

Metal Free Orthodontics: A Review

Abstract

With the increase in the number of adults undergoing orthodontic treatment, there has been a corresponding increase in demand for more esthetic orthodontic appliances. These new appliances combine both acceptable esthetics and adequate technical performance. This article presents the currently available appliances and discusses the potential problems associated with each. Recent advances have also been described.

Key Words

Esthetics; brackets; archwires

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INTRODUCTION

Since 1990's there has been a growing demand for esthetic orthodontic appliances. Orthodontic patients, including a growing population of adults, not only want an improved smile, but they are also increasingly demanding better aesthetics during treatment. This demand has led to the development of orthodontic appliances with acceptable esthetics both for patients and clinicians. The development of appliances that combine both acceptable aesthetics for the patient and adequate technical performance for the clinician is the ultimate goal. There has been a recent trend towards the development of smaller stainless steel brackets but although these generally provide the technical performance required by the orthodontist the aesthetic advantage over conventional sized appliances is limited. Lingual orthodontics satisfies the aesthetic criteria but it can be argued that it produces a decrease in the performance of the appliance and considerable additional technical difficulties and time requirement for the orthodontist. Most of the orthodontic appliances are metallic and silver in color and at the beginning of esthetic production, there were transparent brackets made of ceramic or composite. But the archwires were still made of metals such as titanium molybdenum alloy, nickel titanium, or stainless steel. Recently, coated metallic and fiber-reinforced wires have been introduced to solve esthetic appearance problem. A more recent addition to the orthodontist's armamentarium is Invisalign. This aesthetically orientated technique uses a series of clear plastic aligners to treat simple

to moderate alignment cases, especially in the adult patient. However, complex cases still require fixed appliance treatment and numerous brackets & archwires are now available for those clinicians and patients that are aesthetically orientated.

BRACKETS

Two of the materials used for traditional aesthetic bracket manufacturing are plastic and ceramic brackets.

Plastic Brackets

Plastic brackets were introduced into the market in early 1970's. Initially they were constructed from acrylic followed by unfilled polycarbonate. The disadvantages with these materials were they resulted in staining and odours but more importantly they lacked strength and stiffness resulting in bonding problems, tie wing fractures^[1] and permanent deformation or creep. Permanent deformation occurs when a material is subjected to a constant load over an extended period of time and is particularly important for thermoplastic materials such as polycarbonate resins. Polycarbonate bracket slots distorted with time under a constant physiologic stress rendering them insufficiently strong to withstand longer treatment times or transmit torque.^[2] Polycarbonate brackets also reported significantly higher torque losses and lower torquing moments with compared to metal brackets.^[3] To compensate for the lack of strength and rigidity of the original polycarbonate brackets, high-grade medical polyurethane brackets and polycarbonate brackets reinforced with ceramic or fibreglass fillers and/or metal slots have been

recently introduced. Polycarbonate brackets with metal reinforced slots demonstrated significantly less creep than conventional polycarbonate brackets although torque problems still exist. Approximately 15% loss in torque over 24 hours has been observed with both ceramic reinforced and metal lined polycarbonate brackets.^[4] Torque deformation characteristics of seven commercially available plastic brackets both against each other & with stainless steel brackets were compared in a study. The results 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. Ceramic reinforced polycarbonate brackets showed the highest deformation under torque stresses. The addition of ceramic and fibreglass in the plastic brackets also failed to improve the torque stability of the polycarbonate brackets and pure polyurethane brackets showed no significant difference from pure polycarbonate at optimal torque. A comparison with stainless steel brackets illustrated that plastic brackets are only suited for clinical application if they have a metal slot.^[5] A recent advancement to aesthetic brackets are self-ligating aesthetic brackets. A study conducted to measure and compare the level of frictional resistance generated between stainless steel self-ligating brackets, polycarbonate self-ligating brackets, and conventional stainless steel brackets showed that polycarbonate self-ligating brackets generated significantly greater static and kinetic frictional forces than stainless steel self-ligating brackets but were comparable to conventional stainless steel brackets.^[6]

Ceramic Brackets

In an attempt to improve esthetics while maintaining bracket strength has resulted recently in the development of a ceramic bracket. Ceramic brackets were introduced in the 1980's. The advantages ceramic brackets offer over conventional aesthetic brackets are that they provide higher strength, more resistance to wear and deformation, better colour stability and, most important to the patient is they offer superior aesthetics. Ceramic brackets are available in a variety of structures including true Siamese, semi-Siamese, solid and Lewis/Lang designs and also various appliance systems including Begg and variable force ligation brackets.

Composition & Types of Ceramic Brackets

Ceramics are a broad class of materials consisting of metal oxide elements and non-metal elements that include precious stones, glasses, clays and mixtures of ceramic compounds.^[7] Alumina is a typical member of modern ceramics, formed when aluminum is added to steel to remove oxygen dissolved in the steel.^[8] Alumina may be used as a single-crystal material or as a polycrystalline material. Both monocrystalline and polycrystalline alumina are used to manufacture orthodontic ceramic brackets.^[9] Ceramic brackets are composed of aluminium oxide in one of two forms: polycrystalline or monocrystalline, depending on their method of fabrication. Monocrystalline brackets are manufactured by milling from single crystals of sapphire using diamond tools whereas polycrystalline brackets are sintered using special binders to thermally fuse the particles together. The manufacturing process plays a very important role in the clinical performance of the ceramic brackets. The production of polycrystalline brackets is less complicated, and thus these brackets are more readily available at present. The most apparent difference between polycrystalline and single crystal brackets is in their optical clarity. Single crystal brackets are noticeably clearer than polycrystalline brackets and hence are translucent. Both single crystal and polycrystalline brackets resist staining and discoloration.^[9] Polycrystalline zirconia brackets which reportedly have the greatest toughness amongst all ceramics, have been offered as an alternative to alumina ceramic brackets.^[10] They are cheaper than the monocrystalline ceramic brackets but they are very opaque and can exhibit intrinsic colours making them less aesthetic. Good sliding properties have been reported with both stainless steel and nickel-titanium archwires along with reduced plaque adhesion, clinically acceptable bond strengths and bond failure at the bracket/adhesive interface.^[11] However, zirconia brackets did not offer any significant advantage over polycrystalline alumina brackets with regard to frictional characteristics.¹² As the clinical performance of alumina ceramic brackets has continued to improve over recent years, zirconia brackets have become obsolete.

Clinical problems encountered with ceramic brackets and their management

Various problems encountered with the use of ceramic brackets in clinical practice are- Increased

bond strength, friction, bracket breakage, iatrogenic enamel damage & debonding.

Increased bond strength

Early ceramic brackets used a silane-coupling agent to act as a chemical mediator between the ceramic bracket base and the adhesive resins as the ceramic brackets did not bond chemically with acrylic and diacrylate bonding adhesives due to their inert aluminium oxide composition. This chemical retention resulted in extremely strong bonds that caused the enamel/ adhesive interface to be stressed during debonding, risking irreversible enamel damage in the form of crack and delamination that often required dental restorations. Consequently, the challenge was to develop a bond between the ceramic bracket base and the enamel that clinically has adequate strength to accomplish treatment but can be broken at debond without damage to the enamel surface. The majority of the currently available ceramic brackets rely solely on mechanical retention, using standard light or chemically cured adhesives, without the need for additional special bonding agents. Numerous mechanical base designs are now available ranging from microcrystalline, mechanical ball, dovetail, dimpled chemo/mechanical, silane coated buttons and polymeric bases with many manufacturers claiming consistent bond strengths and debonding characteristics comparable to that of stainless steel mesh. Several studies have compared the bond strength of ceramic brackets with different retention mechanisms and concluded that mechanically retained brackets have adequate bond strength and appear to cause less enamel damage at debond compared to the chemically retained brackets.^[13-15]

Friction

Ceramic brackets vary in fracture toughness and strength depending on the extent of the surface roughness. This in turn affects the overall frictional properties of the bracket. Polycrystalline ceramics, have a higher coefficient of friction than monocrystalline ceramics and stainless steel due to their rougher & more porous surface. Polycrystalline brackets have shown to generate significantly greater frictional forces than stainless steel brackets with any of the archwire combination.^[16] In order to overcome the frictional characteristics of ceramic brackets metal reinforced archwire slots have been introduced. Studies done on these metal inserts have shown conflicting results. In a study conducted by kusy *et al.*, metal lined ceramic brackets were shown to possess

similar frictional characteristics as stainless steel brackets.^[17] Whereas a study conducted by Nishio *et al.*,^[19] demonstrated significantly higher frictional forces with ceramic brackets with metal slots compared to stainless steel brackets. In another study Thorstenson and Kusy^[20] observed that the addition of stainless steel inserts to polycrystalline brackets did not considerably improve the resistance to sliding over those aesthetic brackets without inserts. To reduce friction some manufacturers have come out with silica-lined slots as well as introducing bumps along the floor of the slots as alternatives to metal lined slots.

Bracket breakage

Ceramic brackets have a higher incidence of bracket breakages than with stainless steel brackets due to its low fracture toughness. Tie wings can easily fracture due to the high torsional forces exhibited by rectangular wires and surface flaws within ceramic brackets can lead to cracks and fractures when the bracket is stressed. Injection moulded brackets have a much smoother finish than machined brackets thus reducing the number of surface flaws.

Iatrogenic enamel wear

Ceramic brackets are nine times harder than stainless steel brackets or enamel and severe enamel abrasion from ceramic brackets might occur rapidly, if contacts between teeth and ceramic brackets exist. Rapid and severe enamel wear to the opposing dentition has been reported when ceramic brackets are placed in the lower arch.^[21] The use of polycarbonate brackets in the lower arch has been recommended if overbite is a concern as they are less abrasive to the opposing dentition. Alternatively metal brackets might also be used in lower arch.

Debonding

Many alternative debonding methods have been suggested, to avoid the complications associated with ceramic bracket removal. Few of the debonding methods currently used are-Conventional debonding pliers, Hows, Weingarts or ligature cutters, Ceramic bracket specific debonding pliers, Electrothermal debonding, Ultrasonic scaler, Laser aided debonding & Debonding agents.

ARCHWIRES

Coated metallic and transparent non-metallic archwires are the two types which have been introduced to solve esthetic appearance problem.^[22]

Coated metallic archwires

Coating on archwire material have been introduced to enhance esthetics and to decrease friction. These

wires are designed to be esthetically more acceptable by the patient. Coated metal archwires are nickel-titanium or stainless steel wires treated with a polytetrafluoroethylene (PTFE), epoxyresin, parylene-polymer, or less commonly palladium covering to impart an enamel hue. Manufacturers vary with regard to the coating material, thickness of the coating, and steps within the application process to maximize aesthetics, flake resistance, and mechanical efficiency. Currently, the two most common aesthetic archwires available in the market are coated with either PTFE or epoxy-resin.

PTFE, Teflon. PTFE, commonly recognized by the DuPont Co brand name Teflon, is a synthetic polymer consisting wholly of carbon and fluorine. Due to the strength of the carbon-fluorine bonds, PTFE is nonreactive, heat-resistant, and hydrophobic. PTFE coating is applied to an orthodontic wire by thermal spraying; a process in which finely heated materials are sprayed in a molten condition onto a surface to form a coating. The PTFE layer adds a minimal thickness (.0008 to .001 inch) to the archwire.

Epoxy-resin. Epoxy is a synthetic resin made by combining epoxide with another compound. They are widely used in orthodontic materials, including composite resins, molds, and polyurethane aligners. Epoxy-resin coating is applied to an orthodontic archwire by electrostatic coating, or E-coating. Electrostatic coating is a process that uses electrostatically charged particles to more efficiently coat a workpiece. The epoxy coating does add a more significant thickness (.002 inch) to the archwire. Therefore, a .0180-inch NiTi wire becomes .020-inch diameter with an epoxy coating, or alternatively, the manufacturer may choose to use a smaller diameter wire to compensate for the thickness of the coating. Coating improves aesthetics, but creates a modified surface, which can affect friction, corrosive properties, and the mechanical durability of the wires. There are different opinions in the literature concerning coated archwires. An evaluation of sliding properties and adherence of coating to the archwires revealed that the plastic coating decreased friction between archwires and brackets.^[23] The coated wires are also found to be routinely damaged from mastication and activation of enzymes,^[24] due to which this coating has been described as undurable.²⁵ Other authors have also experienced difficulties, claiming that the colour tends to change with time and that the coating splits during use in

the mouth, exposing the underlying metal.^[26,27] Elayyan et al.,^[28] stated that coated archwires had low esthetic value because 25% of coating was lost within 33 days in vivo and surface quality revealed severe deterioration.

Transparent non-metallic archwires

In the past 20 years, significant advancements have been made to create non-metallic arches whose properties resemble metal alloys. Flexible nonmetallic arches are typically made from glass spindles embedded in a polymeric matrix. Some examples of non-metallic arches include fiber-reinforced polymer (FRP),^[29,30] or newer self-reinforced polymer (SRP).^[31] Fiber reinforced composite wires for orthodontic purposes are fabricated using a procedure called pultrusion³². Fiber bundles are pulled through an extruder, in which they are wetted with a monomer resin. Next, the monomer is cured with heat and pressure, resulting in polymerization. During curing, the wetted fiber is formed into a desired cross sectional morphology, which may be circular or rectangular. This wire may be also be further shaped into a different morphology by further curing, a process known as beta staging. These arches allow for a few millimeters of deformation and may be suitable for levelling and aligning in patients with Class I malocclusions with mild to moderate crowding. More importantly, they display the translucency and transparency ideal for ceramic brackets. Burstone and Kuhlberg³³ have described the clinical application of a new fiber reinforced composite called "Splint-It" which incorporates S2 glass fibers in a bis GMA matrix. This is available in various configurations such as rope, woven strip and unidirectional strip. These materials are only partly polymerized during manufacture (pre-pregs), which makes them flexible, adaptable and easily contourable over the teeth. Later they are completely polymerized and can be bonded directly to teeth. They can be applied for various purposes such as post treatment retention, as full arches or sectional arches, and to reinforce anchorage by joining teeth together. A particular advantage is that due to direct bondability to teeth, they can obviate the need for brackets in specific situations. In addition, they are highly esthetic, and could thus be an effective alternative to lingual appliances. Optiflex archwire^[30] is a non metallic orthodontic wire designed by M.F. Talass in 1992 to combine unique mechanical properties with a highly esthetic appearance. Structure of Optiflex archwire is that it

is made of clear optical fiber comprising of three layers A – Silicon Dioxide Core, B – Silicon Resin Middle Layer, C – Nylon Outer Layer. Silicon dioxide core provides the force for moving teeth. Silicon resin middle layer protects core from moisture and adds strength & Nylon outer layer acts as stain resistant & also prevents damage to wire and further increases the strength. Its advantages are that it is completely stain resistant, effective in moving teeth with light continuous forces, very flexible, has wide range of actions & it can be used with any bracket system. Nonmetallic archwires are brittle and allow for only moderate deformation. Excess deformation or forceful grip with pliers can lead to permanent deformation and irreversible cracks, referred to as “craze lines.” These clear arches are restricted with regard to torque, detailing, and changes in arch width, and they are currently not suitable for patients requiring consolidation or anteroposterior correction.

INVISALIGN

Invisalign is an orthodontic technique that uses a series of clear plastic aligners to move teeth. Invisalign was the brainchild of Zia Chishti and Kelsey Wirth, graduate students in Stanford University's MBA program. The aligners are made from thin, see through plastic, which fits over the buccal, lingual and occlusal surfaces of the teeth. Invisalign uses 3-D computer imaging technology to depict the complete treatment plan from the initial position to the final desired position from which a series of custom-made, clear "aligners" are produced. Each "aligner" moves teeth incrementally and is worn for about two weeks, then replaced by the next in the series until the final position is achieved. Like brackets and arch wires are to braces invisalign aligners move teeth through the appropriate placement of controlled force on the teeth. The principal difference is that invisalign not only controls forces, but also controls the timing of the force application. At each stage, only certain teeth are allowed to move, and these movements are determined by the orthodontic treatment plan for that particular stage. This results in an efficient force delivery system. Generally, invisalign handles simple to moderate nonextraction alignments better than mild to moderate extraction corrections. This is primarily because invisalign only has a limited ability to keep teeth upright during space closure. Attachments, formed by bonding tooth coloured restorative material in a vertical bar to the buccal surface of certain teeth, can give the aligners greater

rotation and angulation control. Indications of invisalign includes mildly crowded and malaligned teeth (1–5 mm), spacing problems (1–5 mm), deep overbite problems (Class II division 2 type malocclusions) where the overbite can be reduced by intrusion and advancement of incisors & narrow arches that can be expanded without tipping the teeth too much. Limitations of invisalign include crowding or spacing over 5 mm, skeletal antero-posterior discrepancies of more than 2 mm, centric relation and centric occlusion discrepancies, severely rotated teeth (more than 20 degrees), open bites (anterior and posterior) that need to be closed, extrusion of teeth, severely tipped teeth (more than 45 degrees), teeth with short clinical crowns, arches with multiple missing teeth & closure of bicuspid extraction spaces.^[34]

ESSIX APPLIANCE

The Essix appliance^[35] is a light, almost invisible removable plastic device that snaps over the teeth and is used mainly for retention. They are fabricated from .030" Essix plastic sheet, which is reduced to .015" during thermoforming. There are two types of Essix plastics: types A and C. Typical applications for type A are for minor tooth movement with divots and windows, bite planes, TMJ splints and intrusion appliances. Type A must be used when bonding acrylic to the appliance. Essix type C plastic has poorer aesthetics compared with type A, but its abrasion resistance is better than Type A. Type C is best used for anterior and full arch retainers. The 2 primary methods of creating a tooth-moving force with the appliance are by spot-thermoforming with a specific pliers and by means of a mounding procedure that alters the surface of the tooth to be moved by sequentially placing small layers of bonding composite on the tooth. The many types of tooth movements that can be attained with the Essix appliance are tipping, differential bodily movement, rotation around a vertical axis, torque, lateral movements into space created by stripping, and the use of Class II and Class III elastics attached to the appliance.

CONCLUSION

There are a variety of appliances available today for an orthodontist to cater to the growing demand of patients towards esthetic appliances. Every appliance has its own merits demerits & its limitations. Hence one must explore the available appliances within their spectrum to combine aesthetics with adequate technical performance.

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