Current Trends in Modifying Surface Topography of Dental Implants - A Literature Review

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Abstract: ***With increase in the world population there is advent in the newer technologies. As there is ongoing increased concern about our physical appearance the relevance of dental implantology has elevated in recent years. Although efforts to develop different implant surface modifications are being applied in commercial dental prostheses today, the inclusion of surface coatings have gained special interest, as they can be tailored to efficiently enhance osseointegration, as well as to reduce bacterial-related infection, minimizing peri-implantitis appearance and its associated risks. The real opportunity in implantology at present is targeted at surface design and modifications to enhance the osseointegration and establishing a biomaterial–tissues interface inducing an appropriate body reaction.***

Keywords: dental implants; osseointegration; peri-implantitis

1. Introduction

Dental implants are most similar to natural teeth in their mastication and aesthetics; they are also biocompatible and require biocompatibility, masticatory feature, and aesthetic follow-up [1]. The American Association of Oral and Maxillofacial Surgeons estimated that two million implants are placed per year worldwide. The longevity of the population and the demand for cosmetic dentistry have led to their increasing use [2]. Implants are expected to have a 90% success rate after 10 to 15 years of implantation. However, between 5% and 11% of dental implants do not result in the required osseointegration in the maxillofacial bone. A startling phenomenon that has arisen from the widespread use of dental implants is the health issue related to peri-implant disease [3]. The failure of the long-term stability of the dental implant occurs because of biological [4], and mechanical causes[5]. Figure 1 shows a schematic representation of a modern implant.

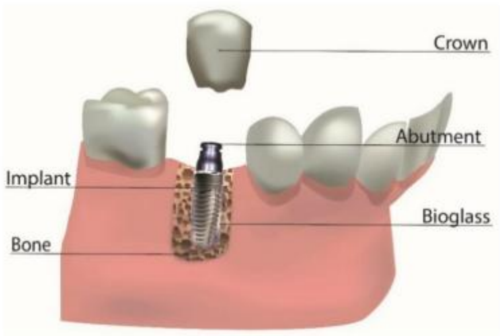

Figure 1. Modern implant placed in oral cavity.

Evolution of Dental Implant Surface Treatment

Dental implant surface modification has been developed over the years on both commercial and research level and can be classified to the following generations (Figure 2);

1) First-generation (mechanical surface modification): Surface machine grinding.
2) Second generation (morphological modification): Grooving, sandblasting, chemical acid etching, laser abrasion, and anodic oxidation.
3) Physicochemical active surface (third generation): Hydroxyapatite (HA) coating and chemical treatment.
4) Fourth generation (biochemical active surface): Biofunctional molecules immobilization such as collagen, peptides, and bone morphogenetic protein (BMP).
5) Fifth generation (biological surface): Stem cells and tissues coatings.5

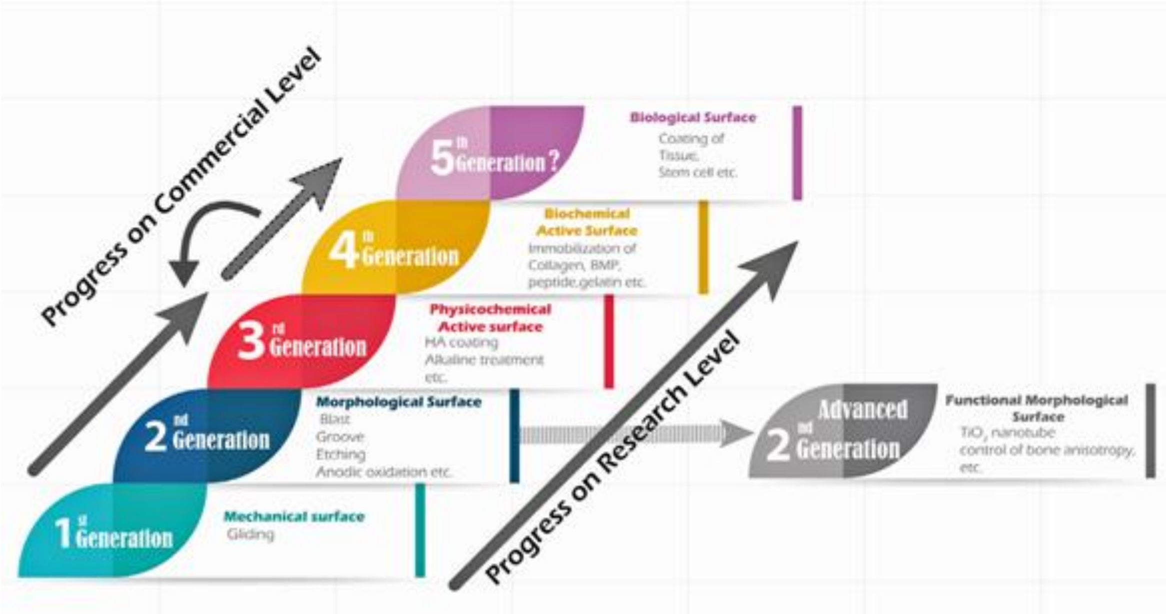

Figure 2: Evolution of surface modification techniques to improve the compatibility of hard tissues

Requirements for Dental Implants Surface

Surface characteristics at the micro-and nanometer scale, wettability, and biochemical bonding in addition to other features are responsible for the implant's success. The surface modification techniques can be classified into mechanical, chemical, and physical methods that mainly increase the surface area either by additive or subtractive procedures.6

Dental implants have several complex interfaces with the host system, which consist of:

1) The subgingival interface between implant and bone.
2) The transgingival soft tissue interface between the implant neck and gingiva
3) The supragingival and transgingival interfaces between implant abutment and the oral cavity and saliva.

Dental implant surfaces have to be optimized to fulfil the different requirement of the corresponding interfaces. First, at the bone interface, osteogenic potentials are of prime importance to achieve osseointegration. At the soft tissue interface, cell adhesive functionality for different cells is essential to aid the gingival attachment and accordingly ensure a tight gingival seal and prevent bacterial intrusion. For the different interfaces, bacterial colonization is one of the main risk factors that can cause peri-implantitis. This inflammatory host reaction can cause bone loss and impedes osseointegration leading to implant failure. Therefore, implant interfaces should resist biofilm formation by preventing bacterial adhesion and possessing antibacterial behavior. As surface wettability one of the most critical parameters for implant interaction with the surrounding biological environment, therefore companies and researchers targeted production of more hydrophilic surfaces with optimized micro-and nanotopography. To sum up, the required osteogenic implant surface should be biocompatible, hydrophilic, and antibacterial with optimized surface roughness to promote healing and rapid, highquality osseointegration.6

Strategies in Implant Modification

The success of dental implants depends on factors such as mechanical overloading, implant-abutment connection design, implant geometry, implant position, bone density, surface finish material of the implant, and micro gap. Osseointegration between the bone and the implant is considered to be the critical factor that interferes in the implant survival rate. Low osseointegration or peri-implant bone loss may cause micro-mobility to the implant and lead to its consequent loss. A peri-implant bone loss of greater than 1 mm in the first year after implantation and greater than 0.2 mm in the following year is considered a failure of the dental implant. Techniques for manufacturing dental implants have played a key role in device design, surface topographies, uncomplicated insertion into the host osseous matter, biocompatibility and costs.7

Current trend in Modifying Surface Topography:

The real opportunity in implantology at present is targeted at surface design and modifications to enhance the osseointegration and establishing a biomaterial–tissues interface inducing an appropriate body reaction. Letsdicuss some of the newer trends in surface topography:

1) Bisphosphonates

Bisphosphonates are the ongoing chosen therapy for osteoporosis. Systemic and local administration of bisphosphonates (such as etidronate, pamidronate, alendronate, risedronate) may increase mineralization, bone mass, and reduce the bone turnover by inhibiting the osteoclastic activity. Similarly, irrigating implant surgical site with aminobisphosphonate solution exhibited better efficacy and enhanced bone formation. Similar findings and remarkable boost in the osseointegration have been reported in an animal model study that administered the bisphosphonate compounds locally around the implants. However, further studies and clinical trials are required to validate effects of bisphosphonates on dental implants osseointegration.6

2) Antibacterial implant surface

In order to get the sustained drug release, therapeutic concentration of antibiotics can be infused into the implant coatings. Coprecipitation of biomimetic calcium phosphate (Ca–P) may enhance the loading capacity of antibiotics to the implant coating and prevention of postsurgical infections. A combination of inorganic Ca–P, zinc, and fluoride ions coated on the implant surface exhibited bioactivity and bactericidal properties. Another source for enhancing antibacterial activity on dental implant surface is by artificially mimicking human antimicrobial peptides by solid phase peptide syntheses (SPPS) or robotic synthesizer.7 Interrogation of human defensins peptides motifs on molecular level as well as on antibacterial level, outcome is quite interesting for future application and exploration in depth for the use of it as coatings. Human oral cavity contains many proteins and peptides such as defensins, cathelicidins, statherin, histatins, neuropeptides, have active role in the defense of oral cavity and are strong candidates for the coating artificially to the dental implant surfaces against microbes.

3) Genetically engineered implant surfaces

Since the discovery of osseointegration-specific genes, it has been an inviting idea to embed one or more of these genes onto the surface of the implant. There are several advantages to this approach: The genes do not degrade in these environments and can be applied to the implant surfaces in suitably low doses. Moreover, these genes are associated with the normal cell cascade of cell differentiation and function. However, there are significant disadvantages, namely the cost of development and the regulatory issues that must be addressed before bringing such a product to the marketplace. Unless there is a significant clinical advantage to be gained by the use of gene-enhanced implant systems, the cost of ensuring safety and efficacy outweighs the benefits.8

4) Implant surfaces enhanced with recombinant peptides

The application of recombinant osteogenic proteins (OP-1), BMP-2, BMP-7, and platelet-derived growth factor to implant surfaces has the potential to enhance their osteoconductive properties. However, the optimal means of bonding these proteins to implant surfaces has not been determined. In addition, retention and controlled release of these proteins has been difficult.8 Additional disadvantages of working with these materials include their high cost and the facts that they are frequently not associated with the normal cellular cascade and, during sterilization of the implant, may be deactivated. In addition, higher concentrations of BMP-2 have triggered troublesome side effects. It is possible to bind these proteins to implant surfaces. Implants with HA and chitosan coatings have been used most often.9 The outcomes of most of these studies indicate that binding BMPs to the implant surface significantly enhances osseointegration. Other researchers have attempted to determine whether coatings of OPs can be used effectively for vertical augmentation of deficient ridges. It was found in animal study that coating porous titanium implant surfaces with recombinant human BMP-2 (rhBMP-2) and rhBMP-7 induced significant bone formation around the neck of the implants, leading to a clinically significant vertical augmentation of the alveolar ridge.

2. Conclusion

There are number of commercially available surface modified titanium implants with promising outcome. These surface adjustments have supported the time effectiveness and prognosis of dental implants in different challenging clinical situations. The understanding of mode of surface modifications still needs further investigations at the nanoscale of titanium surface and its interaction with biological tissues and fluids. Lately, there is a rising trend for metal free dentistry with a lot of patients asking for more esthetic treatment. This motivated the development of esthetic implant materials such as zirconia and PEEK. These materials with completely different characteristics compared to conventional gold standard titanium raised a challenge for effective surface treatment and promoting osseointegration.

There is a growing research for effective surface treatment for newer implant materials with some promising results and products.

The main shortcoming for the current implant surface treatment is the lack of clinical data and requiring plentiful laboratory and clinical research. Unfortunately, there is great diversity of evaluation methods with lack of methodological standardization. This is the main obstacle for development of an agreed evidence-based gold standard or implant surface treatment.1[0] The future of dental implant will rely on improvement of more efficient, advanced and standardized clinical and laboratory research methodology with well-designed multicenter clinical trials to develop a solid evidence for standardized surface treatment. The increasingly active research on implant material surface improvement allows us to expect development of a smart tailored implant surfaces that can optimize the different adjacent interfaces within few years.

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