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Implant Surface Characteristics

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KEYWORDS

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ABSTRACT:

Dental implant surface technologies are being developed to improve the reliability of accelerated implant therapy. These technologies encourage quicker bone development on the implant surface, improving primary stability and reducing crestal bone loss. Post-implantation, bone turnover and remodelling occur at the interface, with nano topography surfaces encouraging bone growth. Research shows that bone cells are sensitive to these topographical characteristics, increasing gene expression for new bone production. It's crucial to critically assess claims and incorporate innovations into practice for better patient care. This review delves into the implant surface characteristics in depth and explores the future possibilities of better treatment outcomes through improvement in implant designs.

INTRODUCTION

Dental implants are increasingly used to replace lost or damaged teeth, with life expectancy increasing. Implant design is crucial for achieving primary stability, involving macrostructure and microstructure. Implants can be conical or cylindrical, with some manufacturers offering tapered versions that combine both shapes. Tapered implants improve primary stability by reducing tension at the bone-implant contact. The implant neck, also known as the crestal module, has seen significant improvement due to its role as the interface between hard and soft tissue. Wall designs can be converging, diverging, or straight, with diverging walls providing more primary stability during insertion.

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Pitch and thread design are crucial for maximizing stress distribution and force transfer between implants and bone, increasing surface area for bone contact, and enhancing primary stability. V-shaped and wider square threads are better for reducing stress and spreading loads. Surface characteristics of implant materials, such as microtopography, play a significant role in promoting osteogenesis and long-term survival. Techniques like sandblasting, acid etching, and coating with titanium oxide or hydroxyapatite particles help achieve the ideal level of surface roughness.

IMPLANT DESIGNS

Surface design focuses on improving the long-term performance and seamless prosthesis replacement procedure of dental implants. Factors such as implant form, macro imperfections, and thread presence or absence are crucial. A study by Lan et al. [1] found that screw implants work best with a thread pitch larger than 0.8 mm, while trapezoid-threaded implants showed superior stability and less stress. Threads are essential for long-term viability and stability of dental implants.[2]

SURFACE DESIGN

The osseointegration of titanium implants [3] is significantly influenced by the surface topography of implants, which includes macroscopic, microscopic, and nanometric aspects of the implant surface.

Based on the scale of various surface features, implant surface roughness is divided into three categories: macro, micro, and nano.

Macro roughness: Features that range in size from millimeters to microns are referred to as macro roughness. The shape of the implant—such as threaded screws and macro-porous structures—directly affects it. Through the promotion of mechanical interaction between the rough surface imperfections and the bone, appropriate macro roughness can improve both initial implant stability and long-term fixation. [4]

Micro roughness**:** Usually falls between 1 and 10 microns.

Junker et al. [5] highlighted that an ideal surface topography at the micron level promotes better interlocking at the implant interface and enhanced bone formation.

METHODS OF SURFACE MODIFICATIONS OF IMPLANT SURFACES

Mechanical methods:

The rough or smooth surfaces created by processes including blasting, machining, polishing, and grinding can improve cell adherence, proliferation, and differentiation.

Chemical Methods:

The surface roughness and composition of implants are altered by chemical treatments such as acid or alkali etching, sol-gel procedures, hydrogen peroxide treatment, anodization, and chemical vapor deposition, which increase surface energy.

Physical Methods**:**

Physical methods used for implant surface modification include sputtering, ion deposition, and plasma spraying. While sputtering is used to produce thin layers on implant surfaces, plasma spraying encompasses both vacuum and atmospheric plasma spraying. It is thought that these techniques enhance mechanical qualities and biological activity.

SURFACE TREATMENT METHODS FOR TITANIUM IMPLANTS

Machined Dental Implants (Turned Surface):

The first generation of dental implants were turning surface implants, initially described by Branemark. These implants have surface imperfections that prevent bone interlocking and delay osseointegration. The Branemark procedure improves clinical results by burying the implant and waiting six months for recovery before loading. Surface roughness and bone-implant contact are positively correlated, and HA-coated or oxidized implants are preferred in low bone quality locations.[6]

Etched surface

Titanium implant surfaces are roughened with strong acids. The titanium oxide layer and some of the underlying material are removed by acid etching. More material is removed from the surface with increasing acid concentration, temperature, and treatment time. A solution of HNO_3 and HF or HCl and H_2SO_4 is frequently used to acid etch titanium implants. Acid

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treatment enhances bio adhesion, increases surface area, and produces consistent surface imperfections. [7–8]

Dual-Etched Surfaces

By submerging titanium implants in a solution of strong HCl and H_2SO_4 that has been heated over 100°C for several minutes, a technique known as dual acid etching is used to roughen the surface of implants. By making it easier for osteogenic cells and fibrin to adhere, this method improves osteo conductivity and promotes direct bone production. Dual acid etching is thought to provide a certain surface pattern that enables implants to adhere to the fibrin scaffold, encouraging osteogenic cell adhesion and bolstering bone growth. Additionally, osteoblastic migration along the surface is guided by this fibrin attachment. Dual acid-etched surfaces increased bone-implant contact and decreased bone resorption, according to Cochran et al. [8]

Hydroxyapatite-Coated Surfaces

A hydroxyapatite ($Ca_{10}(PO_4)_6(OH)_2$) coating at the implant-bone contact is regarded as bioactive because of the sequence of events that results in the development of a calcium phosphate-rich layer on the surface through solid solution ion exchange. This layer eventually changes from octa calcium phosphate to hydroxyapatite, which is physiologically equivalent and becomes a part of the growing bone. [9]

Biesbrock and Edgerton [10] state that issues with HA-coated implants include coating failure, bone deterioration, and microbial adherence. Nonetheless, the authors proposed that these implants could be useful in situations requiring rapid bone-implant contact, such as grafted or type IV bone. Furthermore, HA coatings could be advantageous for short implantation. Vercaigne et al. [11] conducted a comparison investigation and found that, although deterioration was also observed, the bone's reaction to the chemical makeup of HA-coated implants had a bigger effect than surface roughness.

Sol-Gel Coated Implants [12,13]

This simple and affordable technique is utilized to apply consistent chemical compositions to large-area and intricately shaped surfaces. The chemical homogeneity of HA coatings can be greatly enhanced by the sol-gel technique.

An analysis of the bone tissue around the implant surface treated with the sol-gel technique revealed better osseointegration with no negative effects in a brief in vivo laboratory trial by Gan et al. [14]

Sandblasted and Acid-Etched Surface (SLA and Modified-SLA) Implants

Large grit particles (250–500 μm) are sandblasted, and then acid etched to generate the SLA implant surface. While acid etching generates micro-irregularities, sandblasting creates macrostructures. [15] After two weeks of healing, modified SLA surfaces demonstrated much higher bone apposition than regular SLA surfaces, according to a histomorphometry research by Bornstein et al. [16] After four weeks, however, the apposition of both surface types was comparable, with an increase in apposition between the two and four-week periods. According to the study, individuals having early loading implant surgeries may benefit from acid-etched modified implants.

Oxidised surfaces

According to Sul et al. [17], anodization is a method of altering surface composition and topography by increasing surface roughness, thickening the titanium oxide layer, and increasing surface area. It has been noted that osteoblast cell adherence to titanium implants is enhanced by this somewhat rough surface.

Fluoride treatment

Ellingsen [18] found that adding fluoride to titanium implant surfaces greatly increased implant retention following four and eight weeks of recovery in an animal investigation. He clarified that titanium and fluoride have a strong reaction to generate TiF4, which improves bone-to-implant contact even with faster healing durations than grit-blasted implants. Furthermore, compared to implants that were grit-blasted, fluoride-modified surfaces showed a higher resistance to removal torque.

Fluoride-modified titanium surfaces increased implant surfaces' biocompatibility, as shown by Lamolle et al. [19]

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Sputter deposition

Sputtering is a vacuum-based process that ejects a material's molecules after it is bombarded by high-energy ions. Hydroxyapatite is frequently deposited onto implant surfaces using techniques including magnetron sputtering and radio frequency sputtering. Vercaigne et al.'s animal research revealed that implants covered with sputtering techniques had greater rates of bone-to-implant contact.[20]

Bioactive drugs incorporated into dental implants

Bisphosphonates

According to experimental research, adding bisphosphonates to implant surfaces can increase the amount of bone surrounding implant locations. [21,22] A major obstacle still exists, though, in getting anti-resorptive medications to release from the implant surface in a regulated manner.

Simvastatin

A drug called simvastatin reduces the formation of cholesterol in the liver by blocking the enzyme 3-hydroxy-3-methylglutaryl coenzyme reductase, which decreases blood cholesterol levels. [23]

According to Mundy et al. [24], simvastatin may encourage bone growth by causing manifestation of the gene for bone morphogenetic protein (BMP-2).

Antibiotic coating

In addition to removing bacteria that contaminate implant surfaces, Herr et al. [25] showed that tetracycline efficiently eliminates the smear layer, encourages cell proliferation, suppresses collagenase activity, and supports better attachment and bone repair.

Despite Junker et al. [26] 's suggestion that there is enough evidence to support rough surfaces for obtaining predictable osseointegration, conflicting findings are presented via systematic reviews, a Cochrane study by Esposito et al. [27] identifies little data, suggesting that smooth (turned) surfaces may be less susceptible to bone resorption

CONCLUSION

Determining conclusive differences across implant surfaces is difficult due to the absence of high-quality randomized controlled studies. To further understand how different surface alteration patterns affect osseointegration and identify the surface properties and combinations that provide the most consistent results, more study is required.

REFERENCES

1. Lan T H, Du J K, Pan C Y, Lee H E, Chung W H. Biomechanical analysis of alveolar bone stress around implants with different thread designs and pitches in the mandibular molar area. Clin Oral Investig 2012; 16: 363–369.

2. Siegele D, Soltesz U. Numerical investigations of the influence of implant shape on stress distribution in the jaw bone. Int J Oral Maxillo facial Implants 1989; 4:443–440

3.Le Guéhennec L, Soueidan A, Layrolle P, Amouriq. Surface treatments of titanium dental implants for rapid osseointegration. Dent Mater 2007; 23:844–854

4. Wennerberg A, Albrektsson T, Andersson B. Bone tissue response to commercially pure titanium implants blasted with fine and coarse particles of aluminum oxide. Int J Oral Maxillofac Implants 1996;11: 38–45.

5.Junker R, Dimakis A, Thoneick M, Jansen J A. Effects of implant surface coatings and composition on bone integration: a systematic review. Clin Oral Implants Res 2009; 20(4): 185–206.

6. Junker R, Dimakis A, Thoneick M, Jansen J A. EffectS of implant surface coatings and composition on bone integration: a systematic review. Clin Oral Implants Res 2009; 20(4): 185–206.

7.MacDonald D E, Rapuano B E, Deo N, Stranick M, Somasundaran P, Boskey A L. Thermal and chemical modification of titanium aluminum vanadium implant materials: effects on surface properties, glycoprotein adsorption, and MG63 cell attachment.Biomaterials 2004; 25: 3135–3146.

8. Cochran D L, Buser D, Ten Bruggenkate C M et al.The use of reduced healing times on ITI® implants with a sandblasted and acid-etched (SLA) surface: early results from clinical trials on ITI and

Journal of Chemical Health Risks

www.jchr.org

JCHR (2025) 15(6), 718-722 | ISSN:2251-6727

SLA implants. Clin Oral Implants Res 2002; 13: 144–153.

9. Ogiso M, Tabata T, Ichijo T, Borgese D. Examination of human bone surrounded by a dense hydroxyapatite dental implant after long-term use. J Long term Eff Med Implants 1991; 2: 235–247.

10.. Biesbrock A R, Edgerton M. Evaluation of the clinical Predictability of hydroxyapatite-coated endosseous dental implants: a review of the literature. Int J Oral Maxillofac Implants 1995; 10: 712–720.

11. Misch CE. Divisions of available bone in implant dentistry. Int J Oral Implantol 1990; 7: 9–17

12, Vercaigne S, Wolke J G, Naert I, Jansen JA. A histological evaluation of TiO2-gritblasted and Ca-P magnetron sputter coated implants placed into the trabecular bone of the goat: part 2. Clin Oral Implants Res 2000; 11: 314–324.

13.Milev A, Kannangara G, Ben-Nissan B. Morphological stability of hydroxyapatite precursor. Materials Letters 2003; 57: 1960–1965.

14. Gan L, Wang J, Tache A, Valiquette N, Deporter D, Pilliar R. Calcium phosphate sol gel derived thin films on porous-surfaced implants for enhanced osteoconductivity. Part II: short-term in vivo studies. Biomaterials 2004; 25: 5313–532

15.Galli C, Guizzardi S, Passeri G et al. Comparison of human mandibular osteoblasts grown on two commercially available titanium implant surfaces. J Periodontol 2005; 76: 364–372.

16. Bornstein M M, Valderrama P, Jones A A, Wilson T G, Seibl R, Cochran D L. Bone apposition around two different sandblasted and acid-etched titanium implant surfaces: a histomorphometric study in canine mandibles. Clin Oral Implants Res 2008; 19: 233–241.

17. Sul Y T, Johansson C B, Röser K, Albrektsson T. Qualitative and quantitative observations of bone tissue reactions to anodised implants. Biomaterials 2002; 23: 1809–1817

18. Ellingsen J E, Johansson C B, Wennerberg A, Holmén A. Improved retention and bone-to implant contact with fluoride-modified titanium implants. Int J Oral Maxillofac Implants 2004; 19: 659–666.

19. Lamolle S F, Monjo M, Rubert M, Haugen H J, Lyngstadaas S P, Ellingsen J E. The effect of hydro-P, structural and chemical changes and the growth of MC3T3-E1 cells. Biomaterials 2009; 30: 736–742

20. Vercaigne S, Wolke J G, Naert I, Jansen J A. Bone healing capacity of titanium plasma-sprayed and hydroxylapatite-coated oral implants. Clin Oral implants Res 1998; 9: 261–271

21. Osse S, Faucheux C, Soueidan A et al. Novel bio-Novel bio-materials for bisphosphonate delivery. Biomaterials 2005; 26: 2073–2080.

22. Kajiwara H, Yamaza T, Yoshinari M, et al. The bisphosphonate pamidronate on the surface of titanium stimulates bone formation around tibial implants in rats. Biomaterials. 2005;26(6):581-587.

23. Goldstein J L, Brown M S. Regulation of the mevalonate pathway. Nature 1990; 343: 425–430.

24. Mundy G, Garrett R, Harris S et al. Stimulation of bone formation in vitro and in rodents by statins. Science 1999; 286: 1946–1949,

25. Herr Y, Woo J, Kwon Y, Park J, Heo S, Chung J. Implant surface conditioning with tetracycline-HCl: a SEM study. Key Eng Mater 2008; 361: 849–852.

26. Junker R, Dimakis A, Thoneick M, Jansen J A. Effects of implant surface coatings and composition on bone integration: a systematic review. Clin Oral Implants Res 2009; 20(4): 185–206.

27. Esposito M, Murray-Curtis L, Grusovin M, CoulthardP, Worthington H. Interventions for replacing missing teeth: different types of dental implants. Cochrane Database Syst Rev. 2007; 17: CD003815.Update in: Cochrane Database Syst Rev 2014; 7:CD003815.