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INTERNATIONAL JOURNAL OF ADVANCED RESEARCH (IJAR)

Article DOI:10.21474/IJAR01/14887
DOI URL: http://dx.doi.org/10.21474/IJAR01/14887

RESEARCH ARTICLE

CORRELATION OF DENTAL IMPLANTS SURFACE TEXTURE AND OSSEOINTEGRATION – A REVIEW ARTICLE

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Manuscript Info

Manuscript History
Received: 10 April 2022
Final Accepted: 14 May 2022
Published: June 2022

Key words:-
Dental Implants, Implant Surface, Osseointegration, Dentistry, Implantology

Abstract

The key factor in success of dental implants is its ability to integrate with the surrounding bone, or in short, osseointegration. The events leading tosuccess or failure of osseointegration of a dental implant takes place mostly at the tissue- implant surface. It would be no doubt to say, that the implant surface offers the greatest potential to alter the process of osseointegration.Although the main purpose of surface modification of implants is to achieve better osseointegration, a shortened period of healing is desirable for both the clinician and the patient.

Introduction:-

Dental implant is one of the most successful treatment modalities currently available for rehabilitating an edentulous state. The key element in the success of dental implants is its ability of osseointegration as given by Brånemark in his theory of osseointegration. Brånemark et al. defined osseointegration at a light microscopic level as the direct structural and functional connection between ordered living bone and surface of a load-carrying implant.[1] Reliable fixation of currently used endosseous dental implants relies primarily on mechanical interlock of bone and implant surface features at a microscopic and/or macroscopic level. Among the properties of titanium, one of the most important is the surface quality.[2]Under ideal conditions, the bone should integrate with the implant material rather than responding to the material as a foreign substance by encapsulating it with fibrous tissue. During osseointegration, osteoblasts and mineralized matrix contacts the implant surface even when loads are applied.[3]

Endosseous implants

An endosseous implant, or an endodontic endosseous implant, is a type of endosteal implant that is meant to mimic the natural root of a tooth by using a vertical column of bone to anchor the dental implant hardware. Endosseous implants are surgically placed inside the natural jawbone and allowed to heal before placing the artificial tooth or crown on the implant hardware. Endosseous implants are usually contraindicated in children under the age of 16 since the density, size and shape of the bone is still changing. Endosseous dental implants are also highly contraindicated in diabetic patients due to increased risk of infections and poor wound healing.

Dental implant suface

The mechanical stability of a dental implant largely depends on the characteristics of its bulk material.[4] The core of the vast majority of dental implants is composed of titanium or titanium alloy due to the high biocompatibility and corrosion resistance as well as the favorable mechanical properties.[5]The surface topography of dental implants is crucial for adhesion and differentiation of osteoblasts during the initial phase of osseointegration as well as in long-term bone remodeling.[6] Dental implant topography can be classified into:

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1. Macroscale
2. Microscale
3. Nanoscale

The macrotopography of an implant is determined by its visible geometry, for example, threads and tapered design.

Surface modifications of dental implants
Macro-topographic modifications:
Macro roughness comprises features in the range of millimeters to tens of microns. This scale directly relates to implant geometry, with threaded screw and macro porous surface treatments. The primary implant fixation and long-term mechanical stability can be improved by an appropriate macro roughness. This will enhance the mechanical interlocking between the macro rough features of the implant surface and the surrounding bone.[9]

Micro-topographic modifications:
Sandblasted and acid etched dental implants
Sandblasted, large grit, acid-etched implant surface, (SLA) is a type of surface treatment that creates surface roughness with the goal of enhancing osseointegration through greater bone-to-implant contact. The SLA process increases the rate at which osseointegration occurs by using a combination of grit and acid etching to give the surface increased roughness on multiple levels. This allows osteoblasts to proliferate and adhere to the implant surface. Through osseointegration, SLA can help provide increased stability of the implant which will ultimately lengthen its longevity.The macroroughness of the SLA implant surface is manufactured by large grit sandblasting with 0.25–0.5 mm corundum particles at 5 bar. The microtopographic surface structure is the result of a subsequent acid-etching process with HCl/H_2SO_4 at high temperatures generating an active surface area with equal roughness and enhanced cell adhesion.[6]

Grit blasted, acid etched and neutralized implants
The FRIADENT plus implant system is produced in a temperature-controlled process by large grit-blasting (354–500 µm), followed by etching in hydrochloric, sulfuric, hydrofluoric, and oxalic acid and finalized by a proprietary neutralizing technique.[7] The microtopography spans over several levels of magnitude and possesses a mean roughness of 3.19 µm.[7] The macroroughness caused by grit-blasting is interspersed with irregularly shaped micropores. These micropores measure 2–5 µm and contain a second level of even smaller sized micropores.[8]The FRIADENT plus surface exerts dynamic changes in wettability. Upon contact to extracellular matrix proteins, the initial hydrophobic surface shifts to a hydrophilic state, exhibiting a water contact angle of 0°.[7]

Nano-topographic modifications
Discrete crystalline deposition
In NanoTite and its successor the 3i T3 dental implant (BIOMET 3i, Palm Beach Gardens, FL, USA), the Osseotite surface (BIOMET 3i, Palm Beach Gardens, FL, USA) of the respective dual acid-etched titanium alloy implant has been altered with a nanometer scale manufacturing technique. Calcium phosphate (CaP) particles of 20–100 nm are deposited on a double acid-etched surface by a sol-gel process named Discrete Crystalline Deposition (DCD). These CaP particles make up roughly 50% of the surface area[10] and exert a higher adhesive force to the implant surface than former techniques of CaP deposition.[6,11,12] Bacterial adhesion to the NanoTite surface has been shown to be lower compared to the predecessor Osseotite surface.[6]

Laser ablation
Surface preparation by laser ablation of dental implants is another method to enhance bone-to-metal interfaces. Very hard titanium microstructure surfaces, great resistance to weakening, an excellent roughness as well as increased oxide layer are a result of this procedure. Biological studies have demonstrated grooved surfaces which prepare the way for cell attachment and direct the manner in which they grow.[13]It has various benefits over machining, which needs chemical agents and a complex manufacturing system. The advantages of laser technology include the following: (i) a rapid and extremely clean nanofabrication technique; (ii) suitability for the selective changes in implant; (iii) precise, targeted and guided surface roughening.[17]

Anodic oxidation
Surface modifications by electrochemical methods play an important role among the techniques for the fabrication of biocompatible coating materials and microstructures. Anodic spark deposition is an advanced plasmachemical-

electrochemical method of forming ceramic like surfaces on anodic metal substrates of valve metals as titanium.[14] In acidic media, non-noble metals like titanium, tantalum, zirconium and aluminum spontaneously form their oxides. This property can be exploited in anodic spark deposition to create oxides and subsequently specific topography of the base metal. So, titanium surface is oxidized within nanoseconds to provide a thin TiO_2 layer. In general, this TiO_2 layer is considered to be chemically stable.[14]

Titanium oxide blasted and acid etched implants

The specific surface texture is a result of two subtractive, sequential manufacturing steps. Titanium oxide blasting produces the microscale surface roughness. The subsequent etching with hydrofluoric acid shapes the nanostructure of the implant.[15]A pleiotropic manufacturing effect is the accumulation of fluoride on the surface. Fluoride containing surfaces have been hypothesized to propagate the host-to-implant reaction in early osseointegration.[16]Cell studies have demonstrated that the OsseoSpeed surface promotes a branched cell morphology of osteoblasts and an osteogenic gene expression profile as well as osteoinduction and osteogenesis in mesenchymal stem cells compared to TiOblast implants (DENTSPLY Implants, Mannheim, Germany), the titanium oxide blasted precursor.[15]

Recent advancements: Surface coatings

Considering that the biological tissues establish an interface with the materials' surface, the surface modifications (etching, sandblasting, and anodizing) enhance the materials' biological response and osseointegration without affecting the bulk properties. In addition to surface modifications, surface coatings of dental implants using a variety of materials and biomolecules have been explored in recent decades to achieve certain beneficial effects.

Hydroxyapatite coated implants

Hydroxyapatite (HA) is used as a bone substitute because of its innate chemical similarities to natural bone. When an implant is coated with HA, it provides an osteophilic surface, which helps the natural bone affix to the implant. This occurs in part because the coating provides a better textured contact area, and partly because the HA itself has osteoinductive properties that have been shown to increase the activity of osteoblasts; the cells that create bones. Coating an implant with HA can be performed in numerous ways, from plasma spraying, dip coating, electrochemical deposition and more. Plasma spraying is the most widely applied method and has been successfully employed by Himed since its founding in 1991.

Growth factor coated implants

In hemostasis, the first phase of osseointegration, platelets, which have been liberated to the alveolar bone from damaged vessels, degranulate and release specific growth factors that initiate the second phase of osseointegration, the inflammatory phase. These factors comprise platelet-derived growth factor (PDGF).[6]Implants that were coated with recombinant PDGF exhibited enhanced osteogenic differentiation and proliferation in vitro and improved osseointegration compared to control titanium implants in osteoporotic rats.[18]

Extracellular matrix proteins coated implants

The extracellular matrix provides crucial guidance for osteoprogenitor cells that migrate to the implant via interaction of integrins on the cell surface and arginine-glycine-aspartic acid (RGD) motifs of fibronectin. The native extracellular matrix (ECM) happens to consist of a tissue-specific, highly complex network of proteins and polysaccharides which provide structural scaffolding and biochemical cues for surrounding cells, including stem cells. In addition, the main protein components of ECM: collagen, laminin, and fibronectin have substantial impact on tissue-specific stem cell morphogenesis, differentiation, and homeostasis.[19]

Peptide coated implants

A peptide is any of various amides that are derived from two or more amino acids by combination of the amino group of one acid with the carboxyl group of another and are usually obtained by partial hydrolysis of proteins. Particular peptides that facilitate cell adhesion in osseointegration or that exert antibacterial effects have been employed to design novel implant surfaces. 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.[20]

Drug coated implants

Drug-eluting implants are actually active implants that induce healing effects, in addition to their regular task of support. This effect is achieved by controlled release of active pharmaceutical ingredients (API) into the surrounding tissue.[21] The prolonged drug elution from dental implants can be achieved by several techniques for a range of drugs including antimicrobial agents and bisphosphonates to provide targeted drug delivery and therapeutic actions.[22] HA coatings have been successfully used as local drug delivery systems. Statins inhibit the HMG-CoA reductase and are prescribed in dyslipidemia. When incorporated in the implant surface, statins have been claimed to trigger the local liberation of BMPs, thus promoting osseointegration.[23]

Conclusion:-

Alteration of surface topography of dental implant is the most common technique used to achieve long term success of dental implants. By increasing the surface roughness, an increase in the osseointegration rate and the biomechanical fixation of titanium implants have been observed.[24] The surface topography has also been manipulated such as acid etching and blasting onto the surface to get a better topographies which consequently bring better roughness. It is the primary concern of the dentist to minimize the bacterial adhesion and promote the adhesion of the osteogenic cells to achieve the desired osseointegration. Therefore, in order to achieve the desired effects, modifications of surface topography of the dental implant may be rendered necessary.

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