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Influence of Antibacterial Surface Treatment on Dental Implant on Cell Viability- A Review

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Abstract:
Dental implants are commonly used in edentulous patients with good clinical outcomes, but few implant failure cases like Periimplantitis are also seen. The implant success rate to improve for better osseointegration and antibacterial activity, different implant surface modifications have been explored. Surface modifications include sandblasting and acid etching (SLA), plasma spraying, sputter-deposition, anodic oxidation, micro-arc oxidation, sol-gel coating, selective laser melting (SLM), and Layer-by-Layer (LBL) self-assembly. They help in increasing surface roughness and enhance osteoblastic cells' adhesion to the implant surface.
The need for antimicrobial coatings on titanium implant surfaces, at the abutment-implant junction, is due to the high probability of peri-implant disease. In this article, antibacterial activity and when treated superficially cytotoxicity on osteoblastic cells of titanium implants have been discussed.
Keywords: Dental implants, Surface modifications, antimicrobial coatings, Periimplantitis, Titanium surface

INTRODUCTION:

Antibacterial bioactive surfaces are promising for implant rehabilitation success as its prone to oral and systemic conditions, which can hinder osseointegration [1]. Lindhe and Meyle reported an 80% risk of peri-implant mucositis and 28–56% of peri-implantitis [2]. Titanium alloy (Ti) due to its biocompatibility, mechanical properties, and chemical stability is the material of choice for dental implants. But the most widely used Ti–6Al–4V alloy, elements Al and V are neurotoxic. Hence recently, beta titanium alloys have been used, as non-cytotoxic elements like molybdenum (Mb), tantalum (Ta), zirconium (Zr), and niobium (Nb) are incorporated [3,4].
Implant failure is mainly caused by peri-implant infection by specific microbiota like Streptococcus spp., Fusobacterium spp., Prevotella intermedia, Actinobacillus actinomycetemcomitans, Peptostreptococcus micros, Campylobacter rectus, Capnocytophaga rectus, and Porphyromonas gingivalis. Also, it's predisposed more in smokers and periodontal disease patients [5].
Clinical findings associated with exposed implant surface include Continuous oral hygiene measures requirement; Gingival margin instability; Circumferential bone loss progression; Papillary height instability; Peri-implant disease [6].
The antibacterial coating used for a dental implant is ideally at the abutment-implant connection, rather than at the bone-implant interface where osseointegration occurs. Hence, if this connection could be coated to prevent biofilm formation it leads to peri-implant disease prevention [6]. In this article, antibacterial activity and when treated superficially cytotoxicity on osteoblastic cells of titanium implants have been discussed.

DISCUSSION:

Peri-implant disease incidence increases over time with long-term studies showing greater than 20% incidence [7]. A 9-year study in 588 patients showed bleeding on probing associated with bone loss at 45% incidence and more than 2mm bone loss at 14.5% incidence attributed to peri-implant disease, which leads to implant failure [8].
Hickok et al. reported antimicrobial coating delineating the use of three approaches including increased nano topography, antimicrobial elution to retard bacterial adhesion, and antimicrobial agents bonding to the surface all of which affect a long-term antimicrobial function [9].
Antibacterial surface treatments include antibacterial ions addition like silver (Ag), copper (Cu), and zinc (Zn) that disrupts bacterial cell wall and DNA replication. The addition of antibiotics to synthetic poly (lactic acid-co-glycolic acid) (PLGA) and chitosan (CS) polymers directly delivers the drug to the site in lower doses. The addition of antibacterial nanomaterials has also shown promising results [10]. Hence, Bioactive glass (BG) due to its osteoinductive capacity and antibacterial activity, influences the pH and osmolarity of the implantation site. The incorporation of polyethyleneimine quaternary ammonium nanoparticles (QPEI) by electrostatic interaction with bacterial cells promotes antibacterial activity. Also, Chimeric peptides application on titanium surface demonstrates antibacterial activity by electrostatic interaction and by inhibition of RNA replication [11].

Antimicrobial coatings

The antimicrobial coating includes the use of antimicrobial peptides (AMPs), slow-release antibiotics, heavy metals like silver, and antimicrobial organic compounds. Depending on the mode of action implant coating is classified into passive or active. Active coatings release agents into the peri-implant environment whereas Passive coatings do not release the product into the surrounding tissues [12].

Sandblasting and Acid Etching

Titanium implants are sandblasted by large grit corundum particles of 0.25–0.5mm and acid-etched with HCl/H2SO4 at high temperatures following. Han et al. explored similar surface structures of titanium alloys and pure titanium treated with SLA. Zhan et al. found SLA treated Ti alloy had an osteogenesis effect superior to pure titanium [13].

Plasma Spraying
Plasma spraying is a thermal spraying coating process with a high-energy heat source to melt and spray powder for a high-quality coating. Advantages include thermal insulation, prevents wear and tear, and corrosion protection. The titanium plasma spraying (TPS) technique uses titanium particles sprayed onto the implant surface to form a porosity between 30-50 µm. Chappuis et al. reported in a prospective study titanium plasma sprayed implant with 89.5% survival rate after 20 years of function [14]. Becker et al. reported in a retrospective study the long-term survival rate of implants with a TPS surface was 88.03% with a 23-year follow-up [15].

Metal Ions Implantation
Metal elements like silver, cerium, copper, and zinc are loaded into implants has a good antibacterial effect. Silver has a broad-spectrum antibacterial function. The antibacterial mechanism of silver includes the release of silver ions, reactive oxygen species production, and oxidative stress. Li et al. incorporated Ag nanoparticles (NPs) into TiO2 nanotubes prepared on the SLA Ti surface, showing strong release bactericidal activity that changed to contact bactericidal ability [13].

Sputter-Deposition
Sputtering deposition belongs to physical vapor deposition, with no chemical reaction during this process (Figure 1). It is an electronic process in which inert gas ions like argon ions, under an electric field acquire kinetic energy and in a vacuum chamber bombard the sputtering target.
Magnetron sputtering, diode sputtering, radio-frequency sputtering, ion-beam sputtering, and reactive sputtering are different types. Good durability, high quality, and environmentally friendly technique [13].

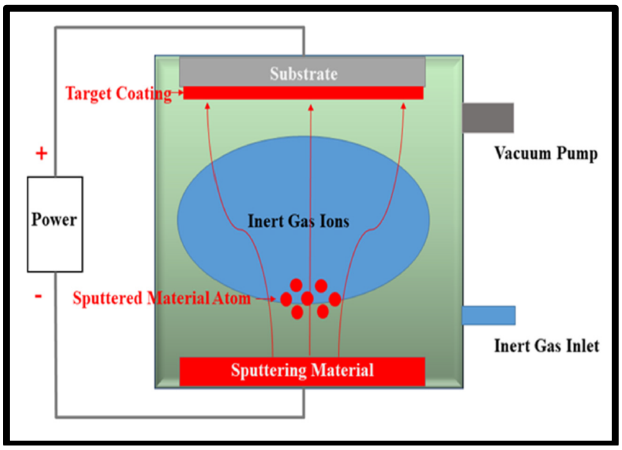

Figure 1: Steps in Sputter deposition

Selective Laser Melting (SLM)
In SLM technology, the energy source used is a laser, and according to the path planning in the 3D CAD slice model, the metal powder bed is scanned layer by layer. To achieve a metallurgical combination the scanned metal powder is melted and solidified, and finally, metal parts are obtained and pre-designed [13].

Anodic Oxidation
Titanium dioxide nanotubes have a surface area, increased coarseness, and hydrophilicity, promoting osseointegration and antibacterial activity. The hydrophilicity and roughness of TiO2 nanotubes affect the initial adhesion of bacteria. Valdez-Salas et al. demonstrated that TiO2 nanotubes can reduce Gram-negative and positive bacteria initial adhesion [16].

Micro-Arc Oxidation
The micro-arc oxidation (MAO) can make the titanium surface grow into a dense ceramic oxide film. The MAO treatment can convert amorphous TiO2 into crystalline anatase TiO2 to reduce bacterial adhesion [13].

Sol-Gel Coating
It is a wet chemical method for preparing metal oxide materials at a low temperature, including coatings, films, fibers, and bulk parts that are difficult to melt. Commonly used alkoxides are alkoxysilanes, aluminates, titanates, and zirconates [13] (Figure 2).

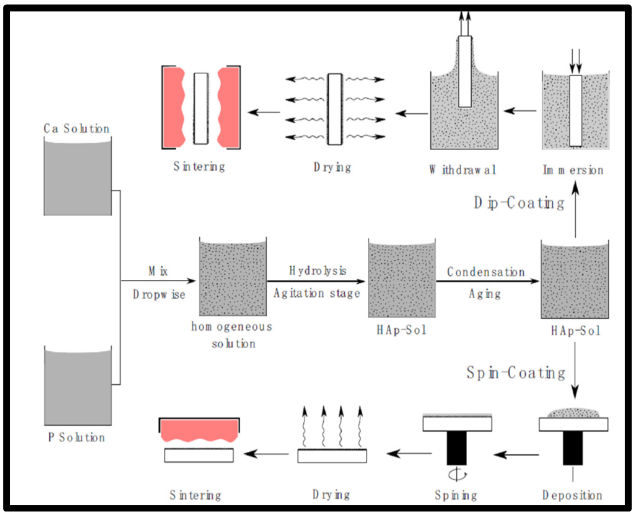

Figure 2: Stages of sol-gel coating

Layer-by-Layer Self-Assembly Technique
Layer-by-Layer (LBL) self-assembly is an approach in which an ultrathin film is developed on solid support by alternating layer-by-layer deposition with weak interaction between each layer. The charged substrate is immersed in a solution of oppositely charged polyelectrolytes and by absorption first monolayer is formed [13].

Bactericidal nanoparticles
Nanoparticles ranging from 1-100nm incorporating copper, zinc, magnesium, silver, and gold has antimicrobial activity and are used for antimicrobial surface modifications. They create unique surfaces with altered physicochemical properties but have a toxicological concern as they are easily phagocytized and may affect intracellular function [13].

Conclusion:

There is a need for antimicrobial coating on implants because over time titanium implant surfaces become exposed in the oral cavity. Then increased efforts are required for implant hygiene maintenance to prevent peri-implantitis risk and implant failure. Different implant surface modifications are available such as SLA, and MAO which increases surface roughness and improve hydrophilicity, making implants biocompatible and accelerating osseointegration. The implant surface with metal ions or antimicrobial peptides is incorporated and has a bacterial resistance effect [6].

The antimicrobial strategy remains an important area of investigation and is an ongoing need to curtail the endemic peri-implant disease prevalence. Future research should focus on innovative modification methods in the laboratory, comparing different surface implants in long-term clinical trials.

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