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Review Article

Macrodesign of Dental implant – A review

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ABSTRACT

Implant design features such as Macro- and Micro-design may influence overall implant success. factors such as thread geometry, thread shape, thread pitch, helix angle, thread depth and width as well as implant crestal module and apical design consideration may affect implant stability. thread geometry affects the distribution of stress forces around the implant. A decreased thread pitch may positively influence implant stability. Excess helix angles in spite of a faster insertion may jeopardize the ability of implants to sustain axial load. Deeper threads seem to have an important effect on the stabilization in poorer bone quality situations. The objective of this article is to give a clear and standardized overview of the main surface characteristics of a given implant surface using a macrodesign characterization. which allows us to improve and deepen our knowledge about implant surfaces, and is a significant step towards establishing a clear link between surface characteristics and biological responses

Introduction

All fields of human activities have been affected by the great advances of technological developments, and so has the field of dentistry.[1] The goal of advanced dentistry is to restore the patient to normal contour, function, comfort, aesthetics, speech and health. The dental implant is now accepted as a promising method to replace a single tooth or multiple adjacent missing teeth, or to support a removable prosthesis for a completely edentulous patient. The clinical success of oral implants is related to their early osseointegration. Geometry and Surface topography are crucial for the short- and long-term success of dental implants. Implant design features are one of the most fundamental elements that have an effect on implant primary stability and an implant's ability to sustain loading during or after osseointegration. Implant design can be divided into the two major categories: Macrodesign and Microdesign. Macrodesign includes implant body shape and thread design [e.g., thread geometry, face angle, thread pitch, thread depth (height), thickness (width) or thread helix angle. Microdesign constitutes implant materials and surface coating.[2]

In this paper, we discussed mainly the effect of implant macrodesign features and their ability

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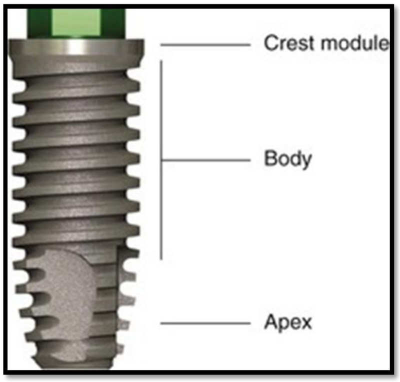

Figure-1 Implant Body Design

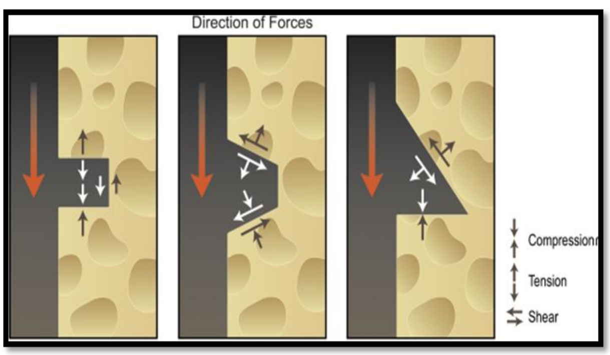

Figure-2 Direction of forces generated at the implant and bone interface resulting from axial loading

in influencing implant osseointegration. Particularly attention was given to thread related characteristics (or thread geometry) such as thread shape , thread pitch, depth , thickness ,face angle and helix with Crest module consideration including antirotational forces and platform switching and Apical design consideration. This article is aimed to discuss macrodesign of implant design features which can have effect on implant's osseointegration and its long term success or failure.

THE MACROSCOPIC FEATURES

The macroscopic features of the implant includes the implant body design, which divides into three zones**, Thread geometry, Crest module consideration and Apical design consideration.** The macroscopic implant body design (Figure-1) is most important during early loading and mature loading periods.

Implant Body Design

There are many different implant body designsavailable in implant dentistry. They may be categorized as **cylinder type, screw type, press fit, or a combination of features**.[1] Dental implants are often designed to answer a primary focus or belief that implant failure may stem from (1) implant surgery, (2) bacterial plaque complications, or (3) loading conditions. These features permit the implant site and implant to be surgically placed most easily.[4,5]

Implant Design Related To Occlusal Forces

Dental implants function to transfer loads to surrounding biological tissues. Thus the primary functional design objective is to dissipate and distribute biomechanical loads to optimize the implant-supported prosthesis function. Biomechanical load management is dependent on two factors: the character of the applied force and the functional surface area over which the load is dissipated.[5]

Force Type and Influence on Implant Body Design

A Cylinder implant, A Tapered threaded implant serves no functional surface area advantage, because the threads of a screw bear the compressive loads to the bone. The tapered, threaded implant provides some surgical advantage during initial insertion, because it inserts down within the osteotomy halfway before engaging bone. However, the lesser surface area of a tapered implant increases the amount of stress at the crestal portion, as demonstrated in three-dimensional finite element studies. In addition, in a tapered threaded implant, threads at the apical half are often less deep, because the outer diameter continues to decrease. This limits the initial fixation of the implant.[6]

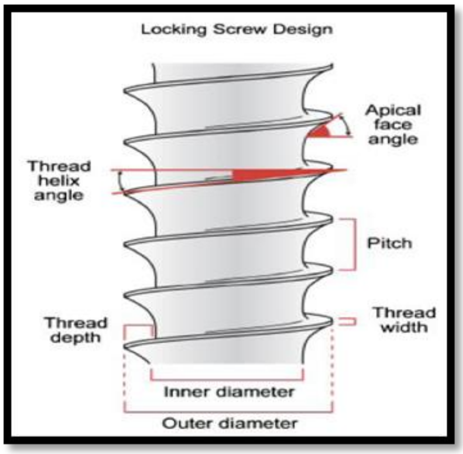

Figure -3 Thread Design

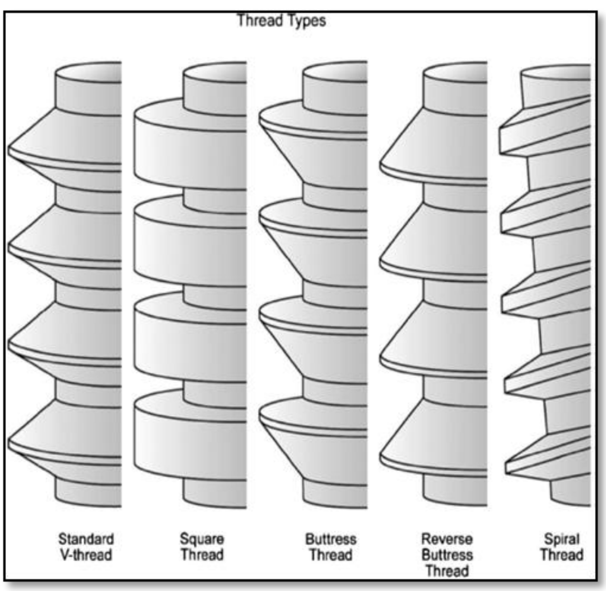

Figure – 4 Thread Shape

A smooth-cylinder implant body results in essentially a shear load at the implant-bone interface. Bone grows to a cylinder-shape implant during initial healing. However, this type of body geometry must rely on a microscopic retention system such as roughening or coating (acid etch, mechanical etch, or coatings such as titanium plasma spray or hydroxylapatite) for the initial loading period.[7] The integrity of the implant interface during initial loading is therefore dependent on the shear strength of the implant surface-to-bone bond.

Force Direction and Influence on Implant Body Design

Bone is weaker when loaded under an angled force. The greater the angle of load, the greater the stresses to the implant-bone interface. A 30-degree angled load will increase the overall stress by 50% compared with along axis load, especially around the crestal portion of the implant. Therefore, under ideal conditions, the implant body long axis should be perpendicular to the curve of Wilson and curve of Spee to apply along axis load to the implant during occlusal load in centric occlusion (where the occlusal forces are usually the greatest). As the angle of load to the implant-bone interface increases, the stresses around the implant increase. As a result, virtually all implants are designed for placement perpendicular to the occlusal plane (figure-2).

THREAD GEOMETRY

Threads are designed to maximize initial contact, enhance surface area, and facilitate dissipation of loads at the bone-implant interface.[2] Functional surface area per unit length of the implant may be modified by varying three geometric thread parameters: Thread shape, Thread pitch, Thread depth, Face angle. (figure-3)

Thread Shape

Thread shape describes the geometry of the implant thread and is a function of differing values with regards to all the terminology describing thread design. Thread pitch, depth, width, lead, and face angle all play a role in the resulting overall geometric shape of a thread. There are currently five major thread shapes used in dentistry today with minor variations across the entire dental implant market. These five shapes

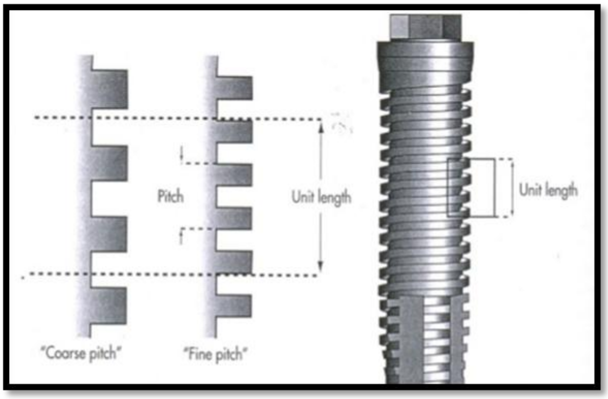

Figure – 5 Thread Pitch

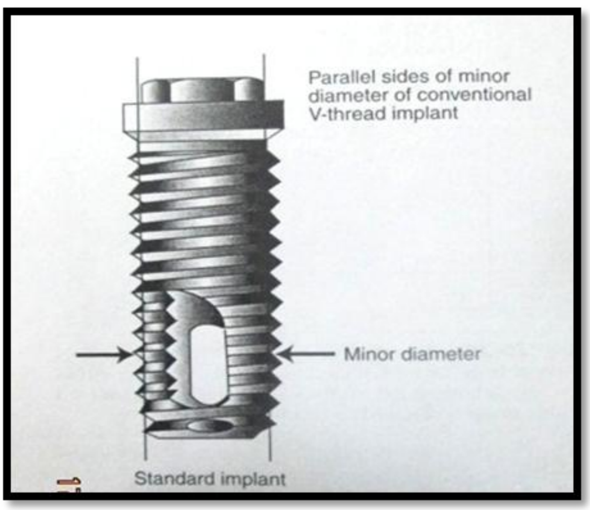

Figure- 6 Thread Depth

include; V-shape, square, buttress, reverse buttress and spiral (Figure-4). One could assume applying the principles previously outlined, that these shapes all distribute the favourable and unfavourable stresses in different ways.

The force transfer for occlusal loads to the bone is similar to that of the V-thread design. Dental implant applications dictate the need for a thread shape optimized for long-term function (load transmission) under occlusal, intrusive (the opposite of pullout) load directions. The square or power thread provides an optimized surface area for intrusive, compressive load transmission. A buttress thread shape may also load the bone with primarily a compressive load transfer.

Thread Pitch

Thread pitch refers to the distance from the center of the thread to the center of the next thread, measured parallel to the axis of the screw. The thread pitch is often known as being inversely related to the number of threads in the unit area and can be calculated by dividing the unit length by the number of threads (Figure-5).[1] If implant length is the same, a smaller pitch means there are a greater amount of threads.

Thread pitch has the most significant effect on changing the surface area on a threaded implant. This is a major point to consider when looking at the anatomical dimensional limitations presented in the oral environment. The thread pitch may be used to help resist the forces to bone with poorer. Therefore if force magnitude is increased, implant length is decreased, or bone density decreased, the thread pitch may be decreased to increase the thread number and increase the functional surface area. The greater the thread number, the greater the initial fixation and the greater the overall surface area after loading. The thread number may be affected by the implant crest module design. When the implant body has an extended smooth crest module, the number of the thread to support the occlusal load is reduced.[8]

Thread Depth

The thread depth is the distance between the major and minor diameter of the thread (figure- 6).[9] Conventional implants provide an uniform thread depth throughout the length of the implant. A tapered implant often has a similar minor diameter, but the outer diameter decreases in relationship to the taper, so the thread depth decrease towards the apical region. The tapered, threaded implant may have less ability to fixate the bone in the apical region at initial insertion and has less functional surface area.

The greater the depth, greater the surface area of the implant. The role thread depth plays are proposed to occur on insertion and BIC of the implant. A shallow thread will be easier to insert into dense bone without having to use a drill to tap the site prior to insertion. A deep thread will allow for much greater primary stability specifically for situations such as soft bone or immediate implant sites.[1,2] The more shallow the thread depths, the easier it is to thread the implant in dense bone, and the less likely bone tapping is required prior to implant insertion.

The Face Angle

The face angle is the angle between the face of a thread and a plane perpendicular to the long axis of the implant. Studies have shown altering the face angle can have an effect on the forces at the bone to implant interface. A relatively small face angle will tend to increase tensile and compressive type forces, while increasing the face angle has been shown to result in an increase of shearing type forces along the implant to bone interface. This concept has been observed to occur regardless of the thread shape within their respective grouping.[5]

Crestal Module consideration

Crest module refers to the neck portion of the implant. Implant neck configurations can be critical for minimizing the marginal bone loss. The crest module of an implant body is the transosteal region, which extends from the implant body and often incorporates the antirotation components of the abutment implant connection. The crest module of the implant has a surgical influence, a biological width influence, a loading profile consideration (characterized as a region of highly concentrated mechanical stress), and a prosthetic influence. Therefore this area of the implant body is a determinant for the overall implant body design.

The crest module of an implant should be slightly larger than the outer thread diameter of the implant body. In this way, the crest module seals completely the osteotomy, providing a barrier and deterrent for the ingress of bacteria or fibrous tissue during initial healing.[10] The seal created by the larger crest module also provides for greater initial stability of the implant following placement, especially in softer unprepared bone, because it compresses the crestal bone region.[11]

The Antirotational feature

The prosthetic features of the crest module may affect the implant design. In an internal hex implant, the antirotational feature of the abutment is designed within the implant body. As a result, the implant body is lower in profile and easier to cover with soft tissue during surgery. In addition, the antirotational feature is often deeper within the body compared with external hex implants. Because the internal antirotation feature is wider than an abutment screw, the wider body diameter at the crest module is reduced. As a result, the threads on the outside of the implant body cannot be designed at or above the antirotational feature of the implants. Therefore greater smooth metal and shear forces are observed above the first implant body thread compared with an implant with an external hex.

The Platform switching

A new implant-to abutment connection referred to as “platform switching”. The platform switching concept is based on the use of an abutment smaller than the implant neck (figure 7). The platform switching concept involves the reduction of the restoration abutment diameter with respect to the

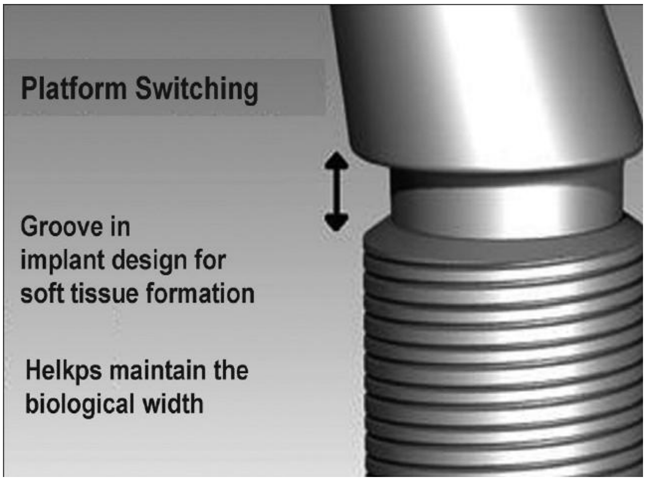

Figure- 7 Platform Switching

diameter of dental implant. Long-term follow up around these wide-platforms showed higher levels of bone preservation. This type of connection moves the perimeter of Implant-abutment junction (IAJ) to the center of implant axis.[12]

Recent studies suggest the formation of a more consistent connective sleeve when the abutment's base is smaller than the implant platform, with advantages in the ability to form a mucosal seal. Regarding biomechanical advantages in the use of platform switching, the results indicate that conventional implants where a high stress area around implant's neck and along its lateral surface is present, in the model with platform switching the stress area is localized to the center of the implant.[13]

Apical Design Considerations

The apical portion of a root form implant is most often tapered to permit the implant to seat within the osteotomy before the implant body engages the crestal bone region. As a result the patient does not need to open the mouth as wide, which is especially of benefit in the posterior regions of dentate patients. This apical feature favors the initial step of implant insertion. The most common design is a hole or vent. In theory, bone can grow through the apical hole and resist tensional loads applied to the implant.

The apical hole region may also increase the surface area available to transmit compressive loads to the bone. A disadvantage of the apical hole occurs when the implant is placed through the sinus floor or becomes exposed through a cortical plate. The apical hole may fill with mucus and becomes a source of retrograde contamination or will likely fill with fibrous tissue. This concern is greatest with an open basket body design, less with a vertical hole of 4 mm, and even less with a round1-mm hole. The apical aspect of a solid implant (without apical hole) may slightly perforate any opposing cortical plate and act as a wedge to seal the opening. The apical end of each implant should be flat rather than pointed. Pointed geometry has less surface area, thereby raising the stress level in that region of bone.[1]

Conclusions

Dental implants are valuable devices for restoring lost teeth. Implants are available in many shapes, sizes, and lengths, using a variety of materials with different surface properties. A dental implant system is atypical and excellent example of integrated product using multiple disciplines including surface science and technology, surface modification and surface physics and chemistry. The success and longevity of dental implants are strongly governed by surface characteristics. While the geometric design of an implant contributes to mechanical stability, the nature of the implant surface itself is also critically important to the osseointegration rate of dental implants.

Different thread shape, threads depth, thread pitch and thread width used for increase applying osteoconductivity. These design features are important to keep in mind when a surgeon is faced with the decision of which implant to place. Applying principles of the design features outlined should allow for the development of faster, more reliable integration of dental implants with higher success rates over time, The objective of this article is to give a clear and standardized overview of the main surface characteristics of a given implant surface using a macrodesign characterization. This approach will allow us to improve and deepen our knowledge about implant surfaces, and is a significant step towards establishing a clear link between surface characteristics and biological responses.

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