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Surface characteristics of dental implants: A review

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ABSTRACT

Objectives. During the last decades, several changes of paradigm have modified our view on how biomaterials' surface characteristics influence the bioresponse. After becoming aware of the role of a certain microroughness for improved cellular contact and osseointegration of dental titanium implants, the likewise important role of surface energy and wettability was increasingly strengthened. Very recently, synergistic effects of nanoscaled topographical features and hydrophilicity at the implant/bone interface have been reported.

Methods. Questions arise about which surface roughness and wetting data are capable to predict the bioresponse and, ultimately, the clinical performance. Current methods and approaches applied for topographical, wetting and surface energetic analyses are highlighted. Current knowledge of possible mechanisms explaining the influence of roughness and hydrophilicity at the biological interface is presented.

Results. Most marketed and experimental surfaces are based on commonly available additive or subtractive surface modifying methods such as blasting, etching or anodizing. Different height, spatial, hybrid and functional roughness parameters have been identified as possible candidates able to predict the outcome at hard and soft tissue interfaces. Likewise, hydrophilic implants have been proven to improve the initial blood contact, to support the wound healing and thereby accelerating the osseointegration.

Significance. There is clear relevance for the influence of topographical and wetting characteristics on a macromolecular and cellular level at endosseous implant/biosystem interfaces. However, we are still far away from designing sophisticated implant surfaces with the best possible, selective functionality for each specific tissue or cavity interface. Firstly, because our knowledge of the respective surface related reactions is at best fragmentary. Secondly, because manufacturing of multi-scaled complex surfaces including distinct nanotopographies, wetting properties, and stable cleanliness is still a technical challenge and far away from being reproducibly transferred to implant surfaces.

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Contents

1. Functional requirements for dental implant surfaces – the concept of hybrid implants

Dental implants are used as artificial tooth roots since more than five decades to fix and support prosthetic suprastructures from single crowns to fixed and removable prostheses. The indication ranges from single tooth gaps up to edentulism. Remarkably, since the pioneering work of Brånemark, Zarb, Albrektsson, Schulte, Schroeder and others in the field of osseointegration [1–7], the material of choice is still titanium or titanium alloy, even though very recently alternative materials have gained increasing interest, first of all zirconia. Due to their white colored surfaces, zirconia implants and abutments are regarded esthetically superior compared to the gray colored titanium and have received broad scientific and clinical interest [8–13]. Nevertheless, titanium implant screws are still the gold standard for oral implant applications, first of all due to their surpassing biocompatibility and their ability to gain osseointegration, i.e., an intimate and direct contact with bone by a cement-free connection at the light-microscopic level.The envisioned idea is still to achieve a direct contact between living bone and the avital implant, aiming in this way to ensure the long-term function of the anchored prosthetic device [14].

Considering the transgingival nature of dental implants forming simultaneously several interfaces to the host biological system, we termed this implant type "hybrid implant" [15] consisting of: (a) the subgingival hard tissue interface of the endosseous implant body, (b) the soft tissue transgingival interface at the implant neck and platform, and (c) the interface to the oral cavity with its salivary environment at the transgingival and the supragingival region, the latter that region visible by eye containing the abutment or suprastructure, e.g., the crown. Any surface of the dental implant or, more precisely, the implant system, should be optimized to fulfill the different demands of the respective interfaces: at the hard tissue interface, osteogenic properties are required to optimize osseointegration; at the soft tissue interface, gingival attachment with cell-adhesive functionality for keratinocytes and fibroblasts is obligatory to ensure a tight epithelial seal that prevents bacterial infiltration. For both interfaces, bacterial colonization is regarded to be a main risk for severe infections such as peri-implantitis [16] This very inflammation goes in hand with a bacterial contamination of implant surfaces followed by a loss of osseointegration due to an immunologic host reaction, called "bone loss". Finally, extensive bone loss leds to implant loss (see Fig YY).

Therefore, trans- as well as supragingivally, implant/saliva interfaces should have antiadhesive or antibacterial functionalities to impede biofilm formation. It has to be noted that a three-dimensional interphase is the primary biological response to an initially only existing two-dimensional implant/biosystem interface. This dynamic formation of a transition zone between two phases with distinct width is associated for instance with hydration and macromolecular adsorption [17,18].

The challenge for advanced surface modifications in the trans-and supragingivally implant region is what has been termed "race for the surface", the contest between bacterial colonization and tissue integration of the same surface after implantation [19]. However, most studies until today have been directed toward the improvement of the biomaterial/bone interface and therefore, our knowledge in the field of the trans- and supragingival regions of implant screws and abutments is at best rudimentary.