CLINICAL INVESTIGATIONS

Prosthetic Abutment Height is a Key Factor in Peri-implant Marginal Bone Loss

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Abstract: *In this study, we analyzed the influence of prosthetic abutment height on marginal bone loss (MBL) around implants in the posterior maxilla. In this retrospective cohort study, the radiographically determined MBL was related to the height of the abutments of internal conical connection implants at 6 and 18 months post-loading. Data were gathered on age, sex, bone substratum, smoking habit, history of periodontitis, and prosthetic features, among other variables. A linear mixed model was used for statistical analysis. The study included 131 patients receiving 315 implants. MBL rates at 6 and 18 months were mainly affected by the abutment height but were also significantly influenced by the bone substratum, periodontitis, and smoking habit. MBL rates were higher for prosthetic abutment < 2 mm vs. ≥ 2 mm, for periodontal vs. non-periodontal patients, for grafted vs. pristine bone, and for a heavier smoking habit. The abutment height is a key factor in MBL. MBL rates followed a non-linear trend, with a greater MBL rate during the first 6 months post-loading than during the next 12 months.*

Key Words: sinus augmentation, peri-implantitis, dental implant, dental implant-abutment connection.

Introduction

Various etiologies have been proposed for marginal bone loss (MBL). It has been attributed to inflammation from biomechanical stress due to an incorrect occlusal prosthesis design (Rungsiyakull *et al.*, 2011) or from a foreign-body reaction to cement in the soft tissues around cemented-retained prostheses (Qian *et al.*, 2012). MBL may also be increased by the presence of pathogenic microflora that promote peri-implant inflammation, increasing pocket depth and bone resorption (Lindhe and Meyle, 2008). It has been observed that resorption is reduced with greater distance between the bone and the area of inflammation induced by bacteria in the implant-crown micro-gap (Piattelli *et al.*, 2003).

The bone level around dental implants is significantly affected by clinical decisions about the biologic width (Hermann *et al.*, 2000, 2001). It has been observed

that post-implantation wound healing consistently entails bone resorption and, therefore, the establishment of an angular bone defect at sites in which the mucosa is thinner than 2 mm before the abutment connection and remains similar over time (Berglundh and Lindhe, 1996). Significantly greater peri-implant bone loss was also reported when this tissue was thinner than 2 mm, regardless of the position of the micro-gap (Linkevicius *et al.*, 2009). A subsequent study found a similar magnitude of initial marginal bone loss between implants applied with a “platform-switching” or traditional implant/abutment approach in areas with mucosal thickness of 2 mm or less (Linkevicius *et al.*, 2010). These observations indicate that mucosal thickness has a major influence on the degree of early peri-implant bone loss (Wennström and Derks, 2012).

However, some authors found a higher MBL rate with a shorter prosthetics abutment, compressing the initial mucosa thickness, possibly due to a re-establishment of the biological width (Vervaeke *et al.*, 2014). Collaert and De Bruyn (2002) proposed a relationship between prosthetic abutment height and

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Figure 1.

Diagram depicting the marginal bone loss (MBL) in relation to the height of the prosthetic abutment. Note that the distance between the antagonist tooth and the bone remains the same in all clinical situations but is comprised of different abutment and crown heights.

peri-implant bone loss, although the absence of statistical analysis prevented meaningful conclusions from being drawn (Collaert and De Bruyn, 2002). Similar results were observed in another study, in which the prosthetic abutment height had an even greater influence on the MBL than did the internal or external implant connection (Galindo-Moreno *et al.*, 2014b).

Hence, according to the above data, MBL around healthy implants can be attributed to the biologic width establishment or to inflammation induced by bacteria present in the micro-gap formed around the crown-implant connection, regardless of the soft-tissue width. In theory, the use of higher abutments to connect the crown to the implant would provide more space for soft-tissue adaptation and would diminish bacteria-promoted inflammation, reducing the bone resorption mediated by these mechanisms.

The main objective of this study was to test the hypothesis that the peri-implant MBL would be reduced with higher abutments, due to the greater distance between crown and bone. Secondary objectives were to evaluate the influence of tobacco consumption, history of periodontitis, and bone substratum type on the MBL around implants in the posterior maxilla and to estimate the opti-

mal distance from the prosthetic crown to the bone surface for minimizing bone resorption.

Materials & Methods

Study Design

The eligible population for this retrospective correlational study was comprised of consecutive patients at 2 private practices who underwent functional restoration of the posterior maxilla between September 2008 and July 2010. Study inclusion criteria were: 18 to 85 yr of age, placement in the posterior maxilla of at least 2 implants splinted in the same screwed prosthetic structure, the presence of at least 5 mm of remnant crestal bone (Wang and Katanji, 2008), and performance of the surgery by the lead author (P.G.-M.). The study protocol was approved by the human research ethical committee of the University of Granada. The same implant system (Astra Tech AB, Mölndal, Sweden) was used in all patients, and all implants were surgically inserted at bone level.

Clinical Variables

Data were gathered for each patient on their age, sex, smoking habit, history of periodontal disease, implant features,

height of prosthetic abutment, and type of restoration. The smoking habit of the patients at the time of the surgery was recorded, classifying them as non-smokers (0 cig/day), mild smokers (0-10 cig/day), or heavy smokers (>10 cig/day). The history of periodontal disease was determined by assessment of the clinical attachment loss (CAL) with a Michigan O probe (Hu-Friedy, Chicago, IL, USA), defining periodontal disease as the presence of at least 4 sites with CAL $\geq$ 3 mm. The height of uni-abutment used to fix the crown to the implant body was 0 mm, 0.5 mm, 1 mm, 2 mm, or 4 mm, as indicated by the manufacturer (Astra Tech AB, Mölndal, Sweden) (Fig. 1). The restoration type was defined as full-arch rehabilitation, fixed partial denture, or overdenture.

Radiographic Evaluation of MBL

Standardized digital panoramic radiographs (Kodak ACR-2000, Eastman Kodak Company, Rochester, NY, USA) taken at the surgical implant installation, at the time of final restoration delivery (baseline), and at 6 and 18 mos after the functional loading were obtained from medical records. They were analyzed by a single independent calibrated examiner using Dent-A-View v1.0 software (DigiDent, DIT, Neshar, Israel). The MBL

Figure 2.

Marginal bone loss (MBL) rates in mm/month (A) in relation to prosthetic abutment height as a continuous variable and (B) as a function of the time since functional loading and the abutment height, classified as short (< 2 mm) or long ($\geq$ 2 mm). Vertical bars are 95% confidence intervals.

was determined by linear measurements taken from the most mesial and distal points of the implant platform to the crestal bone on each panoramic radiograph, corrected according to the known height and width of each implant.

Statistical Analysis

Descriptive statistics, analysis of variance, the exact chi-square test, and the linear mixed model were used to examine and determine the effect of the abutment height (primary predictor) on the MBL rates (primary outcome) at 2 peri-implant sites (mesial and distal, secondary predictor) in 2 time frames (6 and 18 mos after functional loading, secondary predictor). We controlled for the following potential confounders: age, sex, smoking habit, periodontal status, restoration type, bone substratum type, and implant width and length. MBL rates were computed for the mesial and distal rates as the difference between MBL at 18 mos and 6 mos divided by the elapsed time in mos (mm/mo). The initial loss rate (in mos) was calculated as the MBL at 6 mos minus the MBL at baseline (*i.e.*, at the functional loading) divided

by 6. These 2 rates were compared to determine whether the MBL rate was constant across time. When no significant difference was found between aspects (mesial/distal) or times (6 and 18 mos), mean rates were used to examine the effect of abutment height. The abutment height was treated both as a continuous variable and in 2 categories: short abutment (SA), < 2.00 mm in height; and long abutment (LA), $\geq$ 2.00 mm in height. A scaled-identity repeated-covariance matrix was used in all cases, following Schwarz's Bayesian information criterion. Analysis of variance and the exact chi-square test were used to analyze the potential associations of abutment height with patient characteristics and clinical features. The Bonferroni correction for multiple comparisons was applied when required.

Results

The study included 131 patients in whom 315 implants were placed. Seven implants from three patients were excluded because data were missing. Out of the final sample of 308 implants, 137 (44.5%) were LA

implants (abutment $\geq$ 2.00 mm) and 171 (55.5%) were SA implants. Table 1 displays the socio-demographic, clinical, and peri-implant variables of the patients. Table 2 gives the MBL values (in mm) for mesial and distal aspects, and the linear mixed-model estimates for MBL rates (in mm/mo).

Appendix Table 1 exhibits the mean values with standard error for the patients' characteristics and clinical features as a function of the abutment height (SA or LA). Results of the analysis of variance (age, implant width, and implant height) and the exact chi-square test (sex, smoking, periodontal status, prosthesis, and bone substratum) indicated that an overdenture was significantly more frequent in SA *vs.* LA implants ($p = .01$), and that the implant was slightly wider in LA *vs.* SA implants ($p = .01$).

Appendix Table 2 shows the results of the linear mixed models for the effects of patient characteristics and clinical variables on MBL rates. MBL rates were higher for grafted *vs.* pristine bone ($p = .013$), for men *vs.* women ($p = .044$), for smokers *vs.* non-smokers ($p < .001$), and for periodontal *vs.* non-periodontal patients ($p < .001$). Bonferroni-corrected

Table 1.
Clinical, Socio-demographic, and Implant-related Variables of the Study Sample

Variable	Level	N	%
Sex	Males	67	52.3
	Females	61	47.7
Smoking	Smokers	45	35.2
	Non-smokers	83	65.6
Alcohol	No	122	95.3
	Yes	6	4.7
Periodontitis	Yes	80	62.5
	No	48	37.5
Plaque	0	2	0.7
	1	155	50.3
	2	107	34.7
	3	44	14.3
Laterality	Right	146	47.4
	Left	162	52.6
Bone type	Graft	163	52.9
	Pristine	145	47.1
Implant diameter (mm)	3.5	21	6.8
	4	53	17.2
	4.5	186	60.4
	5	48	15.6
Implant length (mm)	11	20	6.5
	13	137	44.5
	15	151	49.0
Abutment height (mm)	0	20	6.5
	0.5	114	37.0
	1	37	12.0
	2	120	39.0
	4	17	5.5
Restoration type	FR	140	45.5
	FPD	138	44.8
	OD	30	9.7

Note: Imp, implant; FR, full-arch rehabilitation; FPD, fixed partial denture; OD, overdenture.

comparisons indicated that MBL rates were lower for full-arch rehabilitations than for fixed partial dentures or overdentures and were lower for fixed partial dentures than for overdentures. A significantly lower MBL rate was observed in wider implants ($p = .05$).

Mixed linear analysis of the mesial and distal rates (Table 2) yielded significant effects of abutment height, $F(1,1216) =$

58.25 , $p < .01$, time, $F(1,126) = 23.53$, $p < .01$, bone type, $F(1,1216) = 6.69$, $p = .01$, smoking, $F(1,1216) = 19.30$, $p < .01$, and periodontitis, $F(1,1216) = 6.42$, $p = .01$. The abutment $\times$ time interaction was not significant, $F(1,1216) = 0.64$, $p > .4$. As shown in Table 2, MBL rates were higher for SA *vs.* LA implants, for the first time period studied (from implant loading to 6 mos post-loading) *vs.* the second (from 6

to 18 mos post loading; Fig. 2B), for periodontal (0.051 mm/mo) *vs.* non-periodontal patients (0.040 mm/mo), for a heavier smoking habit (0.0009 mm/mo), and for grafted (0.050 mm/mo) *vs.* pristine (0.040 mm/mo) bone. As observed in Appendix Table 3, the effect of the abutment height was also significant when considered as a continuous predictor ($p < .001$; Fig 2A).

Discussion

The aim of this study was to determine the influence of prosthetic abutment height on peri-implant marginal bone loss. We hypothesized that a reduced MBL would result from a greater distance between crown and bone and therefore from the utilization of a higher abutment. We found a significantly ($p < .001$) greater MBL in shorter prosthetic abutments (from 0 to 4 mm), in agreement with the finding by Vervaeke *et al.* (2014) of greater bone level changes in implants with short abutments [abutment height < 2 mm (1.17 mm at 1 yr, 1.23 mm at 2 yr); 2 mm, (0.86 mm, 1.03 mm, respectively), or 3 mm (0.38 mm; 0.41 mm)] *vs.* long (≥ 4 mm) abutments at 1 and 2 yr, respectively. In the present study, the abutment height was the variable with most influence on the MBL at both 6 and 18 mos, confirming the desirability of maximizing the distance between crown and bone to obtain a more predictable bone preservation outcome.

The MBL rates at 6 and 18 mos were also influenced by the bone substratum, smoking habit, and periodontal status of our patients. Tobacco consumption is known to promote increased marginal bone loss around implants (Galindo-Moreno *et al.*, 2005), and the present findings suggest that it exerts its effect at early stages of wound healing, possibly by reducing vascularization of the tissues or altering their homeostasis. It has also been shown that, regardless of its etiology, MBL is greater in patients with periodontitis than in those without (Cho-Yan Lee *et al.*, 2012). Increased MBL has also been reported around implants with external *vs.* internal connection (Peñarocha-Diogo *et al.*, 2013), which was reported to have the most influence

Table 2.

Mean Marginal Bone Loss (in mm) at Mesial and Distal Aspects and Mean Marginal Bone Loss Rates (in mm/month) between 0 and 6 Months and between 6 and 12 Months Post-loading as a Function of the Main Predictor and Clinical Variables (standard error in parentheses)

	Aspect	6 months	18 months	Effect	p
MBL					
SA	Mesial	0.180 (0.025)	0.565 (0.043)	SA vs. LA	< .01
	Distal	0.224 (0.028)	0.704 (0.053)	Time	< .01
LA	Mesial	0.063 (0.014)	0.295 (0.043)	Aspect	< .01
	Distal	0.073 (0.015)	0.312 (0.042)	Abut x Time	< .01
MBL rates (mm/month)					
Abutment	SA	0.069 (0.004)	0.049 (0.004)	SA vs. LA	< .01
	LA	0.039 (0.005)	0.024 (0.005)	Time	< .01
Bone	Grafted	0.062 (0.004)	0.045 (0.004)	G vs. P	< .01
	Pristine	0.053 (0.004)	0.035 (0.004)		
Periodontitis	No PD	0.043 (0.004)	0.026 (0.004)	No PD vs. PD	< .01
	PD	0.065 (0.003)	0.048 (0.003)		
Smoking		0.001 (0.0003)	0.0008 (0.0002)	Slope (mm/y)	< .01

Note: SA, short abutment (< 2 mm); LA, long abutment (≥ 2 mm); Abut, abutment; G, grafted bone; P, pristine bone; No PD, no history of periodontitis; PD, history of periodontitis.

on MBL of any variable with the exception of abutment height (Galindo-Moreno *et al.*, 2014a,b).

An important secondary aim in our study was to estimate the optimal distance from the prosthetic crown to the bone surface for minimizing bone resorption. Our results demonstrated that this distance is 2 mm. According to Linkevicius and co-workers (2009, 2010), the width of the keratinized mucosa may be the key factor in maintaining peri-implant marginal bone, with 2 mm being the minimum width of keratinized tissue to preserve the marginal bone around implants, independently of the implant features. However, regardless of the keratinized tissue width, the mucosa can be compressed, as suggested by Collaert and De Bruyn (2002), through the selection of a shorter abutment. Our results indicate that the choice of a shorter abutment may increase MBL and that the keratinized tissue width is not the critical factor. For instance, if the remnant mucosa width is 3 mm after tissue healing in the second surgical stage, we can select a prosthetic abutment of 0 mm, 0.5 mm, 1 mm, or 2 mm. All of these heights will give an

esthetic emergence profile, but, as demonstrated in our study, the MBL will differ according to our important clinical decision on the abutment height.

The MBL rate was elevated during the first 6 mos post-loading and decreased thereafter (Table 2). This non-linear trend in MBL progression after functional loading is consistent with the finding by Vervaeke *et al.* (2014) of no significant increase in MBL between 12 and 24 mos post-loading, based on the cumulative percentage of bone level changes after 12 mos. In fact, there is a tendency for consensus and success criteria to assume that MBL takes place largely during the first year.

The present study differs in some important respects from the very few previous studies on the influence of abutment height on MBL. Thus, unlike the studies by Collaert and De Bruyn (2002) and Vervaeke and co-workers (2014), we studied maxillary implants. Mandibular and maxillary bones differ in their stiffness and hardness because of their distinct macro- and micro-architecture. The difference in bone types between mandible (types 1 and 2) and maxilla (types

3 and 4) is known to influence the osseointegration process and the pattern of resorption around the implant neck (Davies, 2003). We studied implants placed in the posterior maxilla, which has a larger amount of keratinized tissue in comparison with that in the edentulous anterior mandible (Romanos *et al.*, 2010). It has been questioned whether the mucosal lining has the capability to function as a proper barrier tissue (Warrar *et al.*, 1995), and it is widely considered that an “adequate” area of keratinized mucosa is desirable around dental implants to prevent soft-tissue recession and to facilitate oral hygiene measures (Wennstrom and Derks, 2012). Finally, Romanos *et al.* (2010) found a greater biologic width in maxillary *vs.* mandibular sites.

A further difference from previous studies is that we compared outcomes between implants in pristine and grafted bone. Our results confirmed previous findings by our group of slight but significant increases in the MBL around implants placed in grafted *vs.* pristine bone (Galindo-Moreno *et al.*, 2014a).

We studied patients with distinct types of prosthetic rehabilitation, observing less

MBL around implants supporting a fixed partial denture than around those supporting an overdenture, which can be explained by differences in load distribution and biomechanics (Kitamura *et al.*, 2004). In the study by Vervaeke *et al.* (2014), all patients carried an overdenture supported by 2 implants.

Our study had some limitations. Being a retrospective study, it was not possible to homogenize the sample, although our statistical methodology minimized this drawback. We also used panoramic radiography, which is less sensitive than periapical techniques for MBL measurement but provides data on features of the posterior maxilla that can influence implant behavior (*e.g.*, bone type). Moreover, periapical radiography at this localization requires utilization of the bisector technique, and resulting differences in angulation may alter MBL measurements.

The height of the prosthetic abutment was the variable with the most influence on MBL, which was greater around implants with shorter abutments. This parameter must be taken into consideration for adequate maintenance of the bone level around implants over time. MBL rates around dental implants appear to follow a non-linear trend, with a faster bone loss during the first 6 mos post-loading than during the following 12 mos.

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