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IMPACT OF NOVEL DENTAL IMPLANT SURFACE MODIFICATIONS ON OSSEO INTEGRATION AND EARLY HEALING

Dr Sahil Sethi[1], Arka Swarnakar[2], Dr. Pratyushman Hazarika[3], Dr. Sujata Pandey[4], Dr Bela Mahajan[5*], Dr Pramod Kumar[6]

[1]Reader, Department of Prosthodontics and Crown and Bridge, Kalka Dental College and Hospital, Meerut.
[2]Reader, Department of Prosthodontics and crown & bridge, Kothiwal Dental college and Research Centre, Moradabad
[3]Lecturer, Government Dental College, Dibrugarh, Assam
[4]Senior lecturer, Department of Prosthodontics and crown and bridge, Kothiwal dental college and research centre, Moradabad.
[5*]Prof & Head, Dept Oral pathology and microbiology, IDS Sehora, Jammu
[6]Senior Resident, Dept of Dentistry, JLNMCH, Bhagalpur

***Corresponding Author:** Dr Bela Mahajan
drbelamahajan@gmail.com

Abstract

The secret to endosseous dental implants' longterm success is osseo integration. The main surface elements that affect osseointegration include implant surface characteristics including roughness, topography, energy, and composition. Additive and subtractive techniques have both been utilized to improve implant surface roughness in order to increase surface area and enhance the process of osseointegration. One of the most crucial elements for a successful orthopedic surgery in the area of end prosthesis is the long-term and stable anchoring of implants. These changes enable a quicker and more powerful Osseo integration. As opposed to previously changed surfaces, recently added hydrophilic characteristics to roughened surfaces or certain osteogenic peptides coated on surfaces demonstrate improved biocompatibility and have caused quicker Osseo integration. The development of surface engineering techniques might lead to new knowledge about the characteristics, behavior, and reactions of different materials, which would then enable the creation of novel materials, modification methods, and the design of bioimplants in the future.

Keywords: Dental Implants, Surface Modifications, Osseo Integration, Boneimplant interface

INTRODUCTION

The components of a dental implant and how it is treated effect the surface's chemical composition and electrical charge, which directly affect osteoblast adhesion and protein adsorption. For endosseous implants, grade 4 commercially pure titanium (cpTi) is being utilized. When compared to other unalloyed accessible grades, grade 4 cpTi is stronger. Because of its better fatigue characteristics and yield strength, Grade 5 (Ti6Al4V) is an alloyed grade that is specifically designed for dental implant treatments. Dental implants' surface interacts hydrophilically with Dental implants' chemical make-up affects blood properties. Hydrophilic surfaces are favoured over hydrophobic surfaces when it comes to interactions with cells, tissues, and biological fluids. One of the six crucial aspects that affects dental implants' long-term success is their surface properties. Biocompatibility can be enhanced, Osseo integration can be accelerated, and the patient's edentulous time may eventually be cut short by altering the Ti surface's properties. The development of implant surface modifications has several goals, including enhancing clinical performance in areas with poor bone quality or quantity, hastening bone healing to allow for immediate or early loading protocols, and hastening bone growth to enable implant placement in areas with insufficient residual alveolar ridge. The implant's success is determined by a number of factors, including surface properties at the micro- or nanometer scale, hydrophilicity, biochemical bonding, and other characteristics. By utilizing the right modification methods, whether by addition or subtraction, the surface area may be significantly expanded. Additionally, there are three categories of surface treatments: mechanical, chemical, and physical. The interest in surface engineering must be seen as a significant and natural development given that osseo integration is defined as the tight contact between bone and implant (1). Implant surface characteristics are connected to the pace, amount, and quality of the bone response. For instance, for protein adsorption and cell attachment, composition and charges are crucial (2). When compared to hydrophobic surfaces, hydrophilic surfaces seem to prefer interactions with biological fluids and cells (3,4), and hydrophilicity is influenced by the chemical makeup of the surface. Rougher surfaces promote differentiation, development, and attachment of bone cells and improve mineralization; also, the degree of roughness is significant. Implant morphology affects bone metabolism. Surfaces of implants may be "smooth" (machined) or rough. The primary techniques for producing implant roughness that have been documented in the literature are acid etching, sandblasting, titanium plasma spraying, and hydroxyapatite (HA) coating. The creation of implants with micro and submicro (nano) topography is a contemporary trend. Additionally, current research has looked at the bio functionalization of implant surfaces by using various chemicals to enhance their biological properties.

LITERATURE REVIEW

Maziar Khatami et.al (2023) The use of dental implants has grown dramatically across the globe over the last ten years, and the likelihood that future implant failures may need revision surgery is also expected to rise. Insufficient osseointegration and bacterial infections are the two primary causes of implant failure. Long-term stability cannot be provided by the surface coatings and surface modification methods now in use. Additionally, the implant surface characteristics of chemical composition, surface energy, wettability (hydrophilicity/hydrophobicity), coarseness, topography, and surface arrangement have a significant impact on the parameters of cell adhesion and survival. Due to its precise control over surface topography, morphology, wettability, and chemistry, laser surface texturing (LST) is regarded as the most promising technique for producing biocompatible, antibacterial, and appropriate surfaces for improved bone mending. With this method, a wide range of biomaterials may be given micro- and nano-texture patterns. In order to facilitate evaluations of innovative dental implant designs, the current research examined and described the effects of laser surface texturing (LST) on a few physical and chemical parameters of dental implants. **Nike Walter et.al (2022)** Reduction and internal fixation have been used to restore bone integrity ever since the beginning of time. Despite improvements in our knowledge of how fractures heal, complications such implant loosening or infection connected to implants continues to pose a difficult complication. In order to improve bone consolidation and osseointegration, a lot of research is being done nowadays to disclose the effects of implant surface alterations on osteogenic processes. This narrative overview aims to (1) illustrate the development and previously accomplished milestones of implant optimization and (2) identify the critical elements that support improved osseointegration. Currently, numerous research use various physical and chemical roughening strategies. It has been discovered that surface patterning at the nanoscale, which is possible via processes like anodization or laser texturing, is crucial for the biological response. Along with surface roughening, other coating techniques are being researched. The ability of various biomolecules to assist bone growth is now being investigated as an alternative to metal or inorganic chemicals as covering materials. Surface alterations at the micro- and nanoscale may enhance osseointegration. The capacity for osseointegration may be further increased by bioactive substances. Examples of current agents include inorganic substances, growth factors (BMPs and non-BMPs), and antiresorptive medications. Therefore, the progress of implant research strives to actively assist osseointegration processes. **Xiaoyu_Huang et.al (2021)** These days, periimplantitis is a significant issue leading to implant failure. Therefore, early infection prevention and later Osseo integration promotion are two essential elements in resolving this problem. Metal surfaces may be treated using micro-arc oxidation (MAO) to create an oxidation layer. Although the technique has limited antibacterial effects, it has strong osteogenic qualities. Determining that several approaches were necessary to treat severe peri-implantitis, we created PD, a new drug made up of dendrimers loaded with poly(amidoamine) (PAMAM) and dimethylaminododecyl methacrylate (DMADDM), as well as MAO therapy. In this study, we investigated the chemical characteristics of the new compound PD and demonstrated its effective synthesis with loading and encapsulation efficiencies of 23.91% and 31.42%, respectively. We also discuss the two-stage double benefits that PD + MAO can provide: (1) in the first stage, PD + MAO could reduce biofilm adherence and development by releasing DMADDM in the first stage after implant surgery that was highly infected both in vitro and in vivo; and (2) in the second stage, PD + MAO demonstrated potent anti-infection and osteoconductive properties in a rat model of peri-implantitis in vivo. This research describes the two-staged, dual advantages of PD + MAO and shows how it may be used in clinical settings to prevent peri-implantitis, particularly in patients who have a high infection risk.

Gaia Pellegrini et.al (2018) The extracellular matrix's structural characteristics and chemical makeup directly influence cell survival, differentiation potential, and activity, and changes in these factors have an impact on tissue homeostasis. When a dental implant is inserted into bone tissue, a series of molecular and cellular processes are triggered, which cause newly created bone to adhere directly to the titanium surface. The surface structure of the implanted material has an impact on osseointegration because of the implant's contact with mineralized tissue. Mesenchymal stem cells' shape and activity can be altered by surface nanotopography and microtopography, which increases the pace at which these cells differentiate into osteogenic lineage and upregulates osteoblastic genes. To enhance osseointegration, a number of implant surface modification techniques are actively being researched or have just been suggested. The majority of surface treatments aim to form a thick layer of titanium oxide, change the chemical makeup of the surface by adding bioactive molecules and drugs, and create a surface topography that is more appealing for osteoblast differentiation, adhesion, and osteogenic activity. In the current work, information on the interaction between cells and their substrate as well as in vivo tests evaluating how these unique surfaces affect cells are examined. Modern surfaces may speed up and boost implant osseointegration in dental clinical practice, but they may also lessen peri-implant bone loss and encourage the re-osseointegration of a damaged surface. **Ting Ma,et.al (2016)** The early cellular reaction to the dental implant is crucial for the ensuing tissue regeneration surrounding the foreign implant surface. The integration process between implants and peri-implant bone tissue involves a large number of cells and proteins, leading to the ultimate osseointegration. Because of its superior mechanical, biological, and osteoconductivity qualities, titanium is a common biomaterial utilized in dental and orthopedic implants. The osseointegration process and pace of dental implants are influenced by the titanium surface's roughness and chemical makeup. This article reviews many research on the impact of titanium's surface roughness and wettability on the early stages of osseointegration. Furthermore, new surface topographies and chemical compositions have been created based on various surface alterations in attempt to speed up this woundhealing process. The ideal dental implant surface layout takes into account the advancement of implantology for immediate loading and the enhancement of long-term stability. For the creation of innovative surfaces that can accelerate and stabilize the Osseo integration of dental implants, a proper knowledge of the interaction between cells and implant surfaces is necessary.

IMPLANT SURFACE TOPOGRAPHY

The type and texture of the implant's surface greatly influence how the tissues react to it. Textured implants surfaces provide greater surface area for merging with bone during the Osseo integration process than flat surfaces do. The tissues may also develop into textured surfaces. Implant surface roughness may be classified as macro, micro, and nano-sized topologies according on the size of the features. Features with a macro-roughness of between a few millimeters and tens of microns are considered. This scale has a causal relationship to implant shape, including threaded screws and treatments for macroporous surfaces.

A suitable macro-roughness may enhance initial implant fixation and long-term mechanical stability. A micro-roughness is described as falling between 1 and 10 m. The interlocking between mineralized bone and the implant surface is maximized at this level of roughness. In recent years, surfaces having nanoscale topographies have seen widespread application.

Materials used in nanotechnology have nanoscale topography or are made of nanoscale components that vary in size from 1 to 100 nm. The rate of Osseo integration depends on the adherence of osteoblastic cells, protein adsorption, and nanometer roughness.
Surface topography can be classified as

a. Implant surfaces have been categorized by Sykaras N et al. as:
▪ Minimally rough (0.5–1 µm) ▪ Intermediately rough (1–2 µm) ▪ Rough (2–3 µm).

b. based on the texture you got

a. Concave texture (mostly achieved by additive processes like titanium plasma spraying and hydroxyapatite [HA] coating)

b. Convex texture (mostly achieved via subtractive processes like etching and blasting).

c. based on how the irregularities are oriented ▪ Isotopic surfaces: Whatever the direction of the measurement, it has the same topography. ▪ Anisotropic surfaces: It has distinct directionality and varies greatly in roughness.

METHODS OF SURFACE TREATMENT

The techniques used to modify the surface of implants may be roughly categorized into three types: mechanical, chemical, and physical.

Mechanical: These physical treatment treatments often produce rough or smooth surfaces that may promote cell adhesion, proliferation, and differentiation. Include polishing, machining, blasting, and grinding **Chemical:** Chemical processes that take place at the interface between titanium and a solution are the basis for techniques used to chemically modify the surface of titanium and its alloys in order to change its composition, wettability, and surface energy. Sol-gel, chemical vapor deposition, treatment with acids or alkalis, hydrogen peroxide treatment, and anodization are some examples of such processes.

Physical: Plasma spraying, sputtering, and ion deposition are physical techniques for modifying implant surfaces.

THE PROCESS OF OSSEOINTEGRATION

The characteristics of the implant surface have a significant influence in OI, a dynamic process comprising a series of cascade reactions (Figure 1). A series of intracellular and extracellular biological activities play a part in the bone healing process surrounding implants. As soon as the implant is inserted into the body, an inflammatory reaction occurs, causing the production of several proteins such growth factors and cytokines that cause a blood clot. The proteins and lipids in the blood clot will soon be absorbed by the implant surface. These surface-coated proteins might serve as a cue for cell migration and growth. The specific

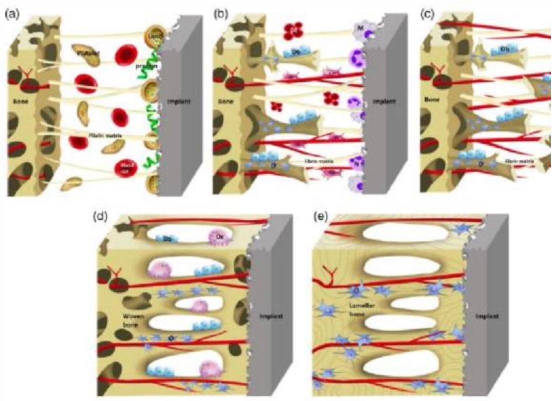

FIGURE 1 Schematic of the process of implants OI. types of proteins and firmness of adhesion depend largely on the characteristics of the topographic details, roughness, and hydrophilicity of the implant's surface. Blood platelets then aid in the creation of the fibrin matrix, which acts as "a bridge" for cell attachment and movement. Over the course of two to three days after implant implantation, macrophages and neutrophils attach to the implants through the "bridge," clearing out pathogens and dead tissue and dissolving the blood clot to create room for new blood vessels. In the space between the implant and host bone after 4 days, angiogenesis develops without developed mesenchymal stem cells (MSCs) around the vascular structure. MSCs may develop into osteoblasts, which can create the extracellular matrix and build immature woven bone, under the influence of growth hormones and cytokines. MSCs may also develop into fibroblasts, which may promote the establishment of a fibrous membrane on the implant site and obstruct the ingrowth of new bone. It is impacted by the surface characteristics and intercellular interactions nearby.

Over the next one to two weeks after implantation, woven bone growth continues.
There are two forms of ontogenesis that MSCs attach to because the fibrin bridge directs their migration. Bone formation that begins right on the implant's surface is known as contact osteogenesis. Distant osteogenesis, on the other hand, develops on the bones or tissues around the implant and may migrate to the implant surface across the fibrin bridge. Choi et al. show that two osteogenesis processes interact and that the surrounding bone, which goes through distance osteogenesis after implantation, may provide signals that cause contact osteogenesis.

SURFACE MODIFICATION TO REDUCE CORROSION

The metals utilized in the implant must be compatible with the human body in order to be selected as biomedical implants. Corrosion is the breakdown of a substance into its individual atoms as a result of chemical interactions between the material and its environment. The thermodynamic state of the material is altered by corrosion, which also electrochemically oxidizes metals in response to oxygen. Numerous metallic implants are known to have excellent corrosion resistance, extending their life. However, research demonstrates that corrosion occurs gradually after a metal is implanted in humans owing to electrochemical interactions. Due to the presence of water, chloride ions, sodium ions, plasma, proteins, and amino acids in saliva, the tissue fluid in our bodies creates reactive interstitial fluid and reacts ionically to biomaterials. The statutory authority in the biomedical business is also harmed by the metal ions from bioimplants, in addition to causing major infections and other health problems. To determine how well an implant's material performs in varied settings, a screening test is crucial.

Any one of three types of corrosion—pitting corrosion, uniform corrosion, or corrosion spurred on by electrochemical or mechanical mechanisms—can occur on the metallic surface of an implant. Numerous surface modification techniques have been developed in order to circumvent and improve the implant's performance due to the corrosive environment encountered within the human body. In an attempt to improve the mechanical properties of implants by making them more bio-functional and corrosion-resistant, surface engineering tool development has drawn a lot of attention in recent years.

The techniques used include uniformly thin coating deposition, surface texturing, ion beam processing, and the development of a stable passivation oxide layer.

The implant's surface hydroxyapatite coating may start to erode over time, changing how the metals act. Before a coating and surface treatment metals develop on the passivated metal surface, a stable surface oxide layer need to appear. This oxide layer is essential for corrosion resistance because it changes the surface oxide layer by releasing metalions. The surface oxide layer's composition may change due to interactions at the interfaces of living tissues and metallic objects. The surface oxide layer of metal implants is a crucial element in biocompatibility.

Ion beam methods, one of the surface modification techniques, make it easier to modify the surfaces of metallic implants. Using an ion beam technology, an additional layer is produced that promotes biocompatibility while enhancing wear resistance and corrosion resistance, such as titanium dioxide (TiO2) and titanium nitride (TiN) film. Bioimplants' surfaces may be hardened using ion implantation methods, which also result in low friction coefficients and a reduction in the release of metal ions, which reduces the implant's tendency to wear. Numerous studies show that the surface properties of the implant are improved by the implantation of oxygen and nitrogen ions. Surface texturing has been used recently to prevent corrosion, improve biocompatibility, and encourage Osseo integration of the implant. To improve the connection between bone and surface implants, procedures such acid etching, plasma spraying, electro polishing, anodic oxidation, and bioactive coatings may be applied. Rough implant surfaces enable quick implant integration by promoting bone healing and biocompatibility.

CONCLUSION

This article reviews many surface modification methods that are often utilized for implants that deal with bone. According on the intended effect and physiochemical characteristics of the substrate, as well as cost, one strategy would be selected practically for surface modification. To encourage OI and improve clinical outcomes, surface modification is a technique used to alter the biological, chemical, and physical characteristics of an implant's surface. We came to the conclusion that there are now both sophisticated and widely utilized methods for surface modification. Surface engineering methods are now being developed in order to learn more about the characteristics, behavior, and reactions of diverse materials, which will enable the creation of novel materials, the modification of existing procedures, and the design of bioimplants in the future.

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