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IMPLANT SURFACE AND TISSUE INTERFACE

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ABSTRACT This literature reviewed concerning implant surface and tissue interface. Information about various implants surfaces and their attachment to the tissue surface and their possible mechanism of cell attachments formation and their effect on implant surface properties on attachment is presented. The different types of implant surface designs and chemical attachment between implant surface and epithelium are demonstrated. The implant and bone interface at ultramicroscopic level shows a glycoprotein layer on implants to which collagen fibers are arranged. The implant surface and connective tissue interface represented with supracrestal connective tissue fibers arranged parallel to the implant surface, because of this it is not as strong as that of the connective tissue and tooth interface, but it is strong enough to withstand the occlusal forces and microbial invasions. The implant epithelial interface is considered as biological seal. A greater understanding of mechanism of attachments of and of factors which enhances the integrity of biologic seal between implant and both the hard and soft tissues should permit an improved prognosis of functioning of implants.

KEYWORDS: Osseointegration, Implant- Bone interface, Implant Epithelial Interface, Implant- Connective tissue Interface.

INTRODUCTION

Tooth loss is a very common problem; therefore the use of dental implants came into common dental practice. In early civilizations, carved sea shells, stones, whereas in middle ages allografts and xenografts were used as implants. Later in modern dentistry Dr.Aaron Gershkoff produced the first successful sub-periosteal implant. Most important development occurred in 1957; is studying the bone healing and regeneration in proximity with metal without being rejected by the Per-Ingvar Branemark and named this phenomenon as “osseointegration”.[1]

In natural dentition the connective tissue fibers connects the tooth cementum to the surrounding alveolar bone, the periodontal ligament tissues not only provides a highly sophisticated manner in which the forces exerted onto the teeth are transferred to the bony surfaces, but also provides additional functions such as mechano-reception; where as in implants receptors responsible for functional capabilities in the Periodontium are missing, epithelial perimucosal seal is observed on implant surface due to lack of cementum and connective tissue fibers insertion.[2]

The implant to tissue interface is an extremely dynamic region of interaction. This interface completely changes characters as it goes from its genesis (placement of implant into the prepared bony site) to its maturity (healed condition).[3]

The osseointegrated interface and associated soft tissue cuff where the implant penetrates the oral mucosa are often thought of as dental analogues. In particular, the interface is more rigid and less displaceable than the periodontal ligament and behaves essentially; elastically as opposed to the viscoelasticity of the periodontal ligament.[4]

Osseointegration is defined as presence of bone tissue directly bordering the implant surface; these osseointegration directly related to observe positive clinical long-term results with implants anchored in the bone.[5]

Successful osseointegration from clinical standpoint is a measure of implant stability, which occurs after implant integration. Implant stability depends on the nature of the contact between bone and implant surface. Primary

stability is accomplished when the implant is placed in the bone in such a position that it is "well seated" and it allows the implant to mechanically adapt to the host bone until secondary stability is achieved. The success of this adaptation, however depends on, the density and dimension of the bone surrounding the implant. A poor bone quantity and quality have been indicated as the main risk factors for implant failure as it may be associated with excessive bone resorption and impairment in the healing process compared with higher density bone.[6]

If the implant is stable in the bone at the time of placement; the interface is more likely to result in osseointegration.[7] A number of factors have been described as being important in determining the nature of implant-bone interface (Branemark etal 1977[8], Albrektsson etal 1981[9]). The factors which were included are: Biocompatibility of implant material, Design with good fit ,Pure surface conditions, Careful surgical technique, A healthy implant bed, Controlled primary loading conditions, Quality of the bone tissue at the site of implantation.

Hence an attempt is made to review the role of implant surface and tissue interface in implant dentistry.

BONE IMPLANT INTERFACE[10, 11]

When compared to compact bone, spongy bone has less density and hardness is not a stable base for primary fixture fixation. In the mandible the spongy bone is denser than maxilla. With primary fixation in compact bone, osseointegration in the maxilla require a longer healing period.

Two basic theories:

- Fibro-osseous integration by Linkow, James & Weis
- Osseointegration by Branemark

Fibro-osseointegration[12]

Weiss defends the presence of collagen fibers at the interface between the implant and bone, and interprets it as a peri-implant with an osteogenic effect. He believes that the collagen fibers invest the implant, originating at the trabeculae of cancellous bone on one side, weaving around the implant, and reinserting into a trabeculae on the other side.

When function is applied to the implant, tension is applied to the fibers ; forces closest to the implant interface causes a compression of the fibers , with a corresponding tension on fibers placed or inserting into trabeculae. The difference between the inner aspect (compression) and outer aspect (tension) of the connective tissue components results in bioelectric current, and this current (a piezoelectric effect) induces differentiation into connective tissue components associated with bone maintenance. Hence the premise of fibers being osteogenic.

Histologic study demonstrates either parallel fiber arrangements to the long axis of the implant, fibers with no real functional arrangement or simply a complete encapsulation. Meffert states that a functioning arrangement around an endosteal implants resembling the periodontal ligament does not exist.

Implant tissue interface

It consists**:**

- Implant and bone interface
- Implant and connective tissue interface
- Implant and epithelial interface

Implant and bone surface[10, 11]

On observing the implant and bone interface at light microscopic level it shows that close adaptation of the regularly organized bone next to Ti implants. Scanning electron microscopic study of the interface shows that parallel alignment of the lamellae of Haversian system of the bone next to the Ti implants. No connective tissue or dead space was observed at interface. Ultra microscopic study of the interface shows that presence of amorphous coat of glycoproteins on the implants to which the collagen fibers are arranged at right angles and are partly embedded into the glycoprotein layer.

Mechanism of attachment: As a general rule cells do not bind directly to the foreign materials. The cells bind to each other or any other foreign materials by a layer of extracellular macromolecules. The glycoprotein layer in between the cells or in between the tissues will be at a thickness of 10-20nm.At the interface the glycoprotein layer of normal thickness is adsorbed on the implant surface within the help of adhesive macromolecules like fibronectin, laminin, epibiolin, epinectin, vitronectin (serum spreading factor), osteopontin, thrombospondin and others. At the molecular level the macromolecules contain tri peptides made up of arginin- glycin- aspartic acid (RGD). The cells like fibroblasts and other connective tissue cells contain binding elements called integrins. The integrins recognizes the RGDs and bind to them. The macromolecules are adherent more firmly to the metallic oxide layer on the Ti implants. The mode of attachment between the oxide layer and the macromolecules may be of covalent bonds, ionic bonds or vanderwalls bonding.

Implant connective tissue interface[13]

The connective tissue above the bone attaches to the implant surface in the similar manner as that of the implant bone interface. The supracrestal connective tissue fibers will be arranged parallel to the surface of the implant. Because of this type of the attachment the interface between the connective tissue and implant is not as strong as that of the connective tissue and tooth interface. But the implant connective tissue interface is strong enough to withstand the occlusal forces and microbial invasions.

Implant epithelial interface[13, 14]

The implant epithelial interface is considered as biological seal. At this interface the glycoprotein layer is adherent to the implant surface to which hemidesmosomes are attached. The hemidesmosomes connect the interface to the plasma membrane of the epithelial cells. Because of this attachment the implant epithelial interface is almost similar to the junctional epithelium. For the endosseous implants the sulcus depth varies from 3 to 4 mm.

Factors important for the establishment of a reliable, long term osseous anchorage of an implanted device[8,9]

Implant biocompatibility, design characteristics, surface characteristics, state of the host bed, surgical technique and loading conditions. There is a need to control these factors more or less simultaneously to achieve the desirable goal of a direct bone anchorage.

Various implant surfaces and their tissue interface

Implant success has been assessed by survival rates, continuous prosthesis stability, radiographic bone loss, and absence of infection in the peri-implant soft tissues. Osseointegration remains the predominant parameter in implant dentistry. The importance of osseointegration is directly related to positive clinical long-term observations with implants anchored in bone, encompassing a fair prognosis and clinical success.

There is an increase in mineral content throughout osseointegration, accompanied by a decrease in the organic constituents (Sodek et al 2000)[15]. Monjo et al 2012[16] supported that the mechanical properties of bone which were greatly influenced by the distribution of organic and mineral constituents; during bone maturation, osteoblasts synthesize a collagenous matrix that subsequently becomes mineralized by the formation of hydroxyapatite crystals within and between the collagen fibrils. This assumption fits well with the negative correlation between the total protein content at the peri-implant bone tissue and the pull-out force.

Rani et al 2012[17] observed that synthesis of alkaline phosphatase (ALP) indicates, differentiation of osteoblasts from non-calcium- depositing to calcium-depositing cells. However they observed a significantly higher level of ALP production by the cells grown on nanoleafy structures compared to other samples after 14 days of growth. Similar effects were observed for the intracellular collagen production after 7 and 14 days of in vitro cultures. Osteoblast cells grown on nanostructured surfaces produced a significantly higher amount of collagen which was observed through scanning electron microscopy.

Monjo et al 2012 [16] stated that alkaline phoshatase (ALP) was thought to be involved in the first step of mineralization. Lower pull-out values with high ALP activity indicating primary mineralization along with bone-tissue remodelling in the interface, whereas high pull-out values with low ALP activity indicating a steady-state bone conditions with a more mature bone-implant interface. Piattelli et al 1995 [18] supported that ALP activity was lost in fully mature osteocytes and resting lining cells, when the bone matrix deposition and mineralization have ceased.

Whereas Rani et al 2012 [17] observed, significantly higher level of ALP production by the cells grown on nano leafy structures compared to other samples after 14 days of growth in an in vitro study. To confirm that enhanced osteoblast function, gene expression analysis was carried out by using real time polymerase chain reaction (RT-PCR), at 7 days of culture and observed that the cells on nanoleafy surfaces expressed 2-fold higher ALP mRNA than the control titanium and also there were further increased nearly about 10-fold after 14 days of incubation. However, the ALP gene expression was more or less reduced in cells cultured on all other nano featured surfaces. Altered stress fiber formation were observed on various nano topographies which might reduce the mechanical forces that activate connections between cytoskeleton and focal adhesion signaling, which in turn can affect the ability of the cells to sense and respond to extracellular stimuli. This was a probable reason for the reduction in ALP and collagen synthesis as well as gene expression on other than the nanoleafy surfaces. It was clearly noted that vertically arrayed, non-periodic, nanoleafy surface provides a topographic induction of changes in cytoskeletal organization, which in turns alters the gene expression profile. Cha 2015 [19] stated that, around low- insertion torque (IT) implants, ALP activity was high, indicating new matrix mineralization. Whereas in high- insertion torque (IT) cases, ALP activity was

restricted to osteocyte lacunae at some distance from the bone-implant interface.

Meenaghan etal 1979 [20] stated that the higher surface energy of glow-discharge-treated implant surfaces with an increased cellularity and associated ground-substance material with a decreased collagen fiber component and absence of inflammation at the implant surface.

Vandamme 2008 [21] observed that well-controlled micro motion of screw shaped implants stimulated tissue differentiation and bone formation in the implant surroundings and at its interface during the healing phase compared to absence of loading. Smooth surfaces do not provide adequate biomechanical coupling with the surrounding bone. Bone stimulation was induced by smooth surfaces when there is an adequate magnitude to induce bone formation.

Cecilia Yan Guo et al 2012 [22] stated that, NaOH-etched and subsequently heat-treated titanium possesses the ability to directly form an apatite layer. This phenomenon was explained by the electrostatic interactions of sodium titanate, Na2Ti3O7, on the titanium material's surface with ions in the living body. These treatment produced a negatively charged sodium titanate layer on the surface of the titanium material, which attracts positively charged Ca2+ ions, these Ca2+ ions exhibit higher binding affinity compared to other cations such as K+, Na+, and Mg2+; consequently, Ca2+ are predominantly absorbed on a negatively charged biomaterial surface in a biological environment. After Ca2+ ions accumulation on the biomaterial's surface, the surface becomes positively charged; hence, the surface starts to attract negatively charged phosphate ions, which react with the Ca2+ ions to form a calcium phosphate (i.e., a type of apatite) layer. Thus calcium phosphate layer takes an amorphous structure after its formation, and it subsequently transforms into more stable crystalline apatite. While it was widely agreed that negative surface-charge is more effective for promoting bone-implant interaction of titanium dental implants. It was found that on a negatively charged biomaterial surface, cells proliferate more actively; meanwhile, multiple layers of cells and enlarged colonies of Osteoblast-like cells were also observed. In contrast, cell adhesion and proliferation on positively charged biomaterial were found to be subdued.

Daniel Perrin et al 2002 [23] stated that sand blasted and acid etched (SLA) surface allows high micromechanical anchorage of bone in the created pits. Curiously, thus soft surface was able to achieve reverse torque resistance as high (Buser et al 1999)[24] or even higher than the titanium- plasma sprayed surface (TPS) .The topography of the SLA surface, with its combination of macro and micro roughness was responsible for enhanced bone response, when compared to that of other titanium surfaces (Buser et al, 1991)[25].

Carl-Johan Ivanoff et al 2003 [26] stated that Albrektsson found that oxidized titanium implants showed significantly more bone-implant contact and higher removal torque values than turned implants after 6 weeks of healing. The rougher, isotropic, oxidized surface showed better bone fixation than the turned surface, as evaluated by the amount of bone in contact with the implant surface and the amount of bone in the threaded areas. However, some small pieces resembling the oxide layer had become loose and were seen in the surrounding soft tissue areas as well as internalized in cells. Most likely this was the result of "tearing off" of the oxide coating during placement of the self-tapping implants into the bone bed. Similar findings have been observed by Sul et al 2002 [27] that around oxidized titanium implants placed in rabbit bone. Thus the thick oxide layer may lead to a strong bone response. The change in the morphology of the oxidized implants (size and distribution of pores) may be another reason, whereas the turned surface lacks such features.

Wiskott 1999 [28], has been observed that the polished neck of dental implants does not osseointegrate as do textured surfaces. Rich & Harris 1981[29] have been observed that certain cell lineages differed in their affinity for various implant surface textures. It was appeared that cells have a tendency to align themselves along the fine striations and grooves which were left after machining (Brunette 1988)[30]. Bowers et al 1992[31] in his in vitro study suggested that cells were more adhered to sandblasted surfaces than that of smooth surfaces. Groessner-Scbreiber & Tuan 1992[32] stated that "rough" textures promote increased cellular activity when compared to "smooth" titanium surfaces.

CONCLUSION

The endosseous dental implant has become a scientifically accepted and predictable treatment for completely and partially edentulous patients. Successful osseointegration is a perquisite for functional dental implants. The osseointegration is a complex process that can be influenced by many factors relating to the surface topography, biocompatibility, and loading conditions all play an important role in osseointegration. Titanium and its alloys are the materials of choice clinically, because of their excellent biocompatibility and superior mechanical properties. The combined effect of surface energy, surface roughness, and topography on implant determines its ultimate ability to integrate into the surrounding tissue. Surface modification technologies involve preparation with either an additive coating or subtractive method. Cell migration, adhesion, and proliferation on implant surfaces

are important prerequisites to initiate the process of tissue regeneration, while modifications of the implant surface by incorporation of biologic mediators of growth and differentiation may be potentially beneficial in enhancing wound healing following implant placement.

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