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Biomaterials in Implant Dentistry: A Review

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ABSTRACT

It has been accepted that no foreign material placed within the living body is completely compatible currently there are many types of biomaterials used for the dental implants. The clinician should have adequate knowledge of these material to select an appropriate material to be used , which directly influences the success and longevity of the treatment. This paper reviews various biomaterials that are used in dental implants.

Key words: Dental implants, Metal, Ceramic, Surface coating.

INTRODUCTION

The restoration of missing teeth is an important aspect of modern dentistry.There is a demand for replacing missing teeth for esthetics and functional aspect.Conventional methods of restoration includes RPD, FPD, CD.Each method have their own advantage and disadvantage. Implant overcome all this drawbacks. Dental implant is a prosthetic device made of alloplastic material(s) implanted into the oral tissues beneath the mucosal or/and periosteal layer, and on/or within the bone to provide retention and support for a fixed or removable dental prosthesis.

Biomaterials

Any substance other than the drug that can be used for any period of time as part of a system that treat, augments or replace any tissues, organ, or function of the body.The term Bioinert refers to any material that once placed in the human body has minimal interaction with its surrounding tissue, examples of these are titanium , Zirconium , alumina.Bioactive refers to a material, which upon being placed within the human body interacts with the surrounding bone and in some cases, even soft tissue. Prime examples of these materials are synthetic hydroxyapatite, glass ceramic and bioglass.Bioresorbable refers to a material that upon placement within the human body starts to dissolve (resorbed) and slowly replaced by advancing tissue (such as bone). Common examples of bioresorbable materials are tricalcium phosphate [$Ca_3(PO_4)_2$] and polylactic, polyglycolic acid, copolymers. Calcium oxide, calcium carbonate and gypsum are other common materials that have been utilised during the last three decades.

Metal implants

Metallic implants undergo one or more of several surface modification to enable them to become suitable for implantation.These modification are Passivation,Anodization,Ion implantation,Texturing .

Stainless steel

Stainless steel is a type of steel with 12% to 30% chromium.It can be classified into 3 types based on its composition-Ferritic steel,Martensitic steel,Austenitic steel.Austenitic steel is most commonly used variety in implantology.It contains 18% chromium- provides corrosion resistance,8% nickel- stabilizes the austeniticstructure,80% iron, 0.05 to 0.15% carbon- for hardness.It hasHigh strength and ductility.Modulus of elasticity :$28*10^6$psi.Tensile strength : 70 to 145 psi.Elongation to fracture is more than 30%. The disadvantages are it Cannot be used in nickel sensitive patient.Susceptible to pit and crevice corrosion.Direct contact with a dissimilar metal crown should be avoided to prevent galvanism.Not corrosion resistant to that extent.

Co-Cr-Mo ALLOYS

They can be cast and annealed for custom made implant designs. It contains 63% cobalt – provides a continuous phase for bi-phasic properties.30% chromium – provide corrosion resistance(oxide formation).5% molybdenum – stabilizer Trace of carbon- hardener .Trace of manganese and nickel.It has an outstanding resistance to corrosion .Tensile strength :95 psi and high Modulus of elasticity :$34*10^6$ psi.If properly fabricated, it has good biocompatibility.Used in sub periosteal framework. It isEconomical with Long term clinical success.ductility is low,so excessive binding should be avoided to prevent fracture.

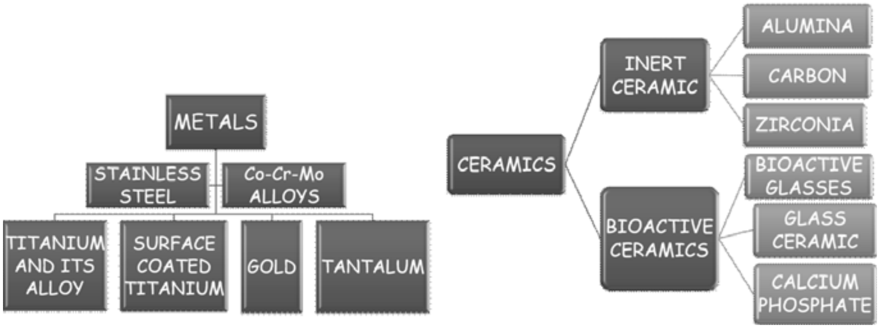
Titanium and its alloys

It is most popular implant material pure element with atomic number 22.Highly reactive.Two forms of titanium (Ti) are principally used for endosseous dental implants.They are commercially pure titanium (cpTi, at least 99.5% pure Ti) and a titanium alloy, titanium-aluminium-vanadium (Ti-6Al-4V).CpTi is available in four grades which vary in their oxygen content. Oxygen functions as a controlled strengthener in cpTi. As oxygen content increases, the strength of the metal increases and its ductility decreases.Nitrogen, carbon, hydrogen and iron are also present, but vary little between grades. Grade I cpTi is the purest and therefore the softest. Grade 4 cpTi has the most oxygen at 0.4% by weight, and is the material used for dental implants.

It consists ofPure titanium 99.9%.(0.6% of the earth's crust and is a million times more abundant than gold.)It exists as rutile (TiO2) OR ilmenite (FeTiO3)and require specific extraction methods to be recovered in its elemental state.titanium alloys are :-Ti -6Al-4V , Ti -6Al-4V extra low interstitial (ELI).Pure Ti can undergo a transformation from a hexagonal- close packed alpha phase to a body- centered – cubic beta phase (883^0C).Alloy element are added to stablize either phase .Ti -6Al-4V is one of the more commonly used Ti alloys.Aluminium acts as an alpha stabilizer for the purpose of increasing strength and decreasing mass.Vanadium ,copper and palladium are beta phase stabilizers which are used to minimize the formation of $TiAl_3$ to decrease its susceptibility to corrosion.Newer titanium alloys have been developed, which include Ti-13Nb and Ti-15Mo-2.8Nb , they may exhibit greater corrosion resistance. Ti-6Al-4V also contains low concentrations of nitrogen, carbon, hydrogen, iron and oxygen, but additionally approximately 6 % by weight aluminium and 4 % by weight vanadium. Besides reducing the melting and casting temperatures, alloying other metals with Ti also increases the strength of the alloy and decreases its density . A stronger bone implant interface may be achieved with cpTi than with Ti-6Al-4 V, as greater removal torque forces were needed to loosen the interfacial connection between cpTi implants and the surrounding bone This may indicate that cpTi is more favourable to bone cell differentiation than Ti-6Al-4V The impaired bone formation with the Ti alloy may be related to the release of aluminium ions, which can be detrimental to bone cell differentiationLow specific gravity with a density of 4.5b/cm^3.Hence it is 40% lighter than steel.High strength compare to stainless steel.Low modulus of elasticity :-Ti – 14 psi $*10^6$,Ti alloy – 17 psi$*10^6$.This signifies the importance of design for proper stress distribution.Low tensile strength – 95 psi.Elongation to fracture is >15.Ti is more ductile than Ti alloy , hence it is preffered for endosteal blade form implants.It has high di- electric property which is responsible for its osteointegration.

Ti and its alloys form tenacious oxides in air or oxygenated solutions.Titanium oxidizes (passivates) on contact with room temperature air and normal tissue fluids.This reactivity is favorable for dental implant devices. Three different oxides are formed that is TiO (Anastase) , TiO_2 (Rutile) , Ti_2O_3(Brookite). TiO_2 is the most stable and most commonly formed on titanium surface . This oxide layers is self healing i.e. if surface is scratched or abraded during implant placement it repassivates instantaneously

Clasification of materials used in dental implant



Osseointegration is excellent.Bio-degradative products from aluminium and vanadium produce favourable tissue response.it has High corrosion resistance with self healing property.

Precious metal

Metals like Gold , Platinum , Palladium are not in use because of their cost and they do not demonstrate osseointegration .

Ceramics

Initial rationale for using ceramics in dentistry was based on the relative biologic inertness of ceramics compared with metals.Ceramics are fully oxidized materials and therefore chemically stable and less likely to elicit an adverse biological response.It promote osseointegration by nature of their excellent osteoconductivity of host cells.Ceramic implants can with stand only relatively low tensile stresses induced by occlusal loads, but can tolerate very high level of compressive stress.

Inert ceramics

The three types of “inert” ceramics of interest are:Carbon,Alumina (Al_2O_3),Zirconia (ZrO_2).These ceramics elicit minimal tissue response.

Alumina

It was outset as implant material in 1970s. It is very inert material and resistance to corrosive environment with excellent biocompatibility. Body does recognize it as a foreign material and tries to isolate it by forming a layer of non-adherent fibrous tissue around implant.It is highly inert under physiological condition, has excellent wear resistance and hardness and can be polished to a high surface finish. It has higher surface wettabilityModulus of elasticity – 54- 56 psi $*10^6$Ultimate bending strength – 43- 80 MPa.Compress strength – 5000 MPa. Disadvantage is that it forms fibrous tissue around implants.

Zirconia

It used with success as implant material in 1960s. It has ability to be polished to a superior surface finish compare to alumina. Zirconium oxide is ivory in color, making it similar to the color of the natural tooth, which is important for restoring teeth in the mouth especially in the anterior region.Zirconium is very resistant to corrosion.Zirconium dental implants are a one piece structure they can only work in one position, unlike a two-piece implant for which angled abutments are available.Zirconia implants do absorb water and become prone to fracture.The main advantage is that it is an excellent biocompatible material with minimal thermal & electrical conductivity at the minimal biodegradation.

Bioactive ceramics

The concept of bioactivity was originally introduced with respect to bioactive glasses via the following hypothesis.The biocompatibility of an implant material is optimal if the material elicits the formation of normal tissues at its surface and in addition, if it establishes a contiguous interface capable of supporting the loads that normally occur at the site of implantation.Bioactive materials are :- Bioactive glasses,Glass ceramicsCalcium phosphate ceramics.

Bioactive glass and glass ceramics

It is a surface active highly biocompatible material .They are non resorbable biomaterial.Developed by L.Hench – 1967.CaO-SiO2-P2O5.Ceravital, which has different alkali oxide concentration from that of bioglass;and apatite- wollastonite glass ceramics,a glass ceramic containing crystalline oxyapatite and fluorapatite and â- wollastonite in a MgO-CaO-SiO2 glassy matrix.It form a strong bond with lining tissue , this bonding is theorized to prevent fibrous encapsulation from occuring at the material interface.Known to form a carbonated hydroxyapatite layer invivo as a result of their Calcium and phosphorus content.Formation of this layer initiated by migration of calcium, phosphate, silica and sodium ions towards tissue as a result of external pH changes.Silica rich gel layer forms on the surface as element are released and lost.This result in formation of calcium phosphorus layer that stimulate osteoblast to proliferateThese osteoblast produce collagen fibrils that become incorporated into the calcium phosphorus layer under later anchored by the calcium phosphorus crystal.Which form strong bone bioglass interface.Bioglass-bioactive material stimulates the formation of bone.This materials often used as grafting materials, ridge augmentation or bony defects than as coating materials for metallic implant.

Calcium phosphate

It is Bioresorbable.These ceramics have biochemical composition similar to natural bone and form direct chemical bonding with surrounding bone due to presence of free calcium and phosphate compounds as implant surface.It has excellent biocompatibility, no local or systemic toxicity, no alteration to natural mineralization process of bone. lower mechanical tensile , shear and fatigue strength. It is Brittle with low ductility. It exists in dense or porous form. Excellent biocompatibility.Attachment between calcium phosphate ceramic and hard and soft tissue .Minimal thermal and electrical conductivity.Modulus of elasticity is closer to bone.Color similar to hard tissue. The Disadvantages are -Low mechanical tensile and shear strength under fatigue loading.Low attachment between coating and substrateOveruse and variable solubility.

Hydroxyapatite

It was successfully used as implant material in 1988 It is similar to the mineral component of bones and hard tissues in mammals. This material has capability to integrate in bone structure and support in growth of the bone.It is thermally unstable with low mechanical strength to withstand long term load bearing applications.

Surface coating

The implant body may covered with porous coating.The two material often used for this process are titanium and hydroxyapatite.Both of these materials are plasma sprayed onto the implant body.

Titanium plasma spray

It has been reported to increase the surface area of the bone to implant interface and act similar to a 3 dimensional surface, which may stimulate adhesion osteogenesis.Surface area increased as great as 600%Increase functional area by 25% to 30%Increase tensile strength of the bone to implant interface.It Resist shear force.Increased surface roughness improve the initial fixation of the implant, especially in softer bone.

Plasma sprayed hydroxyapatite

It was first used by Herman in 1988 .Crystalline HApowder is heated to a temperature of 12000 to 16000 °C in a plasma flame formed by a electric arc through which an argon gas stream passes. HAparticle size is approximately 0.04mm .The particles melt and are sprayed on to the substrate, they fall as drops and solidify.Round interconnected pores are formed. Coating bonds to substrate by mechanical interlocking.There is a lot of controversy regarding the ideal coating thickness of HA coating. Studies have shown that fracture occurred in coatings which were more than 0.1mm in thickness whereas bioresorption was unacceptably rapid with coatings less than 0.03mm. Ideal coating thickness of 0.05 mm is recommended.the advantages are Increased surface area.Increased roughness for initial stability Stronger bone to implant interface.Disadvantgesare Flaking , cracking or scaling on insertion.Increased plaque retention when above bone increased bacteria and nidus for infection.Complication of treatment of failing implant.

CONCLUSION

A wide range of biomaterials are currently in use for implants.Appropriate selection of biomaterials directly influences, clinical success and longevity of implants. Thus the clinician needs to have adequate knowledge of the various biomaterials and their properties for their judicious selection and application in his clinical practice.The recent materials like bioceramics and composite biomaterials which are under consideration and investigation have promising future.

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