# Implant Surface Designs: An Overview

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## Abstract

The aim of the article is to review the literature on designs of dental implants. The different categories of dental implants and the parameters of their designs are analysed in relation to their effect and significance in the process of osseointegration. Biological properties of implants and role of implant design in initial implant stability is described.

**Key words:** Dental implants, Implants designs, Implant surface, Osseointegration

## Introduction

Implant design refers to the 3-dimensional structure of the implant, with all the elements and characteristics that compose it. Form, shape, configuration, surface macrostructure, and macro-irregularities are terms that have been used in the literature to describe aspects of the 3-dimensional structure.[1]

## Discussion

**Biomechanical properties**: When considering an implant design, it would also be helpful, if not essential, to have data on:

1. The percentage of an implant's surface that will actually be supported by hard versus soft interfacial tissues.
2. The mechanical properties of the interfacial tissues.
3. The extent to which the implant will rely on mechanical support from trabecular versus cortical bone.
4. The response of interfacial tissues to the imposed mechanical conditions arising from in vivo loads on the implant.
5. The presence or absence of significant attachment or bonding of interfacial tissues to implant.

**Dental Implant design can be categorized under the following headings:**

1. Implant Design Classification:-
   a. Macro
   b. Micro
2. Design and production of Customized Dental Implants
3. Effect of Thread Pattern Upon Implant Osseo integration

**1. Implant design can be divided into two types**

A. Macro design
B. Micro design

A. **Macro Design-** It includes the following:-
(i) Thread shape
(ii) Thread design (e.g. thread geometry, face angle, thread depth (height), thickness (width) or thread helix angle.[2]

B. **Micro Designs-** Constitutes the following:-
(i) Implant materials
(ii) Surface Morphology
(iii) Surface Coating

**1) A) (i). Thread shape[2]**

Is determined by the thread thickness and thread face angle. Thread shapes available include:-
a) V Shape
b) Square Shape
c) Buttress
d) Reverse Buttress Shape

**1) A) (ii) Thread design**

a) **Face angle:** Is the angle between a face of a thread and a plane perpendicular to the long axis of the Implant. In the implant literature the most suited face angle is that of the apical face where most of the loading forces are dissipated.[2]
b) **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. It may be calculated by dividing unit length by the number of threads. In implants with equal length, the smaller the pitch the more threads present.[2]
c) **The thread helix angle:** In a single threaded implant the pitch equals the lead (the length of

insertion of an implant every time when it is turned 360 degree. Some manufacturers have introduced double or even triple threaded implants where two or three threads run parallel one to the other. This allows a faster insertion of the implant theoretically maintaining a pitch distance more favorable for the mechanical strength of the bone implant interface i.e. a triple threaded implant with a pitch distance of 0.6mm will be inserted 1.8mm every time it is rotated 360 degree. However it has to be considered that as increasing the number of threads running parallel to one other, the thread helix angle changes.[2]

According to a study, the most favourable configuration in terms of implant stability appeared to be the single threaded one followed by the double threaded. The triple threaded was found to be the least stable.[2]

d) **Thread depth and width:** Thread depth is the distance between the major and minor diameter of the thread. Thread width is the distance in the same axial plane between the coronal most and the apical most part, at the tip of a single thread. Both these designs have an effect on total implant surface area. Given the same implant body, a shallow thread depth would allow for an easier implant insertion. Hence it is agreed that the deeper the threads the wider the surface area of the implant. Greater thread depth may be an advantage in areas of softer bone and higher occlusal force because of the higher functional surface area in contact with bone on the other hand shallow thread depth permits easier insertion into denser bone with no need for tapping.[2]

## Implant Length

As the length of an implant increases, so does the overall total surface area. As a result, common axiom has been to place an implant as long as possible and preferably into the opposing cortical plate. Yet, when this axiom is re-evaluated, several challenges ensue. The opposing cortical plate is engaged primarily in the anterior regions of the mouth, especially in anterior mandible. The bite forces are lower and the bone density is greater in the anterior regions. D1 bone is the strongest and densest bone which is rarely clinically observed except in the anterior mandible.

Resistance to lateral loading is provided by the strength of the bone and the intimate contact between the bone and implant. Bicortical stabilization, a rationale often cited for longer implants, is simply not needed in D1 bone because it is already a homogenous cortical bone. A long implant in D2 or D3 bone in the anterior mandible may cause increased surgical risk as a result of bone overheating. A threaded implant in this region may not readily engage the denser bone of the apical cortical plate and the implant threads may strip along the rest of the osteotomy, especially if less dense. Once the implant bone interface is formed, excessively long implants do not receive stress transfer in the apical region and are not needed.[1]

**Implants with different lengths**

In poor D3 and D4 quality bone, functional surface area may be maximized to optimally distribute occlusal loads. D3 and D4 bone are primarily observed in the posterior regions of the jaw, where less available bone is observed compares with anterior regions. Increasing surface area primarily by length in the posterior regions of the jaws requires advanced grafting or nerve repositioning surgery and does not benefit the primary regions of increased stress- the crestal bone region.

Finite element analysis points to the fact that the majority of the maximum stress generated by lateral load can be dissipated as well by implants in the range of 10 to 15 mm in length, compared with implants in the range of 20 to 30mm in length. In addition, the highest stresses were observed in the crestal bone regions, regardless of the implant length. This analysis supports that longer implants are not necessarily better. Instead, there is minimum implant length for each bone density, depending on the width and design. The softer the bone, the greater the length suggested.[3]

## Implant Width

Over the past five decades of endosteal implant history, implants have gradually increased in width. The pin implants of Scialom were less than 2mm wide. The plate form increased the neck in a mesiodistal dimension. The Branemark implant first presented implants of 3.75mm. Today, dental implants generally have reflected the scientific principle that an increase in implant width adequately increases the area over which occlusal forces may be dissipated. The larger the width of the implant, the more it resembles the emergence profile of the natural tooth. However, the titanium implant is 5 to 10 times more rigid than a natural tooth. The increased width of implants 6 to 12mm affects the bending resistance of the implant related to the radius raised to the fourth power.[1]

The implants were at times, so rigid because of their size and biomaterial that inadequate strain was transmitted to bone, which resorbed. Stress shielding was observed when aluminium oxide dental implants were placed which were 33 times more rigid than bone. Implants of similar dimension to the premolar and molars may be too rigid to strain the bone within physiologic ranges, and disuse atrophy may unsue. Crestal bone anatomy, however, typically constrains implant width to less than 5.5mm, except in limited clinical situations[4]

e) **Implant Neck (Crest Module):** The crest module of implant body is the transosteal region from the implant body and characterized as a region of highly concentrated mechanical stress. It is a transition zone to the load bearing structure of the implant body. A smooth, parallel sided crest module will result in shear stresses in this region, making maintenance of bone very difficult. An angled crest module of more than 20 degrees, with surface texture that increases bone contact, will impose a slight beneficial compressive component to the contiguous bone and decrease the risk of bone loss. The crest module of implant body should be slightly larger than the outer thread diameter. Thus, the crest module seats fully over the implant body osteotomy, providing a deterrent for the ingress of bacteria or fibrous tissue. The seal created by the larger crest module also provides for greater initial stability of the implant following placement, especially in soft unprepared bone, as it compresses the region. The larger diameter also increases surface area, which contributes to decrease in stress at the crestal region compared with crest modules of smaller diameter.[1]

Highest bone stresses have been reported to be concentrated in the cortical bone in the region of the implant neck as demonstrated in Finite Element Analysis (FEA) of loaded implants with or without superstructure.[5]

It has been suggested that the implant neck should be smooth/ polished, supporting the belief that the crest module should not be designed for load bearing. The use of a roughened crest module that is level with the crest of the bone may provide a positive stress stimulus to the bone and decrease bone loss in this area, while the smooth part of the crestal module, above the level of crestal bone, should provide an area for connective and epithelial tissue contact. This is consistent with findings from experiments and clinical studies that demonstrated that bone loss begins around the implant neck.[6]

**B) Micro Threads:** Recently the concept of micro threads in the crestal portion has been introduced to maintain marginal bone and soft tissues around the implants. Some authors attributed this bone loss to "Disuse Atrophy". In presence of smooth neck, negligible forces are transmitted to the marginal bone leading to its resorption. However the presence of retentive elements at the implant neck will dissipate some forces leading to the maintenance of the crestal bone height. Lee et al (2007) concluded a human body comparing implants with or without micro threads at the crestal portion.[2] The authors indicated that addition of this retention element might have an effect in preventing marginal bone loss against loading. In general the addition of threads or micro threads up to the crestal module of an implant might provide a potential positive contribution on preservation of marginal bone.[2]

2. **The Design and Production of Customized Dental Implants:** Traditional implants are produced from machined wrought titanium. The classical dental implants consist of an assembly of three components the root form fixture that actually engages the jaw bone; transmucosal abutment and a connecting screw. The transmucosal abutment is the support structure where the dental prosthesis (also known as the crown) is installed. The Root Form fixture is threaded, grooved, perforated, plasma sprayed or coated. Today's rapid manufacturing technologies include Selective Laser Sintering (SLS), Laser Micro Sintering, Selective Laser Melting (SLM), Three dimensional (3D) Laser Cladding, Electron Beam Melting (EBM) and Electron Beam Sintering (EBS). One other design improvement is the replacement of the three component setup that has produced problems in traditional dental implants with a one component implant that has two interfaces: an Implant/Jawbone interface and an Implant/Dental Prosthesis interface.[7]

3. **Effect of Thread Pattern on Implant Osseointegration:** Albrektson et al (1981) reported factors such as surgical techniques, host bed, implant design, implant surface, material biocompatibility and loading conditions have all been showed to affect implant osseointegration. Implant design, Thread shape and Pitch Distance are factors to consider when selecting implant characteristics that would aid in different clinical conditions.[2]

Two main Hypotheses theorized the elements affecting the attainment and maintenance of Osseo integration.

1. The "Biological Hypothesis" focuses on the effect of bacterial plaque and host response patterns on implant survival.
2. "Biomechanical Hypothesis" emphasizes occlusal overload on the supporting bone and the effect of compressive, tensile and shear forces on Osseo integration.[2]

**Role of Implant Design in Initial Implant Stability:** A common factor between early loading and delayed loading of dental implants is the initial stability of the implant, implying that close apposition of bone at the time of implant placement from factors such as bone quality and surgical technique, may be the fundamental criterion in obtaining osseointegration.[8] Such "anchorage" of an implant in bone may also be influenced by the implant design with factors such as overall surface area, length and thread configuration.

The following would be the design principles,[9] one would want to achieve through an implant design:

a. Gain initial stability that would reduce the threshold for the 'tolerated micro motion' and minimize the waiting-period required for loading the implant.
b. Incorporate design factors that would diminish the effect of shear forces on the interface (such as surface roughness related and thread features) so that marginal bone is preserved.
c. Design features that may stimulate bone formation, and/ or facilitate bone healing (secondary osseointegration)

## Summary and Conclusion

Due to the wide variety of implant designs present operator should select the implant very carefully and must see the research information on their properties with the intended treatment plan. Clinicians must have the knowledge of the cellular and molecular events that lead to osseointegration because such knowledge is essential to relate clinical findings with basic mechanism. In the future, better understanding of molecular biology and biomaterials science will generate dental implants with properties and features that will provide an enhanced biological response.

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