INNOVATION IN BIOCOMPATIBLE MATERIALS FOR DENTAL IMPLANTS: CURRENT PERSPECTIVE AND SITUATIONS

Asaftei Victoria[1], Ciornei Mădălina[1], Țabără Eduard Lucian[1*], Agop-Forna Doriana[2], Maxim Alexandra[3*], Norina Forna[1]

1"Gr. T. Popa" U.M.Ph. - Iași, Romania, Faculty of Dentistry, Department of Implantology, Removable Dentures, Dentures Technology
2"Gr. T. Popa" U.M.Ph. - Iași, Romania, Faculty of Dentistry, Department of Surgery
3 Dentist, private practice

Corresponding authors: Agop-Forna Doriana , e-mail: drdorianaforna@gmail.com

*authors had an equal contribution as the first author

Abstract

Peri-implantitis is an inflammatory disease of hard and soft tissues around osseointegrated implants, followed by a progressive damage of alveolar bone. Oral microorganisms can adhere to all types of surfaces by the production of multiple adhesive factors. Inherent properties of materials will influence not only the number of microorganisms, but also their profile and adhesion force onto the material surface. In this perspective, strategies to reduce the adhesion of pathogenic microorganisms on dental implants and their components should be investigated in modern rehabilitation concepts in implant dentistry. To date, several metallic nanoparticle films have been developed to reduce the growth of pathogenic bacteria. However, the main drawback in these approaches is the potential toxicity and accumulative effect of the metals over time. In view of biological issues and in attempt to prevent and/or treat peri-implantitis, biomaterials as carriers of antimicrobial substances have attracted special attention for application as coatings on dental implant devices. In this review we overview currently available biomaterial systems that can be used in the field of oral implantology.

The osseointegration rate of titanium dental implants is related to their composition and surface roughness. Rough-surfaced implants favor both bone anchoring and biomechanical stability. Osteoconductive calcium phosphate coatings promote bone healing and apposition, leading to the rapid biological fixation of implants. The different methods used for increasing surface roughness or applying osteoconductive coatings to titanium dental implants are reviewed. The future of dental implantology should aim to develop surfaces with controlled and standardized topography or chemistry. This approach will be the only way to understand the interactions between proteins, cells and tissues, and implant surfaces. The local release of bone stimulating or resorptive drugs in the peri-implant region may also respond to difficult clinical situations with poor bone quality and quantity. These therapeutic strategies should ultimately enhance the osseointegration process of dental implants for their immediate loading and long-term success.

Keywords: biomaterials, dental implants.

INTRODUCTION

Routinely, missing teeth are being replaced by dental implants. According to the American Academy of Implant Dentistry (AAID), 3 million US citizens have dental implants and this number is rapidly growing by 500 000 annually (https://www.aaid-implant.org/dental-implants/what-are-dental-implants/). As a consequence of the increased number of dental implants, biological complications surrounding these medical devices, prior to, during, or after the osseointegration process, also increase. The continued accumulation of inflammatory infiltrate around the implants promotes disease progression of the hard tissues and concomitantly peri-implant bone loss. In adition the clinical success of oral implants is related to their early osseointegration. Geometry and surface topography are crucial for the short- and long-term success of dental implants. These parameters are associated with delicate surgical techniques, a prerequisite for a successful early clinical outcome 1. After implantation, titanium implants interact with biological fluids and tissues. Direct bone apposition onto the surface of the titanium is critical for the rapid loading of dental implants. After the initial stages of osseointegration, both prosthetic biomechanical factors and patient hygiene are crucial for the long-term success of the implants. There are two types of response after implantation. The first type involves the formation of a fibrous soft tissue capsule around the implant. This fibrous tissue capsule does not ensure proper biomechanical fixation and leads to clinical failure of the dental implant. The second type of bone response is related to direct bone–implant contact without an intervening connective tissue layer. This is what is known as osseointegration. This biological fixation is considered to be a prerequisite for implant-supported prostheses and their long-term success. The rate and quality of osseointegration in titanium implants are related to their surface properties. Surface composition, hydrophilicity and roughness are parameters that may play a role in implant–tissue interaction and osseointegration.

Studies have reported infection-related implant loss in 20% of patients during 5-10 years after implant placement. Despite the high rate of dental implant success (ie, up to 98%), clinicians are increasingly confronted with a new challenge: How to prevent and/or treat peri-implantitis? In this sense, an important and antecedent event that precedes and directly affects bacterial adhesion is the irreversible interaction between material and bacteria, which is mandatory for direct biofilm development.

Surface roughness of dental implants

There are numerous reports that demonstrate that the surface roughness of titanium implants affects the rate of osseointegration and biomechanical fixation 2, 3. Surface roughness can be divided into three levels depending on the scale of the features: macro-, micro- and nano-sized topologies.

The macro level is defined for topographical features as being in the range of millimetres to tens of microns. This scale is directly related to implant geometry, with threaded screw and macroporous

Osteoconductive calcium phosphate coatings on dental implants

Metal implants have been coated with layers of calcium phosphates mainly composed of hydroxyapatite. Following implantation, the release of calcium phosphate into the peri-implant region increases the saturation of body fluids and precipitates a biological apatite onto the surface of the implant 5, 6. This layer of biological apatite might contain endogenous proteins and serve as a matrix for osteogenic cell attachment and growth 7. The bone healing process around the implant is

Future trends in dental implant surfaces

A few strategies should be considered in order to improve both the short and long-term osseointegration of titanium dental implants. These future trends concern the modifications of surface roughness at the nanoscale level for promoting protein adsorption and cell adhesion, biomimetic calcium phosphate coatings for enhancing osteoconduction and the incorporation of biological drugs for accelerating the bone healing process in the peri-implant area.

BIOMATERIAL-BASED SOLUTIONS AS FUTURE PERSPECTIVES TO PREVENT/TREAT PERI-IMPLANTITIS

In an attempt to prevent/treat bacterial colonization on dental implant system components, 7,8, 9, metallic nanoparticles have been investigated as a potential coating material on titanium substrates.10 However, the wide broad-spectrum antimicrobial properties depend on the metallic nanoparticles concentration. Potential concerns have been raised about the effect of metallic nanoparticles on human cells, even at low concentrations. The unanswered questions about cytotoxicity of these compounds upon long-term exposure have triggered great efforts in setting up new possibilities to fight peri-implantitis.11

Nowadays, an interesting paradigm shift brings up new possibilities to antimicrobial drug applications. Considering that antibiotics still remain as important protagonists to treat infection diseases, the idea in reducing microbial resistance can be achieved by controlled and directed delivery of specific drugs.

Hydrogels are hydrated polymers that exhibit meaningful therapeutic versatility, designed for human application. 12 These biomaterials form a strong cross-linked network of natural or synthetic molecules capable of storing biological drugs on their internal spaces. Among biomaterials used for hydrogel fabrication, polysaccharides (eg, dextran and chitosan) and proteins (eg, gelatin and fibrin) are well-studied standards of natural polymers. Regarding synthetic biomaterials, polyvinyl alcohol (PVA),polyethylene glycol (PEG), and poly(acrylic acid) (PAA) are widely used examples of hydrogel-forming polymers. Overall action mechanisms involve either hydrogel ability to encompass different antimicrobial substances into the multilayered polysaccharide for eventual release or by covalently attaching therapeutics to the network.

CONCLUSION

Physicochemical modifications of dental implants play a role in the reduction in microorganism adhesion but do not avoid peri-implantitis. Biomaterials can also be used as carrier coating for antimicrobial agents to support the prevention and/or treatment of peri-implant mucositis and peri-implantitis. Further research in the advancement in materials capable of coordinated and sustained multidrug release is needed to provide new avenues for prevention and/ or treatment of peri-implantitis.

ACKNOWLEDGEMENTS

The authors acknowledge Straumann AG (Bern, Switzerland) for providing the SLA samples, Astra Tech (Astra Zeneca, Rueil-Malmaison, France) for providing the TiOblast™ and OsseoSpeed™ samples. Cam Implants BV (Leiden, The Netherlands) is also acknowledged for providing the TPS and HA plasma-sprayed samples. We also thank Paul Pilet from the Miscoscopy Centre for SEM pictures and Kirsty Snaith for grammar corrections of the manuscript. Erica Dorigatti de Avila was supported by the São Paulo Research Foundation (FAPESP) grant #2016/19650-3 and 2015/03567-7.

REFERENCES

1. Lindhe J, Meyle J, Group D of European Workshop on Periodontology . Peri-implant diseases: Consensus Report of the Sixth European Workshop on Periodontology. J Clin Periodontol. 2008;35(8 suppl):282-285. [PubMed] [Google Scholar]
1. 2.G. Giavaresi et al. Mechanical and histomorphometric evaluation of titanium implants with different surface treatments inserded in sheep cortical bone. **Biomaterials** (2003)

2. 3. S. Hansson et al. The relation between surface roughness and interfacial shear strength for bone-anchored implants. A mathematical model. **J Biomech** (1999)
3. Maniotis AJ, Chen CS, Ingber DE. Demonstration of mechanical connections between integrins, cytoskeletal filaments, and nucleoplasm that stabilize nuclear structure. Proc Natl Acad Sci U S A. 1997;94:849-854. [PMC free article] [PubMed] [Google Scholar]
4. Jain N, Iyer KV, Kumar A, Shivashankar GV. Cell geometric constraints induce modular gene-expression patterns via redistribution of HDAC3 regulated by actomyosin contractility. Proc Natl Acad Sci U S A. 2013;110:11349-11354. [PMC free article] [PubMed] [Google Scholar]
5. Hickok NJ, Shapiro IM. Immobilized antibiotics to prevent orthopaedic implant infections. Adv Drug Deliv Rev. 2012;64:1165-1176. [PMC free article] [PubMed] [Google Scholar]
6. Rasmussen K, Nikrad J, Reilly C, Li Y, Jones RS. N-Acetyl-l-cysteine effects on multi-species oral biofilm formation and bacterial ecology. Lett Appl Microbiol. 2016;62:30-38. [PMC free article] [PubMed] [Google Scholar]
7. Tsuchiya H, Shirai T, Nishida H, et al. Innovative antimicrobial coating of titanium implants with iodine. J Orthop Sci. 2012;17:595-604. [PMC free article] [PubMed] [Google Scholar]
8. Haro Chavez NL, de Avila ED, Barbugli PA, et al. Promising effects of silver tungstate microcrystals on fibroblast human cells and three dimensional collagen matrix models: a novel non-cytotoxic material to fight oral disease. Colloids Surf B Biointerfaces. 2018;170:505-513. [PubMed] [Google Scholar]
9. Ahamed M, Karns M, Goodson M, et al. DNA damage response to different surface chemistry of silver nanoparticles in mammalian cells. Toxicol Appl Pharmacol. 2008;233:404-410. [PubMed] [Google Scholar]
10. Jepsen K, Jepsen S. Antibiotics/antimicrobials: systemic and local administration in the therapy of mild to moderately advanced periodontitis. Periodontol 2000. 2016;71(1):82-112. [PubMed] [Google Scholar]
11. Tibeică, A., Forna, N. C., Tibeică, S. C., Agop-Forna, D., & Costuleanu, M. (2024). PLATELET-RICH PLASMA AND FIBROBLASTS: HORMESIS EFFECTS. Romanian Journal of Oral Rehabilitation, 16(1)
12. Agop-Forna, D., Törok, R., Törok, B., Cretu, C., Budacu, C., & Forna, N. (2022). Guided bone regeneration techniques in alveolar bone reconstruction. Romanian Journal of Oral Rehabilitation, 14(4).
13. FORNA, N., TÖRÖK, R., TÖRÖK, B., & AGOP-FORNA, D. (2023). Postoperative Outcomes in the Surgical Rehabilitation of Alveolar Bone in Implant-Prosthetic Therapy: A Review.