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Review Article

Dental implant design- an insight overview

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ABSTRACT

Dental implants are a proven therapeutic option for replacing missing teeth, with positive long-term health outcomes. Dental implant performance is largely determined by the implant's primary durability, which is affected by surgical procedure, bone quality and quantity, implant surface characteristics, implant geometry, and implant surface characteristics. The implant's geometry and surface can be modified. The implant geometry and surface can be changed if needed to achieve good primary stability and long-term implant therapy effectiveness. Implant architecture refers to the implant's three-dimensional structure, as well as all of the components and elements that make it up. Different surface topographies can affect a sequence of coordinated actions such cell proliferation, osteoblast transformation, and the production of bone tissue. At the macro, micro, and increasingly nano sizes, surface topography of implants may be detected. The surgical location of end osseous oral implants is influenced by the prosthetic architecture, as well as the shape and quality of the alveolar bone. There are several alternatives for replacing missing teeth, but within the past few decades, dental implants have been one of the most common biomaterials for replacing one (or more) missing teeth. In a substantial number of patients, titanium dental implants have been shown to be secure and reliable. This study examines the most important historical information of dental implants, as well as the various vital factors that will ensure successful Osseo-integration and a safe prosthesis anchorage. Not only would Osseo integration improve the predictability of traditional therapeutic protocols, but it would also drastically alter current medical paradigms

Keywords: Dental Implant Design, Osseo integration, Surface Treatment, Tissue-Implant.

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INTRODUCTION

Dental implants provide a good long-term clinical outcome in the oral rehabilitation of missing teeth. The success of the implant is mostly determined by its stability, which is determined by the following factors: surgical technique, bone quality, quantity, implant shape, and implant surface qualities, modified as needed to establish strong primary stability and long-term implant treatment success. The implant's design and material, surface treatments, bone state, surgical technique, and implant loading conditions are all crucial for establishing a successful Osseo integration. The architecture of the implant is linked to its configuration. The implant's and its component's characteristics [1]. Proliferation of cells and bone tissue expansion. The topography of the implant surface can be micro, macro, and now nano-scale.

SCIENTIFIC BASIS FOR IMPLANT DESIGN

Loads must be transferred from dental implants to the surrounding tissue. The regulation of biomechanical stress is influenced by two aspects:

a) Applied force

b) Load distributed over the functional area.

The forces exerted on dental implants can be characterized as follows A) strength of force, b) duration of force, c) Type of force, d) Direction of force, e) Magnification.

Increase in these factors have a certain influence on the selection of the biomaterial and the design of the implant body.

Influence on the design of the implant body

The force type, duration, magnification also influences the design of the implant body are at greater risk of failure due to fatigue.[2] The strength limit of a material is often below half of its maximum tensile strength.

Implant Macro geometry

The macro architecture of dental implants has an effect on the bone response. Teeth, or the edge of the fibers, act mainly as a friction spike when a certain load is applied to them. The amount of surface area required for stress transmission and the initial stiffness of an implant are determined by its form. Surgical placement of smooth cylindrical implants.[3] Threaded implants with circular cross-sections facilitate surgical placement and enable further optimization of the functional surface.[4]

Thread Geometry

The thread design is based on maximizing initial contact. The functional surface can be adapted by varying the following thread geometry parameters[5-7]: (a) thread pitch, (b) thread form, (c) thread depth.

Implant Width

In recent years, the diameter of dental implants has increasingly increased. The scientific theory that raising the width of a dental implant correctly raises the region from which occlusal forces will dissipate is widely followed today. The wider the implant, the more closely it resembles the natural tooth's emergence profile.[8]

Implant Length

The overall surface area of the implant grows as the length of the implant rises. The common axiom in Implantology is to maximize the implant length and engage the opposing cortical bone plate. This approach is used primarily in the anterior mandible, where the forces are less and the bone density is most favorable.[9]

Crest module considerations

The region is considered to be the crest of the body of an implant. It is distinguished by a strongly localized region of mechanical tension. When bone loss has arisen, often implant comb modules are built to minimize plaque build-up. This makes bone preservation difficult in this field. A crest module with a more than 20-degree angle puts a mildly beneficial pressure component on the adjacent bone, reducing the chance of bone loss.[10]

Tissue implant interface[11]

The goal of implant research is to create technologies that induce and speed up the integration of implants with the surrounding tissue. A trans mucosal link between the external environment and interior components is formed when mucous membranes penetrate the mouth cavity.

MACROSCOPIC FEATURES

Thread Geometry

The thread pitch, depth, and configuration or shape all play a part in distribution of implant tension to the surrounding bone.[12]

Thread Pitch

For v-type threads, it's the distance between neighboring thread types measured parallel to the axis, or the number of threads per unit length in the same axial plane and on the same side of the axis.

Thread Depth

This is the distance between the thread's minor and main diameters. When all other parameters stay constant, the thread depth and implant surface area are connected. As the thread depth rises, the implant's surface area grows.[13]

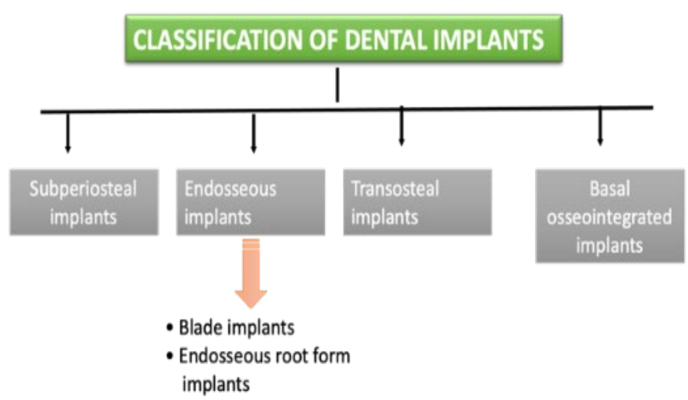
Thread Shape

Thread form is another important part of total thread geometry. Thread forms are crucial in dental design.

Implant surface characteristics

Since In the early 1980s, Albrektsson et al. went on to further develop the idea of Osseo integration by ascribing a probable function for surface properties in the biological response to an implant. Surface characteristics have been increasingly important since then.[14-16] there are a variety of subtractive and additive processes to choose from grit blasting, acid etching using mineral acids, electrochemical anodic oxidation, calcium-phosphate coatings, and numerous combinations of these processes, such as combined grit-blasted/acid etched surfaces, have all been developed and used on commercially available implants.[17-20]

Figure 1. Classification of Dental Implants



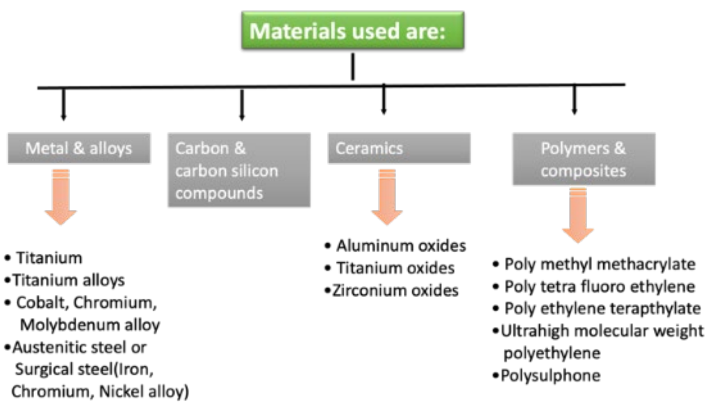
Nano topography

Nano-sized topographical profiles of the adsorbed proteins related to the osteoblasts are found on the implant surfaces. Acid etching of the grit blasted implant surface will improve surface roughness. Enhancing osseous stability by micro and nano surface interaction is one of the key goals. Attempts to improve bone ingrowth (e.g., osteo conduction), improvements in surface topography (that is, surface roughness), and chemically altering the implant surface are among the techniques. Three classes on the basis of quality of implant surfaces were given by Albrektsson and Wennerberg: (1) Mechanical properties, (2) Physicochemical properties, (3) Topographic properties.[21,22]

Implant surface modification

Rapid dental implant advances have resulted in more complicated surface properties from macro to micro to nanometer scales. A variety of methods exist for increasing the surface roughness of the implant: a) Turned surfaces, b) Sandblasted surfaces, c) Acid etched surfaces, d) Sandblasted and acid etched surfaces (SLA), e) Anodized surfaces, f) Plasma sprayed surfaces – titanium plasma spray, g) Sputter deposition, h) Laser modified surfaces[23]

Figure 2: Materials used for Implant placement



Biomaterials can also be classified based on the type of biologic response elicited by them after implantation. Three major types of biodynamic activity reported are:[28,29]

(1) Bioinert, (2) Biotolerant (3) Bioactive

- Bio-inert materials allow contact osteogenesis. Example: stainless steel, titanium, alumina (Al_2O_3), partially stabilized zirconia.
- Bio tolerant materials prevents rejection once implanted into living tissue, but are surrounded by a fibrous layer in the form of a capsule. Example: poly methyl methacrylate and cobalt-chromium (Co-Cr) alloy.
- Bioactive materials promote the production of fresh bone on the implant's surface. Along the implant-bone interface, ion exchange with host tissue creates a chemical bond (bonding osteogenesis). Example: bio-glass, synthetic hydroxyapatite.

Influence of surface topography on soft tissue integration

Changing the surface topography may be done in a variety of ways. The scale of topographical features formed on the implant surface might range from nanometers to millimeters, or from below

Implant surface chemistry and its alteration

Surface energy, Surface charge, and Surface composition are the physiochemical parameters that may be modified to alter the interaction of implants with cells and tissues.

- **Surface Energy**: It is considered as an important factor to guide bone cell adhesion and early-stage bone mineralization in the dental implant-bone interface.[25]
- **Surface Charge**: Both positively and negatively surfaces were found to facilitate bone formation. But the negatively charged are considered being more effective.[26]

Surface Composition: The physical properties of the materials, their surface shape, tissue induction, and their ability to induce an inflammatory or rejection response are all key considerations in this domain.[27]

the scale of cell size to the scale of tissues for protein absorption. The composition of the protein film and the orientation of molecules adsorbed on the implant surface might be affected by surface roughness. Francois et al. - Engraved surfaces (SLA) compared to polished titanium.[30-31] Impact cell and tissue adhesion: - Hormia et al. examined the adhesion and spread of human gingival epithelial cells on three titanium surfaces using immunostaining (electropolished, acid-etched, and sand-blasted). On polished and etched titanium, epithelial cells adhere and disperse more easily than on rougher surfaces (sandblasted titanium).[32,33] The literature on cellular reactions to surface topography is extensive. There have been reports of phenomena, but four cellular actions in the following points may be relevant to the implant interface: [34,35]

1. The mechanism through which directed surface characteristics such as grooves regulate cellular movement is known as contact routing.
2. Cell selection, the process through which surface topographical features such as roughness cause specific cell populations to accumulate preferentially. Macrophages, for example, prefer rough surfaces versus fibroblasts, who prefer smooth surfaces.
3. Cell differentiation in some cases, the differentiation of cells is influenced by the topography of the surfaces with which they are in contact. For example, the production of bone nodules on Ti surfaces with deep grooves is increasing.
4. Matrix organization mediated by cells; traditionally associated to the "two-center white effect," in which extracellular matrix is created as a result of cell traction. Cell and fiber corridors go between two or more connecting centers.

Bone responses to surface topography

1) **Turned surface:** Bone-implant contact increase signifies increased healing around the dental implant. Because of the

inflammation and bone remodeling, biomechanical stability slightly decreases in the initial few weeks, and after 4 weeks becomes fully recovered.[21,36]

2) **Sandblasted surface:** An optimal bone growth is seen as a biological response to blasted implants, when a roughness of 1.5μm is used.[37,38]
3) **Acid-drawn surface:** In multiple investigations, acid-anchored implants had higher bone-to-implant contact than machined implants after 1 and 2 months in a rabbit model, but no differences were detected after 14 days.
4) **Sand blasted and acid etched surfaces :** To unscrew the modified double surface, a higher extraction torque was required than with only acid-etched implants in a 10-week healing a pig model.[41]
5) **Anodized surfaces:** In dogs and rabbits, there is more bone-to-implant contact and biomechanical extraction torque for phosphorus. Compared to machining surfaces, anodized surfaces are more durable. Calcium ions were integrated into the anodized oxide in rabbits to achieve this. There were no statistically significant changes six months after implantation. When it came to the proportion of bone-forming cells, there was a significant difference between the groups.[21,42]

Future prospective of dental implant design and implant surface

The science of Implantology has advanced over the past few decades, and techniques have changed and evolved for the better. The third generation of dental implants is focused on cellular and molecular understanding and information about the biology of the interface. Material surface modifications for damaged tissue conditions. Sandblasting study was hampered by surface runoff and the load distribution on the surface of a traditional dental implant should be of particular concern to researchers. Since a conventional dental implant mimics the complex structure of a screw, studying the load distribution on the surface of the implant should be of considerable importance. To aid Osseo integration, the negative charge on the surface of the dental implant must be maintained. Over time, the electrical charge left on the surface of sandblasted titanium alloys dissipates into the environment. There are two methods for maintaining the negative charge on the surface:

i. Creating a higher number of initial negative charges than is required to allow for natural charge decay until the implant's expiration date, and / or
ii. These approaches must be compatible with the therapeutic charge level at the time the implant is inserted into the patient.

At the moment, a doped surface coating of morphogenetic bone protein will develop, which will gradually be released from the surface and improve the percentage of bone-to-implant contact. Where implants could be unstable, early and easy detection of peri-implant inflammation is expected with the help of biomarkers and enzymes that are released into the peri-implant Sulcular fluid revolutionize the implant maintenance phase and thus increase the overall success of the therapy. Modifications to the implant to increase antibacterial activity can be important to reduce bacterial infection and increase the success of the Osseo integrated implant. Using stem cells in Implantology has several limitations, despite the fact that implants are quite predictable and allow tremendous flexibility in restoring them even in the most complex clinical scenarios. Efforts are being made to overcome these drawbacks and Stem cell technology can be an answer to eradicating them. Studies have shown that stem cell-mediated bone regeneration can be used to treat peri-implant defects. Another technological influence in dentistry will be the use of 3D printing on implants. 3D printed hyperplastic bone shows promise for patients in need of bone grafts for implant placement. This hyper static bone is a combination of bioactive materials and polymers. It can still be layered wet to allow better adhesion between the individual layers. It is more flexible than traditional graft materials and is highly porous, allowing blood vessels to move quickly into the surgical area. Hyperplastic bones are cheap, scalable, and easy to manufacture.

SUMMARY

Dental implants are important tools for replacing missing teeth. Implants come in a range of forms, heights, and are made of a variety of materials with varying surface properties. One of the most desirable properties of an implant is that it allows the tissue implant interface to be simply established and then securely retained. Surface roughness measured in microns. The geometric design of an implant adds to mechanical stability; nevertheless, the type of the implant surface is equally vital for Osseo integration rate. The micro topography profiles of the implants have surface roughness ranging from 1 to 10 microns.

This roughness helps the mineralized bone and implant surface to interlock. The surface roughness of dental implants' nano topographic profile ranges from 1-100 nm. Protein adsorption and osteoplastic cell adhesion influence the rate of Osseo integration. Implants with a rough surface promote both anchoring and biomechanical stability.

There are three types of ways for modifying the surface of implants: chemical, mechanical, and electrical. Despite advancements in implant surface topography, their effect on biological stability and Osseo integration is still unknown. However, research in this field is very active, and in the coming future, many new developments and methods will be implemented.

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