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REVIEW ARTICLE

The Peri-Implant Zone: A Review of Literature

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ABSTRACT

Aim: The peri-implant zone comprises of a stable crestal bone and overlying peri-implant mucosa. Soft tissue esthetics are not attributed to a single parameter. The aim of this article is to highlight the underlying biology of the soft and the hard tissue complex, the associated vital parameters, implant component characteristics which act as the foundation of a successfully osseointegrated implant.

Materials and methods: An electronic Medline was conducted with the search words used as: peri-implant, interdental papilla, peri-implant esthetics. Hand search across the journals referring to implantology, periodontology and prosthodontics was also done.

Conclusion: This article presents a comprehensive review of the various factors responsible in determining a successful soft tissue esthetic outcome in implantology.

Keywords: Peri-implant esthetics, Peri-implant soft tissue, Interdental papilla.

INTRODUCTION

Oral implants pierce through the mucosa, thus establishing the connection between the oral environment and the underlying tissues. The soft tissue connection to the transmucosal part is of crucial importance as it relates to the stability of the peri-implant tissues and the prevention of the peri-implant infection with subsequent destruction of the peri-implant structures. Branemark et al[1] introduced the two-stage protocol in implant dentistry with successful outcomes. Hermetic closure of the gingival tissues is important to minimize the risk of infection and prevent the apical down growth of the epithelium.[2] Recently, more implants are placed following a one-stage surgical approach where an (healing) abutment is placed at the time of implant insertion.

It has been well-documented in literature that bone supporting two piece implants undergoes crestal bone loss after the connection of the abutment and delivery of the prosthesis in single tooth implant replacement, partially edentulous mouth and completely edentulous mouth.[3-5] Albreketsson et al established success criteria for implant treatment that included 1.5 mm loss of crestal bone in the first-year of the implant function and a subsequent 0.2 mm in the following years with mucosal recession as inevitable in implant restorative treatment.[6]

The peri-implant zone primarily comprises of the crestal bone and the healthy soft tissue around it. They are considered necessary for the long-term success of implant-supported restorations. If these two parameters are respected, implant therapy can be a reliable treatment with an impressive outcome.[7] The primary function of a soft tissue barrier at implants is to effectively protect the underlying bone and prevent access for microorganisms and their products. A soft tissue seal with structures similar to that of teeth with a true connective tissue attachment to the implant may improve this protective function.

THE PERI-IMPLANT SOFT TISSUE BIOLOGY

The soft tissue that surrounds dental implants is termed as peri-implant mucosa, and the interface portion between the implant and the mucosa is comprised of one epithelial and one connective tissue component. The epithelial part is called barrier epithelium and resembles the junctional epithelium around teeth.[8-10] It was reported that basal lamina and hemidesmosomes occurred 2 weeks after implant placement[11] and that hemidesmosomes were formed in 2 to 3 days of healing.[12] Functional similarities have been found between the gingival and peri-implant mucosa. Collagen type I is the main constituent part of the supracrestal connective tissue of the peri-implant mucosa in human biopsies. Furthermore, gingiva and peri-implant mucosa have shown similar distribution of collagen type I, III, IV, VII and fibronectin, whereas collagen type V is found in higher amounts in peri-implant tissues.[13]

The mucosa that encircles the implant has more of collagen and fewer fibroblasts as opposed to gingival tissues. The collagen fiber bundles run parallel to the titanium surface without attaching to it versus the perpendicular direction around the tooth.[14] The supracrestal vascular topography surrounding the fixture is reduced and diversly arranged.[15] Junctional epithelium is approximately 2 mm long. Encompassing the fixture in a tissue with low

cellularity and vascularity resembling the cicatricial tissue that requires careful surgical handling.

BIOLOGICAL DIMENSIONS

The dimension of the peri-implant mucosa has been demonstrated to resemble that of the gingiva at teeth and included a 2 mm long epithelial portion and a connective tissue portion about 1 to 1.5 mm long.[14,15] The entire contact length between the implant, the epithelial and the connective tissue portions is defined as the biological width.

Experimental studies have demonstrated that a minimum width of the peri-implant mucosa is required. If the thickness of the peri-implant mucosa was reduced, bone resorption occurred to re-establish the mucosal dimension that was required for protection of the underlying tissues.[16] This physiological dimension was similar in loaded and unloaded conditions.[17] Neither was the soft tissue of the peri-implant mucosa influenced of immediate functional loading or a posterior position in the mandible arch.[18] When different two-part implant systems were compared similar soft tissue dimensions were exhibited.[19] Implant systems that consisted of either one-part or two-part implants were found to exhibit similar soft tissue dimensions.[20] In other studies, it was suggested that the one-piece implants had shorter soft tissue dimensions than the two-piece implants.[21] Healing after different surgical procedures was also evaluated. It was reported that similar soft tissue dimensions were established using a submerged or a nonsubmerged installation technique but a longer epithelial attachment was reported for the submerged installation technique.[22]

FACTORS RESPONSIBLE FOR THE PERI-IMPLANT SOFT TISSUE HEALTH

Factors influencing the Position of the Papilla and Gingival Margin

Important factors influencing papilla are the biologic width and the position of the crestal bone from the contact point. Gingival margin is affected by periodontal biotype, width of the facial bone, abutment material and design, interimplant distance, implant abutment junction, abutment disconnection (one-stage or two-stage) and surgical technique adopted.

Periodontal biotypes are chiefly classified as thick flat and thin scalloped. Both biotypes tend to respond in a different way to inflammation or to surgery. Thin biotype is more prone to recession following procedures.[23] Thick biotype on the other hand is more stable and resistant to recession and the prosthetic maneuvers required at the stage two procedures.[24] Around 1.8 mm of the cortical bone width should be left all around to avoid crestal bone loss and recession.[25] When the vertical distance from the contact point to the alveolar crest is < 5 mm, papilla fill is almost 100%. A minimum of 3 mm of the interimplant distance should be maintained to avoid crestal bone loss and subsequent necrosis of the papilla.[26,27] Full thickness flaps lead to an unavoidable bone resorption. Approximately, 1 mm of alveolar height and width get resorbed till the prosthesis completion.[28]

INFLUENCE OF THE ABUTMENT MATERIAL DESIGN, SURFACE AND CONNECTIONS ON SOFT TISSUE INTEGRATION

Abutment Material

The traditional abutment material of dental implants was commercially pure titanium due to its well-documented biocompatibility and mechanical properties. Esthetic awareness in implant dentistry, however, demands the development and use of other materials than titanium in the abutment part of the implant. In an animal study, Abrahamsson et al analyzed soft tissue healing to abutments made of titanium, gold-alloy, dental porcelain and Al_2O_3 ceramic. It was demonstrated that gold-alloy and dental porcelain failed to establish a soft tissue attachment while abutments made of titanium and ceramic formed an attachment with similar dimensions and tissue structures. In a subsequent animal experiment, however, it was reported that the peri-implant soft tissue dimensions were not influenced, if titanium or gold-alloy was used in the marginal zone of the implant.[29]

Results from microbial sampling studies have revealed less bacteria and plaque accumulation on zirconia disks than on titanium disks.[30,31] An animal model loaded custom-made zirconia and titanium implants demonstrated similar soft tissue dimensions.[32] Soft tissue biopsies that surrounded titanium and zirconia healing caps were analyzed and it was demonstrated that the zirconia healing caps presented a lower inflammatory level in the tissues than that at titanium healing caps.[33]

In clinical studies, titanium and ceramic (Al_2O_3) abutments were compared regarding microbial sampling and soft tissue conditions and no differences between the materials were observed. One of the promising studies by Vigolo et al assessed the peri-implant mucosa health around abutments made of gold-alloy, titanium and no evidence of different response to the materials were found.[34]

Implant Neck Design/Crest Module

Crestal bone loss around endosteal implants is a common phenomenon. The highest bone stress has been reported to be concentrated in the cortical bone in the region of the implant neck as observed in the FEA studies. It has been suggested that the following factors are the most likely causes of the early implant bone loss: Microgap if placed at or below the bone crest, implant crest module, occlusal overload and the reformation of the biologic width around dental implants.[35] The crest module is that part of the implant that receives the crestal stress to the implant after loading. After the implant is loaded, bone loss has been observed

down to the first thread in many submerged implant systems which have different distances from the implant platform to the first thread.[36] It has been hypothesized that the bone loss may slow down at the first thread due to the changes in the shear force of the crest module to a component of compressive force caused by the thread itself.[36]

The implant neck design is one of the areas of development to improve the integrity of the soft tissue integration. Microtextured and macrotextured surfaces have been explored. These designs mainly aimed to enhance the stability of interface for both soft and hard tissue and minimize the marginal bone reduction in the first year of implantation.

Proposed levels of crestal bone loss as reported in the literature was countered by the recent human clinical trial of the laser microtextured implant surface by Pecora et al.[37] In a 3-year postoperative results, it was reported that the laserlock surface treatment enables the reduction of the crestal bone loss to 0.59 mm. Possible reasons are attributed to the reduction of the crestal bone stress through a combination of the implant design and surface modification.

An animal study done to compare the surface design between turned, microtextured and microgrooved implant neck designs revealed that the bone implant contact (BIC) and the overall soft tissue response was higher and better respectively, in microgrooved implants *vs* the turned and microtextured implants.

Influence of Mucosal Thickness on the Soft Tissue Integration

It has been proposed that a minimum of 3 mm of peri-implant mucosa is required for a stable epithelial connective attachment to form. It has been suggested that, if a minimal dimension of gingival tissue is not available, bone loss may occur to ensure the proper development of the biologic width. The transition of the alveolar mucosa to the peri-implant mucosa is a difficult and complex process. Linkevicious et al[38] in a human study done to compare the effects of the tissue thickness at the time of surgery on crestal bone changes around nonsubmerged implants after one year follow-up found that positioning an implant 2 mm supracrestally did not prevent crestal bone loss, if thin gingival tissues are present at the time of implant placement. Implants with thin tissue underwent additional bone loss interproximally versus the group with thick tissue pattern which had significantly less bone loss. The practical conclusive findings of this study were initial tissue thickness if less than 2.5 mm, leads to an expected bone loss of 1.45 mm within the first year of function. In thick tissues, > 2.5 mm or more, marginal bone recession can be avoided if the implant abutment junction is 2 mm or above the bone level, a negligible amount of bone loss (around 0.2 mm) would occur. Measurement of the gingival thickness is mandatory in any evaluation of the marginal bone loss. Also, the thickening of the thin mucosa should be considered before implant placement.

Soft tissue integrity is extremely important to be maintained during the healing phase of the two-stage submerged implant. When gingival tissues above the cover screw of a two-stage implant is perforated unintentionally during healing phase, an inflammatory reaction occurs resulting in marginal bone destruction.[39] Spontaneous perforation of the gingival tissues coronal to implants can be caused by acute and chronic mechanical trauma of prosthetic devices or failure of the primary wound closure due to tension in the flap. Also, a supracrestal location of the implant head can result in irritation and perforation of the mucosa. Unintentional exposed implants loose around 2 mm of the marginal bone.[39] Healing abutment should be placed as soon as the perforation is diagnosed to avoid further bone loss. After placing the healing abutment, the mucosa is supported and raised by the abutment to a dimension that may reach the dimension of the biologic width.[40]

Influence of Abutment Disconnection on Soft Tissues

The presence of a transmucosal component at two-piece implant system can lead to intentional/unintentional disconnections of the abutment. An unintentional abutment loosening will lead to a disruption of the soft tissue integration and to increased bone remodeling. It has been seen that repeated connections/disconnections induces apical repositioning of the soft tissues and marginal bone resorption.[41]

BONE LOSS AND SOFT TISSUE HEALTH

Surgical trauma, occlusal overload, microgap, biologic width, design of the crest module and peri-implantitis have been cited as the crucial factors governing the stability of the crestal bone and in turn the integrity of the soft tissue.[35] Peri-implantitis has been cited as one of the chief factors responsible for implant failure. It is defined as the inflammatory lesion leading to suppuration, deepened pockets and supporting bone loss.[42] Disruption between the host parasite equilibrium owing to the biofilm formation leads to the peri-implant soft tissue breakdown with a progressive bone loss.[43,44] Role of bacteria as an etiology of the peri-implant infection has been the topic of debate in the early era of implantology.[45] However, with the evidence of first detection of bacteria in the peri-implant infection[46] and the elaborate studies that followed suggested that peri-implantitis is a infectious disease process with micro-organisms similar to those found in chronic periodontitis as found around teeth.[47]

Mombelli[48] outlined the clinical features of peri-implantits as—(a) bleeding and suppuration on gentle probing, (b) mucosal swelling and redness, (c) formation of the peri-implant pocket, (d) radiographic evidence of bone

loss and (e) pain is not a frequent feature. Several risk factors have been reported to be associated with the peri-implant diseases.[49] These factors include history of periodontitis, diabetes, genetic traits, poor oral hygiene, smoking, tobacco consumption, alcohol consumption, absence of the keratinized gingiva and the implant surface.

DISCUSSION

A sound integration of the implant components and the hard and soft tissues determine the longevity of the dental implant. Herein lies the importance of the peri-implant bone health, i.e interproximal and the crestal, for the desired health and esthetics of the overlying soft tissue. The implications of the desired interproximal height of bone (IHB) and its importance on the interproximal papilla for a predictable esthetics has been extensively discussed. The interimplant distance and the distance from the crest of the bone to the contact point of the adjacent tooth or implant dictate the dimensions of the soft tissue volume. It has been stated that when the vertical distance from the contact point to the alveolar crest is < 5 mm, papilla fill is almost 100%. A minimum of 3 mm of the interimplant distance should be maintained to avoid crestal bone loss and subsequent necrosis of the papilla.[26,27] The mean papilla length for an implant-tooth relationship has been found to be 6.5 mm; for an implant-implant relationship as 4.5 mm.[50] Facial soft-tissue deficiencies can create the appearance of a tooth/implant that is longer than desired. In the interproximal region, inadequate crestal bone height causes soft tissue deficiency that would result in a missing interproximal papilla resulting in "black triangle".

Significant aspects of the peri-implant histology were highlighted by Ericsson,[43] who described two types of inflammatory lesions in the peri-implant soft tissues. One was associated with the gingival sulcus—called as plaque associated inflammatory cell infiltrate (P/ICT) and the second lesion associated with the implant abutment junction (IAJ) (a/ICT). The peri-implant bone crest is approximately 1 to 1.5 mm apical to the IAJ and that the apical border of the abutment ICT is always separated from the bone crest by 1 mm of healthy connective tissue. This indicates that once the biological dimension is established, the soft tissue seal and attachment to the dental implant provide a protective function to isolate crestal bone from oral environment.[51]

The design of the implant whether one-stage/two-stage also acts as an important parameter for the stability of the soft tissue health as they influence the crestal bone health. In one piece implant, the transmucosal component facing the soft tissues makes part of the implant. It is generally placed according to the one-stage surgery where the implant immediately pierces the soft tissue barrier (nonsubmerged). In two-piece implant, the transmucosal component (the abutment) dedicated at soft tissue integration is a separate part from the implant body. It has an implant abutment junction that lies in the neighborhood of the alveolar bone level. The two-piece implant can either be submerged under the soft tissues (two-stage surgery) or be placed according to the one-stage surgery, like one-piece implant. The clinical implications of the two-stage implants are crucial as these designs exhibit microgap of 1 to 10 micrometer.[52] This microgap has been reported to be as high as 40 to 60 micrometers, which will allow the accumulation of the food debris and bacteria that causes localized inflammation. In addition, this microgap also causes micromovements between the parts during clinical function both of which can lead to localized inflammation and crestal bone loss.[53] The microgap-crestal bone level relationship was studied radiographically by Hermann et al[54] who for the first time, demonstrated that the microgap between the implant/abutment has a direct effect on crestal bone loss. This in turn is responsible for crestal bone loss of 2 mm below the microgap.

Several abutment designs have been reviewed in pursuit of preservation of the crestal bone. Use of nonsubmerged implants to eliminate bone loss is a proven way to accomplish this.[55] A scalloped implant platform was developed to follow the osseous architecture and eliminate crestal bone loss by maintaining the microgap in a supracrestal position.[56] One-piece implants or use of tapered abutment connection is yet another option available proven with accomplished results.[57] Another method is altering the horizontal position of the microgap through switching the diameter of the abutment—platform switch.[58]

CONCLUSION

The peri-implant health is primarily determined by the sound crestal bone levels, and the associating biological factors responsible for the soft tissue health, i.e factors governing the gingival margin health, peri-implant papilla and as correctly said by the proceedings of the 3rd European workshop on periodontology and implant dentistry that the function of peri-implant zone is to act as a protective seal to maintain homeostasis of the internal environment in response to challenges from the external environment.[59]

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