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Review Article

Advancement in orthodontic brackets – Review

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Abstract

Orthodontic brackets have evolved significantly over the years, transforming the way we approach treatment. The design and functional efficiency of orthodontic brackets significantly influence the simplification of treatment mechanics and contribute to reducing overall treatment duration. Orthodontic brackets have seen remarkable advancements since the era of Angle, driven largely by progress in science and technology. The evolution spans from traditional metal brackets, known for their strength and durability towards 3D imaging and computer-aided design to create custom based fitted for each individual patient. Among the most significant innovations is the development of self-ligating brackets, which eliminate the need for conventional elastic ties. By reducing friction, these brackets allow for smoother tooth movement and often reduce the number of appointments needed.

Aesthetic demands have also led to the rise of brackets like ceramic, plastic, composite offering effective treatment with a less noticeable appearance. These options have made orthodontic care more acceptable to adult patients and those concerned about visible braces. Lingual brackets, which are bonded to the inner surfaces of the teeth, have also advanced in design, offering a discreet option for patients seeking invisibility during treatment. Improvements in bracket base design and wire slot geometry have enhanced bonding strength and biomechanical control.

In parallel, digital innovations have enabled customized brackets through 3D imaging and CAD/CAM technology. They are tailored to each patient's tooth shape, improving the accuracy of bracket placement and leading to more efficient, predictable outcomes.

The aim of this article is to review bracket designs, the materials used, and the underlying science, along with their clinical applications, to assist clinicians in making patient-specific treatment decisions.

Keywords: Brackets, Ceramic, Self-ligating, Lingual.

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1. Introduction

Orthodontic brackets attached to the enamel serve as a medium for transmitting the force exerted by an activated archwire to the tooth. In 1887, Angle experimented with using German silver, a blend of copper, nickel, and zinc that contains no actual silver, instead of noble metals. However, the mechanical and chemical characteristics of German silver did not meet contemporary performance standards.

F. Hauptmeyer introduced stainless steel to dentistry in 1919, later its value in orthodontics was confirmed in 1937. Nevertheless, drawbacks including nickel-related hypersensitivity and the potential for corrosion have also been documented.

Plastic brackets were first introduced in the late 1960s, mainly to address aesthetic concerns. However, they fell out of favor due to issues such as creep deformation under torque forces and a tendency to discolor over time.

Later, in 1987, ceramic brackets were introduced as a more aesthetic alternative to conventional stainless-steel brackets. Despite their improved appearance, ceramic brackets presented significant clinical drawbacks, including fragility, risk of enamel damage during removal, and occasional breakage of the tie-wings.

To address concerns about nickel-related allergic reactions and corrosion associated with stainless steel brackets, recent innovations have introduced gold and

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platinum coatings on metal brackets. Furthermore, developments in material science have enabled the use of titanium brackets, valued for their excellent biocompatibility and high resistance to corrosion.

In today's digital era, advancements across various fields have significantly influenced the healthcare system too, including orthodontics. The evolution from the MBT bracket prescription to the latest bracket systems reflects a considerable journey shaped by patient and clinician needs, available resources, and progress in science and technology. Many patients today are concerned about their smile not only before and after treatment but also during the course of treatment, prompting a growing preference for more aesthetic treatment options. In addition to aesthetics, factors such as product effectiveness, ease of use, and affordability play a crucial role in the selection of orthodontic appliances. This article aims to review recent advancements in orthodontic brackets and explore how these developments can benefit both clinicians and patients in meeting the current demands of modern orthodontic care.

2. Discussion

2.1. Stainless steel brackets

Most commonly used metallic backets for orthodontic therapy due to some of its unique properties like biocompatible, high resilience, high yield strength and cost effectiveness. These are made from AISI 304L SS, which it contains 18-20% chromium and 8-10% nickel and small amount of manganese and silicon. The drawbacks of these brackets are primarily their poor esthetics, the need for frequent activations, lower springiness compared to NiTi, and reduced corrosion resistance. Stainless steel with a pitting resistance equivalent value (PRE) greater than 40 is referred to as SR-50A, which exhibits high localized corrosion resistance due to the combined effect of high concentrations of nitrogen (0.331%) and molybdenum (0.904%). In addition, it demonstrates superior mechanical properties owing to the solution-strengthening effect.[1]

2.2. Ceramic brackets

Ceramics are materials that are first shaped and then hardened through heat treatment. The ceramic used in orthodontic brackets is alumina, available in either polycrystalline or monocrystalline form. Alumina is preferred for its esthetic appearance, excellent chemical resistance, and high hardness and strength. Ceramic brackets are manufactured in various edgewise morphologies, including true siamese, semi-siamese, solid, and Lewis/Lang designs. Because of their translucency combined with strength, they are often considered the most suitable option for patients seeking esthetic alternatives.

However, these brackets also have notable shortcomings. Their brittleness and low fracture toughness make them prone to breakage, whether due to external forces or occlusal trauma. Being harder than enamel, ceramic can also cause significant wear of the enamel surfaces, particularly on maxillary incisors and canines in cases of occlusal interference or parafunctional habits.[2] The risk of enamel fracture during debonding remains a concern. Therefore, ceramic brackets should be used cautiously, within the limitations of the material, and not merely as a direct substitute for metal brackets.[2]

2.3. Plastic brackets

Marketed in early 1980 initially made of acrylic later with polycarbonate which was clear type of bracket enhancing aesthetic (**Figure 1**). Studies done by Arzer et al reported higher torque losses and lower torquing moments with polycarbonate brackets compared to metal brackets.[3]

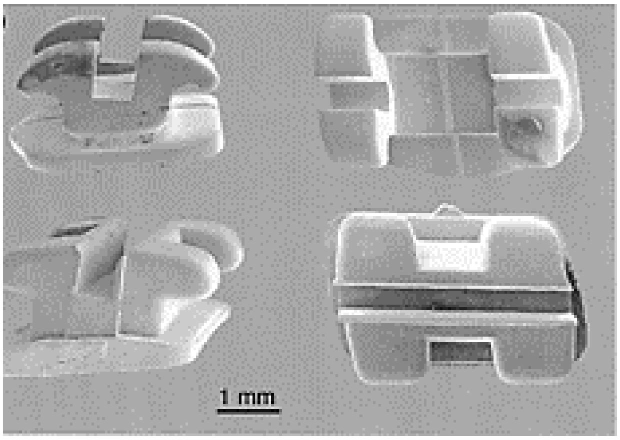

Figure 1: Plastic brackets

Another design, featuring a metal-reinforced slot within a polycarbonate bracket, demonstrated reduced creep compared to conventional polycarbonate brackets.

Sadat-Khonsari et al. evaluated the torque deformation characteristics of seven commercially available plastic brackets in comparison with stainless steel brackets.[4] The study found that metal slot–reinforced brackets exhibited the least amount of deformation, a finding of clinical significance.

2.4. Butterfly brackets

In 1966, the American Board of Orthodontics (ABO) reported common errors observed in cases submitted by candidates who were unsuccessful in the Phase III examination. This led to reasonable modifications to the straight wire concept. One such advancement was the development of the Butterfly System, which introduced a low-profile, twin-wing bracket with rounded tie wings and the elimination of standard hooks, which resulted in an appliance design that was more comfortable, aesthetically pleasing, and hygienic.

The Butterfly System incorporates seven distinct features aimed at enhancing the conventional pre-adjusted appliance system:[5] (**Figure 2**)

1. Stepwise increase in posterior torque
2. Second premolar angulation that can be modified
3. Preventive mandibular anterior torque
4. Progressive angulation in mandibular anterior teeth
5. Molar tubes that can be convertible with a pre-welded -6° angulation
6. Increased versatility for both extraction and non-extraction cases
7. A multifunctional vertical slot offering largely untapped potential

The addition of a vertical slot in this system allowed for the elimination of traditional ball hooks on brackets. Instead, simple hook pins or T-pins can be inserted into the slot, proving particularly useful in managing cases with blocked incisors, highly positioned teeth, or ectopically erupted teeth. Progressive torque was incorporated into the system to correct improper buccolingual inclinations—an error frequently identified by the ABO (American Board of Orthodontics) these errors were frequently linked to the excessive mandibular posterior lingual crown torque incorporated in many straight-wire prescriptions, partly intended to provide “cortical anchorage.”[5]

Together, these design improvements result in better buccolingual occlusion, a flattened Curve of Wilson, reduced posterior overjet, and less prominent palatal cusps.

2.5. Lingual brackets

When it comes to aesthetics, lingual brackets have a distinct advantage, as they fulfill the demand for discreet treatment. These brackets are bonded to the lingual (inner) surfaces of the teeth, rendering them virtually invisible from the front. Since their introduction in the 1970s, lingual bracket systems have undergone significant evolution, becoming a preferred choice among adult patients with high aesthetic concerns.

One of the early innovations in lingual appliances included the incorporation of a bite plane within the maxillary anterior brackets, mesh bonding pads customized to fit the lingual tooth surfaces, and pre-torqued archwire slots calibrated using modified labial torque values.[6]

*2.6. Appliance description (**Figure 3**)*

The most notable advancement in the design is the reduction in bracket size. Modern lingual brackets are smaller and anatomically contoured to fit the lingual vestibule. Incisor and canine brackets measure approximately 2.5 mm in width and 1.5 mm in thickness, while premolar and molar brackets are generally limited to a thickness of 1.5 mm.[7]

Along with reduced size, bracket design has been refined. The latest models include three small wings—two occlusal and one gingival—and a 0.018" × 0.025" archwire slot. The elimination of hooks and bite planes lowers the bracket profile, improving patient comfort during treatment.[8]

2.7. Gold-coated brackets

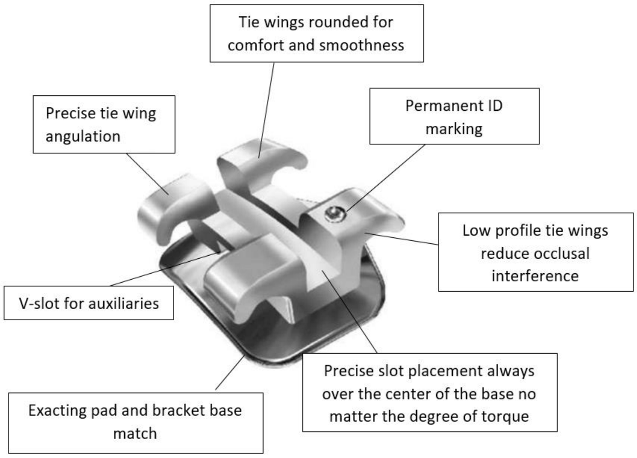

Figure 2: Butterfly brackets

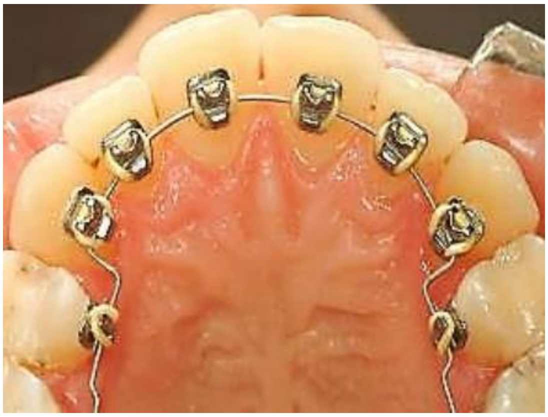

Figure 3: Lingual brackets

Gold-coated stainless-steel brackets have recently been introduced and have rapidly gained popularity, especially for the maxillary posterior and mandibular anterior and posterior regions. They feature 24-karat gold plating, usually applied at a thickness of 300 microinches.

Gold-coated brackets provide a more esthetic option compared to conventional stainless-steel brackets, while also appearing cleaner and more hygienic than ceramic options. Beyond their visual appeal, they possess additional advantages such as anti-inflammatory properties and a lower likelihood of triggering allergic reactions. Patient acceptance of gold-coated attachments is generally high.

Gold lingual brackets have been employed in clinical practice since 2002. The Incognito™ system, a fully customized lingual appliance technology, was introduced in 2004 and has since gained widespread recognition. Its high-quality, hypoallergenic nature and association with luxury have contributed to its popularity, particularly among patients from higher socioeconomic backgrounds. However, gold brackets are considerably more expensive than conventional ones and are not commonly available from all orthodontic practitioners.

Examples: Orthos gold by ormco (**Figure 4**a), Victory Series™ by 3M UNITEK (**Figure 4**b)

2.8. Platinum -coated brackets

Platinum-coated brackets are produced through a specialized process where four layers of gold and a selected metal are ionically implanted onto the surface of stainless steel brackets. This technique results in brackets that are five times more resistant to abrasion than gold-coated ones. (**Figure 4**c) The coating also creates a smoother and harder surface than standard stainless steel, which helps minimize friction and enhances sliding mechanics.

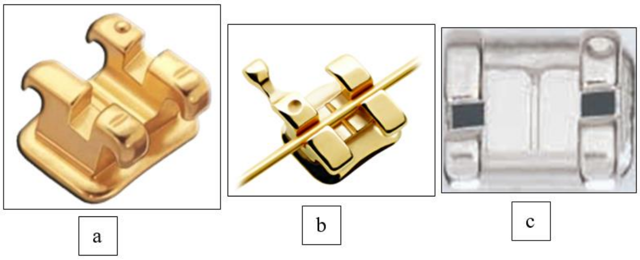

Figure 4: a): Gold-coated brackets; **b)**: Victory Series™ by 3M Unitek; **c):** Platinum -coated brackets

Incorporating platinum through a proprietary implantation process creates a protective barrier that inhibits the release of nickel, cobalt, and chromium. Platinum has proven to outperform other metals in bracket manufacturing and has been favored by the jewelry industry to meet the stringent nickel emission regulations outlined in the European Directive EN1811.

2.9. Self-ligating brackets

They are ligature less brackets which has inbuilt mechanism for closing the bracket slot that could hold arch wire in secure. Both active and passive self-ligating brackets has been developed based on brackets and arch wire interaction.[9]

Advantages[10]

1 Secure & robust ligation
2 Reduced friction
3 Enhanced efficiency & ease of use
4 Reduced overall treatment time
5 Severely crowded teeth can be efficiently aligned.
6 Enables better plaque control and conservation of anchorage.
7 Minimizes the risk of injury to both operator and patient, including prevention of “puncture wounds.”

Features of self-ligating bracket[11]

1. Speed brackets: developed by Strite Industries Ltd. (Cambridge, Ontario, Canada), have been in continuous and successful production since their introduction in 1980. These brackets don't have the familiar tie-wings where earlier brackets had clips which could too easily be displaced or distorted. These drawbacks have been taken care of. (**Figure 5**a)
2. Damon SL brackets: (A Company, San Diego, CA) incorporate a slide mechanism that extends around the labial surface of the bracket. The launch of this bracket was around mid-1990s which made popularity of self-ligating bracket. Nevertheless, these brackets came with disadvantage such as sliding difficulty or sometimes opened inadvertently and they were prone to breakage. (**Figure 5**b)
3. DAMON 2 brackets (Ormco Corp.): to address the shortcoming of above system DAMON 2 brackets were introduced. This has combined with metal injection moulding & slight design changes which made free from inadvertent slide opening or slide breakage. However, the difficulty in consistently opening of the bracket was persistent. (Fig 05C):
4. DAMON 3 and DAMON 3MX Brackets :(Ormco corp.) brackets have a different location and action of the retaining spring, and this has produced a very easy and secure mechanism for opening and closing. DAMON 3 had significant problem like: a high rate of bond failure, separation of metal from reinforced resin components, and fractured tie wings. However, DAMON 3MX has come up with in an all-metal bracket with least problems (**Figure 6**a)
5. In-ovation brackets (GAC international Inc., 355 Knickerbocker Ave., Bohemia, NY 11716), also referred to as System R brackets, shared a conceptual and design similarity with Speed brackets but were manufactured in a twin configuration with tie wings. The In-Ovation R (R denoting “reduced,” in reference to the narrower bracket width) enhanced efficiency by providing a greater interbracket span. This design eventually became recognized as System R. However, notable shortcomings included difficulty in opening the brackets, particularly in the mandibular arch, where visualization of the gingival end of the spring was challenging. Additionally, the limited space for lacebacks, under ties, and elastomerics positioned behind the archwire could further complicate treatment mechanics. Similar limitations were observed with both Speed and System R brackets, which were later addressed by Quick brackets (Forestadent) through the introduction of a labial hole or notch in the clip, enabling bracket opening with the aid of a probe or similar instrument. (**Figure 6** b)
6. SmartClip brackets (3M Unitek, 3M Center, St. Paul, MN 55144-1000) secure the archwire using two C-shaped spring clips positioned on either side of the bracket slot. During insertion or removal, pressure is applied to the archwire rather than directly to the

clips; the archwire then transfers the force required to deflect the clips, thereby facilitating placement or removal.

This mechanism must balance two key functions: allowing easy insertion and removal of archwires through the clip jaws, while also securely maintaining ligation to prevent accidental disengagement—whether with small, flexible wires or larger, stiffer ones. With increasing clinical application, it was observed that the force necessary to insert and remove thicker stainless-steel archwires from SmartClip brackets was excessively high. This limitation was addressed in the newer SmartClip 3 design, which incorporated modifications to reduce the stiffness of the spring clips. Furthermore, SmartClip technology has been extended to an esthetic variant, Clarity SL, a ceramic bracket system featuring metal slots. (**Figure 6**c)

7. Oyster self-ligating brackets**:** Introduced in 2003 as the first translucent self-ligating bracket, the Oyster ESL features a strong, fiberglass-reinforced composite polymer with a removable and replaceable cap. It is composed of 70% polycarbonate (PC) and 30% polyethylene terephthalate (PET). Additional features include a mushroom-shaped hook for elastic attachment. This bracket follows a standard Roth prescription edgewise design, available in either 0.018" or 0.022" slots. (**Figure 6**D)
8. Lingual self-ligating brackets: First presented by Neumann and Holtgrave (1996), who suggested the use of SPEED self-ligating labial brackets for application in the lingual technique. They used labial upper incisor brackets upside down for lingual bonding on the bicuspids and for bonding on the lingual of the incisors. Macchi et al. in 2002 introduced 2D lingual SL brackets by the name of "Philippe self-ligating brackets" It can be directly bonded to the lingual tooth surface because they do not have slots, only 1st and 2nd order movements are possible.
9. DAMON Q2: spinTex instrument used to employ reciprocal forces during opening for reliable wire changes and adjustment throughout treatment. Speciality of this brackets are ample space under tie-wings area which can accommodates powerchain, elastics and other auxiliaries. The refined precision slot of this bracket enhances rotational control, offering optimal precision and predictability. This provides clinicians with the versatility to efficiently manage all cases using simplified mechanics.

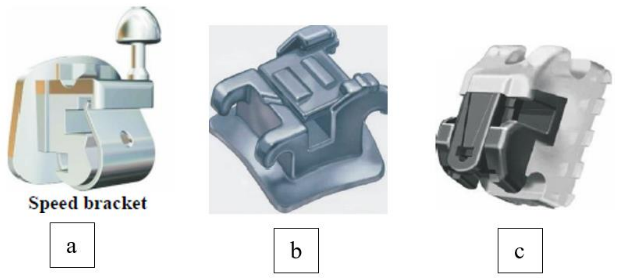

Figure 5: a): Speed brackets; **b):** Damon SL brackets; **c):** Damon 2 brackets (Ormco Corp.)

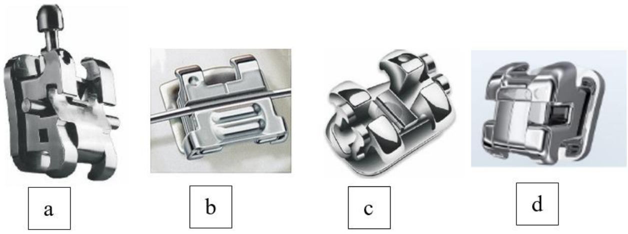

Figure 6: a): Damon 3 and Damon 3MX brackets; **b):** In-Ovation brackets; **c):** Smart clip Brackets; d): Oyster self-ligating brackets

2.10. Smart bracket

Smart brackets are equipped with microelectronic sensors that can monitor the forces and torques acting on teeth in real time. This enables orthodontists to make highly precise adjustments during treatment. These brackets use CMOS sensor chips and wireless technology to transmit data. Examples include the 3M SmartClip SL3 self-ligating brackets and Discovery Smart brackets.

The integration of nanoelectronics, the Internet of Dental Things (IoDT), and smart orthodontic brackets holds exciting potential for future research and innovation. It may lead to the development of intelligent appliances that automatically adjust forces based on real-time feedback, ultimately improving treatment efficiency and outcomes.

2.11. Incognito

Dr. Dirk Wiechmann is the pioneer behind the development of the Incognito system —the design of a lingual metal bracket system is based on computer-aided design and manufacturing (CAD/CAM) technology. It was the first system to feature custom-milled brackets, offering a personalized alternative to traditional injection-molded ones. With the help of CAD/CAM technology, Incognito brackets are custom-designed to precisely fit the unique shape of each tooth's lingual surface.

Advances in the Incognito™ lingual appliance have addressed three key challenges in lingual orthodontics: Patient comfort and speech adaptation are improved because the appliance is custom-made to fit closely to the tooth surface, keeping it as flat as possible. Additionally, the precision of rebonding is enhanced, as the customized bracket base covers most of the lingual tooth surface, allowing direct rebonding without jigs or positioning devices. Finishing and detailing are simplified, as brackets are custom-made and prefabricated archwires that are designed according to the patient's arch form which enable case finishing with high precision, closely matching the planned setup models.[12]

This innovation helped overcome common issues seen with conventional systems—such as inaccurate bracket placement, the need for chairside wire bending, and torque loss. The customized fit not only reduced chair time for the orthodontist but also made the treatment more comfortable for patients

Compared to prefabricated lingual brackets like those from Ormco, patients with Incognito reported fewer problems with speech, chewing, and biting.[13]

2.12. Insignia

The success of the Incognito bracket system also paved the way for labial-based CAD/CAM innovations, such as the Insignia bracket system. The introduction of CAD/CAM technology into both lingual and labial orthodontics marked a turning point in the field—shifting the focus toward fully customized brackets. These brackets are designed to precisely match the anatomy of each individual tooth, improving the fit of the bracket base and enhancing the accuracy of force transmission.

The SmileArc™ in Insignia software enables dentists to modify the vertical positioning of the maxillary incisors, with the mandibular incisors intruding or extruding accordingly for compensation. Although beneficial, this feature still requires clinical measurements to determine the exact degree of intrusion or extrusion needed, as the software does not allow overlaying photographs or 3D images onto the virtual setup.[14] Since no fixed landmarks exist, the smile arc and incisor inclination vary with changes in tooth movement and rotation on the screen. While a lateral cephalogram can help approximate occlusal plane angulation, aligning the dentition to the natural head position would provide far greater accuracy.[15] This customization helps achieve more efficient and controlled tooth movements during treatment.

3. Conclusion

In conclusion, the evolution of bracket systems in orthodontics has significantly transformed both treatment and patient experiences. With improved comfort, efficiency, and aesthetics, modern bracket systems have brought countless smiles to faces. This article highlights recent advancements—including self-ligating brackets, lingual systems, and the innovative Butterfly bracket. As technology continues to advance, even today's cutting-edge brackets may soon be replaced by newer, more refined systems—pushing the boundaries of orthodontic care even further. However, staying updated with these rapid developments can be challenging. It's important to note that while advancements enhance quality, they often come at a higher cost.

4. Source of Funding

None.

5. Conflict of Interest

None.

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