JIACD Continuing Education

Factors Driving Peri-implant Crestal Bone Loss - Literature Review and Discussion: Part 3

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Abstract

Many factors contribute to the cumulative crestal bone loss seen around endosseous dental implants. This can create confusion for the practicing clinician and lead to undesirable outcomes. In this four part review series, we have searched the literature for papers published in English language refereed journals for the decade preceding May 2008 and attempted to identify the major factors associated with peri-implant bone loss. Part three of this article series examines implant geometry, surface roughness, length, and diameter.

KEY WORDS: Crestal bone loss, dental implants, causative factors

Learning Objectives

After reading this article, the reader should be able to:

1. Discuss how implant geometry affects peri-implant crestal bone loss.
2. Discuss how implant neck design affects peri-implant crestal bone loss.
3. Discuss how implant surface roughness affects peri-implant crestal bone loss.
4. Discuss how implant length and diameter affects peri-implant crestal bone loss.

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INTRODUCTION

Many factors, both biological and biomechanical, will have a cumulative impact on the final amount of bone loss seen with dental implants. It is important for clinicians to understand all of these factors in addition to their relative contributions and interactions. This is the third installment of a four part series reviewing factors that drive peri-implant crestal bone loss. Part one of this review examined surgical and anatomical factors associated with peri-implant crestal bone loss. Part two reviewed patient and biologic width factors while, the current installment of this series examines implant geometry, surface roughness, length, and diameter.

MATERIALS AND METHODS

A literature search of papers published in refereed journals in the English language for the decade preceding May 2008 was performed by computer using the National Library of Medicine and SCOPUS Cochrane Oral Health Group databases. Search strategy included a specific series of terms and key words. The reference lists of identified publications, relevant textbooks and professional workshops also were scanned.

Relevant references were selected on the basis of their titles and abstracts. As the final selection method, full texts of publications identified as possibly relevant were reviewed for more detailed evaluation. Publications reviewed included experimental animal studies, prospective and retrospective human clinical studies, a few case reports and relevant review papers. Because of the limited numbers of available studies for some factors and their heterogeneity, focusing on a specific pre-defined question to be answered by a systematic review was not feasible and therefore no meta-analysis was attempted.

DISCUSSION

A number of dental implant related factors may contribute to peri-implant crestal bone loss. The most common of such factors include:

Implant geometry

Endosseous dental implants are essentially threaded screws made of titanium or one of its alloys (e.g. Ti-6Al-4V), although other implants such as plasma-sprayed surfaces press-fit cylinders and tapered truncated cones with porous surface zones formed by sintering Ti alloy powders also have been used.[1,2] Until recently, the majority of threaded implants had a cylindrical (i.e. parallel-sided) shape. However, recently popular tapered shapes that more closely resemble tooth roots have been suggested to provide more optimal stress transfer into crestal bone.[3] Following osseointegration, the bone-to-implant interface of most threaded implants comprises a planar contact without undercut regions. As a result, these transverse force components are transferred primarily as compressive forces to the crestal bone opposing the implant surface forced against it.[4-7] Additionally, the resulting stresses will be greatest in bone next to the most coronal implant thread tips. The resulting high localized compressive stresses can lead to micro-fractures in crestal bone followed by resorption. This coincides with the fact that most crestal bone loss with traditional threaded implants occurs in the first year of function.

Ways to reduce the high compressive forces acting on crestal bone with threaded implant designs would be to use longer implants, wider implants,[8] specific thread pitch heights[9] (especially in cancellous bone)[9] tapered implant shapes, and micro-threads incorporated into the implant neck. Unlike most threaded implant designs, sintered porous-surfaced dental implants achieve integration by 3-dimensional bone ingrowth into and mechanical interlocking with the porous surface region formed by sintering. This type of bone-to-implant interface is able to provide resistance to interfacial tensile (upstream) forces. As a result, there is a more uniform stress distribution around the implant periphery with transverse force components being transferred to crestal bone at all implant aspects. This reduces the likelihood of micro-fracturing and resorption of crestal bone.[2,4,5]

Implant neck design

Traditionally, the cervical or "neck" region of dental implants had a non-threaded, highly polished surface of sufficient height to accommodate biologic width without exposing much of the threaded implant segment meant to maintain implant fixation. Polished collar heights were generally in the range of 0.75 to 2.8mm. Remembering that establishment of biologic width required at least 1.5mm of linear implant surface from the micro-gap, polished collar height became more important with rough and moderately rough implant surfaces which ideally should remain buried in bone to avoid complications like peri-implantitis.[10-13] Naturally, use of platform-switching to add a horizontal component to biologic width allows shorter polished collar regions to be used successfully. However, another effective way to manage the implant collar segment is to add micro-threads to its geometry.

Micro-threads offer two possible advantages. Firstly, their addition increases linear length of coronal implant surface available for biologic width and allows some stress transfer in the coronal region superior to the macro-threaded segment of implant body.[14] This lower level of stress transfer to crestal bone is less likely to cause bone micro-fractures and reduces the probability for stress-shielding and disuse atrophy of crestal bone as may occur with traditional polished implant collars. Both clinical[15-18] and animal[19] studies have documented good retention of crestal bone for implants with incorporated micro-threads. In some studies, bone loss associated with coronally incorporated microthreads ranges from 0.11-0.18mm over 1 to 5 years.[18,20,21] Finite element studies[22] have suggested that creating laser micro-machined grooves (8 to 12 μm wide) to the lower part of a polished collar segment may reduce crestal bone loss in a manner similar to micro-threads (i.e. by altering strains in crestal bone) but, this possibility requires further study.

At present, few implant designs incorporate micro-threads. Rather, there has been a move to shorten or eliminate polished collar segments, with manufacturers electing to have implant collars with moderately rough surfaces in the hope of stimulating crestal bone with low levels of stress transfer as is thought to occur with micro-threads. This has not always been a successful approach as multiple studies have demonstrated increased crestal bone loss secondary to microbial colonization of exposed roughened collars.[12,23-26]

While carrying a moderately rough texture all the way to the top of an implant has not been adequately confirmed to be beneficial, having a polished collar that is too long also may lead to unwanted bone loss. Al-Sayyed et al[27] studied crestal bone loss in dogs around 2-piece, sintered porous-surfaced implants with either short (0.75mm) or long (1.8mm) collars. The short collared implants showed less bone loss, and the difference from long collared implants was linked to 'stress-shielding' of crestal bone and disuse atrophy.[28-30] When histological preparations of retrieved specimens from Al-Sayyed's dog study were examined, the data suggested that the primary driving force in crestal loss seen was biologic width accommodation, not stress-shielding. Additional studies[31,32] support the findings that the effect of stress-shielding with unnecessarily long polished collars is of relevance after biologic width accommodation has had its effect.

Implant surface roughness

Implant surface roughness may be classified as minimally rough, moderately rough, or rough. Machine-turned implant surfaces, as used on the original Branemark-system® threaded implant, are considered to be minimally rough (Sa - 0.5µm) while, only plasma-sprayed surfaces, like those used on the original Straumann ITI implant[33] or titanium plasma-sprayed press-fit implants,[34] are classified as rough(Sa > 2.0 µm). The majority of contemporary threaded implant designs have what are considered to be moderately rough surfaces (Sa between 1.0 - 2.0 µm). Moderately rough implant surfaces have been shown to be more osteoconductive than minimally rough ones[35] and, as a consequence, require shorter initial healing intervals.[36,37] Employing a moderately rough surface increases resistance to torquing (i.e. horizontal shear) forces once integration has developed[38,39] and may be one approach to improving implant outcomes in bone of lower density even with abbreviated healing intervals.[40]

Direct clinical comparisons of minimally rough (machine-turned) and rough (plasma-sprayed) threaded implants certainly have shown that the latter cause greater crestal bone loss and implant loss.[10,11] However, data does not exist on whether incorporating features like minimally rough micro-threads in the collar region and platform-switching might make outcomes with rough surfaced implants more favorable. Certainly, rough surfaces on deeper threads could be of benefit as they provide highly irregular surfaces with undercut features that may allow sufficient mechanical interlock of bone to improve resistance to interfacial tensile forces associated with off-axis loading, at least compared to minimally and moderately rough surfaces.[4]

Direct clinical comparisons of minimally rough and moderately rough threaded implants have been accomplished. In multiple studies with long term follow-up intervals, moderately rough dental implant surfaces repeatedly demonstrated less crestal bone loss and higher survival rates in comparison to minimally rough implants.[26,41-43]

Rocci and colleagues[44] compared anodized with machine-turned threaded implants that all were immediately loaded in posterior mandible locations. Implant failure rates were 14.5% for machine-turned and 4.5% for surface anodized implants. Mean marginal bone loss after 1 year of loading was similar (0.9 mm for surface anodized vs 1mm for machine-turned). Aalam et al[12] provided bone loss data for implants with surfaces roughened by anodization or dual acid-etching compared to machine-turned implants at two years post-loading. No significant differences were seen but, a trend toward greater bone loss was seen with anodized implants which, as discussed earlier, unlike the other two implant types, had no polished collar. In contrast, Watzak et al[62] reported significantly ($P=.03$) less marginal bone loss (1.17mm vs. 1.42mm) with anodized compared to machine-turned surfaces both of which had 1mm polished collars. These implants had been placed in the intra-foraminal region of edentulous mandibles and used to support overdentures during a mean functional period of 33 months.

Implant length and diameter

Both length and diameter (width) of dental implants may influence marginal bone loss. Naert et al[25] evaluated factors influencing marginal loss with machine-turned threaded implants functioning in partially edentulous patients for as long as 15 years. After 6 months in function, significantly ($P=.03$) more bone loss was observed as implant length increased. Implants in lengths of 7mm, 13mm, and 18mm had annual bone loss of 0.02mm, 0.04mm and 0.05mm respectively. It was suggested that longer implants lost more crestal bone because they were more likely to have been placed in sites of predominantly alveolar rather than basal bone, the latter being more resilient to resorption. However, other identified factors may have played a role in this rather surprising outcome. Rokni et al[45] reported a similar negative correlation between crestal bone loss and implant length with sintered porous-surfaced, press-fit implants after 5 years function. Long implants (9 or 12mm) had significantly greater crestal bone loss (0.2 mm more) than short implants (5 or 7mm). Others, however, have found that short threaded implants suffer more crestal bone loss than longer ones. Chung et al[46] presented retrospective findings in 69 patients for 339 implants with various surface roughnesses. After an average of 8.1 years, implant length had a significant ($P< .05$) impact on bone loss with implants < 10mm in length showing greater bone loss (0.19mm vs 0.12mm) than those with lengths ≥ 10mm.

Like implant length, differing implant diameters have been associated with crestal bone loss. Multiple studies have demonstrated that increased implant diameter tends to be associated with reduced crestal bone loss.[47-50] Studies[47,48] using 3-dimensional finite element model analyses suggested a likely correlation between implant diameter and crestal bone loss with maximum stresses occuring around the implant neck and these stresses are likely to be reduced by increasing implant diameter. The greatest effect (31.5% reduction in stress) was found for increasing diameters from 3.6 to 4.2 mm. Moving to a 5.0mm diameter implant reduced stress by a lesser amount (16.4%).

CONCLUSIONS

Implant geometry will affect the type of bone-to-implant surface interface that is responsible for osseointegration. Most threaded implants achieve integration by planar bone-to-implant surface contact and this does not provide resistance to off-axis tensile forces. As a result, excessive compressive stresses can develop in bone abutting the tips of threads and lead to micro-fractures in crestal bone. Sintered porous-surfaced press-fit implants achieve integration by 3-dimensional interdigitation through bone ingrowth resulting in more uniform stress transfer and reduced likelihood of crestal bone micro-fractures and resorption. With threaded implants, ways to reduce high crestal stress concentration include using tapered rather than cylindrical implant shapes and/or incorporating micro-threads into the collar region of the implant body. These smaller threads are thought to promote more physiological crestal stresses resulting in crestal bone retention rather than resorption, as well as reducing peak stresses more apically (next to macro-threaded implant regions). In the absence of micro-threads and/or platform-switching, it is advisable that all dental implants have a short (e.g. 1 to 1.5mm) polished collar segment to allow for successful accommodation of biologic width without exposure of moderately rough or rough implant surfaces. Carrying these rough surfaces to the top of an implant body may in some situations increase the risk of excessive crestal bone loss and other complications.

The biggest impact of giving threaded implants a moderately rough texture is improvement in surface osteoconductivity and shortening of initial healing intervals. These surfaces do not appear to increase resistance to off-axis tensile forces. Because of the added surface area, however, moderately rough threaded implants often do appear to perform better than machined turned implants in bone of low density unless modified surgical procedures are employed to improve initial implant stability.[50]

Finally, both implant length and diameter may affect crestal bone loss at least with some implant designs. Press-fit, sintered porous-surfaced implants for example show significantly less crestal bone loss in lengths of 5 or 7mm as opposed to lengths of 9 and 12mm. With threaded implant designs, study outcomes on the effects of implant length differ. Some investigators have reported greater crestal resorption as implant length increases and some the reverse relationship. Animal and finite element analysis studies have suggested that as implant diameter increases crestal bone micro-fractures and resorption should decrease. ●

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Disclosure

The authors report no conflicts of interest with anything mentioned in this article.

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Continuing Education JIACD Quiz #5

1. Most crestal bone loss associated with dental implants happens when?

a. Within first year of function
b. Between years 2-3 of function
c. Between years 3-5 of function
d. After 10 years of function

2. Ways to reduce compressive forces acting on crestal bone include:

a. Using longer implants
b. Using wider implants
c. Using tapered implant shapes
d. All of the above

3. To avoid complications such as peri-implantitis, roughened implant surfaces should ideally remain buried in bone.

a. True
b. False

4. What advantages are offered by a micro-threaded collar design?

a. Increase linear length of coronal implant surface available for biologic width
b. Allows stress transfer in the apical region superior to the macro-threaded segment of implant body
c. There are no advantages offered by micro-threads
d. All of the above

5. Over one to five years, what is the range of bone loss associated with coronal micro-threads?

a. 0.11 – 0.18mm
b. 0.25 – 0.50mm
c. 0.51 – 0.76mm
d. 1.09 – 1.6mm

6. Implant surface roughness may be classified as:

a. Minimally rough
b. Moderately rough
c. Rough
d. All of the above

7. The majority of contemporary threaded implant designs have what type of surface?

a. Minimally rough
b. Moderately rough
c. Rough
d. Smooth

8. Moderately rough implant surfaces have been shown to be more osteoconductive than minimally rough implant surfaces.

a. True
b. False

9. In multiple studies with long term follow-up intervals, which implant surfaces repeatedly demonstrated less crestal bone loss and higher survival rates?

a. Smooth
b. Minimally rough
c. Moderately rough
d. Rough

10. 3D finite element models suggest that maximum stress occurs at what portion of the implant?

a. Implant neck
b. Implant body
c. Implant apex
d. Stresses are uniformly distributed