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PUBLISHED PAPER'S TITLE : IMPLANT BIOMATERIALS IN DENTISTRY: LITERATURE REVIEW

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Research Paper

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IMPLANT BIOMATERIALS IN DENTISTRY: LITERATURE REVIEW

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Declaration

The Declaration of the author for publication of Research Paper in Asian Journal of Modern and Ayurvedic Medical Science (ISSN 2279-0772) We Mohammad Faisal1 , Chandresh Jaiswara2 , Uzma Ansari3 , the authors of the research paper entitled IMPLANT BIOMATERIALS IN DENTISTRY: LITERATURE REVIEW declare that ,we take the responsibility of the content and material of my paper as we our self have written it and also have read the manuscript of our paper carefully. Also, we hereby give our consent to publish our paper in ajmams , This research paper is our original work and no part of it or it's similar version is published or has been sent for publication anywhere else.we authorise the Editorial Board of the Journal to modify and edit the manuscript. we also give our consent to the publisher of ajmams to own the copyright of our research paper.

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Abstract :

Dental implants are titanium objects analogous to tooth roots that are placed into the jaw bones to and allow the dentist to mount a replacement tooth, multiple teeth or a complete denture. Materials used as dental implants are biocompatible, with adequate toughness, strength, corrosion, wear and fracture resistance. From a chemical point of view, dental implants may be made from metals, ceramics or polymers. The present article provides a comprehensive review on the topic of dental implant materials. The following paper focuses on conventional titanium implants and more recently introduced and increasingly popular zirconia implants.

Introduction :

Dental implants are titanium objects analogous to tooth roots that are placed into the jaw bones to and allow the dentist to mount a replacement tooth, multiple teeth or a complete denture. The basic concept of a dental implant involves a mechanism of direct bone implant connection known as "osseointegration" .The process of osseointegration was first described by Ingvar Branemark[1] who found that when titanium was placed into contact with bone and left undisturbed, the bone grew right against the surface making the titanium objects irremovable without cutting out the bone around the titanium. The phenomenon of osseointegration was defined by the American Academy of Implant Dentistry as "the firm, direct and lasting biological attachment of a metallic implant to vital bone with no intervening connective tissue".

Materials used as dental implants are biocompatible, with adequate toughness, strength, corrosion, wear and fracture resistance. From a chemical point of view, dental implants may be made from metals, ceramics or polymers. In the past 50 yrs titanium and titanium alloys have become the "gold standard" metal used to fabricate dental implants. The use of other metals and metal alloys involving gold, stainless steel and cobalt chromium has become more or less obsolete due to the low success rate and little long-term clinical application and sometimes adverse tissue reactions. At present there is a renewed interest in a bioceramic zirconia (Zirconium Oxide- ZrO_2). ZrO_2 combined with yttrium with trace amounts of hafnium (Hf) to improve its properties. It is a white opaque-looking product, very strong and hard also been used for making crowns and bridges. It has been shown clinically that zirconia also fused to bone (osseointegrated) much like titanium and has been approved for use in Europe in 2008 and in Canada in 2013.

Titanium as an Implant Material :

Ilmenite ($FeO.TiO_2$) and rutile (TiO_2) are the two chief minerals of titanium. In India, Ilmenite and rutile along with other heavy minerals are important constituents of beach sand deposits found right from Moti Daman-Umbrat coast (Gujarat) in the west to Odisha coast in the east. Titanium dioxide occurs in polymorphic forms as rutile, anatase (octahedrite) and brookite. Commercially pure titanium (CpTi) and extra low interstitial Ti-6Al 4V (ELI) are the two most common titanium based materials used for medical purposes. Four commercially pure (cp) Ti grades and one titanium alloy specially made for dental implant applications are currently available according to ASTM as grades 1 to 5. Grades 1 to 4 are unalloyed, while grade 5, which is an alloy of 6% aluminum and 4% vanadium, is the strongest. Commercially pure Grade 2 titanium is mainly used for dental implant applications.

The first generation of titanium implants were smooth surface machined implants .They were used successfully for about 50 yrs. The second generation implants were later developed mainly to shorten the treatment time by accelerated osseointegration which was enabled by implant surface modification. Modified implant surfaces had greater molecular interactions, cellular response and osseointegration.

Surface Treatment of Titanium Implants

Surface conditions, such as surface roughness, surface charge, surface energy, and chemical composition, can enhance osseointegration process. Therefore, modifying titanium implant surface is a promising way to achieve stronger and faster osseointegration of the implants and also promoted shorter healing times from implant placement to restoration. These implant modifications can be achieved either by additive or subtractive methods. The additive methods of implant surface modification include coating and impregnation. Coating is addition of material/agent of various thicknesses superficially on the surface of core material. Titanium plasma spraying(TPS), plasma sprayed hydroxyapatite (HA) coating, alumina coating, and biomimetic calcium phosphate (CaP) coating are the various implant coating methods. Impregnation implies that the material/chemical agent is fully integrated into the titanium core, such as calcium phosphate crystals within TiO_2 layer or incorporation of fluoride ions to surface. Subtractive techniques aim to remove a layer of core material or plastically deform the superficial surface thereby producing surface irregularities that increase the surface area and thus increase the bone implant contact. The common subtractive techniques are large-grit sands or ceramic particle blasts, acid etch, and anodization. Goyal[2] and coworkers observed that the increased roughness can simultaneously increase the surface area of the implant, improve cell migration and attachment to implant, and enhance osseointegration process.

Implant surface modification methods:

The 1st generation dental implants had visible macro-irregularities like macroscopic threads, fenestrations, pores, grooves, steps, threads, or other surface irregularities etc which afforded less initial implant stability, difficult implant osteotomy preparation and inadequate osseointegration for early prosthetic placement due to unpredictable interfacial bone remodeling.
The 2nd generation of dental implants incorporated microscopic surface irregularities that afford the possibility of microscopic interlocking of bone and implant that significantly enhanced the load transmitting capabilities of the interface. Surface coatings and modification of surface topography was done to enhance bone implant integration. Nowadays nanoscale features have been added that have the ability to induce the differentiation of stem cells along the osteogenic pathway and help cell attraction and adhesion to form focal adhesion complexes (FA), and activate intracellular signaling cascade all leading to a better osseointegration.

Grit Blasting **:**

Blasting implant surfaces with particles of various diameters is one of the frequently used methods of surface alteration. Aluminum oxide, titanium oxide and calcium phosphate particles of various sizes (150- 350 μm) grit are used. Clinical studies have shown higher marginal bone levels and survival rates for blasted implant than smooth machined implants[3]. However studies have also shown increased bacterial adhesion around grit blasted implants .Al-Radha[4] et al showed that ZrO2-blasted titanium exhibited greater bacterial adhesion compared to other surface treatments.

Acid Etching **:**

Etching with strong acid produces micropits (0.5-2 μm) in diameter A strong acid like hydrofluoric (HF), nitric (HNO3), and sulphuric (H2SO4) or a combination of these acids is commonly used in this technique. Dual acid etching with HCl and H2SO4 heated above 100ºC has produced surface topography able to attach to fibrin scaffold and promote adhesion of osteogenic cells. Acid etched surfaces had increased cell adhesion and bone formation, thus enhancing the osseointegration. Chou et al compared a machined surface with dual acid etched (HF and HCl/H2SO4 -DAE) and showed that the acid treated surface had greater resistance to reverse torque removal and better osseointegration[5].
Orsini ert al[6] demonstrated that Sandblasting and acid etching (SLA sandblasted, large grit, acid etched surface) produced by large grit (250-500 μm) blasting followed by etching with acids produces rough surface, microtexturing and cleaning and better bone integration

Plasma Spray Coating :

Plasma spraying technique includes spraying thermally melted materials on the implant substrates. Titanium and hydroxyapatite particles are used. Plasma spraying gives a porous surface that bone can penetrate more readily and enhance osseointegration. Titanium plasma spraying consists of injecting titanium powder into a plasma torch at high temperature where particles are projected on to the surface of implants where they condense and fuse together forming a film about 100 nm.Hydroxyapatite coating on Ti alloys substrate has good biocompatibility and mechanical properties due to increased surface area of bone implant contact and . The plasma spray substantially increased the surface area of the implants by increasing their surface roughness. Using calcium and phosphate based materials such as hydroxyapatite as coatings lead to improved maturation of newly formed bone tissue due to osteoconduction of calcium phosphate materials[7].Fouda et al[8] have reported that HA coated titanium implant could enhance the healing period compared to the uncoated implants.Xie et al[9]discovered that HA coatings promote better cell proliferation and attachment. Misch[10] recommends hydroxyapatite coated-titanium sprayed dental implants in the porous D3 and D4 of the posterior maxilla, fresh extraction socket and newly grafted sites.Knabe et al found that a plasma sprayed titanium surface had the highest surface roughness compared to sand blasted and acid etched SLA dental implants.

Cho et al reported that the HA coatings reinforced with zirconia by plasma spraying had greater bond strength and lesser dissolution behavior. The only drawback of these HA coated implants are delamination and dissolution of the coated materials leading to failure of implants.

OTHER METHODS :

Fluoride (F) treatment- Titanium forms titanium fluoride in F solution which enhances osseointegration and osteoblastic differentitation with increased expression of bone matrix proteins[12]. However studies have shown that they decrease the corrosion resistance.

Laser deposition/ablation has been used to increase hardness, corrosion resistance, and achieve high degree of purity with standard roughness and a thickened oxide layer. Laser treatment followed by a hydroxyapatite plasma coating has been seen to promote osteogenesis around the implant and increased primary stability[13].

Sputtering is a process whereby atoms or molecules of a material are ejected in a vacuum chamber by bombardment of high energy ions. Magnetron sputtering allows the mechanical properties of titanium to be preserved while maintaining bioactivity of the coated HA. An outward diffusion of titanium into HA layer, forming TiO_2 at the interface shows strong bonding between coating and titanium. Studies have shown that these coatings were more retentive, with the chemical structure being precisely controlled.

Biocompatibility of Titanium and Its Alloys :

Commercially pure titanium (Cp Ti) is considered to be the best biocompatible metallic material because its surface properties result in the spontaneous build-up of a stable and inert oxide layer. The main physical properties of titanium responsible for the biocompatibility are: low electrical conductivity which contributes to the electrochemical oxidation of titanium leading to the formation of a thin passive oxide layer, oxide layer in turn leads to a high resistance to corrosion, and thermodynamic state at physiological pH values, low ion-formation tendency in aqueous environments, and an isoelectric point of the oxide of 5–6.In aqueous environments Ti and its oxides have low ion-formation tendency and low reactivity with macromolecules..

Ceramic Biomaterials :

Zirconium is an element that follows titanium in the chemical periodic table. Recently high strength zirconia ceramics have become attractive as new materials for dental implants. . Yttrium-stabilized zirconia offers advantages for dental implants because of their higher fracture resilience and higher flexural strength. Zirconium undergoes an oxidation and crystallization process which allows it to transition into a structurally stable and inert crystal that is Yttrium Stabilized Tetragonal Zirconium Polycrystalline (Y-

TZP) also called zirconium dioxide or zirconia. Favorable mechanical properties such as crack deflection, zone shielding, contact shielding, and crack bridging makes zirconia a unique and stable material for use in high-load situations such as that of mastication. Apart from high strength and favorable mechanical properties, Zirconia being radio opaque, of ivory color is similar to color of natural teeth and is especially critical in the esthetic zone with high lip line smiles[14]. Crestal boneless often leads to implant thread exposure revealing a bluish discoloration of the overlying gingiva. Titanium because of its dark grayish color, which often is visible through the peri-implant mucosa (especially thin mucosal biotype) offers poor esthetic outcomes. Anterior implants, gingival recession, unfavorable soft tissue conditions produce compromised esthetics with titanium implants. Studies have revealed that zirconia implants and abutments have low plaque affinity[15]. Hence the inflammatory response and bone resorption induced by ceramic particles are less than those induced by titanium particles. Although zirconia may be used as an implant material by itself, zirconia particles are also used as a coating material of titanium dental implants. A sandblasting process with round zirconia particles may be an alternative surface treatment to enhance the osseointegration of titanium implants. Zirconia particles used for surface modifications of titanium implants have the potential to improve initial bone healing and resistance to removal of torque. Marques et al[16] in their study of bone healing around titanium and zirconia implants found that histological examination revealed similar results regarding to bone healing in zirconia and titanium implants after 7, 14 e 30 days. However they reported earlier bone maturation in zirconia implants after 45 and 60 days. Dubruille[17] reported higher bone to implant contact (BIC) with zirconia than titanium and found an increased proliferation of osteoblasts around zirconia compared to titanium.

However it has been observed that surface modifications are difficult to produce in zirconia. Few studies have indicated that CO2 lasers may help to improve surface roughness. Hydroxyapatite coated zirconia implants have showed higher removal torque values than machined zirconia implants.
Although zirconia is esthetic, has low plaque affinity, has high biocompatibility but the lack of clinical reports on the long term success rates with zirconia implants, caution with regard to certain aspects of zirconia implants, such as tensile strength and modulus of elasticity should be considered[18].

Carbon based biomaterials :

Polyetheretherketone (PEEK)[19] is a biocompatible material that can be reinforced with carbon fibers, to achieve a modulus of 18 GPa, which similar to that of cortical bone. PEEK is a high strength thermoplastic polymer employed in orthopedics, traumatology and calvarial reconstructions[20, 21, 22] (Invibio Ltd, Thornton-Cleveleys, UK). PEEK has shown resistance to degradation in *in-vivo* and hence has been recommended in few studies to substitute titanium as material for dental endosseous implants. However long-term investigations of loaded PEEK implants in vitro and in vivo are necessary.

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