angle and his followers strongly believed in non-extraction treatment. His appliance, (Fig. 1), consisted of a tube on each tooth to provide a horizontally positioned rectangular slot. Angle's edgewise appliance received its name because the archwire was inserted at a 90-degree angle to the plane of insertion. The rectangular wire was tied into a rectangular slot with steel ligatures (Proffit, 2000). A later shift in thought occurred when one of his pupils, Charles Tweed, observed that some of the patients formerly treated by Angle exhibited a noticeable amount of relapse. Tweed then re-treated a number of these cases by extracting four bicuspids to resolve the crowding and in turn, developed his own treatment mechanics. Another shift in orthodontics occurred when Larry Andrews introduced the straight wire appliance. Instead of bending wires to place teeth in the proper orientation with an edgewise bracket, Andrews' appliance had the angulation and torque values built into the brackets commonly known as the appliance prescription. In theory, these pre-adjusted brackets eliminated the need to repeatedly bend first, second, and third order bends each time the patient progressed to the next wire. The straight wire appliance revolutionized orthodontics by making the bracket much more efficient. Since then, many orthodontic companies have developed their own bracket systems with specific prescriptions, treatment philosophies, and mechanics. However, they all shared one common characteristic – ligatures must be placed around tie wings on brackets to hold arch wires in the bracket slot.

2. Ligatures and ligation properties

Different types of ligatures have been used to hold the archwire in the bracket slot. Steel or elastomeric ligatures have been used mainly. The steel ligatures are made of chrome-alloy stainless steel with dimensions vary from .009" to .012" Inch in diameter and twisted with a hand instrument. In some cases, these ligatures are coated with tooth-colored material such as teflon for aesthetic reasons. Steel ligatures produce a variable effect on the bracket/archwire junction depending on their tightness. The advantages with the steel ligatures are that they do not deteriorate in the oral environment and they retain their shape and strength. They also provide less retention of bacterial plaque and are easier to clean than the elastomeric ligatures (Ridley et al., 1979). The drawbacks with steel ligatures are that they are time-consuming and tiresome on the hand of operator (Maijer & Smith, 1990; Shivapuja & Berger, 1994). Harradine, (2003), found that the use of wire ligatures added almost 12 minutes to the time needed to remove and replace two archwires. They also require careful tucking in of the ends to avoid soft tissue trauma and even then can occasionally be displaced between appointments and cause discomfort (Schumacher et al., 1990; Bendar & Gruendeman, 1993).

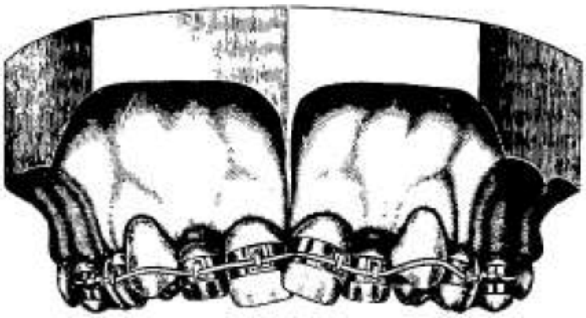

Fig. 1. Early edgewise appliance.

The introduction of elastomeric ligatures in the 1970s is also another milestone in orthodontics which largely replaced steel ligatures. These are quicker and easier to place, and they can be used in chains to close spaces within the arch or prevent spaces from opening. However, conventional ligation with elastomerics fails to provide and maintain full archwire engagement. In addition, they potentially impede good oral hygiene which is a novel situation in orthodontics. Moreover, the physical properties of elastomeric ligatures are imperfect. Elastic ligatures undergo permanent deformation in shape and thus force decays with time. The force decay under constant force application to elastomeric material showed that the greatest amount of force decay occurred during the few hours (Wong, 1976). In addition, they stain permanently shortly after being placed in the oral cavity. More important, elastomeric ligatures have been shown to increase friction in the sliding mechanic systems (Sims et al., 1993; Thomas et al., 1998), and increase the resistance to movement in bracket/archwire systems by 50-175g (Echols, 1975).

2.1 Properties of an Ideal orthodontic ligation system

Regardless of the type of bracket and ligation used, there are several desirable properties for an ideal orthodontic ligation system.

1. Secure and robust ligation

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. Once a wire is ligated, it is desirable that it is resistant to inadvertent loss of ligation. Wire ligatures are good in this respect while elastic ligatures are more easily lost. Elastic ligatures also experience significant force decay over time (Taloumis et al., 1997).

2. Full bracket engagement

Full archwire engagement into the bracket slot is desirable to attain full expression of torque particularly at finishing stages of treatment. Wire ligation can maintain adequate archwire engagement between office visits. On the other hand, elastic ligatures frequently exert insufficient force even on fairly flexible wires.

3. Quick and easy ligation

Wire ligation is a lengthy procedure and this is the main reason they are not frequently used. Elastic ligatures are much faster to remove and replace (Türkkahraman et al., 2005)

4. Low friction

For sliding mechanics, brackets that experience low friction are the most desirable. Low friction is important during the leveling and aligning stages of orthodontic treatment. It will allow a more efficient force delivery, less force dissipation and thus a faster expression of the wire. Low friction is efficient during space closure as well. Wire ligatures are superior to brackets ligated by elastic ligatures in this respect and shown to produce only 30-50% of the frictional forces produced by elastomerics (Shivapuja et al., 1994). Still, forces may reach undesirable levels relative to levels considered ideal for tooth movement (Khambay et al., 2004).

5. Improves patient comfort and hygiene

Wire ligatures can cause tissue laceration if the cut ends are exposed but they are very hygienic. Elastic ligatures are more comfortable than wire ligatures but have the side effect of being less hygienic.

Sliding mechanics in conventional brackets rely on filling the slot with the largest wire possible to provide a certain degree of force control (direction and magnitude) needed to move teeth. With enough force, teeth eventually move to the desired position. Because archwires are held into place with either metal or elastic ligature ties, heavy forces must be introduced into the system in order to overcome the friction created at the bracket/archwire interface before tooth movement can occur. However, some argue that the heavy forces generated by large sized wires and traditional ligation methods are not physiologic because they create force systems high enough to overpower the lip, tongue, and cheek muscular. Clinicians and manufacturers alike sought to develop a product that could replicate the time saving properties of elastomeric modules while lessening or eliminating the friction they caused. This eventually led to the development and popularization of selfligating brackets because they satisfy both criteria and offer a philosophy of orthodontic treatment that greatly differs from this classical school of thought.

3. Self-ligating brackets

3.1 Definition

Self-ligating brackets are ligatureless bracket systems that have a mechanical device built into the bracket to close off the edgewise slot. The cap holds the archwire in the bracket slot and replaces the steel/elastomeric ligature. With the self-ligating brackets, the moveable fourth wall of the bracket is used to convert the slot into a tube.

3.2 Philosophy of self-ligating bracket proponents

Light forces are the key to self-ligation. Proponents suggest that low force, low-friction systems allow teeth to travel to their physiologic position because they do not overpower the musculature or compromise the periodontal tissues. Ischemia is not induced in the surrounding periodontal tissues because the forces generated by the small dimension, high-tech archwires are too low to completely occlude the periodontal vascular supply. Heavy forces on teeth cause hyalinization in the periodontal ligament space which brings tooth movement to a halt. Self-ligating brackets place enough force on the teeth to stimulate tooth movement without completely disrupting the vascular supply and therefore, tooth movement is more effective and physiologic. The final position of the teeth after treatment with the self-ligating bracket systems is determined by the balanced interplay between the oral musculature and periodontal tissues and not by heavy orthodontic forces. Moreover, the design in passive self-ligating bracket also enables teeth to move in the path of least resistance. When the gate is in its closed position, the bracket essentially becomes a tube in which the flexible nickel-titanium archwire can move freely. By greatly reducing the amount of friction with passive self-ligating brackets, low force archwires can work to peak expression and stimulate teeth to move in a more biologically compatible method (Fig. 2). Teeth movement is also more efficient when they are allowed to move individually, and passive self-ligating brackets offer more freedom for teeth to move to their natural position even though they are still interconnected because the archwire is never tightly engaged with the bracket slot (Damon, 1998).

Elastic ligatures create friction and require more force and more frequent adjustments

Self-ligating brackets allow freedom of movement, resulting in faster treatment with gentler forces

Fig. 2. Traditional archwire ligation vs. self-ligating brackets.

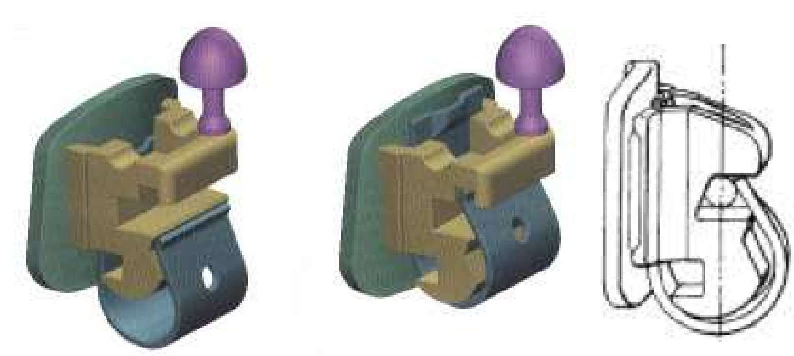

Fig. 3. Active self-ligating brackets in open and closed positions.

3.3 Classification

Two types of self-ligating brackets have been developed, active and passive. These terms refer to the mode in which they interact with the archwire. The active type (Fig. 3) has a spring clip that encroaches on the slot from the labial/buccal aspect and presses against the archwire providing an active seating force on the archwire and ensuring engagement such as In-Ovation (GAC International, Bohemia, NY, USA), SPEED (Strite Industries, Cambridge, Ontario, Canada), and Time brackets (Adenta, Gilching/Munich, Germany).
In the passive type (Fig. 4), the clip does not press against the archwire. Instead, these brackets use a rigid door or latch to entrap the archwire providing more room for the archwire such as Damon (Ormco/"A"Company), SmartClip™ (3M Unitek, USA), and Oyster ESL (Gestenco International, Gothenburg, Sweden).

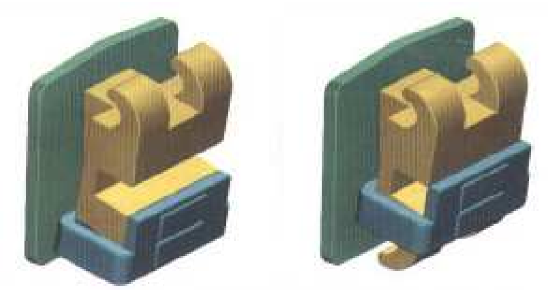

Fig. 4. Passive self-ligating brackets in open and closed positions.

3.4 History and development of self-ligating brackets

Self-ligating brackets were first introduced in the mid-1930s in the form of the Russell attachment by Stolzenberg (Fig. 5). The bracket had a flat-head screw seated snugly in a circular, threaded opening in the face of the bracket that allows for quick and simple archwire changes. Loosening the screw made the system passive and allowed bodily translation on a round wire while tightening it made it active and provided root torquing on a square or a rectangular wire. The bracket system was more comfortable for the patient and resulted in shorter office visits as well. Unfortunately, the Russell attachment did not gain much popularity and virtually disappeared from the market.

Fig. 5. Russell attachment in open and closed positions

The first modern passive self-ligating bracket (Edgelok- Ormco Corporation, Glendora, CA) was introduced in the early 1970s. The bracket had a round body with a rigid labial sliding cap (Fig.6). Because of its passive nature, orthodontists found precise control of tooth movement to be a challenge. Although many design refinements have been introduced since, the basic design has remained unchanged.

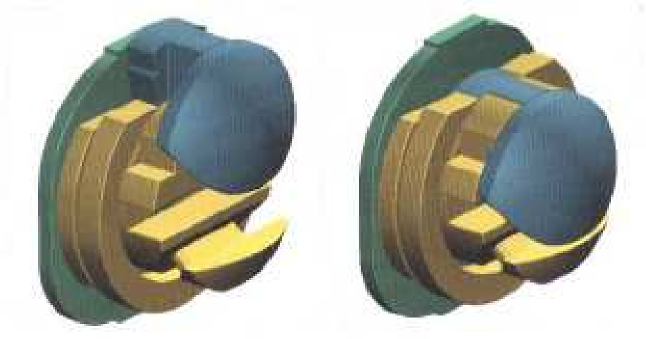

Fig. 6. Edgelok bracket in open and closed positions.

The prototypes of the first active self-ligating bracket (SPEED, Spring-loaded, Delivery) were introduced into the market in 1980. The bracket features a curved, flexible super-elastic nickel-titanium spring clip that embraces the bracket body and passes through the archwire slot.

In 1986, the self-ligating Activa bracket offered another alternative. The Activa bracket had an inflexible, curved arm that rotated occlusogingivally around the cylindrical bracket body (Fig. 7). The arm could be moved into a slot-open or slot-close position with finger pressure alone. Once closed, the rigid outer wall of the movable arm converted the bracket slot into a tube. Another self-ligating bracket model, Time entered the marketplace in 1995. The Time bracket (Fig. 8) features a rigid, curved arm that wraps occlusogingivally around the labial aspect of the bracket body. The stiffness of the bracket arm prevents any substantial interaction with the archwire, thereby rendering Time a passive bracket (Berger & Byloff, 2001).)

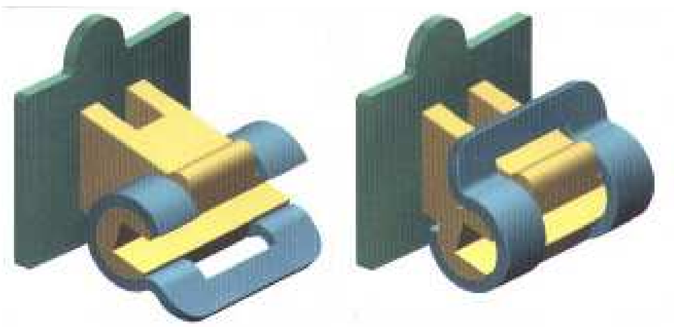

Fig. 7. Activa bracket.

Fig. 8. Time bracket.

Perhaps the most renowned self-ligating bracket system was introduced by Dr. Dwight Damon in 1996. The Damon™ SL I is an edgewise twin bracket with a metal labial cover that straddles the tie wings. In 1999, the next generation Damon™ SL II was brought to the market (Fig. 9). It differed from the original Damon™ SL I by incorporating a flat rectangular slide between the tie wings. A special plier is used to open the metal gates incisally in the maxillary arch and gingivally in the mandibular. Once the slides are closed, the bracket becomes a passive tube. The Damon™ SL bracket system was designed to satisfy the following major criteria (Damon 1998):

a. Andrews Straight-Wire Appliance concept
b. Twin configuration
c. Slide forming a complete tube
d. Passive slide on the outside face of bracket
e. Bracket opening inferiorly in both arches

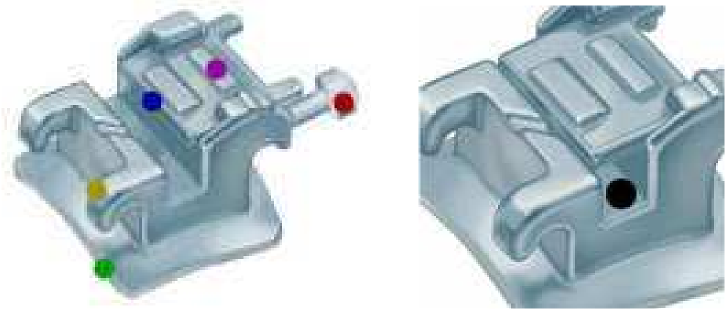

Fig. 9. Damon™ SL II brackets in open and closed positions.

In 2002, the In-Ovation R™ by GAC was introduced. This bracket features an interactive clip because it can provide both passive and active control depending on the archwires used. Round leveling wires can freely move to correct rotations during the initial leveling and aligning phase, while full size rectangular wires are fully engaged into the base of the bracket by the clip in the later stages of treatment for better torque control. A new In-Ovation C™ is now available which has a partial ceramic face for better esthetics (Figure 10).

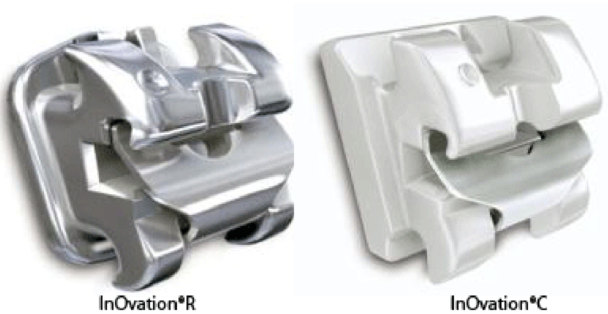

Fig. 10. The GAC In-Ovation R™ and In-Ovation C™ bracket.

In 2004, 3M Unitek introduced the SmartClip™ self-ligating bracket, which is different from other self-ligating brackets in that it does not have a slide or clip to hold the wires (Fig.11). Instead it contains a nickel-titanium clip on each side of the twin bracket that locks in the wire. The archwire is inserted by using finger pressure to push it past the flexible clip. Remove requires a special instrument from 3M Unitek™.

Fig. 11. The unitek smart clip™ bracket.

With the increasing popularity of self-ligating brackets, many different bracket designs are brought to the orthodontic marketplace each year. Consequently, the use of SLBs has increased exponentially; over 42% of American practitioners surveyed reported using at least one system of self-ligating brackets in 2008 (Keim et al., 2008). This figure was just 8.7%in 2002 (Keim et al., 2002). When choosing a self-ligating bracket system, it is important to understand the different types of systems (active vs. passive) in order to obtain the best and most efficient orthodontic results.

4. Clinical performance of self-ligating brackets

Recent advances in bracket technology have resulted in a number of new selfligating bracket systems and greater interest in their use. Much of this interest is in response to information comparing the benefits of self-ligating systems with conventional edgewise brackets and claiming that self-ligating bracket systems provide superior treatment efficiency and efficacy. The proposed benefits include reduced friction between archwire and bracket, reduced clinical forces, reduced treatment time, faster alignment, faster space closure, different arch dimensions, better alignment and occlusal outcomes, less patient pain, and more hygienic. However, these data come from marketing materials, nonrefereed sources, or refereed journals. The purpose of this section is to review the clinically significant effects of self-ligating brackets on orthodontic treatment with respect to the quality of available scientific evidence. Comparing between self-ligating and conventional brackets in different aspects will be addressed as well. These include:

4.1 Subjective pain experience

It is well documented that discomfort is a potential side effect during fixed appliance orthodontic therapy and this can negatively influence the desire to undergo treatment, compliance, and treatment outcome (Patel, 1992; Scheurer et al., 1996). A potentially significant variable that influences treatment-related discomfort is the amount of force applied to the dentition by the orthodontic archwire, particularly during the early stages of treatment. Classical histological studies suggest that light forces are more biologically efficient and less traumatic during orthodontic tooth movement (Reitan, 1956). Therefore, the use of increased force levels might be expected to be associated with increased discomfort. One of the factors affecting prospective tooth movement and hence the amount of force required is the degree of friction that exists between the archwire and bracket; this frictional resistance being influenced primarily by the physical characteristics of the archwire and bracket materials (Ireland et al., 1991), archwire dimensions (Taylor & Ison, 1996), and the method of archwire ligation (Ireland et al., 1991; Shivapuja & Berger, 1994). Indeed, a number of self-ligating bracket systems have been developed in recent years, including Damon ™ , In-Ovation ™ , and SmartClip ™ with the proposed benefit of reduced frictional properties (Read-Ward et al. , 1997 ; Thorstenson & Kusy, 2001 ; Henao & Kusy, 2004). Proponents and manufacturers of these systems suggest that their physical properties produce lower force levels during tooth alignment and sliding mechanics, a more biologically compatible force level and, therefore, a possible reduction in pain associated with orthodontic tooth movement (Berger & Byloff, 2001; http://www.damonbraces.com).
To date (March, 2011), there have been four published clinical trials investigating degree and differences in perceived pain using self-ligating and conventional brackets (Pringle et al., 2010; Mile et al., 2006; Scott et al., 2008; Fleming et al., 2009). Of these, one split-mouth study considered pain reports after both the first and second visits, with patients indicating which system was associated with the greatest discomfort (Mile et al., 2006). Data in three of the trials are presented as continuous pain scores from 0 to 100 on a 100-mm visual analogue scale (VAS) which is one of the most commonly used tools in the measurement of perceived discomfort during orthodontic treatment (Pringle et al., 2010; Scott et al., 2008; Fleming et al., 2009). One trial reported pain scores at 15 time intervals (Pringle et al., 2010), while two trials used four time points: 4 hours, 24 hours, 3 days, and 7 days after appliance placement (Scott et al., 2008; Fleming et al., 2009). The findings from these studies conflicted slightly with one study reporting a tendency to less pain experience with Damon 3 SLBs, although this finding did not reach statistical significance (Pringle et al., 2010). Three studies (Pringle et al., 2010; Scott et al., 2008; Fleming et al., 2009) were regarded as being at low risk of bias, and they reported similar outcomes permitting statistical comparison; pain scores at four analogous time intervals were extracted from each study to facilitate this. Pain intensity over

the first 7 days was reported in these three studies involving 160 patients, with 83 in the SLB group and 77 in the conventional bracket group. Patients in the SLB group reported a mean difference in pain intensity of 0.99 to 5.66 points lower than in the conventional bracket group, the greatest difference being reported 3 days after appliance placement. However, differences were not of statistical significance.
Two studies, (Mile et al., 2006; Fleming et al., 2009), reported greater pain experience during chairside manipulation of self-ligating appliances. However, as the mechanisms of archwire engagement and disengagement are very different using SmartClip (Fleming et al., 2009) and Damon 2 (Mile et al., 2006), it was felt that direct statistical comparison of this research finding would be invalid.

4.2 Bond failure rate

Treatment efficiency involves several factors including breakages. A higher bracket failure rate results in extra visits for the patient and additional clinical time required for repairs. The higher bracket failure rate demonstrated by any bracket system would need to be offset by any time saving in ligation time as well as overall treatment time.
Two studies have considered failure of bonded attachments over 20 weeks (Miles et al., 2006) and 12 months (Pandis et al., 2006) using Damon 2. The date used for assessing failure or time taken for failure to occur was not reported, and only first-time failures for each tooth were recorded. Miles et al., 2006, reported significantly more Damon brackets deboned during the study. This higher failure rate could be due to operator inexperience with the slide mechanism and also due to the bracket design because a shear force can be inadvertently applied when operating the slide. The Damon 2 (as most self ligating bracket designs) is also larger incisogingivally than the conventional twin bracket used and so more likely to interfere with the occlusion.
Pandis et al., 2006, assessed the failure rate of self-ligating and edgewise brackets bonded with a self-etching adhesive and conventional phosphoric acid etching in patients followed for 12 months of active treatment. Similar treatment plans, and mechanotherapy were selected for the study. GAC Microarch edgewise brackets and Oromco Damon 2 brackets were bonded using a split mouth design, using the 3M Transbond Plus Self-etching primer (SEP) and Transbond XT paste; and conventional acid etching, with Orthosolo primer and Enlight paste, applied at an alternate sequence so that the adhesives were equally distributed on the maxillary and mandibular right and left quadrants. No difference was found for the failure rate of self-ligating vs. conventional bracket and between the two bonding modes used. Also, no difference was identified between maxillary and mandibular arch in failure incidence whereas a statistically significant difference was shown for right-sided appliance which may be assigned to masticatory habits.

4.3 Plaque retention and periodontal health

Iatrogenic decalcification of tooth enamel and the development of visible white spot lesions are undesirable and unfortunate consequences of fixed orthodontic therapy, potentially undermining the esthetic benefits often achieved through correction of the malocclusion. It is well documented that fixed appliances increase bacterial plaque accumulation and the risk for white spot lesions (Gorelick et al., 1982; Geiger et al., 1983). During treatment, there is demonstrated increased retention in the amounts of Streptococcus mutans and lactobacilli in saliva and dental plaque (Forsberg et al., 1991). Bonded orthodontic brackets hinder access for good oral hygiene and create microbial shelters, resulting in the accumulation of plaque. The appliance architecture specifically, the archwire ligation method is an additional factor influencing bacterial colonization. Two trials have compared the impact of SLBs and elastomeric ligation on plaque retention (Pellegrini et al., 2009, Pandis et al., 2010). Longer term effects of bracket system on periodontal health and accumulation of debris has also been assessed (Pandis et al., 2008).

Pellegrini et al., 2009, performed randomized clinical study to enumerate and compare plaque bacteria surrounding 2 bracket types, self-ligating vs. elastomeric ligating using a split-mouth design. Patients were recalled and assessed 1 week and 5 weeks after bonding. Results showed that most patients bonded with self-ligating brackets had fewer bacteria in plaque than did teeth bonded with elastomeric legated brackets both at 1 and 5 weeks after bonding.

The oral cavity is a rich ecosystem with a plethora of microorganisms. While both periodontal disease and caries are considered multifactorial diseases, plaque bacteria are the major factor in their onset and progression. However, there are situations which comprise what has been termed 'ecological stress', referring to the shift of the microbiological balance, creating conditions conducive to the growth, and appearance of cariogenic and/or periodontopathic bacteria (Marsh, 2003). The different components of the fixed orthodontic system may contribute to a shift in the balance of the oral ecology. The presence of brackets and ligatures has been shown to be been mainly associated with increased risk of Streptococcus mutans and lactobacilli colonization, among other species, thus initiating a series of events, which may lead to the development of pathology of the hard tissues such as decalcification and, in specific cases, caries development. Moreover, the accumulation of plaque and the resultant alteration of the local microbial milieu may expose the tissues to the risk of developing periodontal inflammation (Øgaard et al., 1988; Fournier et al., 1998 ; Naranjo et al. , 2006).

It has been proposed at bracket ligation mode has an effect on the microbiological profile of the patients' oral environment. Pandis et al., 2010, investigated the effect of bracket type (conventional and selfligating) on the levels of streptococcus mutans and total bacterial counts in whole saliva of , fixed orthodontic patients at the age range of 11-17 years. The patients were subdivided into two groups with random allocation of bracket type (conventional or selfligating). An initial saliva sample was obtained before the initiation of treatment (T1) and a second sample 2 – 3 months following appliance bonding (T2). Salivary streptococcus mutans and total bacteria were enumerated and analysed after growth in culture. The levels of S. mutans in whole saliva of orthodontically treated patients do not seem to be significantly different between conventional and self-ligating brackets. However, the pre-treatment levels of S. mutans are significant predictors of the levels of S. mutans after placement of orthodontic appliances.

Pandis et al., 2008, conducted a cohort study to determine values of periodontal indices for patients treated with self-ligating and conventional brackets. All patients were 12-17 years with aligned mandibular arches, and absence of oral habits and anterior crossbites. Outcome variables were plaque index, gingival index, calculus index, and probing depth for the two bracket cohorts and the results showed that under these conditions the self-ligating brackets do not have an advantage over conventional brackets with respect to the periodontal status.

4.4 Torque expression and arch dimensional change

Correct buccolingual inclination of anterior teeth is considered essential to provide good occlusal relationships in orthodontic treatment. Inclination of the maxillary anterior teeth is particularly critical in establishing an esthetic smile line, proper anterior guidance, and a Class I canine and molar relationship. Undertorqued maxillary anterior teeth affect the arch length and the space requirements. It has been shown that for every 5° of anterior inclination, about 1 mm of arch length is generated. (O'Higgins et al., 1999) Undertorqued posterior teeth have a constricting effect on the maxillary arch, since they do not allow appropriate cusp-to fossa relationships between maxillary and mandibular teeth (Gioka & Iliades, 2004). The manufacturing process of brackets results in some variation in sizes and characteristics, including dimensional accuracy and torque prescription consistency. Various bracket manufacturing processes such as injection-molding, casting, and milling can affect the accuracy of the prescribed torque values, and this has been reported to be about 5% to 10% (Gioka & Iliades, 2004). Huang et al., 2009, reported that torque angle/torque moment behavior is determined by the characteristics of the archwire. The effect of the bracket system is of minor importance, with the exception of self-ligating brackets with an active clip (eg. Speed), which had the lowest torquing moments of all wires.

In relation to the mandibular arch, Pandis et al., 2007; Fleming et al., 2009; and Pandis et al., 2010, reported similar increase in the proclination of mandibular incisors associated with both appliance systems during arch alignment. In general, lateral cephalograms were traced, and mandibular incisor position and inclination were assessed for patients by using angular measurements of mandibular incisor to mandibular plane, mandibular incisor to nasion-Point B line, and mandibular incisor to Point A-pogonion line. Garino & Favero, 2003, stated that satisfactory control of tooth positions during the horizontal, mesio-distal, and torque movements, both in the extraction and non-extraction cases were observed in Speed bracket system

Self-ligating brackets seem to be equally efficient in delivering torque to maxillary incisors relative to conventional brackets in extraction and non-extraction cases. Pandis et al., 2006, conducted a randomized clinical trial employing a random distribution of variables among the studied populations. Similar buccolingual inclination of maxillary incisors in extraction and non-extraction treatment with self-ligating and conventional brackets was reported.

Treatment of a crowded dental arch on a non-extraction basis, without tooth size reduction requires an increase in arch perimeter to allow resolution of crowding and achievement of optimum arch alignment and leveling. Without active distal movement, changes typically involve both transverse expansion and proclination. The ideal scenario would involve little incisor proclination and intercanine expansion, with most of the arch perimeter increase generated by expansion across the molars and premolars. The nature and magnitude of these arch dimensional changes have implications on the long-term stability. Marked expansion of the intercanine dimension and excessive proclination of the mandibular incisors are considered to be particularly unstable (Mills, 1966; Burke et al., 1998). Relapse in such cases may develop due to constriction of the expanded intercanine dimension and uprighting of the mandibular incisors during the post-treatment phase, and is likely to manifest as mandibular incisor irregularity.

Three studies investigated arch dimensions in conventional and self-ligating brackets (All used Damon brackets). Jiang & Fu, 2008, and Pandis et al., 2009, reported the changes after treatment in their prospective studies on non-extraction basis. For intercanine and intermolar widths, there was no significant difference between the two groups. On other hand, Scott et al., 2008, reported the change after progressing to 0.019 x 0.025-in stainless steel archwires in a randomized controlled trial on extraction patients with greater incisor irregularity at the beginning of the treatment. They reported greater increase in intercanine width, probably because the canines were retracted to a wider part of the arch. Intermolar width was not increased with self-ligating brackets in that study, and, according to the authors, it was probably related to forward sliding of the molars into a narrower part of the arch in the extraction patients. In addition, different archwire sequences were used for the two groups in the studies of Jiang & Fu, 2008, and Pandis et al., 2009, whereas Scott et al., 2008, used the same archwires for both groups. The claims that self-ligating brackets facilitate greater and more physiologic arch expansion and, therefore, allow more non-extraction treatment require more evidence**.**

4.5 Orthodontic space closure

Only two studies considered the rate of orthodontic space closure. Miles, 2007, tested the rate of space closure at intervals of 5 weeks until complete closure was achieved. This was a prospective cohort study using a split-mouth design with moderate risk of bias. Miles concluded that there was no significant difference in the rate of en-masse space closure between SmartClip brackets and conventional brackets tied with stainless steel ligatures. However, the sample size was small, and the possibility that any true difference could be obscured in a split-mouth design should be considered. In a very recent study, Mezomo et al., 2011, conducted a randomized clinical trial to measure space closure during the retraction of upper permanent canines after first premolar extraction with self-ligating and conventional brackets. In a random split-mouth design, the retraction of upper canines was performed using an elastomeric chain with 150 g of force. The evaluations were performed on dental casts at time intervals (T0, initial; T1, 4 weeks; T2, 8 weeks; T3, 12 weeks). The amount of movement and the rotation of the canines as well as anchorage loss of the upper first molars were evaluated. Results showed that distal movement of the upper canines and anchorage loss of the first molars were similar with both conventional and self-ligating brackets. However, rotation of the upper canines was minimized with self-ligating brackets ($P < .05$). Existing evidence does not support the claim that lower friction in a self-ligating system permits more rapid space closure in a clinical setting.

4.6 Efficiency of initial orthodontic alignment

Five studies with low to moderate risk of bias, including two randomized controlled trials and three prospective cohort studies, investigated the rate of mandibular incisor alignment (Fleming et al., 2009; Miles et al., 2006; Scott et al., 2008; Miles, 2008; Pandis et al., 2007). Mandibular crowding was selected as a model for examining the efficiency of brackets because correction of this discrepancy largely depends on the “free play” or clearance of the archwire inside the slot walls. All self-ligating brackets were the passive type (Damon, Ormco; SmartClip, 3M Unitek). Pandis et al., 2007, and Scott et al., 2008, reported days needed for alignment but used different end points: visual inspection of correction of proximal contacts and changing to 0.019 x 0.025-in stainless steel archwire. Pandis et al., 2007, enrolled non-extraction patients (Fig. 12 & 13), whereas Scott et al., 2008, enrolled extraction patients. Miles, 2008, and Fleming et al., 2009, reported reduction of irregularity at various times of alignment. A standardized mean difference was calculated, and no significant difference in efficiency of alignment in the mandibular arch was found between both bracket systems. The efficiency of alignment was found to be associated with initial irregularity only. The study of Fleming et al., 2009, used a 3-dimensional analysis, thus making comparison unfeasible. However, they also concluded that, for non-extraction patients with mild mandibular incisor crowding, self-ligating brackets were no more effective at relieving irregularity.

Fig. 12. Alignment of crowded mandibular anterior teeth (canine to canine) with a conventional edgewise brackets (Pandis et al., 2007)

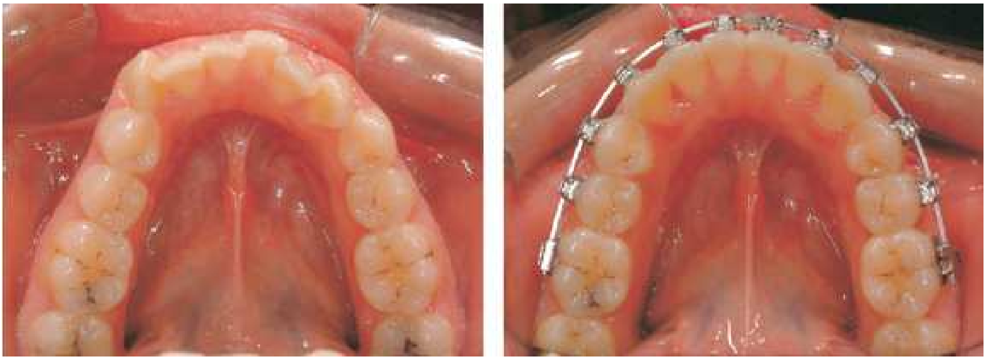

Fig. 13. Alignment of crowded mandibular anterior teeth (canine to canine) with self-ligating brackets (Pandis et al., 2007)

4.7 Apical root resorption

Apical root resorption (ARR) can be defined as blunting or shortening of the root apex, a condition often associated with orthodontic treatment. The teeth more susceptible to ARR are the maxillary and mandibular incisors, and especially the maxillary lateral incisors (Linge & Linge, 1983; Mirabella & Artun, 1995).

The introduction of self-ligating brackets provoked the investigation of archwire ligation on ARR. One of the first reports on the subject was by Blake et al., 1995, who tested the hypothesis that an active self-ligating bracket with an active clip might induce more ARR; their findings, however, did not confirm that hypothesis. The introduction of passive self-ligating systems, with no active spring and alignment performed by wires engaged in a passive tube, with more play, jiggling, and less friction raises again the question of their effect on ARR. Pandis et al., 2008, using panoramic radiographs, reported no mean difference in the amount of apical root resorption of the maxillary incisors with Microarch and Damon 2 systems. Similar results were obtained by Scott et al., 2008, who assessed changes in root lengths of mandibular incisors on periapical radiographs following arch alignment. The mean amount of resorption was slightly greater with the Damon 3 appliance (2.26 vs. 1.21 mm), although the difference failed to reach statistical significance.

4.8 Total treatment time and occlusal indices

One prospective randomized clinical trial and three retrospective cohort studies compared total treatment times between both systems. The very recent (February, 2011) multi-center randomized clinical trial was carried out to compare the effect of bracket type (Damon3 self-ligated or the Synthesis conventional ligated preadjusted bracket systems, both, Ormco, Glendora, Calif) on the duration of orthodontic treatment and the occlusal outcome as measured by the peer assessment rating (PAR). The use of the Damon3 bracket did not reduce overall treatment time or total number of visits, or result in a better occlusal outcome when compared with conventional ligated brackets in the treatment of extraction cases with crowding. For the other retrospective studies, Eberting et al., 2001, and Harradine, 2001, found significantly decreased treatment times of 4 to 6 months and 4 to 7 fewer visits with self-ligating brackets, whereas Hamilton et al., 2008, found that self-ligating brackets appear to offer no measurable advantages in orthodontic treatment time, number of treatment visits, and time spent in initial alignment over conventional pre-adjusted orthodontic brackets. However, the mean treatment times varied in the 3 studies, and the decision regarding when treatment goals had been attained might have differed among the investigators. The same 3 studies also compared the occlusal outcome after treatment. Eberting et al., 2001, used American Board of Orthodontics scores, Hamilton et al., 2008, used the index of complexity, outcome, and need, and Harradine, 2001, used the peer assessment rating. Interestingly, an almost identical pattern was observed in the 2 forest plots. The 2 smaller studies with passive self-ligating brackets (Damon, Ormco) favored self-ligation (Eberting et al., 2001; Harradine, 2001); whereas the larger study with active self-ligating brackets (In-Ovation, GAC) found no significant difference (Hamilton et al., 2008). The results in occlusal quality showed no significant difference at the end of treatment. However, caution should be used regarding these results, since the heterogeneity was high and the 3 studies might have been susceptible to bias from their retrospective designs. Studies with randomized or consecutive assignment are needed to provide further information with more valid comparisons of treatment durations.

4.9 Stability

Some claim that lower forces produced by selfligating bracket systems might result in more physiologic tooth movement and more stable treatment results. However, studies on stability after treatment with self-ligating brackets are lacking at this time.

5. Active vs. passive self-ligating brackets

The Time, In-Ovation, and Speed brackets all have what is called a “spring clip” that encroaches on the slot from the labial/buccal aspect providing an active seating force on the archwire (Fig. 14). The debate over whether a self-ligating bracket should have an active or passive ligation mechanism has been around since their development. Proponents of an active clip claim that it provides a “homing action” on the wire when deflected, providing more control with the appliance (Hanson, 1980). Such brackets have a flexible clip that creates a passive slot depth of 0.0175″ to 0.020″. With small round wires, the bracket is passive, but with larger wires the flexible clip is defected labially and provides an active seating force on the archwire. Passive self-ligating brackets have a slot depth of 0.028″ and do not exert an active force on the wire. Those who advocate a passive clip state that there is less friction in the appliance during sliding mechanics because the slot provides more room for the archwire and they provide no active seating force (Damon, 1998). Several studies have tried to determine how a self-ligating mechanism affects friction during sliding mechanics. Active and passive self-ligating brackets showed different behavior with regard to their resistance to sliding (Brauchli et al., 2011). These studies have all consistently found that when a small round wire lies passively in the slot, the self-ligating brackets produce significantly less friction than conventionally ligated brackets (Berger, 1990; Thorstenson & Kusy, 2001). This is presumably due to the absence of the ligation that provides a seating force against the archwire. When wires of 0.018″ or larger were tested, differences in friction have been found between various self-ligating brackets. Therefore, it might be concluded that low friction can be achieved with the use of passive self-ligating brackets or the combination of low-dimension archwires and active self-ligating appliances.

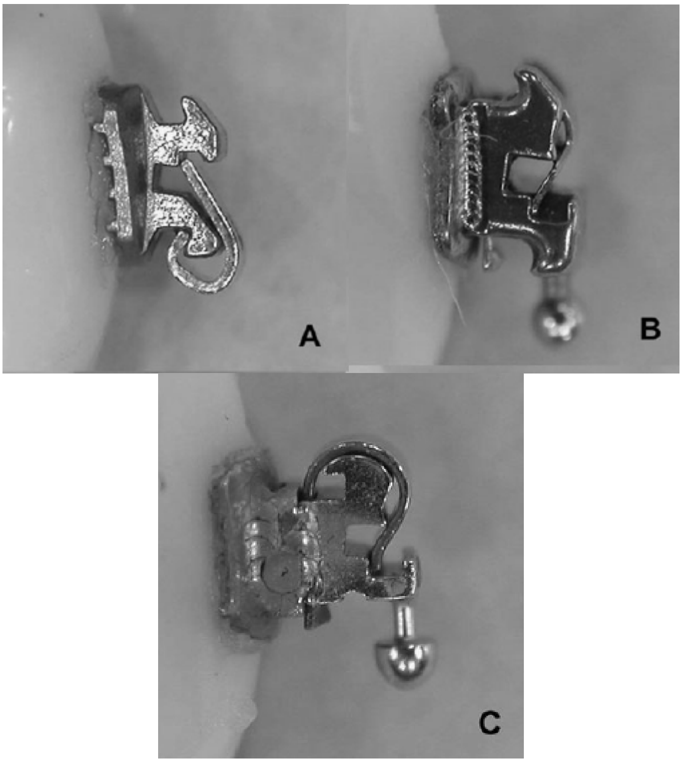

Fig. 14. Profile views of time2 ™ (A), in-ovation R ™ (B), speed ™ (C)

Redlich et al., 2003, found that the Discovery (Dentaurum; Espringen, Germany) and Time (American Orthodontics; Sheboygan, WI) brackets produced about twice as much friction as the control twin bracket with wire sizes greater than 0.018″. The authors attribute the higher frictional forces in the Time brackets to the clip exerting excessive force on the wire. Read-Ward et al., 1997, compared friction between three self-ligating brackets; SPEED (Strite Industries, Ontario, Canada), Activa (‘A’ Company, San Diego, CA), Mobil-Lock Variable-Slot (Forestadent, Strasbourg, France), and a conventional twin bracket Ultratrimm (Dentaurum, Germany). Three stainless steel wires were tested; 0.020″, 0.019 x 0.025″ and 0.021 x 0.025″. They found that with the 0.020″ wire, the Mobil-Lock had the least amount of friction, which was statistically less than the SPEED and Ultratrimm brackets. No significant difference was found between the Mobil-Lock and Activa. It is important to note that the Mobil-Lock and Activa have a passive ligation mechanism and that the SPEED bracket is active with a 0.020″ wire. With a 0.021 x 0.025″ wire, the SPEED bracket produced significantly greater friction than either the Mobil-Lock or Activa brackets. In a similar study, Pizzoni et al.,1998, compared the Damon SL bracket to the SPEED bracket with an active clip and two conventionally ligated brackets. The two self-ligating brackets were not statistically different for a 0.018″ wire, but when 0.017 x 0.025″ wires were used, the active clip on the SPEED bracket produced significantly greater friction than the passive Damon bracket. The literature supports the claim that when using larger wires, passive self-ligating brackets produce less friction than active self-ligating brackets.
The self-ligation design (passive versus active) appears to be the primary variable responsible for the frictional resistance generated by self-ligating brackets during translation. Passively ligated brackets produce less frictional resistance; however, this decreased friction may result in decreased control compared with actively ligated systems. Badawi et al., 2008, measured the torque expressed from two passive (Damon 2 and SmartClip) and two active (In-Ovation and Speed) self-ligating orthodontic brackets. Results showed that active self-ligating brackets demonstrated better torque control due to their active clip forcing the wire into the bracket slot. The active self-ligating brackets expressed higher torque values than the passive self-ligating brackets at clinically usable torsion angles as well. Moreover, the clinically applicable range of torque activation was greater for the active self-ligating brackets than for the passive self-ligating brackets.
Pandis et al., 2010, conducted a randomized clinical trial to compare the time required to complete the alignment of crowded maxillary anterior teeth (canine to canine) between passive (Damon MX, Ormco, Glendora, Calif) and active (In-Ovation R, GAC, Central Islip, NY) self-ligating brackets. The results showed that active and passive self-ligating brackets have no difference in treatment duration in the correction of maxillary anterior crowding, in contrast to the extent of crowding, which had an effect on the duration of treatment.

6. Clinical tips in application of self-ligating brackets

6.1 Archwire engagement with self-ligating brackets

With self-ligating brackets, it is much more important to fully engage the wire before clip closure. The wire can be held into the slot base with a variety of tools such as ligature tucker, or Mitchell’s trimmer. 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. For this purpose, various instruments were developed for engagement of wires, via balanced pressure on both sides of the bracket such as the Cool Tool (Damon) which is rather akin to a torquing key, and the

R tool (GAC) 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 recommended as a routine part of slide closure on teeth where the wire requires lingual pressure for full engagement. In cases where teeth are severely 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. Harradine, 2003, suggested another useful manoeuvre to engage very rotated or displaced tooth with any self-ligating bracket by closing the clip or slide first, and then threading the aligning wire through the closed bracket before engaging the other brackets, i.e. to first convert it to a 'molar' tube.

6.2 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 excess composite resin near this tail during bracket placement as it may can hinder or prevent clip opening particularly 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 Mitchell's trimmer using the hole in the clip. Very specific and extremely effective pliers for Damon brackets are called Kasso Damon pliers. These pliers are recommended for all first-time users since they make all slides very easy to open.

6.3 Prevention of wire pokes

Low friction increases wire displacement. 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 which can be avoided by using tie-backs with flexible wires over extraction sites to lessen the effects of occlusal forces on unprotected spans of wire. Another way is thorough turning in the ends of flexible archwires. An interesting innovation in this respect is the Bendistal plier described by Khouri, 1998. This was 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.

Other options include the use of the crimp-on split tubes available from manufactures such as Unitek and Oromco which can be squeezed onto almost all wires, require no fabrication, are unobtrusive, and effective. It is recommended that these stops are not placed on a significantly active part of the archwire as this would diminish the range of action of the wire where it is most needed. Others suggested selective locking of individual brackets to the archwire with elastomerics to resolve this drawback particularly in those designs which have a full conventional tie-wing assembly.

6.4 Alterations in treatment mechanics

The combination of low friction and full, secure bracket engagement may help in some alteration in treatment mechanics during the progress of treatment.

6.4.1 Longer appointment intervals

Full and secure wire engagement of self-ligating brackets along with the use of low modulus wires makes an extension of the interval between appointments a logical step. Harradine, 2003, proposed patients' follow-up on an eight- to ten-week interval basis.

6.4.2 Initial traction on lighter wires

The increased control of light forces enables more mesio-distal tooth movement to be sensible on lighter, more flexible wires. Moreover, compressed coil springs to move teeth apart can appropriately be placed from initial visits in many instances.

6.4.3 Separate movement of individual teeth

The control of rotation during traction on an individual tooth makes this option much more feasible when required and with more anchorage conservation.

6.5 Bracket placement and bonding

Bracket placement and bonding is a curial step for the long-tem success of treatment. Preferably, both arches should be bonded at the same session and from second molar to second molar in each arch. For teeth that are well displaced from the arch line or where there is insufficient space to place a bracket in ideal position, it is helpful to use a traction hook to gain some initial control of these teeth. For rotated teeth, it is helpful to offset the traction hook so that it is on the part of the crown furthest from the line of the line of the arch to gain some spontaneous derotation.

6.6 Appliance debonding

Debonding of self-ligating brackets may occur by direct failure of the bracket adhesive interface, cohesive failure of the adhesive, direct failure of the adhesive enamel interface or combination of any of these. In Damon system, the best way to debond self-ligating bracket systems is by squeezing two tiewings only with a conventional debonding plier as the bracket will silently float off the adhesive. 3M Unitek™ has Distinguished debonding tool designed for the 3M Unitek Self-Ligating Bracket Systems (Clarity SL Self-Ligating Brackets and SmartClip Self-Ligating Brackets) which may be used with or without the archwire engaged in the bracket slot.

However, the risk of enamel fracture has always been present with stainless steel and ceramic brackets, particularly in teeth where the integrity of the crown is compromised. Alternative methods of debonding metals and ceramic brackets have been designed to minimize the potential for enamel surface. The main purpose of these new methods is to reduce the force levels during the debonding process. Three debonding techniques have been proposed (ultrasonic, electrothermal, and laser).

1. Ultrasonic Debonding

The ultrasonic technique uses specially designed tips applied at the bracket-adhesive interface to erode the adhesive layer between the enamel surface and bracket base. The resulting force magnitudes needed with the ultrasonic approach are significantly lower than those required for the conventional methods of bracket removal (Englehardt et al., 1993; Krell et al., 1993). However, the ultrasonic technique has a major disadvantage. Debonding time using this technique is 30 to 60 seconds per bracket, compared with 1 to 5 seconds for other bracket removal methods (Bishara and Trulove, 1990). In addition, there is excessive wear of the relatively expensive ultrasonic tips. Consequently, this method of bracket removal is not yet recommended for clinical use.

2. Electrothermal Debonding

Electrothermal debonding instruments are essentially rechargeable, cordless heating devices that are placed in contact with the bracket. The instrument transfers heat through the bracket, softening the adhesive and allowing bond failure between the bracket base and the adhesive resin (Sheridan et al., 1986; Scott, 1988). This method is a quick and effective way to debond a bracket. Its major disadvantage is related to the relatively high temperatures generated at the heated tip. Pulpal damage and mucosal burns are possible.

3. Laser debonding

Debonding ceramic brackets was attempted using both CO2 and YAG lasers 5s in combination with mechanical torque. The use of a laser is conceptually similar to the use of the electrothermal approach, that is, through heat generation to soften the adhesive. The laser approach, although still experimental, is more precise with regard to time and amount of heat application, and therefore would have better control of the amount of heat transmitted to the tooth (Hayakawa, 2005; Feldon et al., 2010). A major disadvantage, in addition to the effects of the thermal energy on the pulp, is the high cost of the instrument

6.7 Retention

Retention is one of the controversies of modern orthodontics, with uncertainty being the only certainty. Angle, 1907, stated that "the problem involved in retention is so great, often being greater than the difficulties being encountered in the treatment of the case up to this point". Bramante, 1990, attempted to rationalize the problem and demonstrated that teeth moved through bone by orthodontic appliances often have a tendency to return to their former positions. Moreover, arch form, particularly mandibular arch form, cannot be permanently altered by appliance therapy which means that bone and adjacent tissues must be allowed time to reorganize after treatment. Thus, definite retention is necessary if the finished result of active orthodontic treatment is to be maintained. There is no agreement in the literature of a uniform system of retention, and the clinical orthodontist, in consultation with each patient, must determine the appropriate retention regime for each case. (Zachrisson, 1986). Many appliance types have been used for the retention of post-orthodontic treatment. The first appliances proposed were based on banded fixed appliances (Angle, 1907), then removable retainers were advocated as Hawley retainer, clear overlay removable retainer. Most recently, the use of bonded fixed retainers has been introduced (Kneiflm, 1973; Rubenstein, 1976). These retainers have employed multistrand wire include different wire types with differing diameters. The proposed advantages of the use of multistrand wire are that the irregular surface offers increased mechanical retention for the composite without the need for the placement of retentive loops, and that the flexibility of the wire allows physiologic movement of the teeth, even when several adjacent teeth are bonded (Artun, 1984).

Relapse is a long-term problem and long-term follow-up of patients is practically difficult and financially demanding. The literature demonstrates that, at the time of writing, evidence that addresses the effectiveness of different retention strategies used to maintain tooth position after treatment by Self-ligating orthodontic appliances is lacking. However, Dr. Dwight Damon proposed the use of bonded upper retainer (lateral incisor to lateral incisor) made from 0.16"* 0.022" flat braided archwire and placed on the cingulae of upper incisors to prevent spontaneous debonding. In the lower arch, bonded lower retainer (from canine to canine) using 0.025 single strand stainless steel is recommended as well. Clear overlay retainers are to be used in addition on a night time basis.

7. Limitations of self-ligating brackets

Full archwire engagement, low friction between bracket and archwire, and faster archwire removal and ligation are inherent features of self-ligation brackets which have been clearly demonstrated and quantified in work by various authors. However, self-ligating brackets have some drawbacks that may hinder the wide spread in their use. First: 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. Second: the higher profile in self-ligating brackets, due to the complicated mechanical design, potentially causes more occlusal interferences and lip discomfort. Moreover, currently available self-ligating brackets are more expensive than most good quality tie-wing brackets. 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.

8. Conclusion

Self-ligating brackets (SLBs) are not new conceptually, having been pioneered in the 1930s. They have undergone a revival over the past 30 years with a variety of new appliances being developed. It is divided into 2 main categories, active and passive, according to the mechanism in which they interact with the archwire (encroaching on the slot lumen or not). Self-ligating bracket systems were built on the philosophy of delivering light forces on a low-friction basis, thus insuring more physiologic tooth movement and at balanced oral interplay.

These systems have been gaining popularity in recent years with a host of claimed advantages over conventional appliance systems relating to reduced overall treatment time, less associated subjective discomfort, promotion of periodontal health, superior torque expression, and more favorable arch -dimensional change. Other claimed advantages include possible anchorage conservation, greater amounts of expansion, less proclination of anterior teeth, less need for extractions, and better infection control. However, many of these claims were based on retrospective studies which are potentially biased as there are many uncontrolled factors which may affect the outcome. These include greater experience, differing archwires, altered wire sequences, changes in treatment mechanics, and modified appointment intervals. Observer bias may inadvertently affect the outcome as the practitioner may unknowingly be doing ‘‘a bit more’’ due to enthusiasm with the new product. In this regard, more prospective clinical trials with randomized or consecutive assignment and using identical wire sequences and mechanics are preferred.

While Advocates claim that low-friction SL brackets coupled with light forces enhance the treatment efficiency and address the clinical superiority of self-ligating brackets, other team believes that bracket type does not appear to have a significant influence on treatment efficiency. Treatment efficiency is the product of many mechanical and biologic factors. It is unlikely that any one factor is responsible for the efficiency and rate of tooth movement. The biology of tooth movement is a complex and highly coordinated process at the cellular, molecular, and genetic levels. Individual variation undoubtedly has a fundamental underlying role in tooth movement and treatment efficiency. 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.

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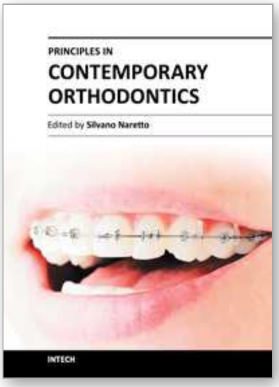

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Orthodontics is a fast developing science as well as the field of medicine in general. The attempt of this book is to propose new possibilities and new ways of thinking about Orthodontics beside the ones presented in established and outstanding publications available elsewhere. Some of the presented chapters transmit basic information, other clinical experiences and further offer even a window to the future. In the hands of the reader this book could provide an useful tool for the exploration of the application of information, knowledge and belief to some orthodontic topics and questions.

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