ADVANCES IN SURFACE TREATMENT OF DENTAL IMPLANTS: A LITERATURE REVIEW

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RESUMO

Amplamente utilizados para substituir dentes perdidos, os implantes dentários nos últimos anos vêm apresentando tecnologias como superfícies com micro e nanotopografia e ajustes nas composições químicas, dentre outros, para melhorar a osseointegração e reduzir o prazo de tratamento, permitindo, assim, carga funcional imediata ou precoce em pacientes com densidade óssea reduzida. Vários métodos são aplicados com intuito de modificar a superfície do implante, como jateamento com areia, corrosão ácida, oxidação anódica, tratamento com flúor, usinagem, pulverização de plasma de titânio e revestimento de fosfato de cálcio; esses métodos podem aumentar notavelmente a área de superfície quando operada a técnica adequadada de modificação, quer por procedimento de adição ou subtração. Tais modificações promovem superfícies rugosas, as quais aumentam a porcentagem de contato osso-implante (BIC) durante o processo de cicatrização óssea inicial. Os principais benefícios da modificação da superfície são melhorar a molhabilidade (hidrofilicidade), adesão e fixação de células a implantes e proliferação celular. Dentre os tratamentos de superfície de implantes dentários destaca-se o jateamento de areia com granulação grossa e ataque-ácido com HCL/H2SO4 (SLA) em altas temperaturas, o revestimento de superfície do implante com hidroxiapatita, oxidação anódica e o duplo ataque ácido. O objetivo deste trabalho é realizar uma revisão de literatura discutindo a importância e eficácia desses métodos para a osseointegração e, por conseguinte, para a redução do período de tratamento.

Palavras-chave: Osseointegração; Implantes dentários; Superfície; Modificação

ABSTRACT

Widely used to replace lost teeth, dental implants have been presenting technologies such as surfaces with micro and nano topography and adjustments in chemical compositions, among others, to improve osseointegration and reduce treatment time, thus allowing immediate or early functional load in patients with reduced bone density. Several methods are applied to modify the implant surface, such as sandblasting, acid corrosion, anodic oxidation, fluoride treatment, machining, titanium plasma spraying, and calcium phosphate coating; these methods can notably increase the surface area when the appropriate modification technique is operated, either by the addition or subtraction procedure. Such modifications promote rough surfaces, which increase the percentage of bone-implant contact (BIC) during the initial bone healing process. The main benefits of surface modification are to improve wettability (hydrophilicity), adhesion and attachment of cells to implants, and cell proliferation. Among the surface treatments for dental implants, sandblasting with large grit and acid-etching with HCL/H2SO4 (SLA) stands out at high temperatures. The surface coating of the implant with hydroxyapatite, anodic oxidation, and double acid-etching. This work aims to conduct a literature review discussing the importance and effectiveness of these methods for osseointegration and, therefore, for reducing the treatment period.

Keywords: Osseointegration; Dental Implants; Surface; Modification

INTRODUCTION

In 1965, Brânemark and colleagues introduced the term osseointegration to describe the successful result of bone-implant integration. Implant stability in the early stages is one of the most critical factors that affect osseointegration (ALMASSRIHNS, ET AL. 2020). In recent years, implant surface technologies with micro nanotopography, compositions, macroscale implant designs, loading protocols, and new surgical procedures have been introduced to improve osseointegration and reduce treatment time, allowing immediate or early functional loading in patients with reduced bone density (SARTORETTO SC, ET AL. 2020).

Once the implant placement is done in a bone site, a cascade of biological events is initiated. First, osteoconduction occurs, which implies the recruitment and migration of osteogenic cells to the implant surface. Then, the new bone formation occurs, resulting in a mineralized matrix interface arrangement, followed by a bone remodeling process. This phenomenon can be influenced by the surface's microtopography (MISCH CE, ET AL. 2009). Many methods are widely used to modify the implant surface, such as sandblasting, acid corrosion, anodic oxidation, fluoride treatment, machining, titanium plasma spray, and calcium phosphate coating; these methods can increase the surface area when the appropriate modification technique is operated, either by the addition or subtraction procedure. The main benefits of surface modification are to improve the hydrophilic capacity, adhesion, and attachment of cells to implants and cell proliferation (CALVO-GUIRADO J, ET AL. 2015; JEMAT A, ET AL. 2015; ALMASSRIHNS, ET AL. 2020).

Currently, nanoscience technology has allowed investigating tissue interactions of biomaterials with roughness variations at the nanometer level of resolution; such an advance is significant since rough surfaces increase the percentage of bone-implant contact (BIC) initial bone healing process. Rough-surface implants are found by modifying the surface of conventional implants, as mentioned above. The sandblasting with large grit and acid-etching with HCL/H2SO4 (SLA) in high temperatures stands out to promote an active surface area, roughness, greater cell adhesion, and improved performance osseointegration. In this sense, among calcium phosphates, hydroxyapatite is used as an implant surface coating material; its nanostructured form increases the bond strength between titanium/bone and the rate of osseointegration in addition to reducing the duration of the treatment period, especially in patients whose bone quality is lower (MEIRELLES L, ET AL. 2007; MISCH CE, ET AL. 2009; NAMGOONG H, ET AL. 2015; SMEETS R, ET AL. 2016; SOHN SH E CHO SA. 2016; PANG KM, ET AL. 2015; SARTORETTO SC, ET AL. 2020).

Among the several approaches to improve the initial response of osteoblasts and osseointegration of implant materials, anodic oxidation has attracted a lot of attention. Dental implants with a moderately rough surface created by anodizing were introduced in the year 2000, under the name TiUnite (TiU), a trading name of Nobel Biocare; this electrochemical method is easily carried out in aqueous/organic electrolyte containing fluoride ion, with a constant voltage application on the titanium specimens. The resulting surface presents micropores with variable diameters, demonstrates the absence of cytotoxicity, and increases protein adsorption, in addition to the accumulation and activation of platelets with fibrin retention; being an economical, simple, and versatile technique (MISCH CE, ET AL. 2009; MISHRA S, ET AL. 2017; LI Y, ET AL. 2019; MARENZI G, ET AL. 2019). Another chemical treatment of great relevance to improving dental implant surface is the double acid-etching, which consists of immersion in hydrofluoric acid (HF), and, subsequently, in a second conditioning step, it is carried out with a solution of HCL and HF by 30 minutes, with a pneumatic stirring to remove the bubbles of hydrogen generated during the chemical reaction. The acid attack on a titanium surface can also be bathed in different combinations with hydrochloric acid (HCL), sulfuric acid (H2SO4), HF, and nitric acid (HNO3). The literature includes many methods for modifying the roughness and surface area of the implants, which can increase cell proliferation, bone regeneration and, further, improve the healing periods in the short and long term (MISCH CE, ET AL. 2009; LARIO J, ET AL. 2018; SARTORETTO SC, ET AL. 2020).

METHODOLOGY

A search was carried out in the PubMed / MEDLINE, SciELO, and BVS databases to identify potentially relevant studies, using the combination of the keywords: implant surface, anodic oxidation, SLActive, hydroxyapatite, and double acid-etching; the inclusion criteria were articles in English and Portuguese between the years 2015 and 2020, and the exclusion criteria were articles that did not provide the abstract. After applying the inclusion and exclusion criteria of a total of 6,912 papers, 28 articles were selected. Also, a selection was made of the articles about the surface of dental implants on which Nobel Biocare and Straumann SLActive were based.

LITERATURE REVIEW

To increase the clinical longevity of titanium (Ti) based on dental implants, modify their topography, and improve the initial response of osteoblasts and osseointegration, many biomaterials have been used on their surface (JEMAT A, ET AL. 2015; LI Y, ET AL. 2019). These modifications can be carried out by ion implantation procedures or controlled chemical reactions (MISCH CE, ET AL. 2009). The clinical success of oral implants depends on the compatibility of surgical biomaterials with tissues, the human host (MISCH CE, ET AL. 2009; LARIO J, ET AL. 2018), and osseointegration rates (JEMAT A, ET AL. 2015; REZENDE DE JESUS RN, ET AL. 2017). Studies show that individual results are found in different follow-up periods and specific parameters (SENER-

YAMANER ID, ET AL. 2017). Therefore, it is important to know each surface's properties, topography, and integration with the tissue.

Blasting followed by acid attack

Recently, a modification was made to a titanium surface to improve bone apposition using sandblasting, large granulation, and acid conditioning (SLActive) (SENER- YAMANER ID, ET AL. 2017). In this modified technique, the titanium surface undergoes the corrosion process under nitrogen protection. It is rinsed and then adequately stored continuously in an isotonic solution of sodium chloride (NaCl) to avoid possible carbon compounds depositions (DARD M, ET AL. 2016). From this modification, it was observed that the surface started to have an exceptionally hydrophilic character due to the initial contact angle with water being 0° (PARK SH, ET AL. 2016; SENER-YAMANER ID, ET AL. 2017). Pre-clinical data pointed out some differences when comparing the SLActive surface and the conventional SLA, such as significantly greater bone-implant contact, bone filling, and removal torque; clinical data, on the other hand, showed greater stability of the modified implant (DARD M, ET AL. 2016). Besides, it has been demonstrated in pre-clinical and clinical studies that implants with hydrophilic surfaces tend to have more significant cell differentiation and aggregation, considerably expanding bone-implant contact (BIC), especially at the beginning of healing (VELLOSO G, ET AL. 2019).
Hydroxyapatite coating synthetic

Hydroxyapatite (HA) is a non-inflammatory, non-toxic, and non-immunogenic material (LEE J, ET AL. 2019). Its excellent chemical compatibility with inorganic components of human bone is an excellent promoter of bone formation (PANG KM, ET AL. 2015; DE LIMA CAVALCANTI JH, ET AL. 2019; LI Y, ET AL. 2019;). It is observed that the HA coating is also capable of decreasing the corrosion index of the substrate alloys (MISCH CE, ET AL. 2009). It has been demonstrated that the use of nanostructured HA has more effective mechanical properties than the conventional one (PANG KM, ET AL. 2015) in addition to being able to provide several benefits to the surface of the titanium implant, such as increased bond strength between the implant and bone and the reduction of the treatment period even in conditions with unfavorable bone quality (SARTORETTO SC, ET AL. 2020). In vitro studies demonstrate a significant improvement in the adherence of mesenchymal stem cells, increased alkaline phosphatase activity, and expression of osteopontin mRNA on surfaces of HA-coated implants when compared to the control group of sandblasted surfaces / acid attack (NAMGOONG H, ET AL. 2015). In vivo studies demonstrate increased roughness and increased bone mineral density on implant surfaces coated with nanostructured HA (PANG KM, ET AL. 2015).

Anodizing

Anodizing is an economical, simple, and versatile electrochemical method capable of producing nanostructured, organized, and controllable surfaces (LI Y, ET AL. 2019). Also, studies demonstrate that, when produced by anodizing, structures of titanium dioxide (TiO2) nanotubes present benefits related to the proliferation and differentiation of osteoblasts (LI Y, ET AL. 2019). In vivo studies have observed that oxidized surfaces interact better with bone tissue than flat surfaces, as rough surfaces tend to induce more stable interactions with bone tissue than flat surfaces (HAN CH et al. 2019). During the initial healing process, there is an increase in protein adsorption, the accumulation and activation of platelets with fibrin network; however, there may also be an accumulation of plaque since the surface may eventually become rugged in the oral cavity, leading to peri- implanting (MISHRA S, ET AL. 2017).

Double acid-etching

It consists of a chemical treatment on metal surfaces that uses, either alone or together, hydrofluoric acid (HF), nitric acid (HNO3), and sulfuric acid (H2SO4) (JEMAT A, ET AL. 2015). The objective of this technique is to change the roughness of the dental implant surface (JEMAT A, ET AL. 2015), ensuring a surface with micro-roughness topography (LARIO J, ET AL. 2018), as well as reducing and eliminating possible contaminants such as iron (MISCH CE, ET AL. 2009). Studies show that the double acid-etching improves osseointegration rates and has better compatibility compared to other surface modification techniques (LARIO J, ET AL. 2018).

DISCUSSION

Osseointegration is the goal of any implant treatment. The composition of the alloy used, the installation technique, the receiving bed, the systemic conditions of the individual, and the material's biocompatibility are decisive factors in the result of the treatment. (ALMASSRI HNS, ET AL. 2020; SARTORETTO SC, ET AL. 2020)

To increase the chances of success, changes to the microscopic part of the surface of dental implants were made so that the metal oxide layer became more attractive to interactions with the biomolecules present in the bone tissue of the recipient individual. (MEIRELLES L, ET AL. 2007; MISCH CE, ET AL. 2009; NAMGOONG H, ET AL. 2015; SMEETS R, ET AL. 2016; SOHN SH E CHO SA. 2016; PANG KM, ET AL. 2015; SARTORETTO SC, ET AL. 2020)

Microscopic changes on the titanium surface cause an increase in the surface area, enabling more excellent cell adhesion to the surgical bed. The increased surface roughness of the implant increases its wettability, positively affecting the protein adsorption capacity and facilitating the initial clot's stability. It also provides an ideal site for anchoring and growing cells that form neoformed bone tissue, desired for stable osseointegration. (MEIRELLES L, ET AL. 2007; MISCH CE, ET AL. 2009; NAMGOONG H, ET AL. 2015; SMEETS R, ET AL. 2016; SOHN SH E CHO SA. 2016; PANG KM, ET AL. 2015; SARTORETTO SC, ET AL. 2020)

One of the most used surface treatments is blasting, acid attack (SLA), and double acidetching. In these treatments, the titanium's surface becomes roughened by decreasing the material of a corrosive treatment. (SENER-YAMANER ID, ET AL. 2017) In the case of surface treatment with hydroxyapatite (HA) coating, this increase in surface area is due to material addition. On the other hand, the anodizing method consists of producing surfaces with micro-roughness also able to provide a suitable site for the incorporation of cells. (LI Y, ET AL. 2019; HAN CH, ET AL. 2019; MISHRA S, ET AL. 2017)

Regardless of titanium's surface topography, its macroscopic characteristics are not sufficient to induce bone growth in a short period. Thus, the surface mentioned above treatments is responsible for improving the biological response to the installation of a dental implant. The increase in bone-implant contact surface caused by such treatments contributes positively to long-term success in osseointegration and is fundamental for all treatments with implants. (SENER-YAMANER ID, ET AL. 2017 VELLOSO G, ET AL. 2019; MISHRA S, ET AL. 2017; SARTORETTO SC, ET AL. 2020).

CONCLUSION

There are an extensive number of implant surfaces available and all of them claiming to improve clinical results. Based in the state of the art of surfaces in Implantology, the development of surfaces with biomimetic capacity which modulated new bone formation around the implants are the mainly challenge to researchers.

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