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Surface Treatment of dental implants: A review

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Abstract: *In present scenario, Dental implants serve as very promising and popular tooth replacement option for the missing natural tooth. Success or failure probabilities of implant are guided by certain local and systemic factors. Initial interaction between implants and surrounding biological tissues depends on the surface characterstics. Surface roughness in particular has attracted huge attention in the past few years to aid in achieving beneficial interaction between the implant and bone. Various attempts have been made to treat implant surface by different materials and methods so as to induce rapid osseointegration. Although such researches claim that these treatments aid in bone healing especially during early healing phase after implant surgery but implant selection should be guided by evidence available and particular case requirement. Present paper reviews the literature on different surface treatments by analyzing various studies about different options available nowadays.*

Keywords: *grit blasting, plasma spray, osseointegration, Bone morphogenicprotiens, Silver nanoparticles*

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I. Introduction

Nowadays dental implants are a predictable and popular treatment option for tooth replacement in completely or partially edentulous patients. The load on remaining teeth and oral structures is decreased as implant offers independent retention and support to various fixed and removable prosthesis. Implants are preferred over conventional treatment due to certain advantages it offers like preservation of bone; preservation of adjacent teeth, durability, better mastication and speech etc.[1] Implant comes in direct bone contact and anchors through osseointegration. Successfulosseointegration revolves around many factors such as biocompatibility of the implant material, quality and quantity of the available bone, surface treatment of the implant, loadingand surgical protocol and various other systemic and local factors.Predictability of clinical success of dental implants can be enhanced by using the newer materials or alterations in designs, surgical or loading protocols on the basis of available literature. Various studies have suggested that rough surface of implant enhances its integration with bone than a smooth implant surface.[2] Several approaches are used to attain a rough surface and ameliorate the process of osseointegration of titanium dental implants. The present paper reviews different methods of treating implant surfaces to enhance bone implant interaction starting from the basic material used in dental implant manufacture.

II. Implant Biomaterial

Pioneers of implant material were porcelain, gold, aluminium, platinum and silver, which were initially used to replace teeth but occurrence of inflammatory reactions amidst fibrous tissue formation lead to cessation of use of these materials.Economically pure titanium is the elite choice as a dental implant material although due to unclear reasons the survival rate may fluctuate. Titanium has been a material of choice in various prosthetic applications in medical field due to biocompatibility. The utmost persuasive affirmation of biocompatibility of Ti is its perpetual use in dental implants. Apart from biocompatibility, other characteristicslike inert behaviour, cost, corrosion resistance, non-allergenicproperty, easy adsorption of proteins, favourable cell growth and differentiation etc. makes titanium a desirable element for biomedical implementation. Oxygen and titanium combines to form an alloy known as commercially pure titanium. Oxygen quantity in surgical implants should be less than 0.5% in order to meet the guideline of British standard specification.[3] At 883ºC transformation in the molecular structure of titanium occurs from alpha phase(hexagonal close packed) to beta phase(body centered cubic). Elements such as oxygen, carbon, nitrogen stabilise the alpha phase whereas molybdenum, niobium& vanadium stabilise beta phase.

Quest of tooth colored biomaterial in order to enhance esthetics lead to introduction of ceramics as implant biomaterial. Ceramic is biocompatible, have high compressive strength and also it is feasible for surface treatment to enhance bonding with bone. Disadvantages with ceramic are brittleness and the tolerance level of ceramic is less for tensile stress caused by occlusalforces. Aluminium oxide (Al2O3) as well as Zirconia (ZrO2) exhibits high bio stability to be used as implants material but alumina possesses higher surface wettability whereas zirconia offers advantage of less plaque accumulation.Bioactive ceramicbiomaterial is Bioglass (SiO2-CaO-Na2O-P2O5-MgO) because it stimulates bone formation. Aluminium oxide (Al2O3) dental implants has been withdrawn from market due to poor survival rate whereas zirconia is distinctive material of choice even in high occlusal forces[4]

Scientists at NRC Industrial Materials Institute, Canada formulated a newer material known as titanium foam by adding foaming agents to a mixture of titanium powder and certain polymer. It offers advantage of increased surface area of implant surface due to porous nature and makes implant less invasive. “Roxolid” is a brand name for a material consisting of titanium and zirconium, which offers enhanced mechanical stability.[5]presently many propositions related to alteration in surface topography and chemistry of implant surface are available in literature. Morphometric Studies clearly show that rough implant surfaces have increase bone implant contact as compared to smooth surface.[6]Therefore several attempts have been made to modify implant surface through various process like amending surface chemistry or topography, oxide thickness, sandblasting, anodic oxidation etc. Grossly the techniques of transforming implant surface can be either additive i.e., sum up particles on implant suface and form mounds for eg. Titaniumplasmaspraye, HA and calcium phosphate (CaP) coatings, ion deposition or subtractive i.e., remove portion of material from surface and form depressions foreg, Al20 3 blasted surfaces , acid-etched surfaces, Machined and acid-etched surface, electropolishing.

III. Titanium Plasma Spray

Roughening of Ti implants with titanium plasma spray was portrayed approx 35 years back. Primarily in 1970, Hahn&Palich described microporous nature of surface of orthopaedic implants, which was later attempted in dental implants by Schroeder et al. [Coating] of titanium plasma is obtained by heating titanium to plasma form and spray this plasma on implant surface which can increase the apertures on implant surface by six times (30 to 50 μm deep), thus enhancing microretention.[7]The surface area of implant after plasma-spray is around 3 times that of a machined surface.Klaus Gotfredsen and Ulf Karlsson studied the difference betweenmachined and TiO2-blasted implants wrt survival rate and marginal bone loss during a 5-yearobservation period. They didn’t find any significant differences in failure rate and marginal bone loss around implants with a machined and TiO2-blasted surface. In a longitudinal multicenter trial in 2000 by Williambeckersignificant bone loss from loading to the2 to 3 year follow-up evaluations was seen in Plasma-sprayed implants. The long-term effectof this bone loss on implant loss is unknown.

Hydroxyapatite coating is an industrial method to enhance implant surface. HA Plasma spraying is done by the heating of Hydroxyapatite with a plasma flame at a temp of around 15000-20000K and then HA is forced on the implant surface in an inert environment. The thickness of coating is approx 50-200 μm and the roughness is 7-24 μm. Hydroxyapatite bonds well with bone and accelerates new bone formation in initial healing period with formation of osteophylic surface.[9]In order to increase bone formation in initial stages in cases like immediate implant placement and poor bone quality HA surface is a good choice.21In vitro studies have prooved that a larger quantity of human osteoblasts cement to hydroxyapatite (HA) surfaces than to titanium. Klaus gotfredsen did a study on rabbit to evaluate the histometrical and biomechanical anchorage of Ti0,-blasted implants and Ti0,-blasted implants coated with hydroxyapatite. He concluded that HA surface has more bone contact and more of lamellar bone as compared to titanium surface in rabbit cortical bone, 13 weeks after implant placement.

IV. Grit Blasting

It works on the concept of bombarding the surface with high velocity hard particles of various sizes, with help of compressed air. According to the size of the bombarding particles, different degree of surface roughness is produced on implant surface. Alumina particles of size range 25-75 μm result in mean surface roughnesses in the range 0.5-1.5 μm , while roughnesses in the range 2-6 μm are reported for surfaces blasted with particle sizes of 200-600 μm.[23] Factors like blasting time, pressure, distance from blasting nozzle also effect size of irregularities. The blasting material should be chemically stable, biocompatible and should not restrict the osseointegration of the titanium implants.

Different ceramic particles have been used, like glass, silica, alumina and titanium oxide particles. Residue of the blasting media may get bury on implant surface and further survives the cleaning process which ultimately end up in hampering osseointegration. To minimize this, proper post blasting cleaning such as chemical etching is done, which can decrease the roughening produced by blasting. Therefore blasting with biocompatible material is advised.[24]There is lack of detailed studies on the composition and thickness of oxide layers on blasted titanium surface. In a study by Ramussen, TiO2-blasted implants were suggested as a certain long term support for fixed prostheses in both the maxilla and the mandible.[10]

V. Acid Etching

Etching the implant surface with strong acids aids in cleaning the surface and attaining homogenous roughening. The most commonly used solutions for acid pickling of titanium and titanium alloy are, 10-30 volume-% of nitric acid HN03 (69 mass-%) and 1-3 volume-% of hydrofluoric acid HF (60 mass-%) in distilled water, mixture of 100 ml Hel (18 mass-%) and 100 ml H2S04 (48 mass-%).Acid etching generally leads to a thin < 10 nm surface oxide layer. These oxide layers have been shown to grow slowly in air, from 3 nm to 6 nm during a 400 day period.Immersion of titanium implants in a mixture of concentrated HCl and H2SO4 heated above 100 ◦C for several minutes is dual acid-etching. It produces a microrough surface for rapid osseointegration while maintaining long-term success over 3 years. Dual acid etched surfaces accelerate the osteoconductive process by attachment of fibrin and osteogenic cells, leading to bone formation straight on the implant.Another approach is flouride treatment of implant surface, which leads to formation of TiF4. This approach results in fluoride embedded on surface to enhance osseointegration and also it creates roughness.[11]

VI. Alkaline Etching

Alkaline etching is a simple technique to modify the titanium surfaces. Treatment of titanium in 4-5 M sodium hydroxide at 600 ^{0}C for 24 hours has been shown to produce sodium titanate gel of 1 µm thick, with an irregular topography and ample of open porosity. This layer primarily consists of TiO_2. Additional heat treatment can help to modify the configuration and composition of this layer. If alkali treatment is done after acid etching, the resulting surface has increased porosity.[12]

VII. Anodization

Anodization of titanium surface is done at high voltage in strong acids (H3PO4, HNO3, H2SO4, HF) resulting in crystallization of surface. It leads to thickening of oxide layer to more than 1000 nm on titanium. This process is affected by acid concentration, compositionand kind of current used. Anodization produces modifications in the microstructure and the crystallinity of the titanium oxide layer. Anodized surfaces leadto firm reinforcement of the bone response with greater values for biomechanical and histomorphometric tests as compared to machined surfaces. Anodized titanium implants are more successfullclinically than turnedtitaniumsurfaces of similar shapes. Rough and microporous surfaces can also be obtained in spark anodizing in sulfuric acid, phosphoric acid or mixtures of these at above 100 V or spark anodization in Calcium and Phosphorus based electrolytes.[13]

VIII. Laser Treatments

Laser technique can be used as an alternative for to previously discussed techniques in order to avoid contamination. Other added advantages of Laser are simplicity, clean, better control of configuration enables implant surface and lack of direct contact. The average surface roughness produced by laser treated acid-etched implant is around 2.28 ìm.Studies have shown increase in bone formation around such implant surface which might be attributed to formation of TiN on the surface[14]

IX. Calcium Phosphate Coating

It is a class of bio-inorganic materials used to modify titanium surfaces for bone related biomedical applications. The influence of the physico-chemical properties of calcium phosphate and of its degradation kinetics on the rate of new bone formation and on the long-term stability of the bone biomaterial interface is still subject of investigations and partly of controversial opinions. Calcium phosphates are released from implant surface after implant placement, which saturates body fluid and a biological apatite layer is precipitated on implant surface. This layer promotes osteogenic cell attachment, growth and bone healing. Studies have shown that fixation of bone to implant is higher in implants with Ca phosphate coating and better long term clinical success rates have been reported.[15]

Due to the problems observed with HA coatings acquired by the plasma-spraying process, other processes like sputter-deposition, sol–gel coating, thermalspraying, hot isostaticpressing, pulsed laser ablation, electrophoretic deposition and biomimetic coating, are developed.

X. Nanosilver

Oral cavity hosts a wide range of microbes which are capable of causing periimplantitisthus these microorganisms always remain a risk factor to dental implant survivability. Therefore, dental implants with antimicrobial surface treatment were introduced. Recently silver nanoparticles (SNPs) have gained much attention due to its antimicrobial property. Silver nanoparticles act infollowing ways against Gram-negative bacteria: (1) nanoparticles of size 1–10 nm adheres to the cell membrane of bacteria and effects permeability and respiration; (2) SNPs enters bacteria interacts with sulfur- and phosphorus-containing compounds like DNA; (3) SNPs emit silver ions, which will have an additional contribution to the bactericidal effect. SNPs are doped over implant surface in concentration of 0.05 ppm byTollens reaction. In a study by Zhao et al. ,AgNPs were inserted into titania nanotubes (TiO2-NTs) on surface of Ti implants by a technique which also involves silver nitrate immersion and ultraviolet radiation. Study shows that during initial days planktonic bacteria was inhibited and bacteria adhesion was prevented for 30 days due to AgNPs-coating.Lu et al. compared implant treated with different concentration of AgNps and he suggested that lower concentration of silver in AgNP is more favourable to enhance osteoblastic growth.[16]

XI. Biomimetic Surface Treatment

Biomimetic surface treatment is still a developing topic of research in implantology. Desirable properties of biomimetic agents are 1) it should be able to bring about differentiation of cell for bone formation; 2) itshould not delaminate; 3) easy to manufacture; 4) affordable; 5) chemically stable;6) non-immunogenic. Bone morphogenetic proteins (BMPs) are a family of proteins responsible for initiation of bone formation. recombinant human bone morphogenetic protein-2 (rhBMP-2) is reported to act as a bone-modulating agent for uses in dentistry over the past few years.[43] Study indicates rh bmp 2 gives very good results as far as their capability of initiating bone formation around dental implants is concerned and also the newly formed bone offers long term stability. Although these proteins are of very high cost but it offers certain advantages like it can adhere to wide range of implant material under physiologic conditions. Roessler et al suggested that RGD peptides boosts bonding of animal osteoblasts to RGD peptides treated titanium surfaces and also RGD peptides positively influence properties of other coatings for biomaterials.Cytokines, platelet rich plasma and collagen type I are also capable of inducing osteoblastic activity when treated on implant surface. Biphosphonate assimilated on surface of titanium implants has shown increased bone density around implant i.e., in the peri-implant area but controlled release of drug is still a challenge.[17] Herr et al.Suggested that treating the implant surfaces with tetracycline not only kills bacteria but it also removes smear layer and decrease collagenase activity; ultimately increasing bone formation.[18]

XII. Conclusion

There are numerous surface treatment methods to enhance bone healing and shorten the period of edentulousness of the patient. When the surface modification is based on clearly outlined biological process then one can better utilise properties of titanium[19]. Still major challenges stand in the path of surface characterization like mostly these techniques are performed in conditions different from natural surface and bodily fluid interface. Only few clinical studies have reported significant differences in implant survival and comparision of different surface characteristics. Further research should aim at generating surfaces with standardized topography so as to understand various tissue reactions with the surface of implant. For a deeper understanding of bone formation around the physico-chemically modified surfaces, newer studies on bone mineralization and bone (coating) -implant interface strength around implants are required[20].

References

[1]. Jivraj, Saj&Chee, W. (2006). Rationale for dental implants. British dental journal. 200. 661-5

[2]. Javed, F., Romanos, G.E., 2010. The role of primary stability for successful immediate loading of dental implants. A literature review. J. Dent. 38, 612–620

[3]. NovaesJr Arthur Belém, Souza Sérgio Luis Scombatti de, Barros Raquel Rezende Martins de, Pereira Karina Kimiko Yamashina, Iezzi Giovanna, Piattelli Adriano. Influence of implant surfaces on osseointegration. Braz. Dent. J. . 2010 ; 21(6): 471-481

[4]. Marziani L. Subperiosteal implantation of supporting framework for a prosthesis. DtschZahnärztl Z 1955; 10: 1115–1129.

[5]. Donath K, Laaß M, Günzl H J. The histopathology of different foreign-body reactions in oral soft tissue and bone tissue. VirchowsArchiv A PatholAnatHistopathol 1992; 420: 131–7.

[6]. Barfeie A, Wilson J, Rees J. Implant surface characteristics and their effect on osseointegration. Br Dent J. 2015;218(5):E9.

[7]. Williams DF. Biocompatibility of clinical implant materials. *Boca Raton, Florida: crc Press*. 1981.

[8]. Van Noort R. Titanium: The implant material of today Review. *Journal of Material Science.* 1987; 22: 3801-3811

[9]. Anusavice, Shen, Rawls: phillip's science of dental materials, 12th edition.

[10]. Prithviraj DR, Deeksha S, Regish KM, Anoop N. A systematic review of zirconia as an implant material. *Indian Journal of Denatl Research.* 2012; 23 (5).

[11]. European Cells and Materials. 2009; 17 (1): 16-17.

[12]. GianlucaGiavaresia, Milena Finia, Alberto Cigadab et al. Mechanical and histomorphometric evaluations of titanium implants with different surface treatments inserted in sheep cortical bone. Biomaterials 24 (2003): 1583–1594

[13]. Le Guéhennec L, Soueidan A, Layrolle P, Amouriq Y. Surface treatments of titanium dental implants for rapid osseointegration. Dent Mater 2007;23:844-854.

[14]. Leimola-Virtanen R, Peltola J, Oksala E, Helenius H, Happonen R-P. ITI titanium plasma-sprayed screw implants in the treatment of edentulous mandibles: A follow-up study of 39 patients. Int J Oral Maxillofac Implants 1995;10:373–378.

[15]. Hahn H, Palich W (1970) Preliminary evaluation of porous metal surfaced titanium for orthopaedic implants. J Biomed Mater Res 4:571-579

[16]. Schroeder A, Stich H, Straumann F, Sutter F (1978) UeberdieAnlagerung von OsteozementaneinenbelastetenImplantatkiirper. SchweizMonatsschrZahnheilkd 88:1051-1057

[17]. Klaus Gotfredsen and Ulf Karlsson. A Prospective 5-year Study of Fixed Partial Prostheses Supported by Implants With Machined and TiO2-blasted Surface. Journal of Prosthodontics 2001; Vol 10, No 1 (March) : pp 2-7

[18]. William Becker, Burton E Becker, Andrea Ricci et al. A Prospective Multicenter Clinical Trial Comparing One- and Two-Stage Titanium Screw-Shaped Fixtures with One-Stage Plasma-Sprayed Solid-Screw Fixtures. Clinical Implant Dentistry and Related Research 2000; Volume 2, Number 3.
[19]. Thomas KA, Kay JF, Cook SD, Jarcho M. The effect of surface macrotexture and hydroxylapatite coating on the mechanical strengths and histologic profiles of titanium implant materials. J Biomed Mater Res 1987;21:1395–1414

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