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Characterisation of Biomaterials and their Medicinal Applications

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Abstract— Biomaterial Science is the physical and biological study of materials and their interactions with the biological environment. A Biomaterial is a synthetic material that is used to replace or restore function to a body tissue or in contact with body fluids for prolonged period of time. During the last two decades, significant advances have been made in the development of biocompatible and biodegradable materials for medicinal applications.

Biomaterials improve the quality of life for an ever increasing number of people each year. Biomaterials provides a three dimensional space to cells to form a tissue with proper structure and function. The range of application is vast and includes such things as joint, artificial limb replacements, artificial arteries, skin, contact lenses and dentures. The implementation of some of these materials may be for medical reasons such as the replacement of diseased tissue required to extend life expectations and/or may be for purely aesthetic sense. Many metals like Ni, Au, Ta, Ti, alloys of Ti, Co, Fe and Polymers like Polyethylene, Acetals, Nylon, Silocones and Ceramics etc. are used as biomaterials. Metallic biomaterials are used for load bearing applications, ceramic biomaterials are for joint surfaces and teeth, while polymeric materials are for flexibility, stability.

In the biomedical field, the goal is to develop and characterize artificial materials or "spare parts" for the use in human body to MEASURE, RESTORE, IMPROVE physical functions and enhance survival and quality of life. The demand for the biomaterials is increasing due to an ageing population with higher quality of life expectations. This review explains some of the most interesting materials and hierarchy to correlate directly with favourable properties and their resulting applications. Some of the important advances have come on the nanoscale also in impacting chemical and medicinal properties of natural and manmade materials. To meet these conflicting needs it is necessary to have reliable methods of characterization of the material and material/host tissue interactions and their availability.

Keywords:Biocompatible, Biodegradable, Polymers, Silicones, Alloys

I Introduction

A Biomaterial is any synthetic material that is used to replace or restore function to a body tissue or in contact with body fluids for prolonged period of time. Biomaterial is any matter, surface that interacts with biological system. Biomaterial science encompasses with medicine, biology, chemistry, tissue engineering and material science. A biomaterial is a non-viable material used as a medical device, intended to interact with biological systems. Biomaterial can be used in the form of living structure or biomedical devices. They are synthesized in the laboratory using many chemical approaches using metallic components, polymers, ceramics, silicones and composite materials.[1]Biomaterial is used to make devices or replace part of living system or to function in contact with living tissue. Biocompatibility is very important for an artificial implant by the surrounding tissue or by the whole body. Biocompatibility is the ability of a material to perform with an appropriate host response in a specific application and no material is universally biocompatible. The influence of metals with biological systems in both major (iron, manganese, magnesium and Zinc) and minor (Cobalt, Copper, Nickel, Molybdenum, Tungsten) ways is through alignment of meatl ions with living organisms evolved over time.[2] Metal ions in biological systems present in enzymes, some structural features like calcium in bones, in transport like the iron in heamoglobin , in control systems like sodium and potassium in nerve cells.

II Types of biomaterials

Biocompatibility is primarily a surface phenomenon. Depending on their availability, application biomaterials are classified in to different types. There are many types depending on several factors.

Their interaction in biological environment classifies them to bioinert, bioadsorbant, bioactive materials. Depending on their origin they can be natural, synthetic or artificial. Depending on the composition biomaterials can be polymers, ceramics, metallic materials and composite materials etc.[4]

a. Based on interaction with the biological environment

Bioinert materials, such as titanium, tantalum, alumina, polyethylene or other polymers, have a very low chemical interaction with adjacent tissues. The tissue can adhere to their surface either by growing itself or using a special adhesive (eg. acrylate). The adhesive procedure is not the ideal way of fixing the orthopedic and dental implants during the long term treatment. Polymeric implants are considered to be safe and effective for a time period ranging from several months to several years. Bioabsorbent materials such as tricalcium phosphate, polyglycolic-polylactic copolymeric acid, and even some porous metallic materials, are designed to be easily absorbed by the body and replace the adjacent tissues (bone or skin). This type materials are used for the transport of drugs or for implantable biodegradable structures (surgical thread etc.). Bioactive material such as vitreous materials, ceramics and hydroxyapatite contain silicon dioxide (SiO_2), sodium oxide (Na_2O), calcium oxide (CaO), phosphorus oxide (P_2O_5) etc., which contribute to the formation of chemical bonds with the tissue. Basically there is an ion exchange reaction between the bioactive material and human body fluids. The biomaterial particles may diffuse in the liquid and vice versa, resulting a biologically active layer of calcium phosphate, which is equivalent to chemical and crystallographic structure of bone. Bioactive materials are recommended to be used for joining bones in case of fractures. Copper and its complexes as important bioactive compounds in vitro and in vivo as potential drugs for therapeutic int, ervention in various diseseases.[4] Transition metal ions are components of biological processes in many diseases including microbial infections, cancer, neurodegenerative disorders.[5] (nature chemical biology 4, 143(2008) Prabhakara CT, Patil S.A, Toragalmath, Kinnal SM, Badami PS)

b. Nature of Biomaterials

Natural biomaterials are used in medicine long time ago. Organs or parts of organs of animals (pig, especially) or even human bones are used for transplants in bone marrow, skin, blood, etc.
More emphasis on replacing natural materials used in human and veterinary medicine with synthetic or synthetic or artificial biomaterials. The artificial biomaterials contain at least one natural component in order to enhance the biocompatibility of the material and to hasten the healing process. A natural component of artificial biomaterial may be a protein polysaccharide belonging to glycosaminoglycan class or a peptide having the role in cell recognition or adhesion process. These components are mostly macromolecules of the extracellular matrix of tissues that are in contact with biomaterials involved in the healing process. The metal complexes are synthesized using Schiff's base with metals like Co(II), Ni(II), Cu(II)

c. Criterion of composition

Metals are some of the biomaterials used for orthopedic implants due to their wear resistance, high hardness and ductility. Metallic materials used to achieve implants are stainless steel, cobalt-chromium-molybdenum alloys, titanium and titanium alloys. Titanium based materials are mainly used to achieve orthopedic implants because of similar mechanical properties with bone tissue. The main disadvantages of these materials are their high rigidity in comparison with host tissue as well as the tendency to modify their physico-mechanical properties in the case of the investigation with computer tomography and magnetic resonance. Degradation of metals and alloys in the human body is a combination of effects due to corrosion and mechanical activities. The resulted metal ions may cause allergenic, carcinogenic and cytotoxic. The cytotoxic effects of metal components of alloys decreases in the series: Cr, Co,V, Fe, Mn, Cu, Ni, Mo.

Titanium is one of the most important materials for biomedical implants in orthopedics and dentistry due to its high corrosion resistance in many biological environments. However, *in vivo* experiments have shown the accumulation of titanium ions in adjacent tissues. It was found that titanium alloys have spontaneous passivity in physiological environments by covering them with a passive film containing TiO_2, Al_2O_3 or small amounts of vanadium oxide. In clinical practice, preference for biomaterials made of alloys, such as titanium alloys, alloys containing Cr, Ni, Co and Mo or stainless steel.

III Applications

The range of applications for biomaterials is large. The number of different biomaterials is also significant. The main property required of a biomaterial is that it does not illicit an adverse reaction when placed into service. A Variety of devices and materials used in the treatment of disease or injury like suture needles, teeth filling, plate, bones etc. The medical techniques with the use of biomaterials compatible investigations have become sophisticated. Biomaterials are used in devices restore normal biological state and also rapid restoration tissues or human functions[6].

- Metallic biomaterials are used for load bearing applications and must have sufficient fatigue strength to endure the rigors of daily activity eg walking, chewing etc.
- Ceramic biomaterials are generally used for their hardness and wear resistance for applications such as articulating surfaces in joints and in teeth as well as bone bonding surfaces in implants.
- Polymeric materials are usually used for their flexibility and stability and also have been used for low friction articulating surfaces.

Table1: Some of the examples of biomaterials

Metals	Ceramics	Polymers
316L stainless steel Co-Cr Alloys Titanium Ti6Al4V	Alumina Zirconia Carbon Hydroxyapatite	Ultra high molecular weight polyethylene Polyurethane

Table 2: Applications of the synthetic materials and modified natural materials in medicine

M	Material	Applications
	Stainless steel	Orthopedic devices, stents
Ti	Titanium	Orthopedic and dental devices
A	Alumina	Orthopedic and dental devices
H	Hydroxyapatite	Orthopedic and dental devices
Si	Silicone rubber	Catheters, tubing
D	Dacron	Vascular grafts
Po	Poly(methyl methacrylate)	Intraocular lenses, bone cement
Po	Polyurethanes	Catheters, pacemaker leads

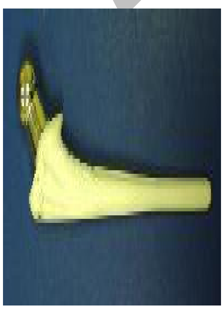
1. Orthopaedic Applications

Metallic, ceramic and polymeric biomaterials are used in orthopaedic applications.(Fig.1) Metallic materials are normally used for load bearing members such as pins and plates and femoral stems etc. Ceramics such as alumina and zirconia are used for wear applications in joint replacements, while hydroxyapatite is used for bone bonding applications to assist implant integration. Polymers such as ultra high molecular weight polyethylene are used as articulating surfaces against ceramic components in joint replacements. Porous alumina has also been used as a bone spacer to replace large sections of bone which have had to be removed due to disease.[7]Composite stems combine the physical properties of alloys with those of other biomaterials. Ceramic or metal femoral heads are used on composite hip stems because composites have relatively poor wear properties (Fig.1: c,d,e)

Fig 1: **Metallic alloys**

a Tantalum and titanium

b. Co- Cr alloy



c

d

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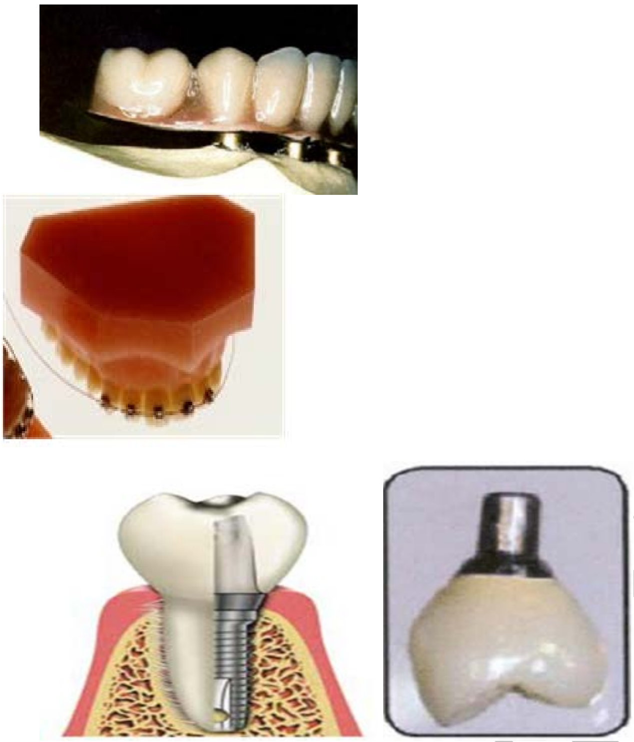
e

Metallic materials are often used as biomaterials for replacing structural components of the human body because when are compared to ceramic and polymeric materials, they have superior mechanical properties. Among the metallic biomaterials Co-Cr alloys, Ti pure and Ti alloys and stainless steel are the most used(Fig.1: a,b). Stainless steels are characterized by corrosion resistance higher than other steels due to the formation of a passive oxide film. That film reduces the corrosion rate by blocking the transport of metallic ions and electrons. The stainless steels are classified into three categories according to their microstructures: ferritic, martensitic and austenitic[8,9]. Among them the austenitic stainless steels which contains Cr and Ni in its composition are responsible for increasing corrosion strength and ensure the stability of the austenitic phase, respectively. 316L stainless steel is the standard molybdenum-bearing grade, second in importance amongst the austenitic stainless steels is immune from sensitization. Compared to chromium-nickel austenitic stainless steels, 316L stainless steel offers higher creep, stress to rupture and tensile strength at elevated temperatures. Used in Medical implants, including pins, screws and orthopaedic implants like total hip and knee replacements[10].

2.Dental Applications

Metallic biomaterials have been used as pins for anchoring tooth implants and as parts of orthodontic devices. Ceramics and titanium alloys uses as tooth implants including alumina and dental porcelains. Hydroxyapatite has been used for coatings on metallic pins and to fill large bone voids resulting from disease or trauma. Polymers are also orthodontic devices such as plates and dentures. Porcelains are biocompatible for dental restoration of composite resins is used to rebuild the tooth structure, change the color[10] and improvement of facial surface[11].

Dental implants



3. Cardiovascular Applications

Many different biomaterials are used in cardiovascular applications depending on the specific application and the design. For instance, carbon in heart valves and polyurethanes for pacemaker leads.[12] (Fig:3)

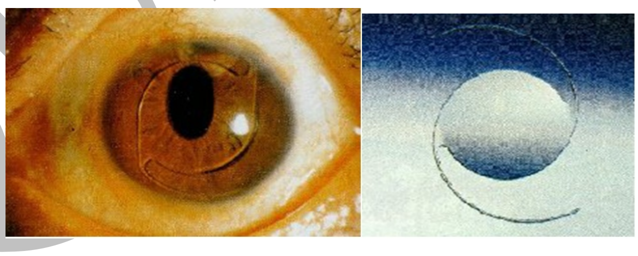
Fig 3: **Heart valves**

a b

C

4. Opthalmic applications: The range of biomaterials used for intraocular lenses remains extremely limited. Among the materials tested, acrylic polymers and silicon elastomeres are the only remaining materials used for optics. Together with lens design, the analysis of the physical and chemical characteristics of biomaterials will contribute to the choice of the best intraocular lens. 3 basic materials used in intraocular lens are PMMA, acrylic, silicone. (Fig.4)

Fig 4: Intraocular lens



a.

5. Cosmetic Surgery

Materials such as silicones have been used in cosmetic surgery for applications such as breast augmentation. Application of biomaterials in plastic surgery has led to the increased availability of commercial products in recent years. The various categories in which biomaterials used are soft tissue fillers, bioengineered skins, cellular dermal matrices, craniofacial surgery, and peripheral nerve repair.[12]

IV. Conclusion

The latest research in biomaterials and their application in the field of engineering, development of medicine, biology, chemistry, physics, artificial

organs, material science, nanotechnology is growing rapidly. The area will be expanded for many factors like ageing population, preference by younger and middle aged people to undertake surgery, improvement in life style, technology and aesthetic sense is growing rapidly

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