The Effect of Maximum Bite Force, Implant Number, and Attachment Type on Marginal Bone Loss around Implants Supporting Mandibular Overdentures: A Retrospective Study

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ABSTRACT

Background: There remains controversy regarding the clinical reasons for late-implant bone loss, which is a critical factor in the long-term success of implant-supported overdentures.

Purpose: Assessment of the effect of such factors as attachment type, number of implants, gender, age, and maximum bite force (MBF) on marginal bone loss (MBL) around implants supporting mandibular overdentures.

Materials and Methods: Sixty-two edentulous patients rehabilitated with two-, three-, or four-implant-supported mandibular overdentures at a university clinic between January 2006 and January 2007 and having a digital panoramic radiograph at the time of loading, were included in this study. All patients received digital panoramic radiographs, and MBL was measured by subtracting bone levels from the first radiograph. MBF was measured using a bite force transducer.

Results: The amount of bone loss 48 months after loading was found to be unrelated to gender, age, implant number, attachment type, and splinting ($p = .741$, $p = .953$, $p = .640$, $p = .763$, $p = .370$, respectively). A significant correlation was observed between the MBF and the MBL of distal implants on the right side ($p < .01$, 79.9%) and the MBF and the MBL of distal implants on the left side ($p = .011$, 34.6%).

Conclusions: MBL around implants supporting mandibular overdentures seems not to be affected by number of implants, attachment type, age, or gender; however, MBL is affected by MBF.

KEY WORDS: dental implant, marginal bone loss, maximum bite force, overdenture

INTRODUCTION

The use of two to four implants to support mandibular overdentures is a good treatment modality, and clinical follow-up studies have reported predictable long-term treatment outcomes.[1,2] Published studies show that mandibular implant-retained overdentures provide significant enhancement in stability, retention, patient satisfaction, and quality of life.[3–6] Enhancement of oral function with mandibular implant-supported overdenture treatment has also been demonstrated by objective methods. Positive effects of mandibular implant-supported overdentures on maximum bite force (MBF) have been demonstrated in many clinical studies.[7,8]

The success rate of dental implants supporting mandibular overdentures is greater than 95%, which is a quite adequate success rate for dental implants.[9] Despite the high success rates with mandibular implants supporting overdentures, failures do arise. Prevention of late-implant bone loss is a critical factor in the long-term success of implant-supported overdentures.[10,11] During the first year, marginal bone loss (MBL) of 1 to 1.5 mm, and 0.2 mm annually thereafter is considered acceptable.[12,13]

The design of an overdenture attachment system should provide optimum force distribution around supporting implants to allow bone loading within

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physiological limits.[11] The effect of attachment type on MBL around implants supporting mandibular overdentures has been investigated in many in vitro and clinical studies.[14–18] Although in vitro investigations have shown variations in stress distribution mechanisms among various attachment types,[19,20] clinical studies failed to show an advantage of any particular attachment sequence on MBL around implants supporting overdentures.[14,16] While in vitro studies have shown lower stresses around unsplinted implants,[21,22] higher forces were shown in one clinical trial.[23]

Proposed factors in early bone resorption around implants include bone quality, surgical trauma, microgap, implant surface characteristics, design, size, loading time, and the placement of the smooth neck portion of the implant in contact with the bone.[12,24–28] The most commonly quoted reasons for MBL are overloading and peri-implantitis.[25,26] However, there remains controversy regarding the clinical factors influencing MBL.

Accordingly, this retrospective study was conducted to evaluate of the effect of factors, such as age, gender, attachment type, splinting, implant number, and MBF, on MBL around dental implants supporting mandibular overdentures.

MATERIALS AND METHODS

Patient Selection

The study sample was composed of edentulous patients who had previously been rehabilitated with two, three, or four implant-supported mandibular overdentures and maxillary complete dentures at a university clinic between January 2006 and January 2007. All patients were personally invited by mail or telephone to participate in this clinical and radiographic examination. The requirements of the Helsinki Declaration were fulfilled, and the patients provided informed consent. Patient inclusion criteria were as follows: absence of any systemic disease that was likely to compromise implant outcome, absence of obvious signs of bruxism, and presence of a digital panoramic radiograph at the time of loading in the university records.

All implants were from the same manufacturer (Astra Tech, Mölndal, Sweden), and surgeries had been performed as recommended by the manufacturer by an experienced oral and maxillofacial surgeon using a one-stage surgical protocol. The overdentures were fabricated with anatomical teeth by two specialists in prosthodontics and delivered to patients 1.5 months after installation of the implants (early loading protocol).

Clinical Examination and MBF Measurements

Clinical examinations and MBF measurements were carried out by two prosthodontists blinded to the study protocol. Implant survival was confirmed to be correlated with absence of clinical mobility, signs of infection or pain, and limited MBL as described by Albrektsson and Isidor.[29] The mandibular overdentures and maxillary complete dentures were inspected thoroughly, and rebasing and relining procedures were carried out if necessary. Evaluation of prosthetic parameters such as occlusion, tissue adaptation, and condition of the retentive mechanism was also performed.

Interocclusal bite forces were measured bilaterally with a bite force transducer carrying two strain gauges (Type EA-06-125MW-120, Measurements Group Inc., Raleigh, NC, USA) connected to a strain gauge measurement system (Strain Indicator and Recorder Model P3, Vishay Micro-Measurements, Raleigh, NC, USA; Figure 1). The strain gauges were positioned between the occlusal surfaces in the first molar region, as described in a published study,[14] and a cubic silicone block of the same height as the bite fork was placed on the other side for occlusal stability. Patients were instructed to bite with as much force as possible, and the highest value observed on the device was recorded. Measurements were repeated three times for each side with a 10-minute relaxation period between each bite in order to obtain a reliable MBF value. The highest of the three measurements was then used as the MBF for each side.

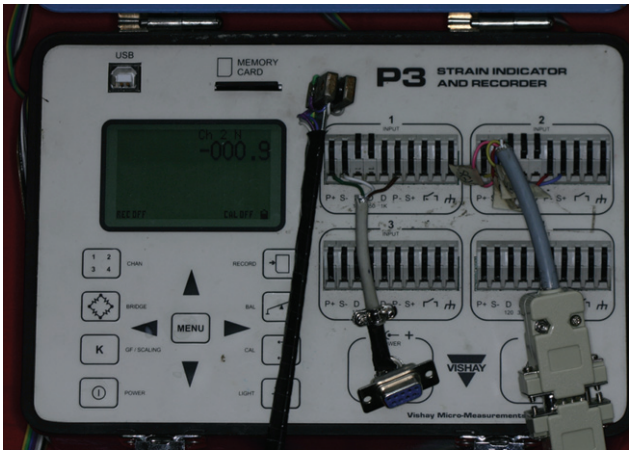

Figure 1 Strain gauge bite force measurement system.

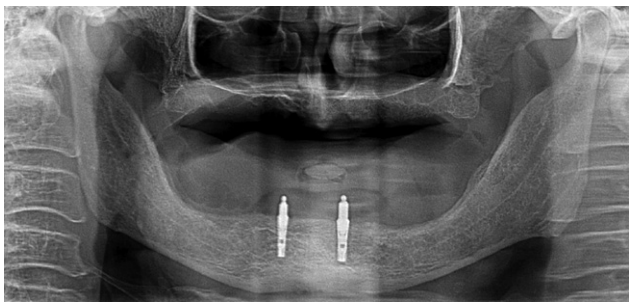

Figure 2 Digital panoramic radiograph showing two ball abutments.

Accordingly, two values were recorded for each patient: the right- and left-side MBF.

MBL Measurements

All of the participants received digital panoramic radiographs (Morita Veraview IC5, J. Morita MFG. Corp., Kyoto, Japan; Figure 2). Measurements were analyzed at 20× magnification using a software program (CorelDraw 11.0; Corel Corp and Coral Ltd, Ottawa, ON, Canada) by two examiners who were blinded to the study and calibrated before the study. The manufacturer's reported diameter of the implant at the collar region was used as a reference point, as follows. The measured distance from the widest part of each implant supracrestally to crestal bone level was divided by the manufacturer-reported width, and this coefficient was used to correct for image distortion in subsequent measurements. Bone levels were determined by applying a distortion coefficient (true bone height is equal to true implant width multiplied by the bone height measured on the radiograph, which is then divided by the implant diameter measured on the radiograph). The level at which the marginal bone attached was assessed by visual evaluation at the distal and mesial surfaces of all implants. The averages of the examiners' measurements were recorded as one value. Two digital panoramic radiographs were available for each patient: one at the time of loading and one at the time of examination. The difference in marginal bone level around each implant was recorded as the MBL value of that implant.

Statistical Analysis

For statistical analysis of the results, the Number Cruncher Statistical System (NCSS) 2007 and Power Analysis and Sample Size 2008 statistical software (NCSS, Kaysville, UT, USA) were used. The following clinical parameters were assessed in relation to MBL: demographic characteristics (age and gender), prosthetic characteristics (three and four implant-supported bars, three implant-supported balls, two-implant-supported locators and ball attachments), number of implants, splinting the implants, and MBF. In addition to reporting descriptive statistics (means and standard deviations), *t*-test was used for the comparison parameters with normal distributions. Comparisons of quantitative data were carried out with a one-way analysis of variance test for the comparison of groups with normal distribution. Pearson's correlation coefficient was calculated between the MBL of the most distal implants and the MBF of that side.

RESULTS

Sixty-two patients (32 women, 30 men) with an average age of 64.0 years (range: 42–90 years) were examined. A total of 169 implants were evaluated. All mandibular overdentures were in situ for at least 3.5 years (mean: 4.3 ± 0.8 years, range: 3.5–4.6 years).

All implants were clinically immobile, without signs of pain; survival rate was 100%. MBL around implants ranged from 0.7 to 1.5 mm.

No statistically significant relationship was detected between MBL measurements on the mesial and distal sides of the same implant ($p = .934$); therefore, the averages of the mesial and the distal measurements were recorded as one value for each implant. Comparing attachment types, the average of the MBL values was calculated and recorded as one value for each attachment type. MBL was found to be unrelated to gender, age, implant number, attachment type, and splinting ($p = .741$, $p = .953$, $p = .640$, $p = .763$, $p = .370$, respectively; see Table 1).

A significant correlation was observed between right MBF and MBL of the most distal implant on the right side ($p < .01$, 79.9%), and left MBF and MBL of the most distal implant on the left side ($p = .011$, 34.6%; see Figure 3, A and B).

DISCUSSION

The implant-supported overdenture is a cost-effective treatment modality for the edentulous patient.[9,17] As the popularity of this treatment increases, it is valuable to analyze the factors affecting its long-term success. The effects of several factors, including implant number, attachment type, and the effect of MBF on MBL around implants supporting a mandibular overdenture – a key

TABLE 1 Evaluation of Marginal Bone Loss Related to Various Factors

	Marginal Bone Loss		
	Number of Patients	Mean ± SD	*p*
Gender*			
Male	30	1.05 ± 0.20	.741
Female	32	1.07 ± 0.20	
Age†			
40–54	18	1.07 ± 0.13	.953
55–64	21	1.07 ± 0.19	
≥65	23	1.05 ± 0.24	
Number of implants†			
2	28	1.04 ± 0.19	.640
3	23	1.09 ± 0.21	
4	11	1.08 ± 0.20	
Attachment type†			
2 balls	14	1.01 ± 0.23	.763
2 locators	14	1.07 ± 0.16	
3 balls	12	1.07 ± 0.17	
3 bars	11	1.13 ± 0.29	
4 bars	11	1.08 ± 0.20	
Splinting*			
Splinted	22	1.10 ± 0.23	.370
Unsplinted	40	1.05 ± 0.19	

*Student *t*-test.
†One-way analysis of variance test.

factor in long-term success[12,13] – are evaluated in this study.

Measurement of MBL over time using radiographs has been reported to be useful for evaluating the success of osseointegration.[11,30–34] The gold standard for radiographic evaluation of MBL around implants has been shown to be intraoral periapical radiographs, where film holders can be mounted directly to the implants.[34] This technique provides the best resolution among all imaging modalities.[33,34] However, film holders are usually very painful for edentulous patients with atrophic interforaminal mandibles, making intraoral periapical radiographs a challenge.[11,31] In such cases, rotational panoramic radiographs are a useful alternative.[11,30,31] However, the superimposition of the vertebral column over the anterior maxilla and mandible frequently produces distortion, especially in the mandibular symphyseal areas of the edentulous mandible.[32,34] Nevertheless, orthopantomography is a reliable radiologic procedure, and because of its standardized projection in the vertical plane, it is well suited for vertical measurements.[11,30–32] It has been shown that panoramic radiographs provide reliable information for assessing the point of bone attachment to implant threads.[11,35] Furthermore, rotational panoramic radiographs have been found to be comparable with intraoral periapical radiographs.[32] For these reasons, panoramic radiography was employed in this study.

This study investigated the effect of five different attachment types with various numbers of supporting implants on MBL. The results indicate that neither attachment type, splinting, nor the number of interforaminal implants influenced MBL, which agrees with in vivo reports[14–17] and a recent systematic review that

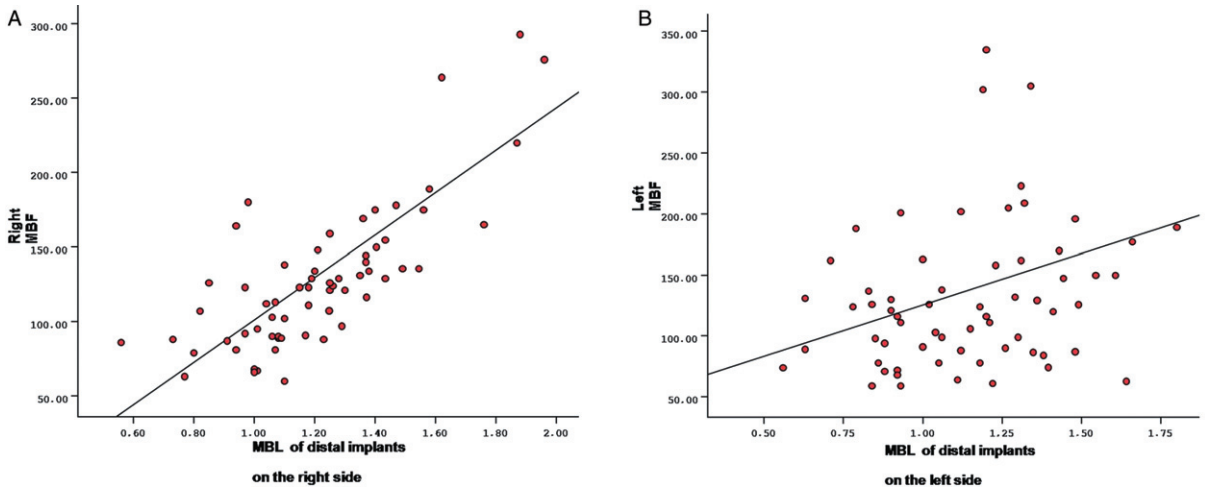

Figure 3 Correlation between right MBF and MBL of the most distal implant on the right side (A). Correlation between left MBF and MBL of the most distal implant on the left side (B).

shows that attachment type only minimally influences MBL around implants supporting mandibular overdentures.[11] The innovation of this study is its simultaneous evaluation of the effect of MBF, attachment type, splinting, and number of implants on MBL.

We found the effect of all attachment types on MBL under loading in the anterior mandible to be similar, but these results may not hold for regions of the mandible where bone density is lower.[36]

The overall implant success rate (100%) after a mean of 4 years of loading indicates that irrespective of attachment type, early loading of mandibular implants supporting a mandibular overdenture is a promising treatment. Furthermore, this positive implant outcome is consistent with other implant-supported overdenture studies.[35,37,38]

In terms of bone loss, all the examined implants met the criteria for success as detailed previously, that is, annual bone not exceeding 1.5 mm in the first year and 0.2 mm per year thereafter.[12,38]

The correlation between MBF and MBL around implants after a mean of 4 years of function was found to be high and statistically significant in this study. In a report by Lindquist and colleagues, factors indicating heavy occlusal loading were associated with increased peri-implant bone loss.[39] The results of a 10-year follow-up study also showed increases in MBL with high MBF but only in smokers.[40] In vitro tests and finite element analyses have shown that MBL is related to increased stress and strain patterns.[41,42] In the present study, high occlusal loads may have created higher stresses around implants, which in turn engenders higher MBL. Thus, patients who would be considered "strong chewers" exhibited higher MBL from generating a heavier load in comparison with patients who were unable to bite as hard. This finding contradicts the results of published clinical studies, which find no correlation between MBF and MBL of implants supporting overdentures.[14,15]

It should be noted that mechanical overload can cause MBL and loss of integration depending on the levels of stress and strain concentrations. The support areas of the overdentures are partly on the mucosa and not only on the implants. Bone remodeling can compensate for excessive forces within the limits of tolerance described in the results of this study. However, it is possible that after 10 years or more of function, mechanical overload could exceed these limits. Longer follow-up studies are therefore needed to draw a more definitive conclusion.

Our findings may be important for evaluating MBL around implants supporting fixed dentures of strong chewers, where forces are transmitted directly to the loaded implants. Increasing the number of implants to support the fixed prosthesis may be useful for strong chewers; this recommendation is supported by studies that show reduction in the forces exerted on an individual implant as the number of implants increases.[43] Longer implants with larger diameters may also prove efficacious as they reduce the stresses in the bone.[44,45] Further clinical studies investigating this effect in implant-supported fixed prostheses are needed to confirm these conclusions.

CONCLUSION

This retrospective study validates the longevity of implants in overdenture therapy for the mandible, finding a 100% survival rate after a mean of 4 years of function. MBL around implants supporting mandibular overdentures was affected by neither the number of implants nor the attachment type; however, MBL was affected by MBF.

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