BIOMATERIAL ADVANCES IN ORTHODONTICS

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Abstract

The practice of orthodontics requires professional skill in the design, application and control of corrective appliances to bring teeth, lips and jaws into proper alignment and to achieve facial balance. To achieve this desirable end, knowledge and skill of an orthodontist, is strongly supported by the use of various biomaterials. The materials used should possess not only adequate physical and mechanical strength to bring about biomechanical changes in the bone, but also should possess the biological properties to sustain in the harsh environment of the oral cavity. These material should also be able to maintain their metallurgical properties under stress and strain. This article highlights the recent advances in such materials used in orthodontics.

Key words: *orthodontic brackets, ceramic brackets, arch wires, stainless steel wires, nickel titanium wires, micro implants*

Introduction

The biomaterials used in the oral cavity should possess certain qualities. It should be non-toxic, possess reasonable strength, hydrolytic stability, high purity and sterilizability. It should also possess reproducible quality and be resistant to tarnish and corrosion.Some of the biomaterials used by an orthodontist are brackets, arch wires, bands, elastics, adhesives and etchants, cements, impression materials, and micro implants.

Brackets

One of the most important passive components of fixed appliances is brackets. They are merely handles for attachment of the force producing agents to move the tooth in all possible direction, similar to a door handle which allows us to open or close a door. They can affect the directions of the force vectors when torque, angulations, and in/out are built into the brackets.[1]

In order to deliver the exact force from the wire to the teeth, brackets should have the correct hardness and strength. They should have a smooth arch wire slot to reduce frictional resistance, and an otherwise smooth surface to reduce plaque deposition. Because most orthodontic brackets are produced with a three-dimensional prescription for each tooth, they should be accurately manufactured to reflect this. They should also have a high corrosion resistance and good biocompatibility. [2]

Stainless steel had been the material of choice for fabrication of many orthodontic components. Stainless steel had shown tendency for corrosion, and also there was a constant need for esthetics, which led to the use of other materials for manufacture of the brackets. Titanium, polycarbonates, ceramic and gold are such material used for brackets.

Titanium Brackets (Fig 1)

Titanium and titanium-based alloys have the greatest corrosion resistance of any known metals. Titanium also has low thermal conductivity, and thus alleviates the sensitivity to extreme temperature changes often experienced by patients wearing metal appliances. They have also solved the problems of

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Figure 1: Titanium Brackets

nickel sensitivity, and inadequate retention. Its one-piece construction requires no brazing layer, and thus it is solder and nickel-free.[3]

Gold-Coated Brackets (Fig 2)

Recently gold-coated steel brackets have been introduced and rapidly gained considerable popularity, particularly for maxillary posterior and mandibular anterior and posterior regions. Brackets are now available with 24 karat gold plating, plated with 300 micro inches of gold.Gold-coated brackets may be regarded as an esthetic improvement over stainless steel attachments, and they are more hygienic than ceramic alternatives. [4]

Figure 2: Gold- Coated Brackets

Platinum Coated Brackets

These bracket have five times the abrasion resistance of gold. A smoother, harder surface than stainlesssteel for reduced friction and improved sliding mechanics is achieved by using this system.

Nickel-free Brackets (Fig 3)

Nickel free brackets are made of Cobalt chromium (CoCr) dental alloy. It is a one piece construction manufactured by metal injection molding,which gives more finish and less friction. They also have a laser structure base finish for better retention.

Figure 3: Nickel-free Brackets

Ceramic Brackets

Ceramic brackets are esthetic, thus are popular among the patients. It also does not stain like the plastic brackets. However it is brittle and hard, thus tends to fracture. The bond strength to enamel is so high that the enamel fractures during debonding. Ceramics used for the manufacturing of ceramic brackets were Alumina and Zirconia. Both can be found as tri-dimensional inorganic macromolecules.

The types of ceramic brackets are
1. *Monocrystalline (Saffire)(Fig 4)*
2. *Polycrystalline alumina(Fig 5)*
3. *Polycrystalline zirconia-yttrium oxide partially stabilized zirconia (YPZC)* [5,6]

Figure 4: Mono Crystalline brackets

Comparison of frictional forces produced in ceramic and stainless steel brackets, when different wires were used, suggested that for most sizes, the wires in ceramic brackets produced significant greater friction. To reduce frictional resistance, development of ceramic brackets with smoother slot surfaces and consisting of metallic (stainless steel and gold), silica lining or ceramic/plastic slot surfaces was considered and presently accomplished[7].(Fig 6)

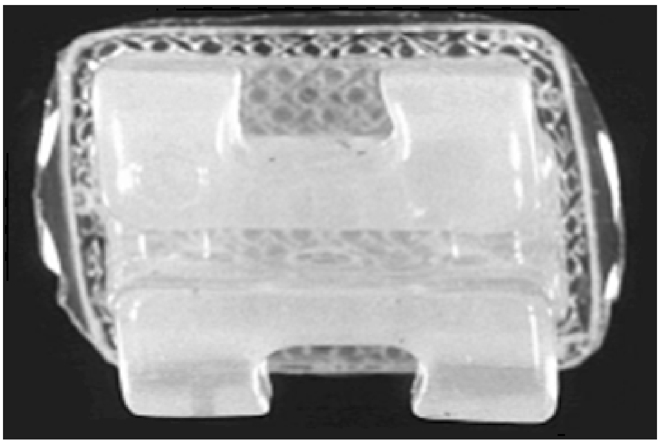

Figure 5: Poly Crystalline

Figure 6: Ceramic with metal slot

Arch Wires

Orthodontic arch wires are one of the most important active elements of the orthodontic armamentarium. They generate the biomechanical forces transmitted through the brackets to effect tooth movement. It is a common saying that "An Orthodontist is as good as the arch wire he uses." The arch wires are broadly classified as metallic and non-metallic. The metallic ones include gold alloys, stainless steel, Cobalt-chromium, Nickel titanium, Beta and Alpha titanium. The non-metallic ones include polymers and composite/ coated materials.

Advances in Stainless steel wires

Nickel Free Stainless Steel

The 18-8 stainless steel is the most commonly used arch wire. Though it exhibits good corrosion resistance, releases nickel and chromium in minor concentration resulting in hypersensitivity reactions. Thus steel is alloyed with 10-14% manganese, and 0.9% nitrogen to compensate for nickel. It has high corrosion resistance and better mechanical properties. Wires under the name Manzanium(Scheu) or Noninium(Dentaurum) are currently available. [8]

Multi-stranded SS wires

Multi-stranded wires are made of a varying number of stainless steel wire strands coaxially placed or coiled around each other in different configurations. Individual strands are of dimensions in the range of 0.005 to 0.010. Five or seven wires are wrapped around a central wire. It is very flexible and requires less force. It is also less expensive than titanium alloys. [9]They are available as triple stranded, co-axial and braided.

Advances in Titanium wires

Titanium Molybdenum alloy (TMA)

This Beta titanium alloy is also called as Titanium niobium alloys. It is soft and easy to form with stiffness 70% lower than SS wires so that creative bends are easily made. This wire is used as finishing wire due to its low spring back and high formability. [10] However exposure to fluoride agents have been found to degrade the properties of the wire.

Titanium Molium alloy

This is an Alpha-beta titanium alloy and has been introduced recently. It has stiffness, elasticity and yield strength that are between stainless steel and beta-titanium wires [11]. It is more resistant to breakage, smoother for reduced friction, and highly polishable and aesthetically pleasing. It is excellent for all phases of treatment.

Advances in Nickel Titanium wires

Popularly this alloy is called as the Nitinol and is characterised by high resiliency, limited formability, shape memory and pseudoelasticity or superelasticity. The last two features are attributed to the phase transformation from the austenitic to martensitic phase on stress. This elasticity allows a wide deflection and activation range by delivering low forces. Low formability, inability to weld and high cost are the disadvantages. The friction at the bracket-wire interface is also more when compared to other wires. They have excellent corrosion resistance.

Graded thermodynamic Nickel Titanium alloys

The response of a tooth to force application and the rate of tooth movement is dependent on the amount of a constant and low force. It is possible to produce variation in arch wire force between arch wires of identical dimension by specifying transition temperature within given range.

The manufacturers have taken this process one step further introducing 'variable transition temperature'within the same arch wire[12]. This takes the form of graded force delivery within the same aligning arch wire providing light force of approximately 80g anteriorly, and a heavier force of 300g posteriorly[13]. The level of force is therefore graded throughout the arch length according to tooth size[14].

Super Cable

Super cable is a seven-stranded round coaxial super elastic NiTi arch wire. The concept is similar to the multi stranded wires of stainless steel. The advantages are increased flexibility and a reduced load deflection rate. However if the wire is not cut with a sharp instrument it can fray. [15]

Advances in improving esthetics in wires

Teflon Coated NiTi

The development of coated arch wires is a testimony to the efforts in search of esthetics. There is a parent NiTi wire over which organic coating is placed.Teflon (polytetraflouro ethylene) is most commonly used for coating. The size of the parent wire for a given slot size is less to accommodate for the thickness of the coating which could significantly alter the force delivering characteristics.Teflon coated arch wires are available in natural tooth shades and in other colors such as blue, green, purple[14].

Other coated wires are Marsenol (coated with poly tetraethyl emulsion, ETE) and Lee White Wire (Epoxy coated).

Organic Polymer Wire(QCM)

Organic polymer retainer wire is made from 1.6mm diameter round polytheline terephthalate. This material can be bent with a plier, but will return to its original shape if it is not heat–treated for a few seconds at temperature less than 230°C(melting point). These wires are used for aesthetic maxillary retainers.

Optiflex

This is a non-metallic orthodontic arch wire designed by Dr. Talass and manufactured by Ormco. It has got unique mechanical properties with a highly aesthetic appearance made of clear optical fiber. It comprises of 3 layers.1. A silicon dioxide core that provides the force for moving tooth 2. A silicon resin middle layer that protects the core form moisture and adds strength. 3. A strain resistant nylon outer layer that prevents damage to the wire and further increases strength.It is esthetic, stain resistant. It's effective in moving teeth using light continuous force and is very flexible. [16]

Fibre-reinforced composite arch wires

Fibre-reinforced polymer composites are highly aesthetic, biocompatible, hydrolytically stable, and absorbs less water. It is as stiff as the metallic wires with desirable formability and frictional resistance. [17] The main advantage is that it can be directly bonded to the tooth obviating the need for the bracket. To reduce the abrasive wear of the composite and the subsequent leaching of the glass, it is coated with parylene. A new fibre which is reinforced with S2 fibre in Bis GMA matrix is available as ropes, woven or uni-directional strips. It is pre polymerized during manufacturing making them flexible and adaptable.

Micro Implants *(Fig 7)*

One of the greatest single innovation in clinical orthodontics is advent of temporary anchorage devices widely known as mini-screws or mini-implants (TAD'S).The use of TADs allows the application of force vectors that were previously difficult to achieve.The use of bone screws has increased the envelope of orthodontic treatment, providing an alternative to orthognathic surgery and allowing asymmetric tooth movements in all three plane of space. [18]

Figure 7: Micro Implants

Conclusion

Technological and material advancement has progressed the quality of orthodontic treatment rendered for the patients. The advances in the biomaterials has enhanced the biomechanical principles used in the treatment of malocclusion. Orthodontists rely so much on the materials that a sub discipline of orthodontic material science has evolved. It is imperative for an orthodontist to be abreast with the latest development so as to use them effectively in the light of scientific evidence.

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