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Review Article

Innovations in Implant Surfaces: A Review of Treatments Affecting Osseointegration Outcomes

*Dr. Arpit Sikri [1], Dr. Jyotsana Sikri [2]

[1] Associate Professor & Post Graduate Teacher, Department of Prosthodontics, Crown & Bridge and Oral Implantology, Bhojia Dental College & Hospital, Budh (Baddi), Teh. Baddi, Distt. Solan, Himachal Pradesh, India
[2] Associate Professor & Post Graduate Teacher, Department of Conservative Dentistry & Endodontics, Bhojia Dental College & Hospital, Budh (Baddi), Teh. Baddi, Distt. Solan, Himachal Pradesh, India

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***Corresponding author:** Dr. Arpit Sikri
Associate Professor & Post Graduate Teacher, Department of Prosthodontics, Crown & Bridge and Oral Implantology, Bhojia Dental College & Hospital, Budh (Baddi), Teh. Baddi, Distt. Solan, Himachal Pradesh, India

Abstract
The design, topography, texture, and surface treatments of dental implant materials are among the important aspects that have been recognised by the development of osseointegration research as determining their quality. In order to investigate the cellular interactions that take place with these materials and assess their impact on the rate and calibre of osseointegration, this study examines the body of research on the various surface treatments for dental implants. Using pertinent keywords including surface treatments, osseointegration, dental implants, and implant surfaces, a thorough bibliographic survey was carried out across several databases. Results show that better osseointegration results are linked to increasing surface roughness and improving hydrophilicity. In particular, chemically changed surfaces and surfaces treated with techniques like sandblasting and acid etching have demonstrated positive clinical outcomes, especially when early loading, poor bone quality, and patients with systemic health issues are involved. There is still disagreement in the literature on the best kind of surface treatment, even though there is evidence that implants with rough surfaces have a larger contact area with bone tissue.

Keywords: *Dental implants, Implant materials, Implants, Osseointegration, Surface properties, Surface roughness, Surface treatments*

Introduction

An indirect finding of what Brånemark referred to as osseointegration was made by Brånemark in the year 1954.[1] This discovery was discovered when he was performing a classic study on blood circulation in the tibias of rabbits. This discovery opened the door for additional study with animal models, which in turn made it possible to treat edentulism with prosthesis fixed to dental implants.The successful prosthetic rehabilitation of totally or partially edentulous ridges with dental implants depends on the osseointegration process. Direct and steady contact between the implant and the surrounding bone is essential to the process's effectiveness.

The geometry of the implant (both macroscopic and microscopic), the titanium's purity, its surface characteristics, and the chemical and biological interactions with bone tissue are some of the variables that affect effective osseointegration.[2] By analysing these variables, clinical decisions can be made more effectively, improving the rate and quality of osseointegration.

When titanium interacts with air or bodily fluids, a dense and durable oxide film forms on the surface, which is intimately related to implants' ability to establish osseointegration. Because it shields the titanium from oxidation and corrosion, this oxide layer is essential. Because corrosion and ion release can be harmful and may impede osseointegration, the thickness and durability of the oxide layer are important for the implant's biomaterial performance.

Important properties that define the rate and quality of osseointegration when in touch with bone tissue include topography, wettability, surface charge, and chemical composition. These characteristics promote the integration of the biomaterial with bone by facilitating interactions between the implant and bone, such as ionic adsorption, protein absorption, cell-surface communication, and signalling for cell differentiation.[3] To create a biochemical link that can quicken the early phases of bone development surrounding the implant, a number of surface treatment methods have been put forth.

Through a review of the literature, this study seeks to give a concise summary of the development of implantology by describing the mechanical and biological mechanisms of osseointegration in turn. The primary objective is to discuss the different types of surface treatments for dental implants and their quantitative and qualitative relationships with osseointegration.

Discussion

To guarantee consistent endurance, dental implants must integrate with three different tissue types: bone, connective, and epithelium.[4] According to Davies, a number of variables, such as primary stability and the amount and quality of bone, affect the outcome of dental implants.[5] According to Sangata, primary stability is essential for osseointegration; as a result, implants with high primary stability are more likely to succeed than those with low primary stability.[6] On the other hand, Goiato et al. contend that although osseointegration is influenced by elements including bone density, the implant's length, and its position in the maxilla or mandible, primary stability shouldn't be considered a prerequisite.[7]

According to Thakral et al., surface texturing methods used to dental implants have a substantial impact on osseointegration, affecting the development of the calcified bone matrix as well as cellular differentiation after implant insertion.[8] Additionally, Wennerberg and Albrektsson noted that treated surfaces have higher bone-to-implant contact (BIC) than smooth implants, and they suggested textured surfaces for regions that have lower BIC after surgery.[9] Att et al., on the other hand, argued that bone deposits happen similarly on smooth and porous surfaces, suggesting that porosity is not necessary for bone apposition.[10]

According to studies by Yan et al. and Park et al., titanium implants coated with hydroxyapatite using plasma spray had more bone at the interface between the implant and bone than smooth surfaces.[11,12] With removal forces of 55 MPa at three months and 62 MPa at six months, indicating considerable bone remodelling, hydroxyapatite plasma spray implants have been thoroughly investigated and are known for their strong osseointegration potential.[13]

In a comparison of titanium plasma spray (TPS) and titanium oxide sandblasted surfaces, Herrero-Climent et al. found that TPS exhibited a unique pattern of bone matrix development.[14] They showed by scanning microscopy that different amounts of both organic and inorganic materials accumulated on each surface throughout the development of bone matrix, suggesting that cellular responses take place regardless of the surfaces' physicochemical characteristics.

Rupp et al. discovered no discernible variations between SLA and SLActive surfaces with comparable topography, which supports this.[15] BIC repair at two and four weeks, however, showed statistically significant variances, indicating that these variations were probably caused by changes in chemical structure rather than topography.

According to a Swedish study by Oates et al., implant stability may be impacted by the rate of bone development, which supports the findings of Rupp et al.[16] The change from primary to secondary stability happened in two weeks for SLActive surfaces and four weeks for SLA surfaces, according to their resonance frequency analysis of osseointegration on both surfaces. These findings demonstrate that implant stability is directly impacted by the rate of bone growth.

Huang et al. investigated how chemical and nanotopographic changes affected osseointegration in its early stages.[17] After four weeks, they used removal torque and histological analysis to examine surface changes such as fluoride treatment, titanium oxide sandblasting, and nano-hydroxyapatite alterations. Elements Ti, O_2, C, and N were found in all study groups' nanostructures on chemically modified implants, according to scanning electron microscopy (SEM) photographs. Implants with chemically nanotopographic alterations had a larger removal torque, which led to the conclusion that these surfaces had special properties that improved bone apposition, which would account for the higher removal torque.

Conclusion

Reduced healing time, early implant loading, enhanced patient comfort, and increased practitioner efficiency are the main results of surface treatments intended to promote osseointegration. Whether dental implants are treated or not, osseointegration occurs on their surfaces. However, by encouraging both qualitative and quantitative bone apposition, surface treatments greatly enhance osseointegration, especially in the early phases. The best kind of surface treatment is still up for debate in the dentistry literature, despite these advantages.

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