Review Article

The Recent Micro Surface Treatment of Dental Implant VS The Primary Stability and The Osseointegration

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Abstract

Implants designs are currently available in a range of lengths, surfaces, body designs, and platform connections. As a consequence, dental implants are superior complexity and high requirements, and as a result, the performance criteria are quite demanding. Through osseointegration, dental implants are designed to achieve primary mechanical stability and develop a strong bone-implant relationship throughout time. The main objective of this study is to review Recent Micro Dental Implant Designs modifications and their effect on osseointegration and to determine the types and important aspects of micro designs of dental implants. A review was performed using the National Library of Medicine, Washington DC (MEDLINE–PubMed) searched for appropriate articles addressing the focused objective to find studies on this topic that included simulated laboratory models, animal studies, and human studies. Articles that were published within the last 22 years; conducted at least in MENA, Europe, or North America regions; indexed on either Wiley Online Library, PUBMED, BiblioMed, or, Google Scholar; were included. Articles written in any language other than English were automatically excluded. Multiple research projects have shown that if the implant surface is changed, osseointegration occurs more quickly and strongly. Surface modifications such as anodizing the implant surface, adding calcium ions, carbon-ion oxygen, strontium-containing hydroxyapatite layer created by micro-arc oxidation, and other additives have been demonstrated to improve osseointegration.

Keywords: Micro designs, Microscopic, Osteointegration, Etching, Surface roughness, Implant geometry

Introduction

Modern dental implants have been recognized as an effective therapeutic option for the replacement of missing dentition. The number of manufacturers and designs obtainable in the dental implant market has recently increased dramatically [1]. Implants designs are currently available in a range of lengths, surfaces, body designs, and platform connections [2]. As a consequence, dental implants are superior complexity and high requirements, and as a result, the performance criteria are quite demanding. Through osseointegration, the micro surface treatment of the implant play a key role in the steadiness of the implant and launching of the bone implant relation throughout time [3]. The micro surface designs of dental implants vary by manufacturer. The evolution of implants was targeting the morphology of the surface, to increase the BIC by expanding the accessible area facing the bone. Several studies have found that surface characteristics including roughness, wettability, electric charge, or chemical composition can influence adhesion, proliferation, and cell differentiation [4]. Dental implant materials when implanted in the body, it triggers a biological reaction that is mediated by the implant's surface interface [5]. The differences in the surface design either through the topology, hydrophilicity, chemical composition coating, or antibacterial capabilities have been linked to enhancing bone formation. However excessive modification has deleterious consequences on the maturity of the osteogenesis process [6]. Etching is one of the most commonly used chemical procedures to treat the implant surface to control the corrosion of the implant. Mechanically, dimples on the surface of the implant with a diameter of 1.5–2 μ which enhance osseointegration by aggregating the surface area for the bone attachment [7].

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How to cite this article: Qutub O, Kayal RA, Almutairi O, Alqazlan A, AlSakakir A, Althawab I, et al. The Recent Micro Surface Treatment of Dental Implant VS The Primary Stability and The Osseointegration. Arch Pharm Pract. 2022;13(S1):9-14.

Chemical coating of the interface part of the implant creates a biologically active area improving interaction with the bone [7].

Objectives

To review the recent micro dental implant design modification and their effect on primary stability/staidness and osseointegration.

Materials and Methods

A review was performed using the National Library of Medicine, Washington DC (MEDLINE–PubMed) searched for appropriate articles addressing the focused objective to find studies on this topic that included simulated laboratory models, animal studies, and human studies. Articles that were published within the last 22 years; conducted at least in MENA, Europe, or North America regions; indexed on either Wiley Online Library, PUBMED, BiblioMed, or, Google Scholar; were included. Articles written in any language other than English were automatically excluded. The following keywords were used: “micro designs”, “microscopic”, “osteointegration”, “etching”, “surface roughness”, “implant geometry”, “primary stability”, “implant coatings”, “chemical composition” and the results were correlated. The most important studies were chosen based on their study design (e.g., prospective double-blinded, cross-sectional, case reports), sample size, and statistical analyses.

Data Collection

The studies were chosen using a “three-step examination. “All relevant literature titles and abstracts were examined in the first step, taking into account the study’s inclusion/exclusion criteria. The whole text of the selected publications was studied, analyzed, and rated in the second step, using the same criteria as before. The third phase involved subjecting the selected relevant studies to a critical appraisal to determine the quality of each article. For greater accuracy and convenience, each study was assigned a unique ID number. Information was separated into two groups from each of the clinical and laboratory studies: (Ia)Title (IIa) Author (IIIa) Year (IVa) Journal (VA) Institution (VIa) Region.

Data Grouping and Filtering

All data were filtered and double-checked after the traditional data extractions to eliminate any human or systemic errors. Following that, filters were applied to the data sheets, and the data was organized by tooth.

Results and Discussion

Acid-Etched Surfaces

Making pits in the implant surface with acid etching allows for bone ingrowth. Several factors can affect the surface of an etched implant, including the type of acid, the temperature of the treatment, and the time of treatment. The etching forms irregularity on the implant surface at a range of 0.5–3 μ [8]. Klokkevold and coworkers demonstrated the efficacy of acid etching alone in improving osseointegration through the micro holes that contribute to bone interlocking. The SLA surface treatment is a common method to improve the contact surface for osseointegration [9]. The etched-treated implants show longer survival rates regardless of the length. Research showed; if a rough acid-etched implant is utilized in conjunction with the right procedures, it can Osseo integrate and produce predictable results [10].

Bioactive Drugs Incorporated Dental Implants (Bisphosphonates, Simvastatin, Antibiotic Coating, and Synthetic Peptide Coating)

Bioactive materials enhance the proliferation of bone cells toward the implant surface promoting osseointegration [11]. Bisphosphonates are extensively used as anti-catabolic compounds that lower osteoclast activity and result in lower bone turnover, greater bone mass, and better mineralization [12]. Antimicrobial peptides (AMP) are a promising coating biofilm on titanium dental implants improving the antibacterial action and osseointegration capabilities. Moreover, adding strontium and silver to the implant titanium’s surfaces promote good cytocompatibility with an antibacterial activity that hastens osseointegration [13].

Coating by the osteoinductive proteins (BMPs) mends the role of osteoblast to promote osseointegration that prolongs implant longevity. The methods for modifying and incorporating coatings into the implant surface are time-consuming and costly. Furthermore, biocompatibility and osseointegration qualities may be compromised in the pursuit of optimum antibacterial capabilities. The balance will always be crucial in evaluating a coating's potential. Both osseointegration and antibacterial characteristics are desirable in an implant [14].

Antibiotics in sufficient concentrations can be incorporated into the coating for long-term medication release. Coprecipitation with a biomimetic CaP coating can allow for a greater dose of antibiotics to be loaded, reducing the likelihood of infection after surgery at high-risk implant sites [15].

Platelet Rich Plasma (PRP) and Platelet Rich Fibrin (PRF)

Platelet-Rich Plasma (PRP) and Platelet-Rich Fibrin (PRF) are autogenous platelets concentrates that contain high levels of growth factors including PDGF, TGF-beta, IGF, EGF, and VEGF that accelerate healing and bone formation. They are used in dental implant surgery for bone repair before or in parallel with implant treatments, as well as socket preservation. Their use improves the density and maturation of bone grafts. PRP enhances soft and hard tissue repair and reduces post-operative complications. [16, 17] also supports reducing pain [18, 19]. On the other hand, the PRF is costly and reasonable, has no bio-chemical treatment of the blood, had superior healing time, consider safer due to the absence of anticoagulants, and attracting osteoblast migration [17]. Moreover, it acts as a reservoir of growth factors releasing them slowly over 10-days [11]. Cortese A *et al.* [20]; reported in their study that all implants had great primary stability, and the only drawback of PRF is the amount presented is limited to the donor blood [21]. Good quality PRF is based mainly on how fast to collect the blood is transported to the centrifuge. Also To achieve clot polymerization, a glass-coated tube is required [20].

Grit Blasting

Blasting the implants with biocompatible particles such as aluminum, titanium oxide, and calcium phosphate increases roughening the interface surface of the titanium implant. The blasting particles should be chemically stable and shouldn't interfere with the osseointegration processs [22].

The most common particle used is alumina for roughening the implant surface. However, is frequently retained in the implant surface even after cleaning and sterilization.Acid etching along with grit blasting facilitate the achievement of favorable result on implant osseointegration [23].

Fluoride Treated Surfaces

Bone development is improved when implant surfaces are treated with fluoride ions. Fluoride promotes the proliferation of undifferentiated osteoblasts and osteoprogenitor cells. Then Alkaline phosphatase activity is increased, and the cells are differentiating [24]. Fluoride also promotes bone mineralization by attracting calcium deposits [25]. In an animal investigation, Ellingsen found that fluoride surface modification dramatically improved titanium implant retention after four and eight weeks of recovery. When equated to grit-blasted implantations with a faster healing time, the fluoride ions react with the titanium; generating TiF_4 that enhances the osteointegration and more removal torque [26].

Collagen Type I Coatings

Collagen type-I, the primary structural protein in bone, possesses bone-regeneration characteristics. Sverzut *et al.* (2012) titanium surface implants that were compared with collagen Type I coating, they were acid etched (AETi). individuals who are not coated with collagen, it's been discovered that covering AETi with collagen helps to fasten osseointegration by cellular stimulation of bone growth at both the cellular and molecular levels. The titanium implant that has been acid etched when compared to type I Collagen, had a BIC percent of 31.78. AETi, which was 45.99, was treated. As a result, type I collagen coating is used. So positively influences osseointegration [27]. Advantages include increased bone formation, Improved bone healing, and maturation compared to un-coated implants [28].

Calcium-Phosphate-Coated Implant (CaP)

The calcium phosphate layered implants show improved osseointegration during the early stages of healing, as well as a faster healing response and the ability to overcome challenges such as poor bone density and irradiation [29]. Fontana, Rocchietta, and colleagues (2011) investigated the effectiveness of the role of calcium phosphate coating in osseointegration. They compared the surface of calcium phosphate to that of titanium. In terms of bone-implant interaction, a porous oxide surface is preferable. The tibiae of 36 rabbits were fixed with 216 implants. After 2, 4, and 9 weeks, histomorphometric analysis was performed, demonstrating that the rabbit tibia had an oxidized surface placed into its BIC values were higher than on the Ca–P surface, however Insignificant in terms of statistics. according to the findings, The calcium phosphate coating did not affect enhancing the bone-implant contact [29].

Oxidized Surfaces

The use of an implant surface that has undergone oxidation, produces a thicker titanium oxide coating and more pronounced roughness, resulting in a 95 percent increase in a surface area. The oxidized surface shortened the healing period and lowered the time required to accomplish secondary stability [30]. At pristine and regenerated bone, the oxidized implant surface stimulated more BIC than the untreated. The oxidized implant had a higher BIC and torque removal than an etched implant, according to Gottlow. Higher osteoconductivity and a shorter healing period are two advantages of this oxidized surface [30]. Sennerby and Miyamoto also found that oxidized surface implants had a higher early stability than etched and sandblasted implants, especially in type IV bone. Patients with periodontitis who smoke may benefit from oxidized surface implants [31] with longevity lasting up to 10 years of follow up considering the high percentage of the smoking patient (1\4 of the patient), with systemic disease (1\5 of the patient) and with parafunctional habits (1\5 of the patient) [30].

Calcium Chloride Treatment

Calcium chloride is used to treat hypocalcemia, hyperkalemia, and magnesium intoxication brought on by excessive magnesium sulfate intake. Using calcium chloride enhanced the early bone response by maintaining the implant surface purity [32]. $CaCl_2$ does not influence cells' compatibility or safety [33]. This treatment creates a smooth interface of the soft tissue around the implant by improving the gingival epithelial-like cell and fibroblast adhesion to titanium disks. Hydrothermal therapy (HT) with CaCl solution ($CaCl_2$) has been shown to improve bone–titanium implant compatibility in previous studies [34].

Machined Implants

The irregular titanium implant surface is the baseline for the dental implant. Three general categories of surface roughness are used to classify them; machined/minimal (less than 0.5 μ), moderate (less than 2.0 μ), and rough (more than 2.0 μ) [35]. As the implant gets rough as it attracts bacterial colonization and plaque accumulation leading to compromise in the implant success rate [36]. The longevity of the machined implant range from 85 up to 97 percent, in comparison to the rough implant which reached 100 percent [35].

Titanium Plasma Sprayed (TPS)

The BIC of the implant increased up to six-fold by this porous covering, decreasing the pressure per unit area and lowering the bone resorption [37]. Joo L. Ong *et al*. 2003 compare TPS to HA, and it was noted that HA implants had much longer bone contact lengths than TPS implants [38]. V Chappuis *et al* in 2013 showed a longevity of 89% for the titanium plasma-sprayed surface over a decay follow-up period [39].

Plasma Oxidation

Plasma is the 4th state of matter in physical science, and the acellular medium of blood in biology. One of the methods used in dental implants is to functionalize the surface of titanium and increase its biocompatibility [40]. Plasma oxidation is used to improve the contact surface angle of the implant surface. The plasma-oxidized SLA provides a wider contact point on the implant surface that enhances the removal torque and the BIC [41].

Extracellular Matrix Protein

The ECM that is released by the fibroblast such as; collagen, chondroitin sulfate, vitronectin, and fibronectin during osseointegration promote the osteoprogenitor cells to the functional surface. Coated implants with ECM were found to improve bone formation and maturation, supporting the favorable effect on osseointegration. ECM coatings on bone implants, particularly those containing high-sulfation GAG derivatives, appear to aid bone regeneration and growth within very porous PCL frameworks [42].

Growth Factors Coatings

Alterations of implants, namely the introduction of growth factors (GFs) to bioactive surfaces, are crucial to increase implant longevity and, as a result, reduce revision surgeries. Bioactive coatings allow for critical osteoconduction and osteoinduction, prolonging the implant's life [43]. Even though the clinical application of bio-active compounds is limited due to high production costs and biosafety issues, a lot of research has been done in this field. Using growth factor coating to promote stem cell proliferation and induce bone. These growth factors include IGF, BMP, FGF, PDGF, and VEGF [44]. In vivo, BMP enhances bone cells to produce mature bone [45] while angiogenesis and bone healing can be facilitated by VEGF [46]. Nevertheless, there is a trend to suggest that growth factors have a favorable effect, but there is no conclusive evidence to approve it [47].

Sol-Gel Coated Implants

It is a wet-chemical layering method for ceramic material fabrication [48]. Sol-gel coating provides several benefits over other systems, including the ability to produce coatings with homogeneity purity at low processing temperatures and a cheap cost [49]. This method creates an intimate, homogenous mix of various colloidal oxides resulting in a simply moldable gel. Additionally, the sol-gel technique can enable a slow release of different components to incorporate into the soil and diapers uniformly [48].

Laser Ablation

Another approach for modifying the surface of dental implants is laser ablation. A collar treated by laser ablation creates nano-channels that increase the hydrophilicity in biological response and cell recruitment, as well as faster bone healing, with a failure rate of less than 8% [50].

Conclusion

The Titanium dental implant's surface modification is aimed at enhancing the biological reactions at the contact surface area. All Researchers implement the importance of surface treatment and modification to enhance and accelerate the healing process and bone integration. Multiple research projects have shown that if the implant surface is changed, osseointegration establishes faster and stronger. Surface modifications such as anodizing the implant surface, adding calcium ions, carbon-ion oxygen, strontium-containing hydroxyapatite layer created by micro-arc oxidation, and other additives have been demonstrated to improve osseointegration.

ACKNOWLEDGMENTS: Special thanks to the Faculty of Dentistry at King Abdulaziz University and the Deanship of Scientific Research (DSR) for supporting this project. The research proposal was approved by the Regional Research and Ethics committee of King Abdulaziz University.

CONFLICT OF INTEREST: The authors declare that there are no conflicts of interests.

FINANCIAL SUPPORT: The study did not receive any external funding.

ETHICS STATEMENT: None

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