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REVIEW ARTICLE

BIOMATERIALS IN DENTAL IMPLANTOLOGY- A REVIEW

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ABSTRACT

Selection of a suitable implant biomaterial is the most important criteria for the success of treatment. Implantology has become mainstream practice and accepted as a desirable treatment and as an alternative to conventional removable and fixed dental prosthesis. It is mandatory for a clinician to have a knowledge about various biomaterial used for dental implants for their judicious selection and application. This literature review makes an effort to summarize the evolution of various biomaterials their properties and characteristics and its impact on treatment outcome.

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INTRODUCTION

The ideal goal of modern dentistry is to restore the patient to normal contour, function, comfort, esthetics, speech and health. A dentist provides the restoration for a living, whether removing caries from a tooth or replacing several teeth. Unique ability of implant dentistry is to achieve this ideal goal regardless of the atrophy, disease, or injury of the stomagnognathic system (Carl E Misch, 1999). Study of material science along with biomechanical sciences provides an optimal idea about the design and materials concepts for surgical implants. Biomaterial is defined as "a non drug substance suitable for inclusion in systems which augment or replace the function of bodily tissues or organs (Heness, 2004)". The physical, mechanical, chemical and electrical properties of the basic materials component must be evaluated for any biomaterial application as this provide the key input that how the host tissue at the implant site responds to a foreign material. A thorough knowledge of different biomaterials is required for their judicious selection and application in implantology.

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Classification of biomaterials

Based on biocompatibility

Biomaterials are broadly classified into:

- **Bioinert:** Refers to any material which do not initiate a response or interact when introduced to biological tissue. In other words, introducing the material to the body will not cause a reaction with the host. Some of the examples are stainless steel, titanium, zirconium, alumina and ultra-high molecular weight polyethylene.
- **Bioactive:** refers to materials, once placed inside the oral cavity reacts with surrounding hard tissues as well as soft tissues. Examples are synthetic hydroxyapatite, glass ceramic and bioglass.
- **Bioresorbable:** these materials on placement begin to resorb and slowly get replaced with bone. Examples are tricalciumphosphate, polylactic-polyglycolic acid copolymers, calcium oxide, calcium carbonate, and gypsum (Yasumasa Akagawa, 2003).

Based on chemical composition

Biomaterials can be classified into metals, ceramics and polymers.

- **Metals:** titanium, titanium alloys, stainless steel, cobalt chromium alloys, gold alloys and tantalum.
- **Ceramics:** alumina, hydroxyapatite, beta-tricalcium phosphate, carbon, bioglass, zirconia, and zirconia toughened alumina.
- **Polymers:** polymethyl methacrylate, polytetrafluroethylene, polyethylene, polysulfone, polyurethane, and poly ether ketone (Heness, 2004).

History of dental implant: History shows that it has always made sense to replace a tooth with an implant.
The desire to replace missing teeth with something similar to the root of a tooth dates back thousands of years.

Up to 1800

550 – Evidences of oldest dental implant was found in the Kalavak Necropolis, Turkey

600 – Wilson Popenoe discovered a skull in the Ulua river valley of Honduras, which had an artificial tooth replacing lower lateral incisor, carved out of dark stone.

936 – Albucasis de Condue an Arab surgeon described the transplantation procedures. He used ox bone to replace missing teeth. He wrote a paper on transplants in edentulous areas.

1500 - Wooden dowel and crown prosthesis was designed in Japan which was an early ENDODONTIC IMPLANT-SUPPORTED PROSTHESIS.

1700 – Ambroise Pare, a French physician, a surgeon replaced missing teeth with implants made made up of bone and ivory.

1728 – John Hunter suggested the possibility of transplanting teeth of one human to another

1791 – Titanium sometimes called the space age metaldiscovered by William Gregor and named by Martin Heinrich Klaproth

1789 – Zirconium dioxide was accidentally identified by the German chemist Martin Heinrich Klaproth.

1800 – 1950

1809 – Maggillio gave the first reference to modern style implants by introducing the usage of gold in the shape of tooth root

1886 – Harris placed a tooth root shaped platinum post with lead coating

1888 – Berry reported about root form implants made up of lead.

1895 – Bonwell used gold and iridium tubes implanted into bone to restore a single tooth as to support complete dentures.

1898 – R E Payne at national dental association meeting gave the first clinical demonstration by placing a silver capsule in the extracted tooth socket.

1903 – Sholl in Pennsylvania, implanted porcelain tooth with corrugated porcelain root.

1910 – Puremetallic titanium was first prepared by Mathew A Hunter by heating $TiCl_4$ with sodium at 700-800^0 C.

1913 – Greenfield introduced and planted hollow basket implant made of mesh work of 24 guage iridium-platinum wires soldered with 24 karat gold.

1938 –Stock placed the threaded vitallium implant into the extraction socket, which was the first long term endosseous implant.
1947 – Formiggini in 1947 developed a single helix wire spiral implant made from tantalum or stainless steel.

1950- to present

1952 – Per- Ingvar Branemark developed the two stage threaded titanium endosseous root form implant.

1967 – Linkow developed the first screw type of implant vent plant. This was the first self tapping, self threading implant.

1967 –blade implants were developed by Linkow and Roberts
1970 – Grenoble placed Vitreous Carbon implant.

1974 – Kirsch developed the IMZ implant system.

1974 – Straumann introduces the world's 1st one stage implant
1975 – Small introduced the transosteal mandibular staple implant which was modified by Basker.

1985 – Victor Sendax developed MDI(Mini dental implants)
1986 – Dr. Gerald Niznickinvented the Hollow basket design made of Ti alloy.

1989 – Ledreman developed New Ledremanscrew implant Surface roughened by sand blasting and acid etching.

1996 – ENDOPORE a root form implant developed Douglas made of Ti alloy and sintered with same alloy producing porous surface.

1996 – NOVUM concept by Branemark.

1997 – SLA surface treatment introduced by Straumann.

2004 – All on four concept introduced by Dr Paulo Malo.

2004 – Introduction of Nobel guide by Nobel Biocare.

2009 – Introduction of a new hybrid implant material ROXOLID that contain 85% Ti and 15% Zr.

2012 – Osseocare pro- world's first drill unit operated by iPad.

Properties of implant biomaterials

Implant material should have certain ideal physical, mechanical, chemical and biological properties to fulfill these basic criteria

• Implant properties can be studied under

- Bulk properties
- Surface properties

A: Bulk properties

Modulus of elasticity: Implant material with modulus of elasticity comparable to bone (18 GPa) must be selected to ensure more uniform distribution of stress at implant and to minimize the relative movement at implant bone interface.

Tensile, compressive and shear strength: An implant material should have high tensile and compressive strength to prevent fractures and improve functional stability. Improved stress transfer from the implant to bone is reported interfacial shear strength is increased, and lower stresses in the implant.

Yield strength, fatigue strength: An implant material should have high yield strength and fatigue strength to prevent brittle fracture under cyclic loading.

Ductility: According to ADA a minimum ductility of 8% is required for dental implant. Ductility in implant is necessary for contouring and shaping of an implant.

Hardness and Toughness: Increase in hardness decreases the incidence of wear of implant material and increase in toughness prevents fracture of the implants.[4,5]

B: Surface properties

Surface tension and surface energy: It determines the wettability of implant by wetting fluid (blood) and cleanliness of implant surface. Osteoblasts show improved adhesion on implant surface. Surface energy also affects adsorption of proteins.

Surface roughness: Alterations in the surface roughness of implants influence the response of cells and tissue by increasing the surface area of the implant adjacent to bone and thereby improving cell attachment to the bone.

Biocompatibility: This is property of implant material to show favorable response in given biological environment in a particular function. It depends on the corrosion resistance and cytotoxicity of corrosion products.

Corrosion and corrosion resistance: It is the loss of metallic ions from metal surface to the surrounding environment. There are mainly four types of corrosion namely pitting corrosion crevice corrosion, galvanic corrosion and electrochemical corrosion.[4-6]

TYPES OF BIOMATERIALS

Dental implant Materials: Metals and Alloys (Titanium and Titanium alloys, Cobalt-Chromium-Molybdenum Alloys, stainless steel) Ceramics (Aluminium oxide, Zirconium oxide, bioactive and biodegradable ceramics) Carbon and Carbon silicon, Polymers and Composites (Polymethylmethacrylate (PMMA) Polyethylene (UHMW-PE), Polytetrafluoroethylene (PTFE),Silicone rubber, Polysulfone) (O'Brien).

Titanium

Titanium exhibits as pure element with an atomic number of 22 and atomic weight 47.9. Titanium is one of the most biocompatible material due to its corrosion resistance. This is due to the formation of surface oxide layer. This layer exhibits low level of charge transfer. According to the American society for testing and materials (ASTM) there are six types of titanium. Among these, there are four grades of commercially pure titanium and two titanium alloys. The two alloys are Ti-6AL-4V and Ti-6Al-4V-ELI (extra low interstitial alloys). The four grades of commercially pure titanium differ inmechanical and physical properties and are related to the oxygen residues in metal. Grade 1 is the purest and softest form. As grades goes up, strongest the titanium becomes (Donatella Duraccio Federico Mussano Maria Giulia Faga, 2015).

Cobalt chromium molybdenum alloys: Elemental composition of this alloy consists of cobalt 63%, chromium30%, molbdenum5% and traces of carbon, manganese and nickel. Cobalt based implants shows higher elastic modulus and wear resistance than titanium alloys. When compared to bone Co-Cr alloys shows higher elastic modulus, greater density and stiffness which leads to greater stress shielding than in case of Ti and Ti alloys. The biocompatibility and osseointegrationcapacity of Co-Cr alloys is lower than that of Ti. Thus in clinical setting, it is common that Ti to be used for the elements that will in direct contact with the bone and Co-Cr to be the material of choice that do not interface with the bone.

Stainless Steel Alloys: Elemental composition of alloy consists of 18 % chromium for corrosion resistance 8 % nickel to stabilize the austenitic structure 80% iron and 0.05-0.15% carbon.The surgical stainless steel alloys have a long history of use for orthopedic and dental implant devices. . The ramus blade, ramus frame, stabilizer pins (old), and some mucosal insert systems have been made from the iron-based alloy. The iron-based alloys have galvanic potentials and corrosion characteristics that could result in concerns about galvanic coupling and biocorrosion if interconnected with titanium, cobalt, zirconium, or carbon implant biomaterials.

Tantalum Based Alloys: Tantalum was discovered by Swedish chemist Anders Gustav Ekebereg in 1802. It is a rare, high corrosion resistant transition metal element (atomic number 73). It shows corrosion resistance even in acidic media. This property of tantalum is due to the stable, naïve Ta_2O_5 protective film formed on the implant surface. Porous tantalum has excellent bone bonding properties, which makes it an attractive material for artificial joints as bulk material or as a coating on stainless steel and titanium implants to enhance corrosion resistance and osseointegration.

Trabecular metal dental implants: Trabecular metal is a porous biomaterial with a structure and stiffness similar to trabecular bone. The coronal apical and internal implant structures are made of titanium alloy (Ti-6Al-4V) with a micro textured surface which created by grit blasting with hydroxyapatite. Mid-section of the implant is made of tantalum (98%) over a vitreous carbon substrate (2%).

Alumina: Aluminum oxide (Al_2O_3) dental implants showgood osseointegration but was withdrawn from market because of its poor survival rate. High – density, high – purity (95%) alumina was chosen for dental implant manufacturing because of its combination of excellent corrosion resistance, good compatibility, high wear resistance and high strength. Alumina has modulus of elasticity of 420 GPa, and a fracture toughness of 4 Mpa.

The high hardness and modulus of elasticity make the material brittle. Combined with relatively low bending strength and fracture toughness, the material is prone to fracture when loaded unfavorably.

Zirconia: Zirconia, metal dioxide (ZrO_2) was identified in 1789 by German chemist Martin Heinrich Klaproth. This material is the second most common material used in dental implants. It has higher flexural strength, fracture toughness, lower young's modulus along with minimal ion release. Zirconia is ivory in color making similar to that of natural tooth color, thus can be used in restoring teeth in anterior region.It achieves osseointegration with minimal plaque accumulation and better maintenance of soft tissues and esthetically pleasing (Starikov, 2007).

Titanium - zirconium alloy (straumann roxolid): Titanium zirconium alloys with 13%-17% zirconium have better mechanical properties, such as increased elongation and fatigue strength than pure titanium. Because of its superior mechanical properties, thin implant and implant components that can be subjected to high strains (Chevalier, 2006).

PEEK (Poly-ether-ether-ketone): PEEK is a synthetic semi crystalline thermoplastic polymer that exhibits high strength, high thermal stability excellent processing performance and reasonable biocompatibility. Its elastic modulus is similar to that of bone makes this material available option for dental implant manufacturing. But its inherent bioinert nature hinder its good combination with surrounding bone, limits its wider clinical applications (Andreas Schwitalla, 2013).

Hydroxyapatite: It used as a material for repair of residual resorption in 1970s. It was successfully used as an implant material in 1988. It is similar to that of mineral component of bones. It is capable of integration with and supports bone growth. But it is thermally unstable with low mechanical strength.

Glass Ceramics: These are bioactive ceramics first introduced in 1971. These materials have high mechanical strength, but less resistant to tensile and bending stress and extremely brittle. They chemically bond to the bone due to the formation of calcium phosphate surface layer.

Sterilization of Implants: Today in most cases manufacturers guarantees precleaned and presterilized implants, ready to be inserted. In case of implants to be resterilised conventional sterilization techinques are not satisfactory. Three techniques used for the sterilization of implants are Radiofrequency glow discharge technique or plasma cleaning, UV sterilization, and by Gamma radiation (Subashini Govindraj, 2015).

Conclusion

A wide range of biomaterials are currently available for dental implants. Appropriate selection of biomaterials influences the success and longevity of implants. With a long history of dental implantology and ever since modern dental implants were introduced more than 40 years ago, the development of the ideal implant has been a major research subject in the field, thereby changing the practice of implant dentistry. More research on better dental implant materials, design parameters, surface treatment technologies and analysis techniques is still required to improve the outcomes.

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