CRESTAL BONE CHANGES AROUND IMPLANTS WITH A REDUCED ABUTMENT DIAMETER PLACED NON-SUBMERGED AND IN AT SUBCRESTAL POSITIONS: A 1-YEAR RADIOGRAPHIC EVALUATION

By

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OF THE UNIVERSITY OF FLORIDA IN PARTIAL FULFILLMENT
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To all of those who mentored me during my residency

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Peri-implant tissue stability, in regards to the gingival tissues and alveolar bone which support the dental implant, is a goal following dental implant treatment. Greater tissue stability results in improved esthetics, function, and oral hygiene access. It has been shown that dental implants tend to lose bone over time, which ultimately results in soft tissue loss. There have been recent studies, however, that suggest that implant design may contribute to peri-implant tissue stability. The primary aim of this study was to retrospectively evaluate radiographic bone loss of implants with a morse taper abutment connection placed non-submerged and in a subcrestal position with a mean follow-up period of 1 year.

Records of 50 consecutive partially edentulous patients where missing teeth were replaced and restored with dental implants were reviewed. For each implant, the radiographs from the surgical appointment were compared to images from the 1-year follow-up visit and evaluated regarding (i) degree of subcrestal positioning of the implant as well as (ii) changes of marginal hard tissue height over time and (iii) if marginal hard tissue could be detected on the implant platform at the follow-up visit.

The overall survival rate from baseline to last recorded follow-up visit was 100%. At the surgery the implants were placed 1.37 mm (mesial) and 1.28 mm (distal) subcrestally. The mean marginal loss of hard tissues was 0.11 ± 0.30 mm. There were no statistical significances regarding loss of marginal peri-implant hard tissues between mesial and distal surfaces or maxilla vs. mandible. There was no statistical significant correlation regarding degree of subcrestal implant positioning and loss of marginal mineralized hard tissue ($r=0.15$, $p<0.05$). Mineralized hard tissue on the implant shoulder was demonstrated on 69% of the implants at the 1-year follow up visit.

The present study report minimal loss of mineralized hard tissue around dental implants placed non-submerged and in a subcrestal position and also demonstrated a hard tissue healing extended onto the implant shoulders on most of the observed implants.

CHAPTER 1
INTRODUCTION

Tooth restorations using implant-supported prostheses for functional and esthetic rehabilitation of patients has become an established and widely used treatment modality in modern dentistry. The preservation of the peri-implant bone is one important factor for success. The quantity and quality of the bone surrounding an implant not only affect implant osseointegration, but also influences the shape and contour of the overlying soft tissues which are important for the esthetic outcome of treatment. Only with careful considerations of the biological principles of the peri-implant soft and hard tissues, as well as an appropriate selection of implant type and position, can a functional and esthetic treatment result be achieved.[1,2]

In abundant clinical studies describing two-piece implants, it has been reported a vertical marginal peri-implant bone loss of 1-1.5 mm during the first year of function, followed by a yearly bone loss of 0.1-0.2 mm.[3-6] However, when one-piece implants were utilized, minimal marginal bone loss was found.[7,8]

The importance of position, size and geometry of the implant on marginal bone levels has been a subject of various studies. These studies have demonstrated that numerous factors can influence potential marginal bone loss around implants. Bacterial colonization of the fixture-abutment interface (FAI) microgap is reported to be one of these factors.[9-11] Design of the fixture-abutment complex and loading forces when implants are in function are other important factors.[12-16]

In some studies using two-piece implants with altered horizontal relationship between the fixture diameter and the abutment diameter minimal bone loss was observed. [17-23] The positive effect of this concept using abutments with reduced diameter is explained by an increased distance from the FAI to the crestal bone. In theory, this concept implies a reduced risk for peri-implant soft tissue inflammation and subsequent bone loss in situations with submucosal bacterial colonization. The platform shifting concept has also been reported to direct the stress concentration area away from the cervical bone-implant inter face decreasing the risk for bone loss around the implant.[24,25]

There is limited information of two-part implants being placed in subcrestal positions. In a recent animal study it was suggested that osseointegration may occur coronal to the FAI in situations where the implant margin was placed 2 mm apical to the bone crest. [26]

The aim of our investigation was to evaluate radiographically the crestal bone changes around implants with reduced abutment diameters placed non-submerged and in subcrestal positions. In this investigation, radiographs from a consecutive number of patients who received dental implants from a single manufacturer were analyzed for the amount of crestal bone loss with at least a year follow-up. In addition, a notation for each implant was included with respect to the presence or absence of mineralized hard tissue above the implant shoulder at the last follow-up radiograph.

The data analyzed revealed a modest mean crestal bone loss of 0.11mm for the implants, and the presence of mineralized hard tissue was noted for 69% of the implants at the last follow-up radiograph. This data indicates a minimal mean crestal bone loss for the implants, in comparison to the standard acceptable bone loss at 1-year, as well as the presence of mineralized hard tissue over the implant shoulder for most of the analyzed implants.

Hypothesis: The analyzed implants will have less than 1 mm of bone loss calculated after 1-year post implant placement.

CHAPTER 2
BACKGROUND

History of Dental Implants

The modern root form dental implant of today traces its roots back to the magnificent work of Dr. Per-Ingvar Branemark, where he discovered that a titanium dental implant could become anchored to the host bone, a phenemona known as osseointegration.[33] "Root form" refers to the creation of the dental implant in a manner that approximates the shape and form of a tooth root. It was not until a later time, however, that histological evidence of this phenomena osseointegration was demonstrated.[34]

In the beginning, dental implants were made of commercially-pure titanium, and they assumed a screw-like configuration that contained a smooth surface in between the threads. The abutment connection was an external hex configuration, which displayed a hex on top of the implant to which the abutment could be connected. This particular implant has had documentation for over 30 years.[35] It is with this original implant design that a standard numerical value for acceptable crestal bone loss was adopted. A value of bone loss that was acceptable in evaluating implants was 1-1.5mm bone loss the first year after placement, followed by 0.2mm annually thereafter.[3, 4] When using this implant system, it was expected to have this amount of bone loss, and it was universally accepted.

Despite the long-term documentation of the original root form dental implant, some inherent problems were encountered. As stated earlier, these implants tended to lose bone over time and it was accepted.[3, 4] This bone loss becomes an important issue when related to the front teeth that are visible in someone during smiling. As the bone loss happens, the gingival tissue that covers the bone will also be lost, potentially resulting in an unpleasing esthetic complication. Other complications that were encountered with this implant system include screw loosening and/or fracture.[36]

In order to overcome the limitations of the original root form dental implant, some design modifications to the implant were introduced. These new design aspects included the roughening of the implant surface, as well as the development of an internal hex connection instead of an external hex connection. The roughened surface was thought to be more beneficial in comparison to the smooth surface in that it provided a greater surface area for bone contact, better mechanical stablity following placement, better retention of the blood clot, and finally, a greater stimulation of the bone healing process.[37-39] The internal hex connection was developed to reduce the number of prosthetic complications that were experienced with the external hex system.[36]

The design of today's root form dental implant has corrected some of the inherent problems that were experienced with the smooth surface implant by incorporating a roughened surface, as well as an internal hex abutment connection design. The implant of today, however, lacks the long-term documentation that is found supporting the original smooth surface implant.

Dental Implants in Health

The dental implant tissues in health resemble those of a natural tooth, however, there are some differences that exist. First, the term used to describe the soft tissue attachment to a tooth is termed the dentogingival junction, and is composed of an average sulcus depth of 0.69mm, epithelial attachment of 0.97mm, and a connective tissue attachment of 1.07mm.[40] The term used to describe the soft tissue attachment to the implant is transmucosal attachment.[41] This attachment is composed of the barrier epithelium of approximately 2mm and the connective tissue of about 1-1.5mm, and these are attached to the implant through hemodesmosomes.[41] The intrinsic characteristics of the tissues are also different in comparison to a natural tooth. Around an implant, the connective tissue contains more collagen, but it has fewer fibroblasts and vascular structures, and the collagen tends to run parallel to the implant, as opposed to lateral, coronal, and apical directions of the collagen around a tooth.[42] The clinical probing depth around implants is typically deeper than probing depths around natural teeth.[43] The location of the alveolar bone level in implants should be at the shoulder or top edge of the implant, or the area where the rough surface treatment ends.

Reasons for Crestal Bone Loss Around Implants

There have been numerous reports in the literature explaining the reasons for crestal bone loss around implants. In general, reasons for bone loss can be divided into the following categories: patient factors and implant design factors. Smoking has been shown to have a detrimental effect on the peri-implant bone levels. A recent study[44] suggested that smoking was a factor in indentifying a subject with progressive bone loss around an implant with 69% accuracy. In a long-term follow-up of implant treatment, it was concluded that patients who had a history of periodontal disease and patients that smoked are more likely to develop bone loss around implants.[45] The patient's ability in performing proper oral hygiene procedures has also been shown to influence bone levels around implants.[46]

Another factor that relates to implant bone loss relates to implant design. It has been noted that bacterial colonization of the implant-abutment interface can occur, thus resulting in an inflammatory reaction near the bone level.[9-11] Movement between the abutment and the implant can also cause bone loss.[13] This movement has been demonstrated in a recent study[15] where implants from different manufacturers were loaded with their respective abutments and filmed during force application with a high speed camera. Only two implant systems in this study did not demonstrate movement.

Thus, it can be deduced that an implant with an internal hex connection without a microgap, or movement between the abutment and the top of the implant, and a roughened surface, may have a positive effect on maintenance of the surrounding bone level. The implant system used in our investigation had a rough surface treatment extending to the shoulder of the implant and a morse taper internal hex connection which eliminated the microgap. It was also one of the two implant systems aforementioned that did not demonstrate movement between the abutment and the implant.

CHAPTER 3
MATERIALS AND METHODS

This study is a retrospective review of the records of 50 consecutive partially edentulous patients where missing teeth were restored with dental implants placed by one periodontist in a private practice in Jacksonville, FL.

Participant Population

The subject sample consisted of 36 females and 14 males with a mean age of 54 years (range 21-80 years) treated by one periodontist (A.F.) in a private practice. The study protocol was reviewed and approved by the University of Florida Institutional Review Board, USA. All patients were systemically healthy and one of the patients was a current smoker Patients were excluded if they had a severe or chronic systemic disease or were pregnant or lactating. Initially, a careful periodontal examination including assessment of plaque, gingivitis, probing pocket depth and radiographic bone loss at all remaining teeth was performed. This was followed by oral hygiene instruction and if indicated periodontal treatment. Table 3-1 illustrates the demographics of the study population.

Surgical Procedure

Surgeries were carried out under local anesthesia by one periodontist, Dr. Alan Fetner, and except for the grafting procedure described below, all procedures were performed according to the implant manufacturer's protocol. At implant placement, particular attention was made to place the facial implant-abutment junction in a 1-2 mm subcrestal position. All surgeries were done in one stage where either a healing abutment (sulcus former) or a permanent abutment was connected to the fixture during the surgical procedure. On 46 of the fixtures, accounting for 35% of the fixtures, healing abutments were initially attached to the fixtures. In cases where the permanent abutment was placed as a part of the surgical procedure, which occurred in 64% of the fixtures, an acrylic crown restoration was fabricated and positioned immediately as a temporary prosthesis out of occlusion. In these situations the length of the abutments was chosen to attain the crown periphery with a location 1-2 mm below the mucosal margin.

After placement of the fixture-abutment complex, the remaining osseous wound defect between the bone crest and the coronal aspect of the implant was grafted with PepGen-15, a bone grafting material comprised of synthetic peptide p15 and bovine hydroxylapatite. Finally, the flaps were closed and secured with interrupted Chromic gut sutures. Each patient received 500 mg of amoxicillin three times per day for 7 days from the day of implant surgery in an effort to help prevent post-surgical infection.

Implant Locations

A total of 69 screw-shaped implants, 51 in the maxilla and 18 in the mandible were installed. Figure 3-1 is describing the distribution of placed implants according to position in the jaw. Thirty-seven patients had one implant placed, while eleven subjects received two implants positioned in different jaws. Two patients received four and six implants, respectively. Sixty-four implants had a diameter of 3.5 mm and five 4.5 mm, while the length varied between 9.5 to 14 mm.

Post-operative Care

The final prosthetic construction was completed 3-4 months after implant insertion by the referring dentist following the implant manufacturers' manual. Careful oral hygiene instruction was given to all patients at the installation of the permanent prosthetic construction and in addition the oral hygiene was reinforced at follow-up visits.

Radiographic Analysis

Postoperative radiographic examination was performed immediately after the surgical procedure, at crown installation, at the 1-year follow-up visit, as well as at any more follow-up visits deemed necessary by the surgeon. The periapical radiographs were taken in a standardized manner using a paralleling device and a digital imaging software system, namely, ImageJ, provided by the National Institutes of Health.

Two periodontists and one periodontal resident worked together to interpret the radiographs. For each implant, the radiographs were evaluated regarding (i) degree of subcrestal positioning at surgery as well as (ii) changes of marginal hard tissue height over time and (iii) if marginal hard tissue could be detected on the implant platform at the follow-up visit. The subcrestal position of the implant was determined by measurements from the marginal bone crest level to the implant shoulder (Figure 3-2). The changes of marginal hard tissue height were calculated by the distance between the fixture shoulder and the first visible marginal hard tissue to implant contact. In situations where the marginal hard tissue was seen above the reference point, it was still recorded as zero to avoid introducing any bias in the results. The presence or absence of mineralized hard tissue on the shoulder was represented by a (+) or (-), respectively. All measurements were determined at the mesial and distal surface of each implant using a magnification (x7) of the images. The radiographs were downloaded as 16 bit, JPEG files, and analyzed with an image processing system[27] on a MacIntosh laptop computer. The geometry of the implant was used to assess the distortion of the images. In situations where mesial or distal sites on the implant were not visible on the radiographs, a decision was made to exclude the implant site from the analyses. The error of the method used for appraising the measurements on the radiographs was calculated by reassessing 10 randomly selected cases including 40 sites. The mean difference between repeated measurements of the 40 sites was found to be 0.04mm (SD 0.33mm).

Table 3-1. Characteristics of the patient sample.

Number of patients	50
Gender (male/female)	14/36
Smokers	1
Mean age (years)	54.1 (13.2)

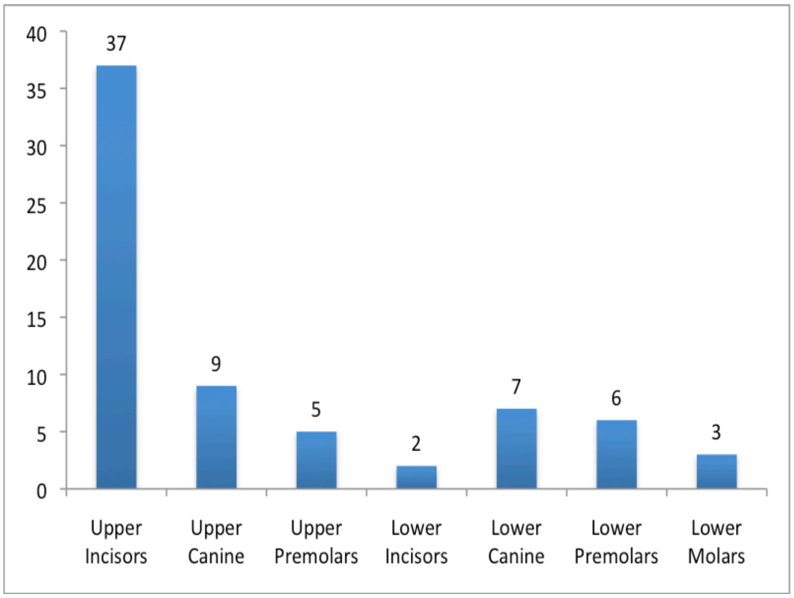

Figure 3-1. Distribution of placed implants (n=69) according to position in the jaw.

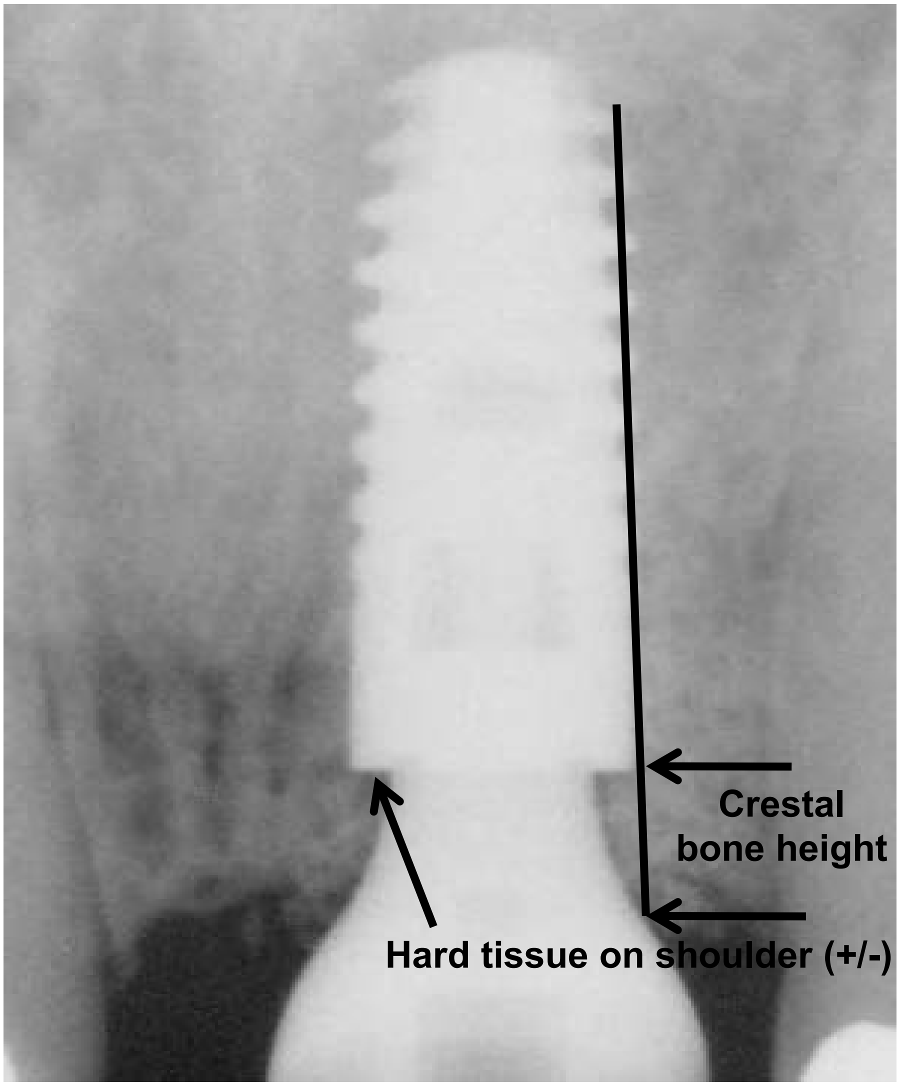

Figure 3-2. The subcrestal position of the implant was determined by measurements from the marginal bone crest level to the implant shoulder. The presence or absence of mineralized hard tissue on the shoulder was represented by a (+) or (-), respectively

CHAPTER 4
RESULTS

The overall survival rate from baseline to last recorded follow-up visit was 100%. From the total of 138 sites, 131 were available for radiographic interpretation, 68 mesial and 63 distal sites. Mean follow up time was 14 months. At the surgery the implants were placed 1.37 mm (mesial) and 1.28 mm (distal) subcrestally and at last recorded follow-up visit 61/69 still demonstrated a subcrestal location.

Mean marginal hard tissue loss (SD) from the time of implant installation to the last follow-up examination for different gender, jaws, mesial and distal sites and in smokers and non- smokers (site level) is described in Table 4-1. The mean loss of marginal hard tissue measured from the implant shoulder was 0.11 ± 0.30 mm measured on site level (n=131) and 0.11 ± 0.27 mm on implant level (n=69). Men were showing 0.13 ± 0.36 mm loss of marginal hard tissues and women 0.09 ± 0.27 mm. For maxillary implants the mean loss of marginal mineralized tissue was 0.12 ± 0.33 mm compared to 0.05 ± 0.21 mm for mandibular implants. The cumulative percent of implants and sites showing loss of peri-implant hard tissues during the observation period is illustrated in Figure 4-1 and Figure 4-2. During the observation time 75% of the implants and 84% of the sites did not experience any bone loss. There were no statistical significances regarding loss of marginal hard tissues between mesial and distal surfaces or maxilla vs. mandible. In contrast, the frequency of implants loosing greater than 0.5 mm mineralized hard tissue measured according to Figure 3-2 was 14 % in the maxilla and 6% in the mandible. Mineralized hard tissue on the implant shoulder was demonstrated on 69% of the implants at the 1-year follow up visit.

The results of the Pearson correlation analysis with respect to subcrestal implant position, loss of mineralized hard tissue and presence of hard tissue on the implant platform are illustrated in Table 4-2. There was no statistical significant correlation regarding subcrestal implant position and loss of marginal mineralized hard tissue ($r=0.15$, $p>0.05$). In contrast there was a significant correlation regarding subcrestal implant position and presence of hard tissue on the implant shoulder at the last follow-up examination ($r=0.21$, $p<0.05$).

Table 4-1. Mean marginal hard tissue loss (SD) from the time of implant installation to the last follow-up examination for different gender, jaws, mesial and distal sites and in smokers and non- smokers (site level).

Variable	n	Mean loss (mm)	SD	P	Hard tissue on platform (%)
Jaw:					
Maxilla	95	0.12	0.33	>0.05	67
Mandible	36	0.05	0.21		72
All	131	0.11	0.30		69
Gender					
Male	45	0.13	0.36	>0.05	77
Female	86	0.09	0.27		63
Surface					
Mesial	68	0.09	0.26	>0.05	71
Distal	63	0.12	0.35		67

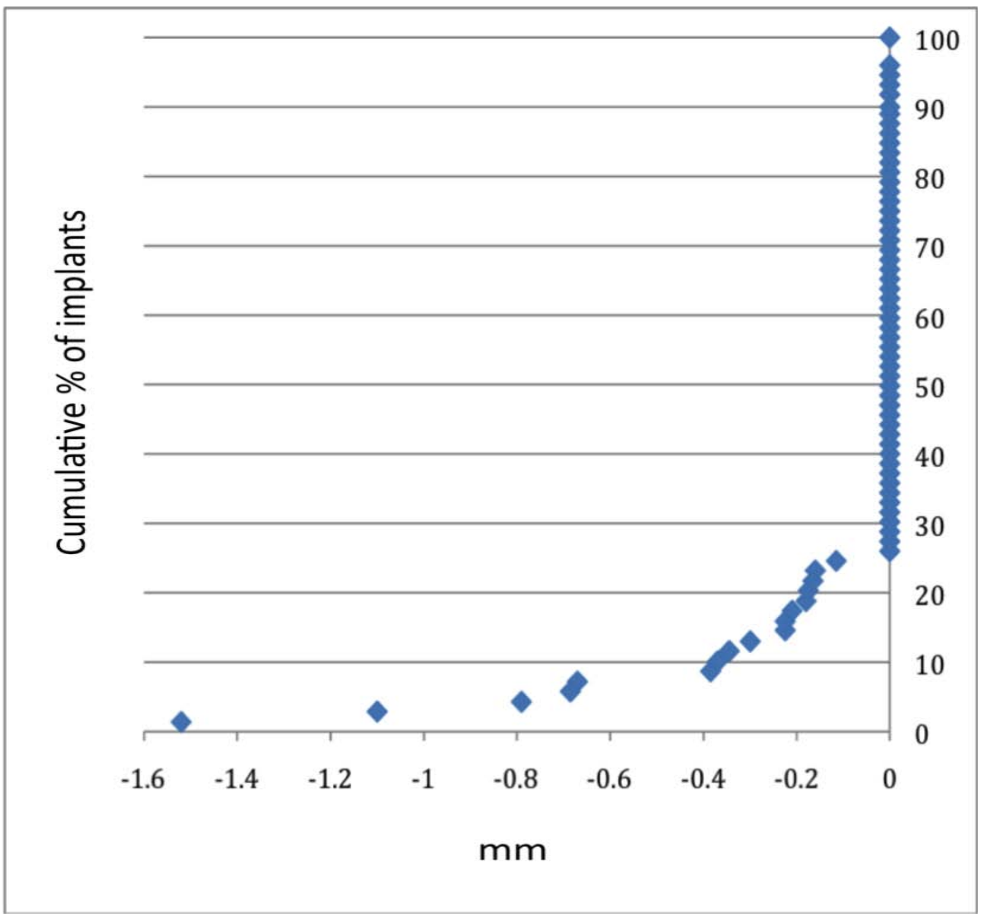

Figure 4-1. Cumulative distribution of implants according to mean peri-implant hard tissue loss between implant installation and follow-up examination

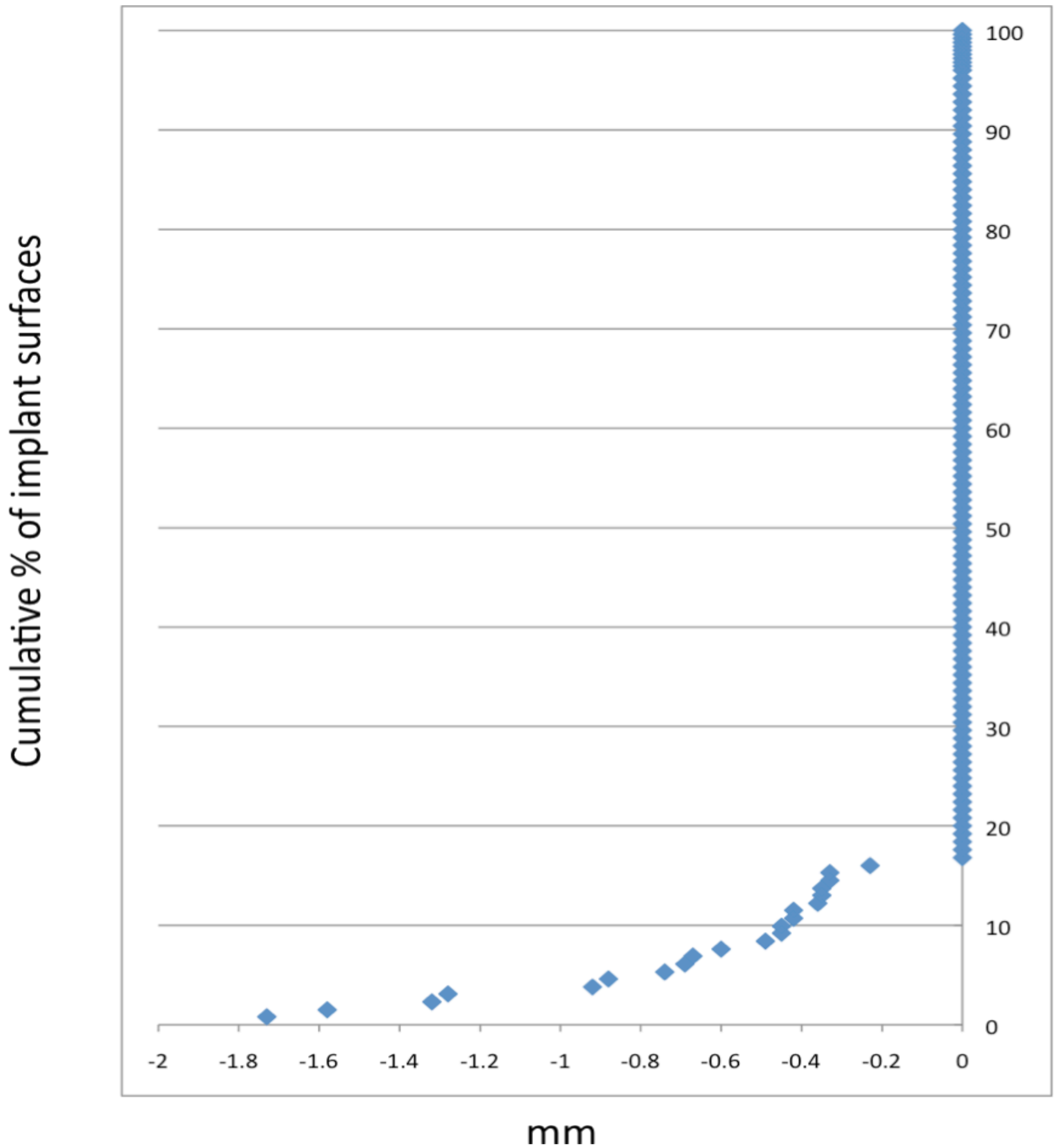

Figure 4-2. Cumulative distribution of implant surfaces according to peri-implant bone loss between implant installation and follow-up examination.

Table 4-2. Pearson correlation analysis with respect to subcrestal implant position, bone loss and presence of bone on the platform at the last follow-up examination.

Outcome	Coefficient	P-value
Bone Loss	0.15	>0.05
Bone on the implant platform	0.21	<0.05*

*=statistically significant p<0.05.

CHAPTER 5
DISCUSSION

The present study demonstrated that the marginal peri-implant hard tissue changes that occurred using an implant system with a reduced abutment diameter in relation to the fixture diameter, as well as a Morse taper implant-abutment connection were minimal during the first year of function. Further, no implant failure was seen, resulting in an overall survival rate of 100%.

Albrektsson et al. [3] accepted 1mm peri-implant bone loss during the first year of function, followed by an annual loss <0.2mm after the first year in service as a criteria for implant success. Albrektsson & Isidor [4]also proposed criterion for implant success and they suggested an average peri-implant marginal bone loss of less than 1.5 mm the first year after insertion of the prosthesis and less than 0.2 mm annual bone loss after that as a standard for successful therapy. In the present study the mean loss of marginal hard tissues during the first year was 0.11 mm measured from the time of implant placement. In this comparison it is reasonable to conclude encouraging short-time outcomes regarding the implant treatment in the present study.

One feature of the two-piece implant system reported in the present study is altered horizontal relationship between the fixture diameter and the abutment diameter. In recent studies of treatment using implants with this concept, minimal marginal peri-implant bone loss was reported.[20-22, 28-30] The positive effect of this design called platform shifting is explained by an increased distance from the FAI to the crestal bone creating an establishment of increased biologic width reducing the risk of inflammatory induced bone loss in cases of peri-implant submucosal bacterial colonization. In a 5-year prospective study, Wennström et al. [21] reported mean bone level changes from the time of crown placement to the first year of 0.02 (0.65) mm measured on implant level. This study differs from the present by having baseline measurements at the time of crown installation and not directly after surgery. Another difference is that Wennström and coworkers were including gain of marginal bone after baseline measures in their calculations while we in the present study only recorded loss. If the mineralized hard tissue was seen above the reference point, it was in the present study still recorded as zero. Norton [22] reported the results from implant therapy in 54 patients where the implants had been in function for a mean of 37 months. The average marginal bone loss was reported to be 0.65 mm. When bone was seen above the reference point it was still recorded as zero the same way as in the present study.

The effect of different positioning, as well as implant size and implant geometry on marginal implant bone levels has been a subject of various studies and several factors are considered important. [12-14,16] Bacterial colonization of the FAI microgap, precision fit between the implant components, torque forces when the components are connected, and loading forces when the implants are in function are examples of factors assumed to affect the outcomes of treatment regarding the marginal implant bone level. In an in-vitro study, the micromovement at the FAI was measured for nine different implant systems. [15] In this study of dynamic behavior of dental implants with different designs of the fixture-abutment connection, the authors reported results for implants loaded at an angle of 30 degrees and when a force up to 200 N was applied. The implant system used in the present study was one of four systems not reported to exhibit micromovements when loaded at 100 N and one of two systems not showing measurable microgap when loaded at 200 N. The authors[15] speculated that certain implant designs would minimize the pumping effect between the fixture and the abutment and thus prevent marginal peri-implant bone loss.

All implants in the present study were placed in a subcrestal position. There is however, limited information available regarding outcomes of this type of treatment. In three animal studies using two-part implants with non-matching implant and abutment diameters the result of subcrestal implant placement on marginal bone levels has been reported. In a recent study, radiographic analysis of implants placed at the level of the crest, 1 mm above the crest, or 1mm below the bone crest revealed greatest bone loss at implants placed subcrestally. [16] In another animal study by Welander et al.,[26] placing the FAI 2 mm subcrestally, it was suggested that osseointegration may occur coronal to the fixture/abutment interface. The authors in this study are indicating that the result may depend on certain surface characteristics of the implant components. The test implants in this study had a surface modification extending to the implant margin and, thus also included the shoulder part of the implant. In the present study we also utilized implants with a microstructured surface treatment including the cervical collar and extending onto the implant shoulder. Finally, in an animal study by Weng et al. [31], implants that were placed in a subcrestal position presented with bone growth onto the implant shoulder in nearly all histological sections.

Effects of altered vertical implant positioning in patients were reported by Hämmerle et al. [32]. In this study one-stage transmucosal implants with the border between the rough and the smooth surface were sunk 1mm into a subcrestal position and this was compared to implants placed according to manufacturers recommendation with the border between the rough and the smooth surface precisely at the alveolar crest.. The implants in the subcrestal group lost 2.26 mm of the clinical bone height during the first 12 months and the control implants 1.02 mm during the same time period. The authors concluded that subcrestal placement of implants with smooth/polished collars should not be recommended.

Variation in surface treatment, implant geometry and relation between the osseous wound defect and the implant may explain the different outcomes of the studies describe above. When a circular hole is made in bone, and an implant is placed, a tissue repair process will start. The natural healing can be disturbed by irritations from bacterial plaque around the implant or in the FAI as well as micromovements of the fixture/abutment complex, excessive loading forces, or by other irritants. However, with minimal irritations and a fixture-abutment interface location creating an acceptable biological width, it seems reasonable to assume that the subcrestal bone defect created during surgery will heal without further bone loss. The results of the present study denoted minimal loss of mineralized hard tissue around dental implants placed non-submerged and in a subcrestal position. In addition, the results also demonstrated a hard tissue healing extended onto the platforms on most of the observed implants.

In spite of the promising results of this retrospective radiographic study, some limitations should be discussed to keep in the background while interpreting the results. First, only mesial and distal bone levels were assessed, while no assessment was made of the facial or lingual bone levels. This is an inherent limitation in interpreting periapical films, yet is a common method used for bone level assessment around teeth and implants. Another limitation of the study to keep in mind is that no radiographic stent was used to take reproducible radiographs. Bone levels could potentially be altered as a result of variable positioning of the beam, as well as x-ray holder.

Further studies are needed to validate the optimal vertical positioning of an implant in relation to the alveolar crest and also to elucidate if different implant diameters will impact the results. All implants in this study, except five, had the same diameter so it was not possible to compare the amount of crestal bone loss between implants of different diameters. A previous study[33] reported increased crestal bone loss in implants placed in close proximity. The minimal peri-implant loss of mineralized hard tissue in the present study may indicate the possibility of placing implants with this design closely adjacent without increased marginal bone loss. In the future, longer term studies of peri-implant bone loss for this particular implant system will aid elucidating the effects it has on peri-implant tissue stability.

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BIOGRAPHICAL SKETCH

Dr. Ryan Donovan was born in Bradenton, FL and studied chemistry at the University of South Florida, where he graduated in the spring of 2003. After which, he attended dental school at the University of Florida, where he received his doctorate of dental medicine degree in 2007. From there, he entered a 3-year post-doctoral residency program in periodontics at the University of Florida. Upon graduation in the spring of 2010, he plans on opening his own private practice in Fort Myers, Florida.