Review Article

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Implant Biomaterials

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ABSTRACT

Background: In the current treatment modalities for edentulous conditions, dental implants play a pivotal role. Dental implants have gained popularity and often are being opted as a first treatment option. The study of material sciences, along with the biomechanical sciences provides insight into design and material concepts for surgical implants. The basic pre-requisites for the implant biomaterials are appropriate mechanical properties as well as biocompatibility. Extensive research work and advancements in the field of biomaterials available for dental implants are being conducted. These materials are esthetically pleasing and also fulfils functional requirements. This literature review will give an outline of the implant biomaterials in dentistry, its future trends and its apt selection.

Keywords: Biomaterials, Titanium, Zirconia, Ceramic, Surface roughness, Biocompatibility, Corrosion.

INTRODUCTION

Restoration of the patient normal function, speech, health and esthetics is the goal of dentistry. Amongst various modalities Implantology emerged as a milestone in long term preservation of residual ridge and health of adjacent teeth. Being the closest replacement to natural teeth, implants have been successful in providing the desired retention and fulfilling patient's preference for a fixed prosthesis over a removable one[2]. With the emerging concept of osseointegration, devices are designed to mimic as much as possible cell interactions that normally takes place during the process of bone remodelling

A biomaterial is any substance to fix the defects, repair, replacement of defective organ in the body. It is a result of development and the integration of various branches of materials (metals, composites, ceramics and polymers). The basic knowledge of how the surface and bulk properties of implant biomaterials related to dental implants is important. Because of the wide range of biomaterials properties demonstrated by the classes of materials available, it is not advisable to fabricate any new implant design without a thorough biomechanical analysis. An ideal implant biomaterial should be biocompatible, with enough toughness, mechanical strength as well as corrosion, wear and fracture resistance[1].

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At present, the most noteworthy metal used in dental implantology is titanium (Ti). Currently, the implant materials available are diverse. As extensive research work and recent advancements in the field of biomaterials for dental implants going on, newer materials came into existence such as zirconia, roxolid, surface-modified titanium implants. These materials not only fulfil the functional requirements but are also esthetically pleasing[2].

PROPERTIES OF IMPLANT BIOMATERIALS

Mechanical properties

i.Elastic modulus (Modulus of elasticity)- It should be equivalent to bone (18 GPa).

ii.Tensile, shear, and compressive strength: These properties should essentially be high to prevent implant failure.

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

iv. Ductility: According to the American Dental Association, a minimum of 8% ductility is required.

Surface properties

Surface tension and surface energy: It determines the wettability of implant by wetting fluid like blood and cleanliness of the surface of the implant.

Surface roughness: Attachment of cell to the bone is improved by increasing the surface area of implant adjacent to the bone as changes in surface roughness influence response of cells and tissues.

Biocompatibility: It is the property of implant material to show favourable response in a given biological environment in a particular function. It depends on the corrosion resistance and cytotoxicity of corrosion products. The concept of biomaterial biocompatibility does not refer to total inertness, but rather the ability of a material to perform with an appropriate response in a specific application. Biocompatibility is affected by the intrinsic nature of the material, as well as it is design and construction[3].

Corrosion and corrosion resistance: Corrosion is a special concern in dental implants as it is placed into the oral cavity where electrolyte and oxygen compositions differ from that of tissue fluids. There is a significant difference in pH in areas below plaque and within the oral cavity. This increases the range of pH that implants are exposed in the oral cavity.

CLASSIFICATION

Based on biocompatibility- Biomaterials are broadly classified into three major categories:

i. Bioinert: These are the materials which, when placed, has minimal interaction with the tissue surrounding it, thus leading to osteogenesis. Examples -stainless steel, titanium, zirconium, alumina, and ultra-high-molecular-weight polyethene

ii. Bioactive: These are the materials once placed inside the oral cavity to react with the hard tissues as well as the soft tissues. Examples are synthetic hydroxyapatite, glass-ceramic, and bioglass.

iii. Bioresorbable: These materials are resorbable, and they gradually resorb and get slowly replaced by bone. Examples - tricalcium phosphate, polylactic–polyglycolic acid copolymers, calcium oxide, calcium carbonate, and gypsum.

Based on chemical composition, -Biomaterials can be classified into three categories.

i. Metals: titanium, titanium alloys, stainless steel, cobalt-chromium alloys, gold alloys, and tantalum

ii. Ceramics: alumina, hydroxyapatite,beta-tricalcium phosphate, carbon, carbon/silicon, bioglass, zirconia, and zirconia-toughened alumina

iii. Polymers: polymethyl methacrylate, polytetrafluoroethylene, polyethene, polysulfone, polyurethane, and polyether ether ketone[1]

SELECTING AN IMPLANT MATERIAL

The implants should be selected in such a manner so as to minimize the negative biologic response while maintaining acceptable function and for long term success of implants. This is because the biologic environment does not accept any material unconditionally. The other factors to consider are implant design, abutment choices and availability, surface finish, and biomechanical considerations. If the implants are located in a high load zone (e.g., in the posterior areas of the arch), the clinician might consider using a higher-strength material such as CP grade IV titanium or one of the titanium alloys[1,6]

BIOMECHANICS

The attachment of bone to implants serves as the basis for the biomechanics analysis performed for dental implants. A close approximation of osseointegrated bone with the surface of an implant fixture permits the transfer of stresses with a little relative displacement of the bone and implant. The stresses that are generated are highly affected by three main variables:

(1) Masticatory factors (frequency, bite force, and mandibular movements)

(2) Support for the prosthesis (implant-supported, implant-tissue–supported, implant-tooth supported)

(3) The mechanical properties of the materials involved in the implant restoration (elastic modulus, ductility, fracture strength)

Future Areas of Application- The simultaneous evolution of the biomechanical sciences also provides optimization of design and material concepts for surgical implants[1].

These future trends concern

(1)The modification of surface roughness at the nanoscale level for promoting protein adsorption and cell adhesion.

(2) Biomimetic calcium phosphate coatings for enhancing osteoconduction

(3) The incorporation of biological drugs for accelerating the bone healing process in the peri-implant area

(4) Inclusion of nanoparticles organic components such as chlorhexidine and polysaccharides, among which particular emphasis is given to chitosan [11].

(5) The use of nanotopographical modifications on the implant surface to induce intrinsic osteoinductive signalling of the surface adherent cells is an approach of current interest[6].

IMPLANTS IN 21ST CENTURY

Titanium: Titanium is being used successfully as an implant material, and this success with titanium implants is credited to its excellent biocompatibility due to the formation of a stable oxide layer on its surface. On the basis of difference in oxygen content, it can be divided into four grades; Grade 4 is having the most (0.4%) and grade 1 the least (0.18%) oxygen content. This difference occurs due to the presence of minute contaminants. For corrosion resistance, iron is added, and aluminium is added for increased strength and decreased density and vanadium acts as an aluminium scavenger to prevent corrosion.

Ti is the material of choice for intraosseous applications.

Disadvantage: Esthetic issue is there due to the grey colour of titanium, and this is more pronounced when soft tissue situation is not optimal, and the dark colour shines through the thin mucosa.

Titanium alloys Ti6Al4V -Titanium reacts with several other elements like silver, Al, Ar, Cu, Fe,Va and Zn to form alloys. Three forms alpha, beta and alpha-beta are present. When pure titanium is heated with elements like Al, Va in certain concentrations and cooled, these different types originate. Such elements added to titanium act as phase stabilizers. Aluminium is an alpha-phase condition stabilizer which increases the strength and decreases the weight of the alloy. Vanadium acts as a beta-phase stabilizer. Alpha-beta variety alloys are most commonly used for dental alloys which contain 6% Al and 4% Va. (Ti 6 Al 4V)

Ceramics- Because of their inert behaviour and good strength and minimum thermal and electrical conductivity, ceramics are used as surgical implant device. Due to low ductility and brittleness use of ceramics is limited.

Zirconia: Since the early nineties, Zirconia was used for dental prosthetic surgery with endosseous implants. Straumann Roxolidwhich is Titanium zirconium alloy contains 13%-17% zirconium (TiZr1317) has better mechanical properties, such as increased elongation and the fatigue strength as compared to pure titanium. Roxolid fulfils requirements of dental implantologists and is 50% stronger than pure titanium[3].

CONCLUSION

The various implant biomaterials have evolved over a period of time and found significance in most of the implant-related literature. Improvement in bulk and surface properties has helped us establish selection criteria for the choice of implant. It is imperative for clinician to be well versed with these properties. Through research in dental implant technology has constantly been improving in recent years; prospective clinical studies are needed to confirm potential benefits about new implant biomaterials.

CONFLICTS OF INTEREST

The authors declare they have no potential conflict of interests regarding this article.

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