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Different Surface Modifications of Titanium Implant: A Review

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Abstract
Titanium implant surfaces have been modified in various ways to improve biocompatibility and accelerate osseointegration, which results in a shorter edentulous period for a patient. This article reviewed some important modified titanium surfaces. Several methods are widely used to modify the topography or chemistry of titanium surface, including blasting, acid etching, anodic oxidation, fluoride treatment, and calcium phosphate coating. Such modified surfaces demonstrate faster and stronger osseointegration than the turned commercially pure titanium surface. Past literature has revealed most of the surface treatments able to brings a good effect to the dental implants.

Keywords: *Titanium implants ,osseointegration, surface modification, biocompatiblity, corrosion resistance.*

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I. Introduction

Dental implants are devices that are surgically inserted into the maxillary and/or mandibular alveolar bone to restore the missing tooth. Dental implant should have a direct contact with the bone: a phenomenon called osseointegration.[1] Different implant surface modifications have been investigated to improve osseointegration. Modern osseointegrated implants were developed by Branemark and Albrektsson.[2] Surface characteristics determine the long term success of dental implants by providing excellent biocompatibility , faster osseointegration and edentulous period of the patient can be shortened.[3] This review will present the various implant surfaces modifications and how each is achieved.

EVOLUTION

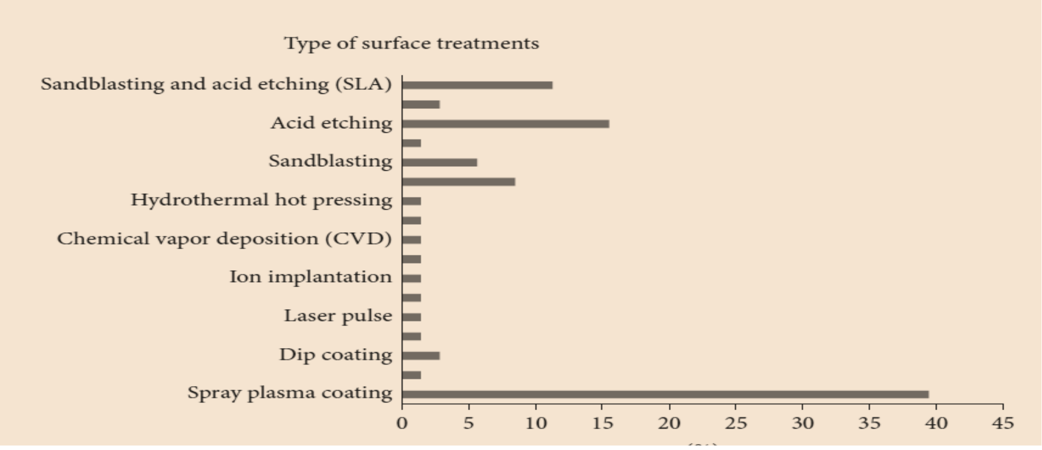
1. First-generation (mechanical surface modification): Surface machine grinding.
2. Second generation (morphological modification): Grooving, sandblasting, chemical acid etching, laser abrasion, and anodic oxidation.
3. Physicochemical active surface (third generation): Hydroxyapatite (HA) coating and chemical treatment.
4. Fourth generation (biochemical active surface): Biofunctional molecules immobilization such as collagen, peptides, and bone morphogenetic protein (BMP).
5. Fifth generation (biological surface): Stem cells and tissues coatings.[4]

Requirements for dental implants surface
Dental implants have several complex interfaces with the host system:
1. The subgingival interface between implant and bone.
2. The transgingival soft tissue interface between the implant neck and gingiva
3. The supragingival and transgingival interfaces between implant abutment and the oral cavity and saliva

TITANIUM IMPLANTS

Titanium is the material of choice for dental implant as its properties met the most important requirements such as excellent biocompatibility,[5] corrosion resistance, high strength, and relatively low modulus of elasticity,[6]good formability, and machinability. Additionally, surface modifications are being utilised on implant surfaces , mainly to improve wettability, cell-implant adhesion and attachment, cell proliferation, and osseointegration, and thus faster healing and shorter treatment duration.

SURFACE MODIFICATION TECHNIQUES



Percentages of commonly used surface treatment for titanium dental implants.

1.Grit blasting

Roughening of the titanium surface can be done by blasting with ceramic particles on implant surface. Various particles including titania, alumina, and calcium phosphate can be used for blasting. Alumina (Al2O3) is the most commonly used blasting particles. Different roughness can be obtained based on particles shape, size and speed at which it is propelled. The surface roughness is usually anisotropic due to the presence of craters, ridges, and enclosed particles on the surface.[7] Implant surface blasting with alumina particles (25–75 µm) produces an isotropic surface (average roughness ∼ 1.1–1.5 µm). Blasting with larger alumina particles (∼250 µm) produced less isotropic surface (average roughness ∼ 2.0 µm and less).[8]The main drawback is that the release of the blasting particles in the surrounding tissues may interfere with osseointegration and decrease the corrosion resistance of the titanium implants. Also, the rough surface tends to accumulate more compared to smooth surfaces.[7]This technique has been modified by further acid etching. [9]

2.Acid etching

Acid etching using strong acids such as nitric acid, hydrofluoric acid and sulfuric acid or their combinations. Acid etching of titanium result in removal of passive layer and exposure of the underlying implant material. The acid concentration, processing time, and temperature influence the amount of implant material removed. [10] Acid etching produces homogeneous surface roughness, activates more surface area, and improves biological adhesion. It has a lower risk of implant surface contamination compared to blasting, as there are no particle remnants on the surface.[11]This surface enhances the migration and retention of osteogenic cells. There is variation in acid etching method between different manufacturers regarding concentration, time, and temperature used. The acid etching treatment form micropits on implant surface [12] and formation of titanium hydrides that are replaced by oxygen and slowing down the transformation of implant surface. In addition, nanosized titanium particles are formed on the surface that favors the adhesion of proteins through the surface nano roughness.[13] Fluoride containing acids have been used for titanium implant surface treatment. Fluoride etching showed improved surface hydrophilicity of titanium implants. Fluoride-modified titanium implants have better substantial bone anchorage compared to unmodified implants following initial healing.[14]The optical interferometer microscopy data of the fluoride-modified implant surface showed a mean surface area roughness of 1.24–1.26 µm.[15]

4.Grit blasting and acid etching combination

Blasting with large particles (∼250–500 µm) is followed by acid etching. This produces micro texture and results in better bone formation compared to each method alone. This technique provides a new hydrophilic chemically activated surface. The sequential grit blasting and alkaline treatment showed improvement in the shear strength, bioactivity and osseointegration in animals.[9]

5. Alkaline treatment

Alkaline oxidation can be achieved by soaking the implant in high alkaline solutions followed by heat treatment. There are several examples of such methods (eg, soaking in 4–5 M) sodium hydroxide solution and heat treatment at 600^{o}C for 24 hours or soaking in boiling alkali solution of 0.2 M sodium hydroxide and heat treatment at 1400^o C for 5 hours). The alkaline treatment can be preceded by acid etching to increase the porosity of the titanium surface.[16]

6. Anodization

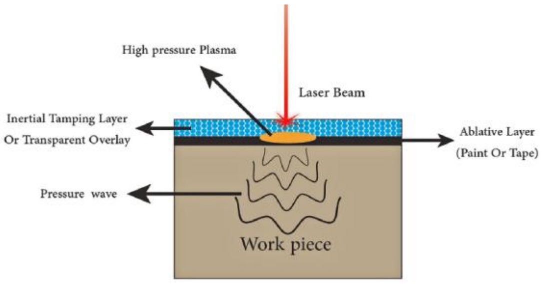
Anodization of implants surface is done by placing a dental implant in the anode side of a galvanic cell with phosphoric acid electrolyte. The surface oxides grow (∼5–10,000 nm). This treatment gives surface roughness range from 0.06 to 12 µm showing micro and nanopores and developed surface area of 37% .[13]The anodized surface shows a surface oxide coating of 2 µm thickness. The implant surface layer also contains phosphorus (5%) in the form of phosphates. The surface morphology could be modified by varying the anode potential, the electrolyte composition, the temperature, and the current. Ions such as phosphorus, Calcium and magnesium can also be integrated into the implant surface via modification of the electrolyte composition.

7.Shot Peening

Surface peening makes plastic deformation causing an alteration of surface mechanical characteristics. It makes the surface more resistant to microcracks propagation and induce nanocrystallization.[17]The high-energy shot-peening (HESP) is a unique technique of cold working used industrially for surface modification. HESP treated titanium implant shows a nanoscale topography with improved roughness and wettability leading to enhanced cellular and biomolecular adhesion. [18]

8. Laser peening

Laser peening is a cold work mechanical process done by laser pulses hitting the surface with high power generating shockwaves. These waves cause plastic deformation on the surface layer and affect subsurface layer by associated dynamic compressive stresses that are decreased from surface to deeper layers .[19]



1. An absorbent layer is coated to the target surface that vaporizes when subjected to short duration pulse pressure forming plasma deposition. Absorbent layer (sacrificial) prevents implant from laser ablation and melting. Different porous materials have been used, such as copper, aluminium, vinyl tape, lead, and zinc.
2. Tamping layer (transparent overlay), it is applied to confine the plasma to the surface, increasing the shock magnitude. This is known as the confining medium. Different media (such as water, glass, or quartz) can be used for this purpose.
3. Finally, once shockwave stresses surpass the metal yield strength, plastic deformation happens. This plastic deformation leads to the multiplication of dislocation movement modifying the metal microstructure and accordingly the metal properties.

Laser peened material undergoes plastic deformation, enhanced material properties (hardness, tensile strength, fatigue strength, and wear-resistance) .[19] Typical requirements for laser peening are Q-switched laser system based on neodymium (Nd) such as Nd-doped glass, orthovanadate, and yttrium aluminium garnet, or ytterbium-doped YAG (Yb:YAG) with a diverse range of laser wavelengths including 1054 nm (infrared), 532 nm (green), and 355 nm (ultraviolet) are used. The shock (laser pulse length) applies a time ranges (10–100 ns), energy (1–100 J per shot), and spot (diameter) of 1–6 mm. Different geometries of the laser spot can be employed such as circular, elliptical, rectangular, and square. The square laser spot shows better uniformity and reasonable overlapping rate .[20]

9.Coatings

Several synthetic and natural agents, such as bioceramics, molecules (e.g., BMP-2) and drugs (e.g., bisphosphonate) with osteogenic potentials or inhibiting osteoclastic activity, have been used for implant coating aiming to enhance osseointegration. Of the bioceramics, HA is one of the most common material due to its bioactivity and biocompatibility .[21]In the 1980s, the first commercially available implant with HA coating was introduced

Conventional 50 μm HA coating on the implant surface can be done with by various methods such as:

1. Plasma spraying: A high-temperature flame that melts and ionizes HA powder partially and coated the surface by spraying. Fluoroapatite is the most stable type of calcium phosphate coating. The HA plasma-sprayed coatings bond by mechanical interlocking with treated implant surface by either grit blasting or modified acid etching. This specific interface between the titanium, oxide layer and the HA coating is considered as a weak link with risk of adhesive failure during insertion or osseointegration.[22]
2. The vacuum deposition technique: It is done by the striking metal target in a vacuum chamber leading to sputtering or ablation of atoms that coats the positioned metal substrate. Examples are ion beam sputtering, pulsed laser deposition, and radiofrequency sputtering.[21]
3. The sol–gel and dip-coating method: It is done by firing the coating (800–900°C) to melt bioceramics carrier to achieve coatings' bonding strength to the implant substrate. The implant is dipped in a bioceramics precursor solution then the implant is withdrawn at a determined time. The implant is then heated to dense the coating .[21]
4. Electrolytic process: Electrolytic deposition and electrophoresis are processes that deposit HA out of the electrolytic cell with a suitable electrolyte solution. It can uniformly deposit HA on the porous surface of titanium and maintain the original composition of the ceramic coat material .[23]

The nanotite implant has been introduced with nanosurface of 20 nm thick hydroxyapatite coat. Microarc oxidation can also create a porous titanium oxide layer of 1–5 μm thickness. This titanium oxide layer has been reported to improve osteogenesis. Nanotitania coatings can also be prepared by sol–gel method. This offer more cell protein binding sites enhancing the bone contact.

II. Conclusions

There are number of commercially available surface modified titanium implants with promising outcome. These surface adjustments have supported the time effectiveness and prognosis of dental implants in different challenging clinical situations. There is a growing research for effective surface treatment for newer implant materials with some promising results and products. The main shortcoming for the current implant surface treatment is the lack of clinical data and requiring plentiful laboratory and clinical research. The future of dental implant will rely on improvement of more efficient, advanced and standardized clinical and laboratory research methodology with well-designed multicenter clinical trials to develop a solid evidence for standardized surface treatment. The increasingly active research on implant material surface improvement allows us to expect development of a smart tailored implant surfaces that can optimize the different adjacent interfaces within few years.

References

[1]. Albrektsson, T., Johansson, C., 2001. Osteoinduction, osteoconduction and osseointegration.Eur. Spine J. 10 (2), S96–S101.

[2]. Albrektsson, T., Branemark, P.I., Hansson, H.A., Lindstrom, J., 1981. Osseointegrated titanium implants: requirements for ensuring a long-lasting, direct bone-to-implant anchorage in man. Acta Orthopaed. Scand. 52 (2), 155–170.

[3]. Cooper LF, Masuda T, Yliheikkila PK, Felton DA. Generalizations regarding the process and phenomenon of osseointegration. Part II. In vitro studies. Int J Oral Maxillofac Implants. 1998;13:163–174.

[4]. Hanawa, T., 2017. Surface treatment and modification of metals to add biofunction. Dent.Mater. J. 36, 533–538.

[5]. S. Vishnu and D. Kusum, "Advances in surface modification of dental implants frommicron to nanotopography," International Journal of Research in Dentistry, vol. 1, pp. 1–10, 2011.

[6]. K.-Y. Hung, S.-C. Lo, C.-S. Shih, Y.-C. Yang, H.-P. Feng, and Y.-C. Lin, "Titanium surface modified by hydroxyapatite coating for dental implants," Surface and Coatings Technology, vol. 231,pp. 337–345, 2013.

[7]. Fouziya, B., Uthappa, M.A., Amara, D., Tom, N., Byrappa, S., Sunny, K., 2016. Surface modifications of titanium implants–The new, the old, and the never heard of options. J. Adv. Clin.Res. Insights 3 (6), 215–219.

[8]. Garg, H., Bedi, G., Garg, A., 2012. Implant surface modifications: a review. J. Clin. Diagn. Res.6 (2), 319–324.

[9]. Goel, M., Mehta, R., Kumar, A., Kumar, V., Bhayana, G., Wadhwa, S., 2014. Implant surface modification and osseointegration—past, present and future. J. Oral Health Commun. Dent. 8.

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

[11]. Braceras, I., De Maeztu, M., Alava, J., Gay-Escoda, C., 2009. In vivo low-density bone apposition on different implant surface materials. Int. J. Oral Maxillof. Surg. 38, 274–278.

[12]. Patil, P.S., Bhongade, M., 2016. Dental implant surface modifications: a review. J. Dent. Med.Sci. 15, 132–141

[13]. Wennerberg, A., Albrektsson, T., 2010. On implant surfaces: a review of current knowledge and opinions. Int. J. Oral Maxillof. Implants 25.

[14]. Ellingsen, J.E., Johansson, C.B., Wennerberg, A., Holmén, A., 2004. Improved retention and bone-to-implant contact with fluoride-modified titanium implants. Int. J. Oral Maxillof. Implants 19.

[15]. Meirelles GC, Santos JN, Chagas PO, Moura AP, Pinheiro AL. A comparative study of the effects of laser photobiomodulation on the healing of third-degree burns: a histological study in rats. Photomed Laser Surg. 2008;26:159–166

[16]. Wen HB, Liu Q, De Wijn JR, De Groot K, Cui FZ. Preparation of bioactive microporous titanium surface by a new two-step chemical treatment. J Mater Sci Mater Med. 1998;9:121–128

[17]. Deng, Z., Yin, B., Li, W., Liu, J., Yang, J., Zheng, T., Zhang, D., Yu, H., Liu, X., Ma, J., 2014.Surface characteristics of and in vitro behavior of osteoblast-like cells on titanium with nanotopography prepared by high-energy shot peening. Int. J. Nanomed. 9, 5565–5573

[18]. Jindal, S., Bansal, R., Singh, B.P., Pandey, R., Narayanan, S., Wani, M.R., Singh, V., 2014. Enhanced osteoblast proliferation and corrosion resistance of commercially pure titanium through surface nanostructuring by ultrasonic shot peening and stress relieving. J. Oral Implantol. 40, 347–355.

[19]. Gujba, A.K., Medraj, M., 2014. Laser peening process and its impact on materials properties in comparison with shot peening and ultrasonic impact peening. Materials 7, 7925–7974.

[20]. Tani, G., Orazi, L., Fortunato, A., Ascari, A., Campana, G., 2011. Warm laser shock peening: new developments and process optimization. CIRP Ann. 60, 219–222.

[21]. Garg, H., Bedi, G., Garg, A., 2012. Implant surface modifications: a review. J. Clin. Diagn. Res.6 (2), 319–324.

[22]. Coelho, P.G., Cardaropoli, G., Suzuki, M., Lemons, J.E., 2009. Histomorphometric evaluation of a nanothickness bioceramic deposition on endosseous implants: a study in dogs. Clin.Implant Dent. Related Res. 11, 292–302.

[23]. Muddugangadhar, B., Shamanna, A., Tripathi, S.S., Dikshit, M.S.D., 2011. Biomaterials for dental implants: an overview. Int. J. Oral Implantol. Clin. Res., 13–24.

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