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The Influence Of Titanium Dental Implant Surface On Osseointegration: A Review.

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ABSTRACT

Succes of dental implants relies amongst other factors, on implant surface as it is known that it helps osseointegration. An important challenge in the field of implantology is development of implant coatings which mimic native bone and therefore increase bone in growth. Pubmed was searched in order to find out novelties regarding dental implant surfaces and success of osseointegration. Forty-nine articles were included which were published. Although various dental implant surface technologies are commercially available, new studies are needed as there are no sufficient data which surface treatment is the most suitable one.
Keywords: dental implant, surface, osseointegration, dental materials

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INTRODUCTION

Decreasing the time needed for osseointegration has always been a big challenge for modern implant dentistry. The main factor which helps to decrease the time needed for osseointegration is the newly developed surfaces being used, as well as their microstructures, in relation to their osseoinductive properties. Furthermore, microroughness such as pits, grooves and protrusions enable osteogenic cells to attach and to deposit bone, resulting in bone-to-implant interface. Some of the manufacturing techniques for obtaining microroughness are machining, acid-etching, sandblasting, anodization, grit-blasting and different coating procedures[1]. Titaniumdental implantsare commonly used for the replacement of lost teeth, but theysometimes present failures due to the infection on surrounding tissues[2]. Several materials are investigated as dental implantcoatings such as bioactive glass and bioactive ceramics, titanium/titanium nitride, carbon, fluoride, bisphosphonates, bone stimulating factors, hydroxyapatite (HA) and calcium phosphate[3].

Hydroxyapatite coatings are still the most biocompatible coatings[3]. The most common coating techniques are plasma spraying and hydrocoating. Recently nanoscale technology has been employed as well[3]. Xuereb et al.[4] performed search of The Cochrane Library, Medline, and PubMed and included 82 articles. The same authors[4] stated that clinical trials are still required to provide compelling evidence-based results for long-term outcomes of different coatings of dental implants. Barfeie et al.[5] performed search on the PubMed/Medline, Scopus and The Cochrane Library databases from 1950 onwards and concluded that roughimplantsurfaces bring better osseointegration compared with smooth surfaces however, results from different studies vary. Last but not least, authors stated[5]that is not clear which combination of differentsurfacemodifications provide a more predictable outcome and that more high quality studies are required to investigate otpimal implantsurfaces.

Therefore the aim of this study was to search Pubmed to reveal which new materials are used for treatment of dental implant surface in order to obtain better osseointegration.

MATERIALS AND METHODS

Pubmed was searched in the last15 years in order to find out novelties regarding dental implant surface and its effect onosseointegration and implant therapy success.

RESULTS

Forty-nine articles upon dental implant surface were included in this review published till 2017.

DISCUSSION

Still, dental implants with better osseointegration abilities as well as antibacterial ones are actively under investigation. The main factor that decreases time for osseointegration are new implant surfaces. Naddeo et al.[6] concluded that rough surface (TriVent), promotes cell differentiation a bit earlier than the TiUnitesurface (one coated with a ceramic layer mimicking native bone), although the latter promotes greater cell proliferation.Gardin et al.[7] reported that the grit-blasted and acid-etched treatment seems to favor the adhesion and proliferation of human adipose-derived stem cells and improve the osteoinductivity of Tidental implantsurfaces.

Friadent plus surface and DENTSPLY Implants (Mannheim, Germay) are manufactured by large grit-blasting, followed by etching in hydrochloric, sulfuric, hydrofluoric and oxalic acid finalized by a neutralizing technique[8]. In a clinical study of 321 patients, Degidi et al.[9] have compared 3 different DENTSPLY implants with the FRIADENT plus surface. One year after placement of 802 implants, there was no significant difference between the testedgroups and overall success rate was 99.6%.

Gomez-Moreno et al.[10] searched PubMed, Science Direct, ISI Web of Knowledge, and the Cochrane base databases to identify articles published between 1999 and 2013 on melatonin use inimplantdentistry. Melatonin has antioxidant properties and ability to detoxify free radicals, therefore melatonin may inhibit bone resorption. Ten articles were selected. The same authors[10] suggested that topical application of melatonin increased bone-to-implantcontact values and new bone formation, therefore improving long-term survival and success of dental implants.Beolchini et al.[11] reported on dogs that fluoroboric acid treatment of titaniumimplantsurfaces resulted in improved osseointegration after 3 months. The same authors[11] used fourimplantswith different surfaces; one basicsurface(ZirTi®) was sandblasted with zirconium microspheres and acid etched additionally with hydrofluoric acid. A secondsurfacewas treated with fluoroboric acid instead of hydrofluoric acid. The remainder of the other two surfaces was additionally treated with H_2O_2.Razavi et al.[12] showed that thesurfacecoating of magnesiumimplantwithfluoridated hydroxyapatite may improve the biocompatibility of theimplant.It is thought that nanotopography of dental implants influence cell-implant interactions resulting in increased adhesion of osteogenic cells[13]. Descrete Crystalline Deposition is process when calcium phosphate (CaP) particles of 20-100 nm are deposited on a double acid-etched surface increasing the roughness up to 50% of the surface area rather than former techniques of CaP deposition[14]. Of 139 NanoTite (BIOMET 3i, Palm Beach Gardens, FL, USA) implants placed in 42 patients, 112 were inserted in the maxilla and 27 implants in mandible.

Implants were inserted in an immediate loading approach and after 1-year survival rate was 99.4% and the mean marginal bone resorption was 1.01 mm[15]. Liu et al.[16]suggested that porous tantalum is highly corrosion-resistant and biocompatible, therefore it can boost the proliferation and differentiation of primary osteoblasts i.e. it can allow bone ingrowth and establish osseoincorporation.Ko et al.[17] suggested that sandblasted and acid etched surface with anchored tetracalcium phosphate particles as a physical anchor on the implants surface accelerates bone mineralisation. Fischer et al.[18] conducted a prospective clinical trial on 24 patients with edentulous maxillae treated with full-arch prostheses which were supported by 139 sandblasted implants. A 10-year implant survival rate was 95.1% and a mean bone loss of 1.07 mm[18]. Similar results was seen in theretrospective study on 303 partially edentulous patients treated with 511 sandblasted implants[19]. The same authors reported a 10-year implant survival rate of 98.8% with low rate of peri-implantitis which amounted to 1.8%[19]. Cochran et al.[20] conducted a multicenter study on 120 patients treated with 385 sandblasted implants in an early loading protocol. After 5 years success rate was 98.8% and a cummulative survival rate was 99.1%. Further, Lixin et al.[21] reported a cummulative 4-year survival rate of 99.2% in a retrospective study on 40 edentulous patients treated with 353sandbalsted implants.Chen et al.[22] added osteogenic growth peptide and fibronection within mineral which was formed on titanium through adsorption and coprecipitation methods, and concluded that this improved osseointegration. Shizhen et al.[23] used electrolytic etching in order to produce micro-nano dimensional titanium surfaces which in turn exhibited higher adhesion and proliferation of osteoblasts when compared to the mechanical ones. Albertini et al.[24] suggested that a newsurface-recently obtained by thermochemical processes- produces, by crystallization, a layer of apatite with the same mineral content as human bone that is chemically bonded to the titaniumsurface. Therefore the same authors[24] concluded that thissurfacecan be an excellent candidate for immediate or early loading procedures. Simion et al.[25]performed study on dogs and concluded that within the limits of this study, it can be stated that osseointegration follows a similar healing pattern with machined and oxidizedimplant surfaces. Manfro et al.[26] performed study on 45 implants which were placed in different kinds of bones in humans and concluded that anodizedsurfaceimplantspresent primary osseointegration after 60 days of healing, after which they can function normally. Moreover, only one implant failed to osseointegrate.Mishra et al.[27] performed review of the literature regarding the anodized implantsurface, bone response and their clinical success. Out of 215 included articles, 47 were human studies. Their literature search found favorable results in terms of clinical success rateof anodized implantsurface in compromised bone and immediately extracted sockets.

In electrochemically modified TiUnite (Nobel Biocare Holding AG, Zurich, Switzerland) implants, the thickness of the TiO_2 layer increases to 600-1000 nm. This type of surface have been shown to predispose adhesion, proliferation and extracellular matrix deposition of human gingival fibroblasts[28]. Increased bone-to-implant contact of TiUnite microimplants were reported in study of Ivanoff[29]. The 5-month survival rate for TiUnite was 100% and for control group was 96.4% in the clinical study of 394 implants inserted in 136 patients[30].

The surface of OsseoSpeed implant (DENTSPLY Implants, Mannheim, Germany) is developed by titanium oxide blasting and etching with hydrofluoric acid. It has been hypothesized that fluoride containing surfaces propagate the host-to-implant reaction in early osseointegration[31]. Mertens and Steveling[32] have investigated clinical outcome of 42 OsseoSpeed implants inserted in 15 patients. After 5-yearsof follow-up, overall survival rate was 97% and the mean marginal bone loss was 0.1 mm. Similar results have been reported in theprospective clinical study by Raes et al.[33]. A 1-year survival rate of immediately provisionalized OsseoSpeed implants inserted in 48 patients was 98%. Further, Collaert et al.[34] conducted a prospective clinical trial of 25 edentulous patients. Each patient was treated with 5 OsseoSpeed mandibular implants.

After 2 years, mean marginal bone loss was 0.11 mm and overall survival rate was 100%. However, it is important to emphasize that, despite the favorable results of these studies, none of them had a control group.Lee et al.[35] performed study on rabbits and reported that TiO_2 nanotube arrays that were fabricated by two-step anodic oxidation could potentially be used as a reservoir for recombinant human bone morphogenetic protein 2 to reinforce osseointegration on the surface of dental implants. They were compared with machined surface, sandblasted large-grit and acid-etched surface of dental implants and showed better osseointegration. Study of Salou et al.[36]showed that the nanostructured surfaces (nanotubes measuring 60 nm in diameter on both S-NANO (roughness: 0.05 µm) and R-NANO (roughness: 0.40 µm) surfaces) improved osteointegration similar or higher than the microsurface (typical random cavities (roughness: 2.09 µm). Buxadera-Palomero et al.[37]reported that the polyethylene glycol-like antifouling coating obtained by plasma polymerization on Ti might serve in dental applications, as it reduces the possibility of infection while allowing the tissue integration around the implant.

Modification of nanotopography which develops micro- and nanoscale microchannels is laser ablation. These microchannels act as a biologic seal inhibiting epithelial downgrowth and by eliciting the attachment of connective tissue and bone[38]. The Laser Lok implants (BioHorizons, Birmigham, AL, USA) have been processed in laser micromachining step to generate a pettern to the implant collar. Pecora et al.[39]conducted controlled clinical trial on 15 patients. Twenty Laser-Lok implants were inserted and clinical parameters were evaluated. Control implant with conventional machined collar was inserted adjacent to the test implant. The results of the mean probing depth and the mean crestal bone loss suggested the development of connective tissue around Laser-Lok implants compared to the control implants. 2-year survival rate of 96.1% for Laser-Lok implants have been reported after immediate loading in study of Farronato[40]. Further, beneficial results regarding microtextured implant collars have also been reported in the studies[41, 42].Yoo et al.[43]studied histomorphometric, biomechanical, and histological bone response to acid-etched (AA) in comparison with grit-blasted/acid-etched (GB) and machined control (C) implants within sites of relatively low-bone remodeling rates. The same authors[20]concluded that improved bone-to-implant response was observed for the acid-etched (AA) implant surface.Last but not least, Jemat et al.[2] found within published studies that an acid etched surface-modified and a coating application on commercial pure titanium implant was most preferable regrading the good surface roughness.Therefore, the same authors[3] concluded that a combination of a good surface roughness and mechanical properties of titanium could lead tosuccessful dental implants.

Another important aspect of osseointegration is surface wettability or hydrophilicity. It is believed that, this chemical property promote differentiation and maturation of osteoblasts, thus accelerating the osseointegration[44]. The high surface energy of hydrophilic SLActive dental implants (Straumann Holding AG, Basel, Switzerland) is sustained by hydrated surface which minimizes absorption of hydrocarbons and carbonates from air[45]. Wennerberg et al.[46]compared SLActive implants to sandblasted implants with early loading protocols in 20 irradiated patients. After 1-year period of follow-up overall survival rate for SLActive and sandblasted implants were 100% and 96%, respectively. They also recorded low crestal bone loss in both groups without significant difference. TiGrade IV and TiZr small-diameter implants with SLActive surface were studied in randomizedcontrolled trial by Al-Nawas et al[47]. After 1-year survival rates for Ti Grade IV and TiZr were 97.8% and 98.9%, respectively.

Further, UV light enhances bioactivity and osseointegration of dental implant surface by altering the titanium dioxide. Up till now there are limited data on photofunctionalized dental implants. The results of two publications (one case series and one retrospective study) indicate improved bioactivity and increased osseointegration when UV treatment is applied on the implant surface[48, 49].

CONCLUSION

Various designs of dental implants representing different geometries and surface technologies are commercially available for treatment option. However, new studies are needed as there are no sufficient data which surface treatment is the most suitable one.

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