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IMPLANT DESIGN AND STRATEGIES TO REDUCE MARGINAL BONE LOSS: A REVIEW.

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Abstract: Marginal bone loss around implants is a threat to a long term implant survival. In an attempt to improve the long-term bone maintenance around implants, the effect of biomechanical aspects of dental implant design on the quality and strength of osseointegration, the bone-implant interface and their relationships to the long-term success of dental implants were evaluated. The implant design is based on many interrelated factors including the implant geometry, mechanical properties, the initial and long-term stability, the role of surface roughness and implant thread designs. There is no optimal design criterion. However, implants can be engineered to maximize strength, interfacial stability and load transfer by using different materials, surfaces and thread designs. Therefore, this article reviews and discusses design elements of various dental implants which affects the quality of osseointegration and maximize marginal bone preservation.

Key words: Dental implants, implant design, platform switching, surface roughness, implant microthread designs.

Introduction:

Tooth loss progresses due to continued alveolar bone resorption and decreased masticatory performance. These problems have been associated with a negative impact on psychosocial well-being, especially among elderly individuals. Replacement of missing tooth with dental implants has led to an important revolution in modern clinical dentistry. Branemark in the early 1960s was the first to introduce osseointegrated dental implants to allow firm anchorage of titanium implant screws into living bone and he named this process as Osseointegration. The long-term clinical success of dental implants depends mainly on the preservation of the bony support around the implant.[1]

Dental implants are tiny structures that are subjected to considerable loads. Despite the high success and survival rates of dental implants, failures may occur that determine the success criteria of dental implants which includes hard and soft tissue responses. Especially, marginal bone loss (MBL) around the implant is the most important criteria to obtain success. The main theories explaining marginal bone loss are controversial and includes infection or overloading the implant.[1,2]

The infection theory states that implants behave like a natural teeth and are susceptible to similar types of disease as natural teeth, the major difference being the term i.e. periodontitis is used for natural teeth and peri-implantitis being used for implants.[2]

The overloading theory states that the marginal bone loss (MBL) could occur due to altered occlusion and excessive occlusal forces may cause further bone resorption around implants. Overloading has been identified as a primary factor behind dental implant failure. If bone is subjected to extreme stress, bone resorption tend to occur. The peak bone stresses normally appear in the marginal bone. The anchorage strength is maximized if the implant is given a design such that it minimizes the peak bone stress caused by a standardized load. The use of different designs of the implant-abutment interfaces imply that the functional load is distributed in different ways upon the implant.[2,]

Marginal bone loss around implants is a threat to a long-term implant survival. The remodelling process involves marginal bone resorption that is affected by one or more of the following factors: (1) infectious process; (2) excessive loading; (3) the location, shape, and size of the implant-abutment microgap and its microbial contamination; (4) biologic width geometry and implant surface roughness; (5) peri-implant inflammatory infiltrate; (6) micro-movements of the implant and prosthetic components; (7) repeated screwing and unscrewing; (8) implant-neck; and (9) traumatic surgical technique.[1,3]

Gozde Ozyanat Ozgur et al, analysed the reason behind the long term marginal bone loss and he demonstrated that the bone loss is higher in the posterior region than anterior region. When the crown/implant ratio is 1.5/2 the marginal bone loss will be significantly higher. The occlusal table width/implant diameter is 2.5/2.99 and more than 3 the MBL will be significantly high. Therefore the MBL is affected by the location of implant and excessive crown/implant and occlusal table width/implant ratio may result in increased rate of marginal bone loss.[1]

The crestal bone level changes were frequently observed at dental implants, after exposure to the oral environment. The etiology of this peri-implant crestal bone resorption is still unknown, even if several causes like surgical trauma, peri-implantitis, occlusal overload, formation of a biological width, macroscopic and microscopic characteristics of the neck of the implant, implant-abutment interface design, bacterial infiltration of the microgap, position of the microgap.[3]

Over the years, various attempts are made to prevent or reduce marginal bone loss through modification of the implant-abutment connection, implant thread design and surface roughness. Some of these modifications are:

1. PLATFORM SWITCHING:

The connection between the implant fixture and its restorative abutment is termed as implant abutment interface (IAI) or “microgap”. The microgap is susceptible to micro-movements during clinical function and also permits micro-leakage of fluids. The bacterial colonization of the microgap is described with the presence of an inflammatory cell infiltrate at the implant-abutment junction and the presence of infiltrated connective tissue shows immune response to bacteria colonizing at the implant-abutment junction (IAJ). The sustained state of inflammatory cell infiltrate promotes osteoclast formation and activation which contributes to bone loss. The infiltrated connective tissue (ICT) is responsible for bone remodelling. So, placing the microgap inwards may shift the infiltrated connective tissue further from the alveolar crest and moving implant-abutment junction (IAJ) away from the external edge of the implant shoulder and from crest bone which may help to reduce the bone resorption shifting the inflammatory cell infiltrate within the angle formed at the interface, away from the adjacent crestal bone.[3]

The platform-switched abutment design concept has been proposed in the mid ‘80s to overcome some of the detrimental effects related to the implant-abutment connection microgap, were the larger diameter implants were restored with narrower abutments. If the prosthetic connection base is narrower than the implant’s cervical collar, there will be less marginal bone resorption and a better esthetic outcome, and also platform switching may increase the distance between the abutment inflammatory cell infiltrate and the alveolar crest, thus decreasing the bone‑resorptive effect.[4]

In 1991, Implant Innovations, introduced 5 mm and 6 mm diameter implants. These implants were intended to increase the bone to implant contact, when the shorter implants are placed in areas of limited bone height. At that time, prosthetic components of similar dimension were not easily available; hence clinicians restored them with standard 4.1 mm diameter components, which created a 0.45-0.95 mm circumferential horizontal difference in dimension between the implant seating surface and the attached component.

After a 5-year period, the typical pattern of crestal bone resorption was not observed in platform switched implants. Thus, the discovery of the concept was a coincidence. Platform switching concept was introduced in the literature by Lazzara, Porter, and Gardner. Through the placement of smaller prosthetic components on the implant platform, the implant-abutment junction is moved inward from the implant shoulder and further away from the bone, shifting the inflammatory cell infiltrate to the central axis of the implant and away from the adjacent crestal bone. The concept of platform switching showed that platform switching decreased bone resorption to 0.95 mm and also significantly reduces bone resorption than compared with conventional implants.[1]

Stefan fickl et al demonstrated that implants with a platform-switched configuration showed significantly less bone loss at the time of insertion of definitive prosthesis was 0.30 ± 0.07 mm and 0.68 ± 0.17 mm in non-platform switched implants and at 1 year, platform switched implant showed 0.39 ± 0.07 mm and 1.00 ± 0.22 mm when compared to the non-platform-switched implants. Hence, Platform-switched implants seem to limit crestal bone remodelling.[10]

By increasing the discrepancy between the diameter of the implant platform and the restorative abutment may lead to a decrease in the amount of subsequent coronal bone loss.

Roberto cocchetto et al demonstrated that wide platform switched implant with a body diameter of 5.0 mm, an expanded platform with maximum diameter of 5.8mm at the collar and prosthetic seating surface of 5.0 mm with implant lengths of 8.5, 10.0, 11.5 or 13.00 mm showed less crestal bone loss than compared with regular platform switched or traditional non- platform switched implants.[11]

Implant platform modification technique:

The implant platform modification technique consists of different diameters of implant platform and abutment. Xavier Vela-Nebot et al demonstrated that modified implant platform can reduce bone loss significantly than compared with a matching diameter implant platforms and abutments. The maximum bone resorption was observed 3.10mm in matching diameter implant platform and abutment group and 1.20mm in the modified implant platform group.[12]

Alexander veis et al evaluated peri-implant marginal bone loss using modified abutment connections at various crestal level placements showed that the crestal placement of implant abutment connection resulted in higher marginal bone resorption in both straight and platform switched abutments. Hence, the platform switching concept is beneficial only when it is placed subcrestally.[13]

2. DENTAL IMPLANT THREAD DESIGNS:

The fixation of osseointegrated implants primarily depends upon the mechanical interlocking. Several studies has been demonstrated that the bone implant interfacial shear strength can be increased by means of a rough surface.[5] There are a variety of dental implant thread designs are commercially available. Dental implant thread designs have influence on insertion torque and primary stability and can also enhance initial contact, dissipate load forces, and increase surface area at the bone-implant interface. Thread shape is important in providing long term function under occlusal loads and the thread depth increases the functional surface area. The direction of forces arising from the occlusal load in a restored implant is influenced by apical face angle of thread and the thread depth increases the load transfer to flexible cancellous bone than to crestal cortical bone which contributes to less cortical bone resorption.[5,6]

Implant geometry may also have an impact on marginal bone loss. There are 4 main geometric thread parameters, they are: pitch, lead, shape, and depth.

Pitch has the most significant influence on surface area and also improves the anchorage of implants. Thread lead influences the amount of revolutions required to insert an implant in reverse proportion. As the thread lead grows, the thread helix angle grows accordingly, which potentially effect on the forces transmitted to the bone.

Thread shape is important in providing long-term function under occlusal load. The direction of forces arising from occlusal load in a restored implant is influenced by the apical face angle of the thread. Thread shapes in dental implant designs include square, V-shaped, buttress, and reverse buttress. A square thread design can reduce the shear force and increase the compressive load. The standard V-shaped thread, called a “fixture” in engineering, has 10 times greater shear load on bone compared with a square thread. Buttress thread shape is optimized for pull-out loads and has parallel major and minor diameter. The reverse buttress thread is flat on the top, and optimized for pull-out loads.

Profound thread depth increases functional surface area. This is advantageous in soft bone. A shallow thread is more easily inserted, which is advantageous for denser bone. Implant design can have progressive threads with higher thread depth in the apical area that gradually decreases coronally which increases the load transfer to the more flexible cancellous bone and decrease load transfer to the crestal cortical bone. This may contribute to less cortical bone resorption.

Zeev Ormianer et al in his study compared different types of implant thread designs which includes:

a. Spiral implants- These implants have a progressive thread design with a tapered body and core and have a double-lead thread design with a wide step between threads. The lead is 2.1 mm hence the pitch is 1.05mm. The coronal threads are shallower and thicker square threads, the middle threads are deeper and thinner square threads, whereas the apical threads are deep V-shape threads. In the apical area, the core is narrow, deep sharp threads that act like a blades.

b. Dual-fit implants (DFIs) - These implants also have a progressive thread with the same sequence in the corono-apical direction as the Spiral implants (SPI). Dual-fit thread implants have a smaller lead of 1.2 mm and a pitch of 0.6 mm than compared to Spiral implants (SPI). A smaller pitch defines a thread helix angle which is more obtuse and there are more threads in the same implant length. The apical v shaped threads are shallower with an implant core that is not narrow.

c. Arrow implants- These are narrow, 1-piece implants with a single- lead V-thread design. The threads have a relatively straight face angle, therefore have a bone condensing property. Their body and core are tapered, with a narrow and rounded apex.

Implants with a larger pitch, deeper apical threads, and a narrower implant core showed less long-term bone loss. The best survival rates was observed in 1-piece V-thread design implants where the average bone loss was 1.90mm than compared to Spiral implants (SPI) 2.02mm and Dual-fit thread implants (DFI) 2.10mm.6.

Liang kong et al demonstrated that the stress distribution and the magnitude of the stress peaks in cortical and cancellous bone may depend on variation of the shapes of the thread of an idealized, axially and buccolingually loads and screw-shaped bone implants. In all loading situations, the highest stress in the bone was mainly concentrated in the cortical bone, around the implant. Because of a great difference between the stress values in the cortical and cancellous bone. Square design showed better stress distribution than v-shaped and buttress designs under axial and buccolingual load.[15]

3. SURFACE ROUGHNESS OF DENTAL IMPLANT:

Primary implant stability may be influenced by bone quality and quantity, implant geometry and site preparation technique. So, technical modifications can be done to adapt to different clinical situations by increasing surface roughness, which may establish the biologic width and optimize initial stability and maximize the crestal cortical bone preservation by translating shear strains at the interface to a more compressive component. The different titanium implant surface configuration may give rise to divergent manner of tissue integration which may yield to more or less direct bone to implant contact or different values for removal torque. The interface between bone and different smooth or rough titanium surfaces have indicated that rough surface render more direct bone-implant contact than smooth surface and also have a better early anchorage in bone tissue.[7,8]

The surface roughness and the free surface energy of implant surface exposed to the oral environment may strongly influence the colonization of bacteria organized in biofilms and may lead to the development of peri-implant disease.[9] peri-implantitis may lead to complete disintegration and implant loss. Several attempts are used to stop the progression of the disease and to regenerate the lost tissues. New surgical approach with a modification of the implant surface called implantoplasty. Implantoplasty usually consists of removal of implant threads and smoothening rough implant surfaces with rotary instruments. This therapy reduces the severity of inflammatory reaction and re-establishes a physiological biologic width by reducing pocket depth.[9]

Dental implants are usually associated with higher rates of integration failure. This may be due to poorer bone quality. Therefore, enhancing bone growth towards implant surface is essential in cases with poor bone quality. Implants with rough surface have better early anchorage in bone tissue and a higher percentage of bone implant contact than implants with smooth surfaces. The amount of bone formation at the interface may be affected by surface topography.[8]

A number of studies demonstrated that increased surface topography results in increased bone to implant contact early after implant placement. The use of implants with micro rough titanium surfaces have paved the way for developing further surface topographies to promote enhanced peri-implant bone apposition during the early stages of bone regeneration. The chemically modified sand-blasted acid-etched (SLA) surface compared to the standard sand-blasted acid-etched (SLA) surface may improve osseointegration during the initial phases of healing.

Giovanna Orsini et al demonstrated that a thin deposits of hydroxyapatite (HA) and calcium phosphate (CaP) crystals on implant surfaces may accelerate early bone formation and increases the strength of the bond between implant and bone. Osteoconduction is increased along the CaP-treated surface during the first 2 months after implant placement. These nanometric deposition of CaP crystals can shorten the implant healing period, providing earlier fixation, and minimizing micromotion, thus allowing earlier loading protocols and restoration of function for implants placed in areas with low-density bone.[8]

Hammerele et al, implants with increased sink depth i.e, the subcrestal positioning by 1mm of the border between the rough and smooth machined surfaces of titanium implants compared with titanium implant placed in regular position i.e, the border between rough and smooth surface positioned at the level of alveolar crest showed increased bone loss in both the surfaces.[7]

The rough and the free surface energy of implant surfaces exposed to the oral environment may strongly influence the colonization of bacteria organized in biofilms which lead to the development of peri-implant disease. Earlier, peri-implantitis is termed for infectious pathological conditions of peri-implant tissues. Later on, it is termed specifically as a destructive inflammatory processes around osseointegrated implants in function that lead to per-implant pocket formation and progressive supporting bone loss. Many other factors like smoking and history of periodontitis may be associated with the development of peri-implantitis.

A new approach with resective therapy or combined resective and regenerative surgical therapy along with a modification of implant surface is termed as “implantoplasty”. Resective therapy include reduction of severity of the inflammatory reaction and to re-establish a physiological biologic width by reducing pocket depth. Where, as implantoplasty consists of removal of implant threads and smoothening rough implant surfaces with rotary instruments.

Ramel et al, in his study evaluated six impantoplasty procedures to decrease surface roughness and shorten the treatment time. The most frequently, diamond burs or carbide bone cutters are used to remove the threads of the exposed implant surface then followed by silicon polisher to smoothen the rough implant surface. Silicon polishers may cause immunological reactions and interfere with healing process. So, Arkansas stone torpedo shaped aluminium oxide bur is used as an adjunct to silicon polishers along with diamond burs showed optimal treatment option for decreasing roughness.[9]

In recent years, some strategies are developed in the treatment of peri-implantitis. A new approach to biomedical device-associated infections is based on biocide materials. Silver as a nonspecific biocide agent act strongly against a broad spectrum of bacterial and fungal species, including antibiotic-resistant strains. It is believed that silver nanoparticles (Ag NPs) are more reactive than bulk metallic forms because of the more active sites that result from a high specific surface. The sealing of soft tissue on the implant surface plays a role in the prevention of peri-implantitis. The transmucosal elements should have a polished surface to prevent adhesion of biofilm. Therefore, the use of a coating that can reduce bacterial activity in peri-implant tissue which lead to a greater stability of the gingival seal.

Arturo Martinez et al demonstrated that the use of transepithelial abutments with a biocide coating can protect the mucosa seal. Implants coated by soda lime glass containing silver nanoparticles titanium abutments are capable to constrain the bone loss. This particular coating not only decreases the total bone recession caused by peri-implantitis but also causes a less pronounced asymmetry with a more regular bone resorption crater.[14]

Conclusion:

Many factors contribute to marginal bone loss around implants and its solution cannot be attributed to any single parameter. A close contact between bone and implant may be essential feature that permits the transfer of stress from implant to the bone without any appreciable relative motion and thus providing a physiological stress to induce bone remodelling. The treatment modality in low-density bone should be considered to accommodate the changes occurring in the establishment of a biological width and the use of implant design features that optimize initial stability and maximize the marginal bone preservation.

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