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Orthodontic Bracket Materials – An Up-to-Date Review

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Abstract

Orthodontic tooth movement is effectuated with the orthodontic brackets. And hence the treatment effect depends on the type of orthodontic bracket materials used. So, the clinician should have thorough knowledge of all the properties of orthodontic materials available before incorporating them in clinical practice This review article elaborates the different orthodontic bracket materials – metal, ceramic and polymer brackets which have been clinically used and discusses in detail the mechanical, aesthetic and biological characteristics of the bracket materials with the evidence obtained from the literature. It also provides a sound knowledge about the other uncommon bracket materials like self healing and smart brackets. It focuses on understanding the drawbacks of the conventional bracket materials so that in future it might pave the way for more research in this field towards an ideal orthodontic bracket material which might be clinically better than the other removable orthodontic appliances.

Keywords: Orthodontic brackets, mechanical properties, biocompatibility, aesthetics

Full-length article **Corresponding author's* e-mail:srinidhiramasundaram@gmail.com

1. Introduction

Orthodontics is a branch of dentistry which embraces correcting tooth position by delivering force to the malaligned teeth. This is effectuated with orthodontic brackets bonded to the tooth. Force is applied with the help of archwire engaged in the slots of the bracket. In 1871, William E Magill addressed a new strategy of banding every tooth. Earlier, gold and silver were mostly used for banding as they were more ductile and malleable. The term bracket was given by Dr Edward H Angle after the introduction of Ribbon Arch Appliance in 1916 [1]. Initially vertical slots were practiced where pins were used to engage the archwires. But later in 1925, vertical sots were supplanted by horizontal slots and pins by ligatures. This marked the introduction of Edgewise bracket in 1928. These brackets with horizontal slot allow tooth movements in all the three dimensions and have wider bases. During the middle of the last century, new techniques and theory of Dr P R Begg stirred the orthodontic profession where modified ribbon arch type bracket with gingivally facing slot was used. In 1972, preadjusted straight wire appliance was introduced with built in tooth movements and was published in the name, "The straight-wire appliance" in the year 1979 [2]. It was only in 1970; bonding overtook banding after the adoption of new technique of etching of enamel. This was introduced by Michael Buonocore in 1955 [3]. In 1965, with the advent of epoxy resin bonding, Newman began to apply these findings to direct bonding orthodontic attachment [4]. Following which, many modifications to the bracket base design were advocated to acquire bracket with high bond strength. Stainless steel which has been used promisingly in the field of orthodontics for decades was introduced by Lucien De Coster [5]. The initial brackets made from stainless steel had a mesh base morphology. This was based on the mechanism that increased surface area increases the bond strength. Maijer and Smith demonstrated the release of corrosive products from AISI type 316 L stainless steel brackets [6]. A newer stainless steel alloy was proposed by Oshida called 2205 stainless steel alloy which has better corrosion resistance and improved microhardness compared to 316L stainless steel. As stainless steel is less biocompatible and allergic due to the presence of nickel, other metal brackets have been launched. This includes titanium brackets and cobalt chromium brackets. In the 1980s there was an increasing surge in the number of adult patients in the field of orthodontics which paved the way for the research in aesthetic orthodontic brackets. In 1960, the first transparent bracket was introduced by Newman and his co-workers.

The first plastic bracket was unfilled polycarbonate brackets launched in early 1970s. These plastic brackets which were fabricated earlier had disadvantages of having low elastic modulus and increased absorption of colorants. To overcome these shortcomings, reinforced polycarbonate brackets were launched. Other polymers which have been utilized in the fabrication of orthodontic brackets are polyurethane, polyoxymethylene and still many more. Studies are being conducted worldwide to minimize their drawbacks and to provide brackets of improved properties. In

1980, the first alumina based ceramic brackets emerged. It suffered with the limitations of being bulky, increased incidence of tie wing fracture, higher reports of enamel damage during debonding and increased friction. This led to further researches leading to the discovery of zirconia based ceramic brackets. Wide researches are available on the literature regarding different orthodontic bracket system. This article focuses on different orthodontic bracket materials available and explains its mechanical, aesthetic and biological properties with articles available in the literature. Thus it will provide a thorough knowledge on the features of the orthodontic bracket materials which are routinely used in clinical practice.

2. Classification

A wide range of raw materials are available for the fabrication of orthodontic brackets. This includes the following.

1. Metal brackets-
   - Stainless steel brackets
   - Titanium brackets
   - Cobalt chromium brackets
2. Plastic brackets
3. Ceramic brackets -
   - Alumina based
   - Zirconia based
4. Smart brackets
5. Coated brackets
6. Others:
   - Magnetic brackets
   - Self healing brackets
   - The insignia system
   - Biomimetic adhesives and brackets
   - Self ligating bracket

2. Metal brackets

2.1. Stainless steel brackets

2.1.1. Manufacturing process

Most commonly used orthodontic bracket material is austenitic type stainless steel alloys- mainly 303, 304, 316L. Stainless steel brackets can be manufactured by joining two parts of a bracket – base and wing using brazing alloys. The most commonly used brazing alloy was silver. This suffered with the limitations of cadmium toxicity and galvanic corrosion. So, gold based brazing alloys were adopted. This caused dissolution of stainless steel which led to the corrosion of bracket base. Since it is difficult to find a brazing alloy which is both stiffer to withstand the force and flexible during debonding, other methods of manufacturing brackets were introduced. The most commonly used process is metal injection molding. It is done by mixing metal powder of a few microns with binders, dispersants and lubricants to a homogenous mixture. Then they are subjected to the injection molding machine to provide one- piece appliance. Laser welding is the recently introduced which yielded bracket with less wing fracture failure and better corrosion prevention [7][8][9].

2.1.2. Hardness

The Vickers Hardness of brackets manufactured from metal injection molding varied from 154 to 287 VH, which is lower than the hardness of the wing components of conventional stainless steel brackets. The hardness varied with type of archwires being used. Stainless steel archwires showed a hardness of 600VH while the NiTiarchwires demonstrated from 300 to 430 VH. So, for better hardness, the use of MIM (Metal Injection Molding) brackets with NiTarchwires is recommended [7] [9].

2.1.3. Friction and surface roughness

Friction is known to be determined in large part by surface roughness.The significantly lower frictional resistance provided by stainless steel brackets is more likely a result of their lower surface roughness, which can be clearly visible using scanning electron microscope. D Prattern (1990) observed that the stainless steel brackets had lower coefficients of friction than the ceramic brackets under all conditions [10]. Saulo Regis Jr et al (2011) had concluded in their study that metallic brackets undergo significant degradation during orthodontic treatment which might be due to increased friction [11].

2.1.4. Biocompatibility

There has been a considerable discussion in the literature about corrosion and sensitivity to the nickel present in stainless steel brackets. Prasetyady et al (2017) performed cytotoxicity tests and verified that this material had as high percentages of viable cells; that is, stainless steel did not produce irreversible damage to cells at short exposure times [12]. R. Maijer and D. C. Smith (1982) demonstrated that the presence of voids and poor oral hygiene had led to crevice corrosion of the Type 304 stainless steel [6]. Patricio J. Espinoza-Montero et al (2022) on examining stainless steel had concluded that stainless steel is more prone to corrosion, and nickel released from orthodontic devices caused allergic reactions and gingival overgrowth into patients [13].

2.1.5. 2205 alloy

Due to nickel allergy, various other stainless- steel types had been introduced. These stainless steel types have comparatively less nickel. One such stainless steel is 2205 alloy. Jeffrey A. Platt et al (1997) had demonstrated that 2205 alloy has less corrosion than the 316L alloy and can be used as an improved alternative to 316L steel [14].

2.1.6. PH- 17 Steel

Another steel type is the precipitation- hardening 17-4 steel. Claude G. Matasa (1998) showed that this exhibited higher hardness than the 316L [15].

2.2. SR-50A brackets

Keun-Taek Oh et al (2005) studied the experimentally manufactured SR-50A brackets and concluded that the SR-50A bracket has good frictional property, corrosion resistance and biocompatibility with a lower occurrence of allergic reaction [16].

2.2.1. Base morphology

To obtain brackets with better shear bond strength, the morphology of the bracket base play a crucial role. The sizes of the wire mesh used were 40, 60, 80, and 100 meshes. Some of the mesh type bases include foil mesh base, mini mesh base, micro mesh base, laminated mesh base, Dyna bond base, Ormesh wide central, supermesh MB base. And the non mesh types include micro-loc base, Dyna lock integral base, micro etch base, laminated perforated base, peripheral perforated base and laser structured base [17].

2.3. Titanium brackets

Titanium (Ti) has been introduced to be an alternative to the metallic orthodontic brackets. R.P.Kusy et al (1998) observed that titanium brackets are more biocompatible than stainless steel with nickel having been eliminated from their constitution [18]. This is due to its lack of allergenicity and increased corrosion resistance. There is also an increased evidence of titanium being used in biomedical applications, such as dental implants, arthroplasty components, and plates/screws used in orthopedic and maxillofacial surgery.

2.3.1. Manufacturing process

Commercially available products have followed two different strategies: a single-unit (monolithic) fabricated from commercially pure titanium bracket and a two-component bracket fabricated from both commercially pure Ti (base) and Ti-6Al-4V (wing), with the base and wing joined by laser welding. T. Deguchi (1996) and Christina Gioka (2004) showed that the latter showed large gaps along the base – wing interface leading to the consequence of wing breakage during activation shown in figure 1. These interfacial gaps also encourage plaque accumulation establishing crevice corrosion [7] [19].

2.3.2. Hardness

Rupali Kapur (1999) and Christina Gioka (2004) evaluated the properties of titanium brackets [20] [19]. Titanium brackets have lower hardness of around 280 – 360 VHN compared to NiTi and Stainless steel archwires. This causes an increased wear rate of the bracket slot walls during orthodontic treatment. To overcome this titanium requires surface treatments before being employed. Low hardness reduces the transfer of torque from an activated archwire to bracket. The wear of the bracket slot and/or wire surfaces arising from the low hardness of the alloys, may preclude a full engagement of the wire to the slot walls, and possible plastic deformation of the wing. But Garrett Melenka et al (2014) had concluded that the titanium brackets plastically deformed less than the stainless-steel brackets after torquing [21].The wear process developed during sliding of archwires into the bracket slot walls may exacerbate the corrosion potential for these appliances.

2.3.3. Biocompatibility

From the corrosion perspective, the laser welded brackets may be more prone to galvanic corrosion due to increased wear [20]. But further clinical evidences are required to prove them. Systematic review of Afaf Houb-Dine et al (2018) concluded that lengthy exposure to fluoride ions and acidic pH decreased the resistance to corrosion of Ti attachments [22].

2.4. Cobalt chromium bracket

It is a metal bracket with superior properties. Cobalt chromium provides increased surface hardness, reducing frictional forces.These brackets are cast rather than machined or milled. They possess low-frictionpropertie due to their smooth archwire slot. These have low nickel content which can be a biocompatible treatment option for nickel-sensitive patients. These are also corrosion resistant [23].

3. Plastic brackets

Plastic brackets were first marketed in the early 1970's. Initially constructed from acrylic and later manufactured from unfilled polycarbonate. The first generation of these brackets exhibited staining and odours, low strength and stiffness resulting in tie wing fractures and excessive creep deformation during clinical use. Researches were attempted to alleviate these problems.

3.1.Polycarbonate bracket

Dobrin et al (1975), Randy G. Alkire et al (1997) found that polycarbonate bracket slots distorted with time under a constant physiologic stress of 2000 g/mm [24] [25]. Polycarbonate bracket's creep made them insufficient to withstand longer treatment times. To compensate for the lack of strength and rigidity of the original polycarbonate brackets, alternatives were introduced. This include high-grade medical polyurethane brackets, ceramic and fiberglass reinforced polycarbonate brackets and polycarbonate with metal slots.

3.2.Metal slot reinforced polycarbonate

Josef C. Feldner et al (1994) found that the metal slot reinforced polycarbonate produced the highest torque and lowest deformation value and Sung-Hwan Choi et al (2014) confirmed the low frictional resistance of metal slot reinforced metal bracket [26] [27]. Though polycarbonate brackets with metal reinforced slots demonstrate significantly less creep than conventional polycarbonate brackets, torque problems still exist. Approximately 15% loss in torque over 24 hours has been observed with both ceramic reinforced and metal lined polycarbonate brackets. However, they are significantly better than polycarbonate brackets.

3.3. Torque deformation

When comparing torque deformation characteristics of seven commercially available plastic brackets against stainless steel brackets, Sadat-Khonsari et al (2004) showed that metal slot reinforced brackets were subjected to the lowest degree of deformation, followed by pure polyurethane, pure polycarbonate and fibreglass reinforced polycarbonate brackets [28]. Ceramic reinforced polycarbonate brackets demonstrated the highest deformation.

3.4. Polyoxymethylene and Polyester

Masami Kato et al (2011) evaluated the properties of plastic brackets and concluded that Polyoxymethylene

(POM) had larger surface roughness and hardness. Polyester (PE) can be considered to be a stable material in terms of color stability [29].

3.5. Biocompatibility

In term of biocompatibility, Krishnan et al (1993) reported that bisphenol A (BPA) was released from experimental polycarbonate instruments and supported the growth of MCF-7 human breast cancer cells [30]. Research had been carried out in introducing an alternate polymer which could be used in the bracket system. One such is polyoxymethylene (POM) but Robert P. Kusy et al , John Q. Whitley (2005) and Masami Kato et al (2011) noticed a small release of formaldehyde from this material in vitro due to abrasion and heat application [31] [29]. But Julia Krauss et al (2010) mentioned that the polyoxymethylene bracket material had the highest values of fracture toughness and Vickers hardness, and the lowest values of wear. As polyoxymethylene is resistant to wear, the amount of formaldehyde leaching into the oral cavity is considered to be negligible [32].

4. Ceramic brackets

4.1 Alumina-based ceramic brackets

There are two types of alumina-based ceramic brackets, namely, the polycrystalline alumina and the single crystal alumina due to their distinct differences in fabrication. Their manufacturing processes play an important role in determining their physical properties and so their clinical performance. Single crystal brackets have better optical, which tend to be translucent. But both single crystal and polycrystalline brackets resist staining and discoloration.

4.1.1. Tensile strength

A significant advantage of them over the stainless steel is extremely high hardness of aluminium oxide. If contacts between teeth and ceramic brackets exist, it causes severe enamel abrasion. The ability to resist structural failure, called tensile strength, is much stronger in monocrystalline alumina than in polycrystalline alumina that is in turn significantly stronger than stainless steel. Tensile strength characteristics of ceramic depend on the condition of the surface of the ceramic.

4.1.2. Fracture toughness

Garland E Scott Jr (1998) discussed the mechanical properties of ceramic concluding that a shallow scratch on the surface of a ceramic bracket will drastically reduce the load required for fracture [33]. Andreas Karamouzos et al (1997) mentioned that the fracture toughness in ceramics is 20 to 40 times less than in stainless steel making it much easier to fracture a ceramic bracket than a metallic one [34]. Among ceramic materials, polycrystalline alumina possess higher fracture toughness than single-crystal alumina.

4.1.3. Frictional characteristics

Don H. Pratten et al (1990), Kazuo Tanne (1991) , A. J. Ireland (1991), James R. Bednar (1991), Keith et al (1993)had reported that that under all conditions tested, stainless steel brackets generate lower frictional forces than ceramic brackets [10] [35] [36] [37] [38]. C R Saunders and R P Kusy (1994) on examining the surface topography of ceramic brackets had concluded that monocrystalline alumina brackets are smoother than polycrystalline samples, but their frictional characteristics are comparable [39]. Study conducted by Padmaraj V. Angolkar et al (1990)indicated that friction in the ceramic brackets increased as wire size increased, and rectangular wires produced greater friction than round wires with ceramic bracket [40].To reduce frictional resistance, development of ceramic brackets with smoother slot surfaces and consisting of metallic slots have been introduced.

4.1.4. Drawbacks

Keith et al (1993) observed abrasive wear of archwire surface when used with ceramic bracket [36]. Bracket-wing fracture is a frequent problem encountered by clinicians. Ceramic brackets are more prone to fracture due to the low fracture toughness of aluminium oxide. Ceramic brackets can cause enamel damage of the occluding teeth and this can be prevented by using special elastomeric rings that cover the occlusal surface of the ceramic brackets. This can also prevented by incorporating techniques that eliminate occlusal interferences. In terms of biofilm formation, Ira Dewi Lindel et al (2011) had concluded in their study that that ceramic brackets exhibit less long-term biofilm accumulation than metal brackets [41].In an attempt to overcome the potential damage of enamel during debonding, a ceramic bracket with a thin polycarbonate laminate on the base has been manufactured.

The bond to the enamel is through the thin polycarbonate laminate which makes it easier to debond metallic brackets.

4.1.5. Base morphology

Three base morphology that provides retention are,

- Mechanical retention where large grooves are cut in the base of the bracket. This provides mechanical interlock.
- Chemical adhesion by the use of a silane layer which forms siloxane network.
- Micromechanical retention through the use of a number of configurations, including protruding crystals, grooves, a porous surface, and spherical glass particles.

4.2. Zirconia-based ceramic brackets

Since alumina based ceramic brackets have the above mentioned shortcomings, research has been direct towards new substitute for alumina. One such substitute is yttria-stabilized zirconia. It has cubic crystal structure of zirconium dioxide which is made stable at room temperature by an addition of yttrium oxide. Polycrystalline zirconia brackets are an alternative to alumina ceramic brackets as they have the greatest toughness amongst all ceramics. They possess good sliding properties with reduced plaque adhesion, clinically acceptable bond strengths and bond failure loci at the bracket/adhesive interface. But they are less aesthetic as they exhibit their intrinsic colour. And Olga Keith (1994) found no significant advantage of zirconia brackets over polycrystalline alumina brackets with regard to their frictional characteristics [36].

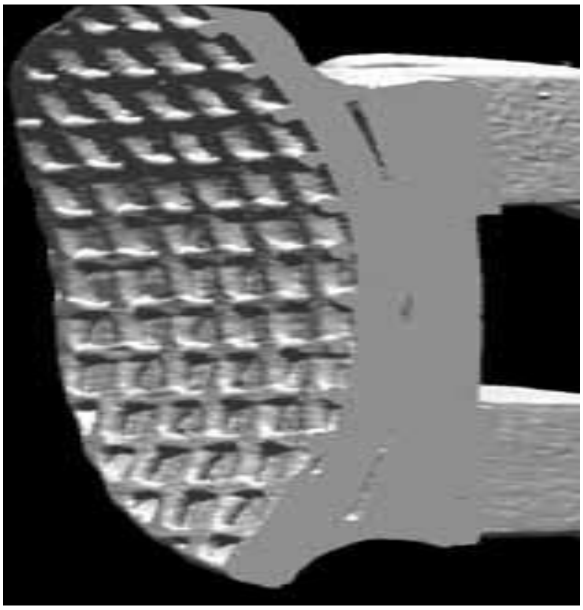

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Figure 1: Detail of a 3-D X-ray microtomography image of a bracket manufactured with laser welding. Note the gaps appearing in the base-wing interface, which are due to the lack of continuous joining [9].

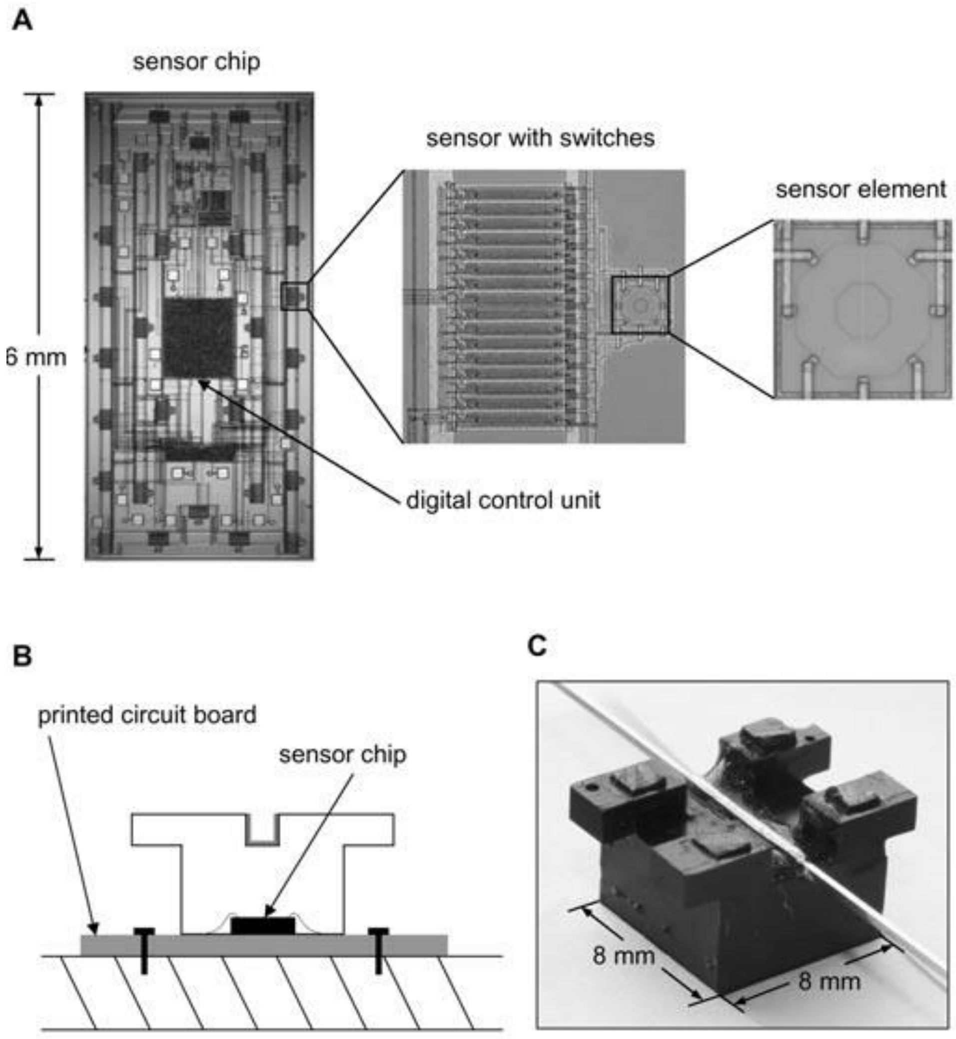

Figure 2: Mechanism of smart bracket [43]

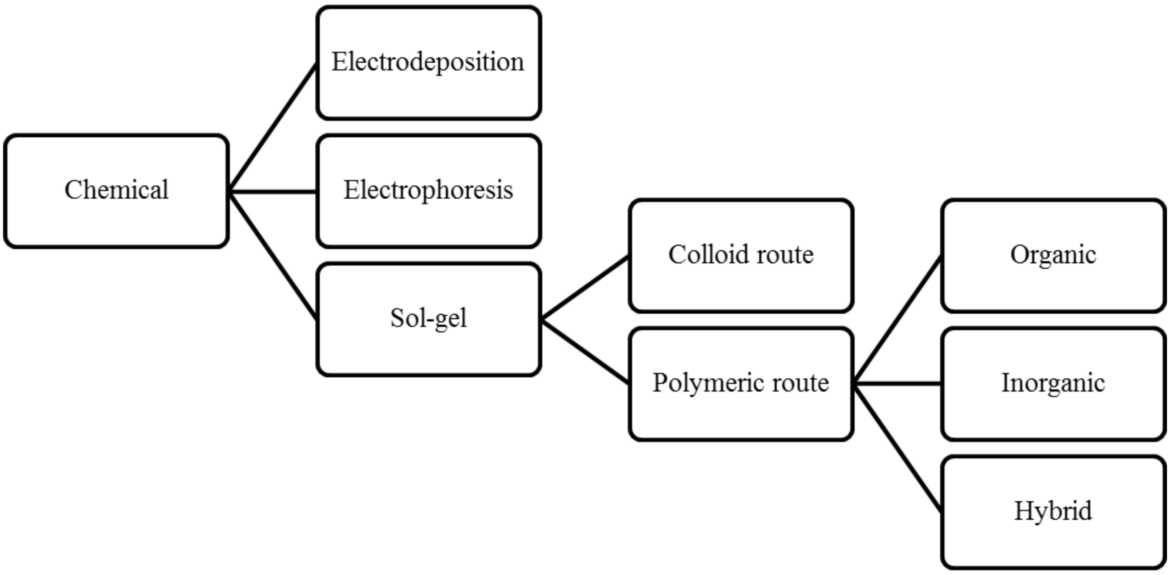

Figure 3: Classification of processes used for coating

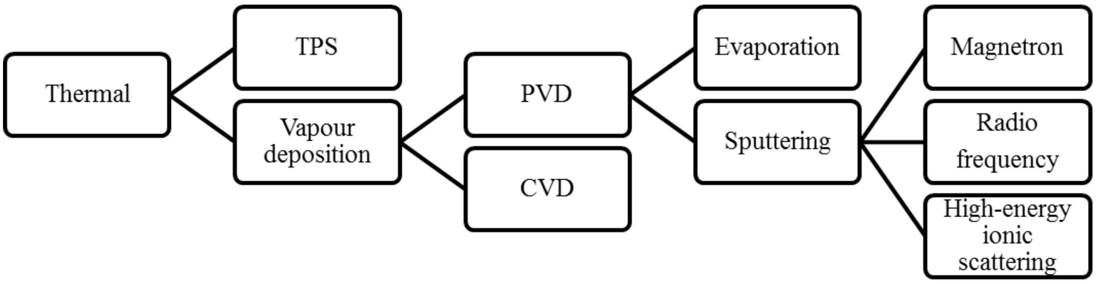

Figure 4: Classification of processes used for coating

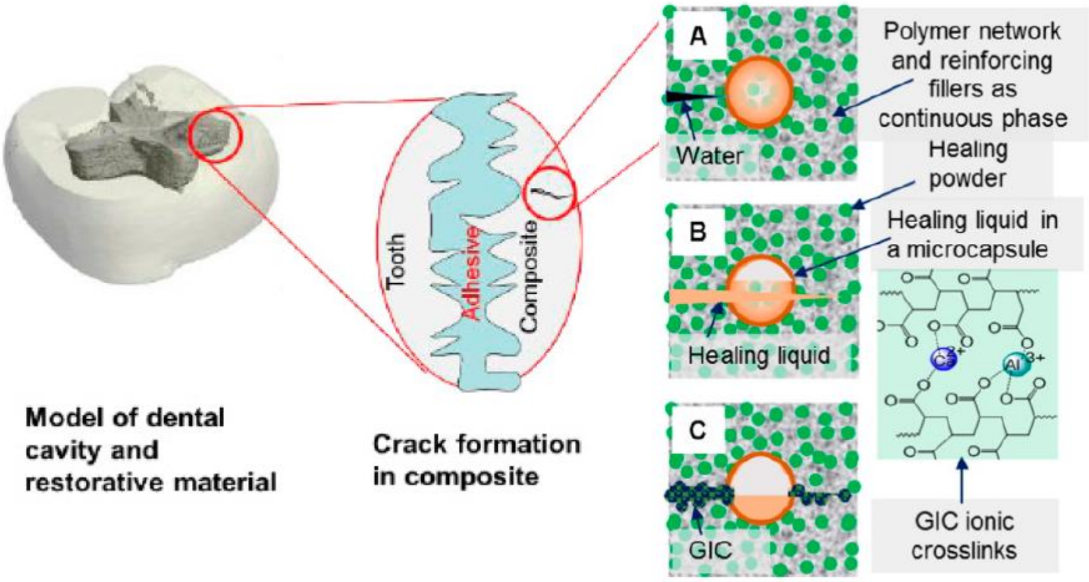

Figure 5: Mechanism of self-healing bracket [54]

5. Smart brackets

For an ideal treatment and to reduce iatrogenic effects, the 'Smart Bracket' has been developed for a next generation of fixed orthodontic appliances facilitating the orthodontist to quantitatively measure forces and torques applied to each tooth. Mechanism of smart bracket is shown in figure 2. Smart bracket is based on the concept of combining an orthodontic bracket with an integrated CMOS (Complementary Metal-Oxide-Semiconductor)-based stress sensor system. When an external force is applied, it causes mechanical deformation of the bracket body. The sensor system has diffused silicon resistors which can measure the mechanical stress in the surface of the sensor die In addition; the measurement information is transmitted wirelessly to the computer screen reader that the orthodontist place near each tooth during an examination. In this way, an objective feedback is provided to the orthodontist [42] [43].

6. Coated orthodontic brackets

The application of coatings is one of the approaches that are available to modify the surface of materials. However, wear of the coating is of great concern. Coating techniques which have been implemented in orthodontics to improve the surface properties of such materials include physical vapor deposition, physical sputtering, electrodeposition, sol gel method, plasma-based ion implantation/deposition [44].Nano material coating has advantage of reducing enamel demineralisation, bacterial aggregation, surface roughness and friction [45] [46].Classification of processes used for coating is shown in figure 3 and figure 4.

6.1. Silver-coated orthodontic brackets

Commonly, Silver coatings are used due to its superior antibacterial and antibiotic characteristics. Tania Ghasemi et al (2017) ,Irania Jasso-Ruiz et al (2019) had concluded in their study that surface modification of orthodontic brackets with silver nanoparticles can be used to prevent the accumulation of dental plaque and the development of dental caries during orthodontic treatment [47][48] . Addition of Palladium (Pd) to the silver coating increases the hardness and wear resistance. This prevents the corrosion caused by chewing food. Silver coatings reduce friction at high temperatures, and have the lowest contact resistance among metals.

6.2. Titanium-coated orthodontic brackets

Titanium coatings are used due to its biocompatibility properties. The bracket coated with the TiO2 thin film strongly prevents the adherence of *S. mutans*. It shows high antimicrobial activity against *S. mutans*, *L. acidophilus*, *A. viscous*, and *C. albicans*. This also prevents enamel demineralisation and gingivitis that occur during orthodontic treatment. Alok Girish Shah et al (2011) , Tania Ghasemi et al (2017) , and Parisa Salehi et al (2018) assessed titanium oxide surface modified stainless steel orthodontic brackets and proved its antimicrobial activity [49][47][50].In a study by Na *et al*., friction between the brackets coated with titanium dioxide (TiO2) nanoparticles and wire was measured and was concluded that reduced duration of orthodontic treatment and better treatment outcomes was obtained due to reduced friction [51].TiO2 nanoparticles reduced the coefficient of friction by a protective layer on abrasive surfaces and are used as lubricants

6.3. Others

Many studies were conducted aimed to evaluate the lubricating feature of copper nanoparticles. Coated copper nano-additives can significantly improve abrasion resistance as well as reduce the coefficient of friction. It also has antibacterial property.

- These are available with 24 karat gold plating, plated with 300 micro inches of gold. These are regarded as an esthetic improvement over stainless steel attachments.
- The platinum coated brackets are five times the abrasion resistance of gold. This exhibit reduced friction and improved sliding. It also acts as a barrier against the diffusion of nickel, cobalt and chromium.
- Brackets coated with ZnO, CuO, Gold (Au), Silica (SiO2) also have excellent antimicrobial properties [52].

7. Other brackets

7.1. Magnetic edgewise brackets

Magnetic edgewise bracket was first introduced by Kawata [53].

The samarium-cobalt magnets were prepared by attaching an edgewise bracket to the surface of the magnet and plating it with chromium to prevent corrosion of the magnet and with nickel to solder the bracket to the surface. The layer of nickel allowed the edgewise bracket to be soldered to the surface below 500oC.Finally, a mesh base was soldered onto the rear of the magnetic bracket, allowing the bracket and magnet combination to be bonded to the surface of the teeth by means of a direct bonding system. The edgewise bracket with 0.018-inch slot width was used. However, if the distance between the malpositioned teeth is over 3 mm and the magnetic force is thus not sufficient to retract these teeth, a power chain can be added to assist the magnetic force in the initial stage. When these teeth come closer together, that is, within 3 mm, the power chain is removed and the additional retraction can be done through the available magnetic force.

This reduced treatment time as compared with the conventional methods. Magnetic forces working directly to move the teeth also produce an electrocurrent and this electrocurrent (piezoelectric) will remodel the alveolar bone. As magnetic force is dependent upon Coulomb's law and works through the shortest distance between two points in space, the canines can be moved to second premolars through the shortest distance by the magnetic force. The treatment time using magnets is shorter when compared with the use of traditional orthodontic appliances. Furthermore, the magnetic method also seems to favorably influence or actually prevent periodontal problems, root resorption and caries.

7.2. Self-healing brackets

Huyang et al. reported a new model of self-healing dental composites (SHDC) where a reparative GIC will fill and seal whenever a crack is generated in a composite. This innovation may also involve polymer brackets. The integration in these materials of nanosized bubbles filled with auto-polymerized monomer may result in fewer bracket breakages. The fracture of the bracket would cause bursting of the nanosized bubbles and exposure of the monomer to the air, thus promoting the polymerization and filling of the crack-induced gaps [54]. Mechanism of self healing bracket is shown in Figure 5.

7.3. The *insignia system*

It uses a computer to mill special brackets for each tooth of each patient. The clinician makes adjustments using Insignia's Approver** software to refine the:

- Characteristics involving torque, tip, in/out, intrusion, and extrusion of each tooth.
- Archform, within the patient-specific biological limits set by the osseous structure.
- Smile arc.
- Dental contacts in the final centric occlusion

Transfer jigs are utilized in bonding the brackets indirectly. Bracket-transfer jigs are precisely milled from a high-tech, spongy material to fit the occlusal surfaces of the teeth, making bracket positioning accurate and reliable. The jigs are constructed so that three-quarters of the bracket-pad edges are visible during bonding, thus facilitating removal of excess composite material before polymerization [55].

7.4. *Biomimetic adhesives and brackets*

Geckos are lizards that exhibit a flat pad that is densely packed with fine hairs split at the ends, resulting in an increased number of contact points leading to a significant increase in the adhesion through localized van der Waals forces. But, it is only suitable in dry environments, not on wet surfaces. Then, another natural example of bonding is mussels which overcomes the weakness of the gecko mechanism. Combining the gecko and mussel adhesion mechanisms leads to a new adhesive material which is called "geckel". This functions like a sticky note and exhibits a strong yet reversible adhesion in both air and water. Mussel-mimetic polymers have an amino acid called L-3,4-dihydroxyphenylalanine (DOPA) which is found in high concentrations in the "glue" proteins of mussels. Contrary to the gecko-based approach, pillar arrays (400–600 nm in diameter and length) coated with the mussel-mimetic polymer improved wet adhesion 15 times more than uncoated pillar arrays. A deep understanding of this type of biomimetic adhesive could be used in the manufacturing brackets. Brackets having bases with pads mimicking the gecko foot and covered with a layer of DOPA would provide sufficient bond strength to sound enamel without prior enamel conditioning and would avoid color and structural alterations of enamel [54].

7.5. Self-ligating brackets

Self-ligating Brackets have attracted much attention in recent years, and their use has increased considerably. Constant archwire engagement, reduced friction, reduction in appointments, reduction of generated forces, greater arch expansion and reduced incisor proclination are some of the benefits attributed to Self-Ligating Brackets. Reported disadvantages include higher cost, failure of the closing mechanism, higher profile, and reduced torque expression [56]. As this review is about the orthodontic bracket materials and not about the method of ligation, the self ligating brackets are not discussed in detail bracket materials.

8. Conclusion

The treatment outcome of the orthodontic treatment partly depends on the materials of the orthodontic appliances. Ideal orthodontic bracket materials should have the mechanical properties of possessing better hardness, frictional resistance, abrasive resistance, tensile strength, ability to withstand creep, optical stability, improved bracket base design, being biocompatible and aesthetically appealing. Through the years, the orthodontic bracket materials have evolved towards aesthetics. This has led to the introduction of number of bracket materials. But for the selection of the bracket materials clinically, the physical properties of the material, biocompatibility, patient's history should also be taken into account.

Ongoing research works on the orthodontic bracket materials has led to the use of advanced manufacturing methods, enhanced bracket base design for improved retention, use of titanium alloy in bracket manufacturing, metal oxide reinforced polymer bracket for better physical and optical properties, smart brackets and coating conventional metal brackets with noble metals for improving mechanical and incorporating antibacterial property. So, the clinician should have thorough knowledge of all the properties of orthodontic materials available before incorporating them in clinical practice

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