SURFACE MODIFICATIONS OF IMPLANTS

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INTRODUCTION

An implant is a medical device which is made from one or more biomaterials, that is intentionally placed in the body either totally or that is partially buried beneath an epithelial surface.The biomaterials which are used most commonly for the dental implants are metals and their alloys, namely commercially pure Titanium(Ti) (1-4grades) and titanium alloys like Ti-6Al-4V.Ti does not trigger a foreign body reaction and are established materials for dental implants because of their physical strength,material stability, and tissue compatibility.The first generation of dental implants were successful clinically,which had machined surfaces. However, the healing period for these implants were as long as 6–9 months before they are osseointegrated enough to be loaded(1).Thus,the quest for an ideal implant surface modification that can osseointegrate to bone faster and with a stronger bone- to-implant interface is still in process.The present review highlights the various surface modifications of Implants..

CLASSIFICATION OF IMPLANT SURFACES:

Surface topography of implants can be described as

- Macro topography
- Micro topography
- Nano topography

(i)MACROTOPOGRAPHY:

The macrotopography of an implant is determined by its visible geometry, like threads and tapered design. The appropriate macrogeometry combined with adequate implant drill hole preparation is the basis of clinical success in dental implantology.

Three basic concepts of bone healing pathways depending on the physical proximity at the bone to-implant interface(2) are.

1- Tight fit results when the diameter of the inner thread equals the dimensions of the socket- Compression necrosis of neighboring bone and subsequent bone remodelling.

2- , The diameter of the outer thread is the same as the diameter of the implant cavity- Formation of Healing chamber .

3- , The surgical instrumentation line lies right between the inner and the outer thread- Compression and Healing chambers coexist.

Healing chamber formation might be of significant importance for subsequent concepts of micro- and nanotopography, since migration of osteogenic cells requires void space.

IMPLANT THREADS:

The threads of the implant increase the surface area available to distribute occlusal forces into the supporting bone.

1. THREAD PITCH

Thread pitch can be defined as the distance from a point on one thread to a corresponding point on the adjacent thread, measured parallel to the axis. Smaller thread pitch increases surface area.

2. THREAD SHAPE

Thread forms in dental implant designs include square, V-form, buttress, and reverse buttress. The buttress or square thread provides an optimized surface area for intrusive, compressive load transmission.

3. THREAD DEPTH

The thread depth is measured as the distance between the root and the crest of the thread. The deeper the thread, the larger the surface area available for compressive force transfer to the supporting bone .

(ii) MICROTOPOGRAPHY:

Microtopography is linked to microroughness on a micrometer scale (1–100 μm). Changes in surface topography itself alter growth, metabolism, and migration as well as cytokine and growth factor production of osteogenic cells(2).

(iii)NANOTOPOGRAPHY:

Nanotopography of dental implant influences cell-implant interactions at the cellular and protein level. The nanotopographical features of Ti implant surfaces have been known to be contributors to osteoblast activities and osteoclast reactions(2)

METHODS OF IMPLANT SURFACE ALTERATION: CLASSIFICATIONS OF METHODS:

These include

- Morphological,
- Physiochemical and
- Biochemical methods(3).

The morphological methods involve alterations in the surface morphology and roughness. The physiochemical methods involve modification of the surface energy, the surface charge and the surface composition. The biochemical surface modification utilizes the biology and the biochemistry of the cellular function and differentiation .(3)

(i)PHYSICAL AND SUBTRACTIVE:

1. MACHINING:

‗Machined surface' means a turned, milled or sometimes a polished surface. It has a surface area roughness (Sa) value of 0.3–1.0 μm.The turned surface frequently serves as a control as it has no modification process and it helps to evaluate the biocompatibility of modified surfaces(4).

2. SANDBLASTING:

The sandblasted implant is grit blasted by small particle eg.Alumina or Titanium oxide under high pressure,Medium grit particles of size 250-500µm and Large grit sandblasting particles Eg. Corundum of size 0.25-0.5mm The surface morphology is determined by the particle characteristics like its material, size (25, 75, and 250 µm),shape, density,and speed at which it is propelled. The blasting procedures leave residual particles on the implant surfaces,which modifies the bone-healing process.(5)

3. LASER ETCHING OR LASER PEENING OR LASER ABLATION:

Laser-etched implants uses Laser as a micromachining tool to produce selective modification at micrometer and nanometer level . The implants are ultrasonically cleaned and then they are etched by using an Nd:YAG laser at a power of 50kw, frequency of 7.5khz and 16.4A current. (6)Laser treated Ti implants had reduced surface contamination thereby improves the response of the bone.

4. POROUS TANTALUM TRABECULAR METAL:

The titanium alloy and the porous tantalum trabecular metal of the implant are prepared separately. The porous vitreous carbon scaffold acts as a second layer on the titanium implants. Tantalum is deposited onto the vitreous carbon scaffolds using chemical vapor deposition or infiltration and then laser welded onto the titanium alloy core. The porous layer, with a structure similar to trabecular bone, is used to improve the bonding between the osseous tissue and the dental implants through osseointegration(7) and enhances secondary stability. (7)

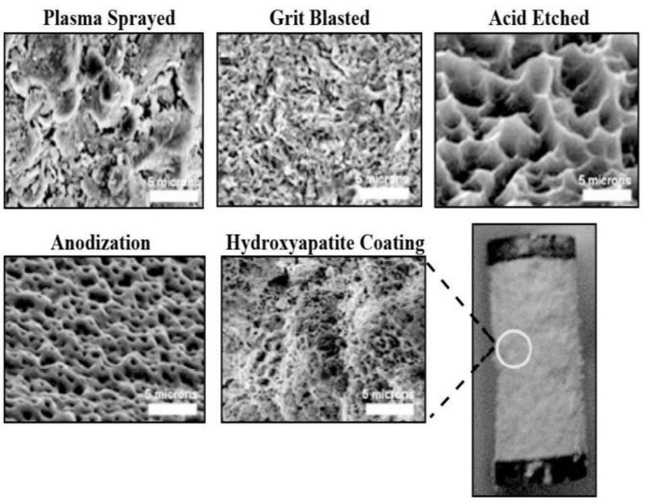


Fig.1Surface topography of implants undergoing different types of treatments

(ii) CHEMICAL AND ADDITIVE:

1.ACID ETCHING:

The commonly used acids are strong acids like hydrofluoric (HF), nitric (HNO_3), and sulphuric (H_2SO_4) or their combination (8). Acid etched surfaces had increased cell adhesion and bone formation, thus enhancing the osseointegration.(9)The significance of this technique is that it renders the substrate with homogeneous roughening

2.SANDBLASTED,LARGE-GRIT,ACID-ETCHED(SLA):

Acid etching can be done by using an HCL/H_2SO_4 mixture or by pickling in 2% HF 10%HNO_3 after sand blasting of the surface and this increases the surface reactivity of the metal. Blasting produces the microscale surface roughness and the subsequent etching with acid shapes the nanostructure of the implant(10).The surface of a dental implant is originally hydrophobic . Hydrophilicity accelerates the bone healing process and enhances alkaline phosphatase activity(11) .Therefore,there have been attempts to add hydrophilicity to an SLA surface.(12)

3. ALKALINE TREATMENT:

Alkaline oxidation can be achieved by soaking the implant in high alkaline solutions followed by heat treatment. (Eg, soaking in 4–5 M sodium hydroxide solution and heat treatment at 6008C for 24 hours)(9).The alkaline treatment can be preceded by acid etching to increase the porosity of the titanium surface.

4. ANODIZATION:

Anodized titanium Surface Implant (ASI) is formed by passing current through the implant as the anode and with phosphoric acid as the electrolyte forming the surface oxide(TiO_2)of thickness 600–1000nm from 17–200 nm in conventional titanium implants. Thereby through its porous topography it increases bone formation (13).

5. PEROXIDATION:

Peroxidation of the implant surface produces a titania gel layer through treatment with a peroxide-based chemical agent eg:Hydrogen peroxide. When titanium surfaces react with hydrogen peroxide, titania gel layers are formed. The thickness of titania layer formed can be controlled by adjusting the treatment time(14).

6.FLUORIDE MODIFICATION:-

The fluoride modification involved blasting with titanium oxide (TiO2) and treating with dilute hydrofluoric acid achieving a surface roughness of 1.24–1.26 µm(15). The fluoride-treated Ti surface has shown stronger binding between the bone and the surface than the control Ti surface.

7. VACUUM TREATMENT:

Radiofrequency magnetron sputtering, Beam sputtering, Pulsed laser deposition are the various techniques used for deposition of HA through vacuum deposition.(16)Radio frequency magnetron sputtering which produces a very thin, stable, homogeneous coating on implant surface is done in a mix of argon and reactive gases.It is done to derive a desired HA stoichiometry.Vacuum treatment of the implant surface can also be achieved by glow discharge deposition of coating material from a solid target or by reactions in the gas phase or by bombardment of high energy ions.This method can also be used to develop antimicrobial surfaces on the implant via deposition of fluoride and silver (Ag) ions .

8. PLASMA COATING OR SPRAYING:

Plasma coating or spraying is done by blowing the stream of the HA powder through a very high temperature flame that partially melts and ionizes the powder, as it emerges from the flame, hitting the metallic surface which has to be coated thus producing around 50µmthick HA coatings.(16)The plasma sprayed HA showed greater surface area of bone apposition to the implant.

(iii) BIOLOGICAL / BIOMIMETIC SURFACE ALTERATION 1.HYDROXYAPATITE COATINGS.

HA and other calcium phosphorus coating materials are osteoconductive. The deposition of calcium phosphate onto titanium surfaces can be achieved by using a titanium cathode and a platinum anode to generate a current producing a brushite coating, which is hydrothermally processed to apatite on the implant surface.(17) The HA coating consists of amorphous and crystalline forms .Crystalline coatings are superior to the amorphous with respect to the bone implant contact.(18)

2.GROWTH FACTORS:

These factors comprise Platelet-Derived Growth Factor (PDGF), Transforming Growth Factor beta (TGF-β), and Fibroblast Growth Factor (FGF)and Vascular Endothelial Growth Factor) (VEGF). PDGF and FGF initiate the proliferative phase of osseointegration(17). BMP, BMP-2, Growth and Differentiating factors (GDF) are some of the osteogenic agents that can be incorporated into biomimetic calcium phosphate coatings.

BMP-2 is known to have a direct effect on osteogenic cells to promote bone formation..

3.EXTRACELLULAR MATRIX PROTEINS:

Fibroblasts are triggered by FGF to secrete extracellular matrix proteins like collagen, chondroitin sulfate, fibronectin, vitronectin, and other proteoglycans which guide the osteoprogenitor cells to migrate to the implant via interaction of integrins on the cell surface.(19)The bone healing process starts from the adhesion of the osteogenic cells to surfaces, and these adhesion proteins can play a role in accelerating osseointegration 4.PEPTIDES:

Peptides are biomolecules composed of short sequences of amino acids resembling fragments of larger proteins. The RGD peptide is an important sequence of extracellular matrix proteins that acts as a binding site for integrin receptors in adhesion and migration of osteogenic cells.(17) These core functional peptides have lower antigenicity and are more promising candidates for implant surface treatment .(20)

5. MESSENGER MOLECULES:

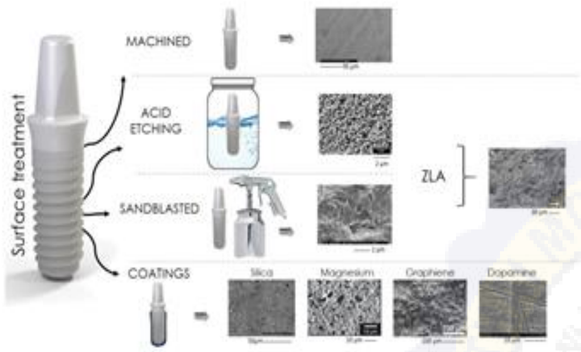
Sclerostin is one of the messenger molecules that mediates the osteoblast -osteoclast interaction. It is secreted by osteocytes and serves as an inhibitor of osteogenesis by blocking osteoblastic bone formation(16).

6. DRUG COATINGS:

HA coatings have been successfully used as local drug delivery systems. Statins trigger the local liberation of BMPs, thereby promoting osseointegration. Bisphosphonates can also be coupled with RGD peptides and chemically absorbed on titanium to produce synergistic osteogenic effects(21).

7. ANTIBIOTICS:

Cephalothin, Carbenicillin, Amoxicillin,Cefamandol, Tobramycin, Gentamicin, and Vancomycin are some of the antibiotics that can bind to calcium-based coatings of implants,and are then released from it.(22)



NEWER TRENDS:

1. TIO2 NANOTUBE:

Anodic oxidation is done at a nanoscale(1–100 nm) in an electrochemical cell composed of Ti at the anode and platinum at the cathode in which the TiO_2 layer is formed on the Ti implant surface of the anode. A fluoride-based electrolyte is used and the nano-morphology of the TiO_2 layer is changed, and the TiO_2 nanotube layer is developed. Both osteoblasts and osteoclasts showed maximal cellular responses to Ti surfaces.Another characteristic of this nano-modified surface is a drug delivery effect(23).

2. DUAL ACID ETCHING (DAE):

DAE is to treating the surface via chemical or acid in sequence or with the combination of both. Rapid osseointegration can be achieved by dual etching through micro rough surface(9) .

3. NANOTITANIA COATINGS:

Various methods include Sol gel method, Pulsed laser deposition, Electrophoretic deposition, Ion beam assisted deposition and Sputter coating. Nanotitania coatings were prepared by using the sol-gel technique is done by dissolving Tetra isopropyl orthotitanate was dissolved in absolute ethanol. The two solutions were mixed rapidly and stirred effectively for 3 minutes.The coating sol was aged at 0ºC for 24hours before the Ti substrates were dip coated and then coated substrates were heat treated at 500ºC for 10minutes and cleaned ultrasonically.(23)The Nanotitania implants exhibited an ordered arrangement, forming a homogenous layer on underlying topography.

4. PHOTOFUNTIONALIZATION:

UV treatment of implant surfaces reduces the degree of surface hydrocarbon and increases surface energy and wettability(24).It raises the level of protein absorption and cellular attachment to titanium surfaces and restores bioactivity(24).

CONCLUSION:

Surface modification of the dental implant focuses on improving initial biologic responses to the implant surface. The surface chemistry, the surface topography, and the surface energy of the titanium surface has a crucial effect on osteoblast and osteocyte function. The central focus of implant development is to minimize bacterial adhesion while promoting recruitment, adhesion, and proliferation of osteogenic as well as fibroblastic cells in order to gain a high degree of hard and soft tissue integration.

Clinicians should have sound knowledge on surface modification methods of dental implants for careful and suitable selection of implant system to ensure long term success of implant therapy.

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