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Dental Implant–Tissue Interface

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Abstract: The biomechanal interface between implant and tooth surfaces are critical for both the soft and tissue tissue integration. Here, the current review discuss the clinical importance of these dental implant–tissue Interface.

Keywords: Interface; surface; dental implant.

Introduction

Main factors affecting materials –tissue interface (General Guidelines). Factors greatly affect the materials–tissue interface include material surface properties and processes at such interface.

a) Material Surface Properties

The surface of a material is a termination of an extended; three-dimensional structure. Thus, generally represents an increase in energy due to unsaturated bonds (the surface energy). If there is a reactive environment at the surface, the bonds react to form new bonds and compounds, to ***lower its surface energy***. (1)

If the reacted surface is placed in another new environment, it is likely to react again to lower further the energy of the system. There is thus a ***built-in thermodynamic driving force*** for reactions.

An ***example*** here is titanium, which is used for dental implants and in orthopedic devices. When fresh titanium is exposed to air it reacts rapidly with atmospheric oxygen to form a surface oxide which is typically a few nanometers thick. The oxide stoichiometry is approximately TiO_2. The surface is never perfectly clean TiO_2, for the TiO_2 terminated surface tends to bind molecules or atoms from the surroundings as a mono-molecular layer. Even ***inert surfaces*** such as gold or diamond tend to lower their surface energy by suitable terminations on the ***atomic scale***. For example, diamond may terminate by C-H bonds at the surface. (1)

At the tissue-material interface, surfaces properties such as ***chemical composition***, ***wettability***, and ***topography*** play a determinant role in the biological interactions, particularly the ***microstructure*** and ***surface roughness***.

b) Processes at the Material-Tissue Interface

The molecular events at the material-tissue interface involve ***small molecules***, like water. The molecular events also involve ***larger molecules*** like proteins. Eventually the larger structures like ***cells***, which have lower mobility,

will reach the surface with its organic over-layer. Depending on the nature of the material surface and its organic coating, cells react differently to different biomaterials.

Dental Implant–Tissue Interface

One of the challenges in implantology is to achieve and maintain the ***osseointegration*** as well as the ***epithelial junction*** of the gingiva with implants. An intimate junction of the gingival tissue with the neck of dental implants may prevent bacteria colorizations which cause peri-implantitis while direct bone bonding may ensure a biomechanical anchoring of the artificial dental root.[1-5]

The first step of the osseointegration of implants is called ***primary stability*** and is related to the mechanical anchorage, design of implants, and bone structure. This primary interlock decreases with time at the benefit of the ***secondary anchorage***, which is characterized by a biological bonding at the interface between bone tissues and implant surface. ***Between*** the primary mechanical and secondary biological anchorage, a decrease of implant stability could be observed. [6]

Many studies have attempted to enhance the osseointegration of implants by ***various surface modifications***. The aim is to provide implants with surface biological properties for the adsorption of proteins, the adhesion and differentiation of cells, and tissue integration. However, the control of these surface properties at the protein and cell levels, thus in the nanometer range, remains a challenge for researchers and dental implants manufacturers.

Nanotechnologies may produce surfaces with controlled topography and chemistry that would help understanding biological interactions and developing novel implant surfaces with predictable tissue-integrative properties [6, 7]. Various surface treatments such as lithography, ionic implantation, anodization, and plasma treatments may be applied to the surfaces of dental implants to produce controlled features at the nanometer scale. These surfaces may then be screened by using high throughput biological assays *in vitro*. For instance, specific protein adsorption, cell adhesion, and differentiation of stem cells should be studied in relation to the surface properties. This approach may define the ideal surface for a specific biological response. Following *in vitro* screening, nanostructured surfaces may then be tested in animal models[4].

a) Interactions of Surface Dental Implants with Blood

During surgery, blood vessels are injured and, thus, dental implant surfaces interact with blood components. Various plasma proteins get adsorbed on the material surface within a minute, depending on the surface properties of the material [8]. A hydrophilic surface is better for blood coagulation than a hydrophobic surface. Consequently, dental implants manufacturers have developed high hydrophilic and rough implant surfaces for better osseointegration [9]. Adsorption of proteins such as fibronectin, vitronectin on surface of dental implants could promote cell adhesion by ***cell-binding RGD domain*** (arg-gly-asp). This RGD sequence interacts with integrin present on the cell membrane [10]. Interactions between cell membrane integrins and proteins coated onto

implant surface play a key role in adhesion of many cells types. After proteins absorption, the osseointegration is characterized by platelets adhesion and fibrin clots formation at the injured blood vessels site.[4]

There is a controversy about the role of platelet-rich plasma on the osseointegration. It has been shown that implants in contact with platelet-rich plasma (PRP) with a platelet concentration of approximately1,000,000 protein/μL have a positive effect on osteointegration. At lower concentrations of PRP, the effect was not optimal, while higher concentrations resulted in a paradoxically inhibitory effect of bone regeneration. Other studies were not in agreement with this PRP beneficial effect on the osseointegration of dental implants. [11]

The assessment of bioactivity of surface-treated dental implants should be tested *in vitro* using biological fluids containing blood components [12].

b) Interactions between Surfaces and Mesenchymal Stem Cells

Following blood clotting around dental implants, several cells interact with surfaces for tissue healing. Mesenchymal stem cells (MSCs) attracted to the injured site by chemotactic factors have a determinant role in peri implant tissue healing.

b-i) Origin of Mesenchymal Stem Cells

Mesenchymal stem cells (MSCs) are stem cells derived from somatic tissue which can be differentiated into mesenchymal lineages such as bone, cartilage, fat, and skin. In addition, MSCs are present in blood at low concentrations serving as a sort of internal repair system.

Mesenchymal stem cells are distinguished from other cell types by two important characteristics. ***First***, they are unspecialized cells able to renew themselves through cell division, sometimes after long periods of inactivity. ***Second***, under certain physiologic or experimental conditions, they can be induced to become tissue- or organ-specific cells with special functions. Thus, MSCs have high proliferative and multipotent capacity leading to differentiated cells. [4]

b-ii) Migration, Adhesion, and Proliferation

Cell migration, adhesion, and proliferation on implant surfaces are a prerequisite to initiate the tissue regeneration. Authors have shown that some factors present in tissues and secreted during the inflammatory phase are

able to attract MSCs to the injured site [13, 14]. MSCs migration and proliferation were stimulated by many growth factors [15-19]. These factors are certainly released in the injured sites by cells involved in tissue healing. Furthermore, plasma clot serves as storage to fibrin molecules and releases system for a variety of bioactive factors including growth factors that attract and differentiate MSCs into specific lineages [20-22].

After MSC recruitment in the injured site, cells adhere on the local extracellular matrix as well as on the implant surface beginning an extensive proliferation in order to build up new tissue. Again, surface modifications of implants in the nanometer range condition the biological responses. [4]

b-iii)Differentiation

MSCs are stimulated by ***some specific factors*** to differentiate into the adequate cell line. Under the influence of these factors, MSCs switch to osteoblastic cells in contact to bone tissue while they differentiate into fibroblastic lineage in the gingival tissue region. These two differentiation pathways are in concurrence around dental implants. In some cases, implants are encapsulated by fibrous tissue due to the proliferation and differentiation of MSCs into fibroblastic cells causing implant failure [23]. However, fibroblasts adhesion and proliferation have been shown to be lower on nanoscale implant surface [24-26].

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