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Preliminary Study to Evaluate Marginal Bone Loss in Cases of 2- and 3-Implant-Supported Fixed Partial Prostheses of the Posterior Mandible

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Purpose: The purpose of this study was to evaluate, by radiographic examinations, the marginal bone resorption around implants in cases of 2 and 3 implant-supported fixed partial prostheses (FPPs) at the posterior mandible.

Methods: A retrospective study of 41 patients (23 males, 18 females) of an average age of 67 years (range, 53–85), with 2 and 3 implants-supported FPPs in the posterior mandible that were treated during 2006 to 2015. The mean follow-up time was 6.32 years (range, 2–10). Twenty-four patients had FPPs on 2 implants (a total of 48 implants). Seventeen patients had FPPs on 3 implants (a total of 51 implants). Clinical and radiographic follow-up examinations were performed. All radiographs were analyzed for changes in marginal bone height surrounding the implants.

Results: The mean marginal bone loss around the most mesial implant was slightly higher in the 2-implant group (0.833 mm) compared with the 3-implant group (0.431 mm). The correlation between the mean marginal bone loss around the most mesial implant and the number of implants was of borderline value ($P = 0.055$).

Conclusions: Considering the limitations of this preliminary study, the authors found that the mesial implant in the 2-implant group is more susceptible to marginal bone loss.

Key Words: Dental implants, fixed partial prostheses, marginal bone loss, posterior mandible

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In recent decades, replacement of missing teeth in partially edentulous patients using dental implants was considered one of the preferred therapeutic options.[1]

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Once the dental implant is inserted and initial anchoring is obtained, a healing process begins during which the bone is built around the implant to create a tight and continuous bone/implant interface—osseointegration (OI).[2] A primary implant stability is crucial to obtain OI.[2,3]

The osteoclasts and osteoblasts are responsible for the growth, healing, and reconstruction of bone and they respond to both biological and mechanical stimuli. In patients with dental implants, the metabolism of the bone is challenged by a foreign body, which induced stresses and strains on the surrounding bone during functional loading.[4,5,6] The continuous clinical experience leads to the understanding that the response of the bone around the implants is different from its response to natural teeth.[7,8] Most bone loss around teeth is regarded as a biofilm-mediated infection, whereas bone loss around implants may occur for a number of reasons, some of which are not related to infection but rather to complications with treatment.[9] Many researchers still believe that progressive bone loss around the implant is caused by an inflammatory reaction of peri-implantitis.[9,10]

Peri-implantitis is an inflammatory process characterized by loss of supporting bone and damage to OI, unlike peri-implant mucositis, which is a reversible inflammatory process in the soft tissues surrounding a functioning implant.[10,11] Albrektsson et al discuss various causes that can affect marginal bone loss. A series of complications combined to activate the immune system, ultimately shifting the delicate balance between the osteoblast and the osteoclast resulting in bone resorption—that is, this is multifactorial problem.[9,12] They concluded that "there is substantial clinical evidence to support the theory that marginal bone loss around oral implants may be an aseptic reaction that results from nonoptimal implant designs, poor clinical handling, patient behavior or genetics."[9]

Occlusal overload is often regarded as one of the main causes for peri-implant bone loss in the posterior segments of the jaw.[1,13] Exertion of long-term overloads may gradually damage the implant-bone connection, and as a result of that a connective tissue capsule formed around the outline of the implant, eventually, causing to the failure of the implant.[14,15] In addition, overload may cause mechanic complications such as screws fracture/release, fractured restoration, and even fractures in the implant neck itself.[16]

Studies were performed in an attempt to evaluate the influence of the excessive forces and plaque accumulation on marginal bone loss. Isidor et al showed in an in vivo study with monkeys that excessive occlusal overload can cause implant increased mobility and complete loss of OI after several months of loading. In contrast, all implants with a plaque accumulation maintained osseointegrated, and a gradually increasing loss of radiographic marginal bone height was observed.[14,15]

Overload itself cannot be the trigger for disease development around the implants. Nevertheless, overload combined with inflammatory tissue; the overload may have accelerated the progress rate of the bone loss.[17]

Melson and Lang tested the influence of orthodontic forces on the alveolar bone around the implants in monkeys. None of the implants had lost OI after 11 weeks of orthodontic loading, but significantly influenced the turnover of the surrounding alveolar bone around the implant. Therefore, concluded that the occlusal forces would have to exceed the physiological range could jeopardize the tissue integrity of an implant.[18]

The crestal bone around dental implants may act as a fulcrum point for lever action when a force (bending moment) is applied. This may lead to crestal bone loss.[13,19] One of the main factors in treatment planning of implant-supported FPP is the controlled distribution of loads. To reduce occlusal forces, one must ensure a uniform distribution of the occlusal contacts and appropriate design the position and the number of the implants.[1] However, the number of implants has a financial implication to the patient. The available bone volume, bone quality, and density at the implant site affect the distribution of forces and the implants' survivability through functional load.[13] In cases where available bone volume was not sufficient for 3 implants, or replacement of only 2 teeth was necessary, the use of 2 implants was the treatment of choice. Reduction of the number of supporting implants in partially edentulous patients may jeopardize the long-term treatment outcome and increase the frequency of biological and mechanical complications.[20]

Conducted follow-up and regular checkup examinations are crucial to follow up the marginal bone loss around oral implants: radiological follow-up, combined with a clinical checkup, is an important tool that enables comparative imaging evaluation of the state of the implant and its surrounding hard tissues.[21] Bone loss is one of the first symptoms of an implant's failure. Early diagnosis is crucial for rehabilitation prognosis.[20]

The purpose of this study was to evaluate by radiographic examinations; the marginal bone loss around implants in cases of 2 and 3 implant-supported fixed partial prostheses (FPPs) at the posterior mandible.

MATERIALS AND METHODS

Study Design and Sample

This retrospective study included 41 patients, 23 males and 18 females. Average age was 67 ± 7.46 years. All the patients underwent implant placement and FPP of the posterior mandible between the years 2006 and 2015. Radiological follow-up was conducted. Patients were divided into 2 groups: 2-implant group that included 24 patients (total of 48 implants), and 3-implant group, which included 17 patients (total of 51 implants).

Inclusion criteria were as follows:

1. Patients with posterior partially edentulous mandible.
2. Treatments were conducted at the dental clinics of the School of Dental Medicine, Tel-Aviv University, by specialized dentists.
3. Fixed partially prostheses over 2 and/or 3 implants.
4. Fixed partial prostheses that include 2 and/or 3 crown units.
5. Lack of clinical signs of gingival inflammation around the implants (redness, edema, bleeding on probing, and abscess).

Data Extraction

The data taken from the medical documentation were date of implantation; implant type; implant width and length; restoration type—cemented/screwed; smoking, diabetes, and parafunctional habits. For each patient, only one side that contains FPP over 2 or 3 implants was selected randomly.

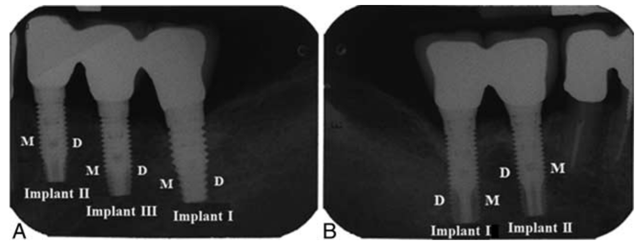

FIGURE 1. Implant marking. Representative X-ray photographs of a 3-implant-supported FPP (A) and a 2-implant-supporting FPP (B). M = mesial, D = distal.

All patients were invited for a single follow-up meeting, completed a health questionnaire and signed an informed consent form as approval to participate in the study. The study was approved by the ethical Helsinki committee (Helsinki, Finland) of Tel-Aviv University.

Each patient was marked by a reference number for data registration. Each patient underwent a clinical and radiographical examination. The clinical parameters examined were lack of inflammatory signs and restoration's integrity. An orthoradial X-ray images were taken using the Planmeca ProX device (70 kV, 8 mA, long cone). The images were compared with X-ray images that were taken at the time of implant surgery for the height of the bone level.

Measurement of Peri-Implant Bone Levels

All the X-ray images were originally developed manually. Therefore, for comparison purposes, the follow-up imaging was also developed manually. All the images were performed using the XCP device (Dentsply Rinn, Rinn Corporation, Elgin, IL), which helps stabilizing the central ray of the cone vertically to the film, thus reducing the radiological distortion. The images were scanned using Epson America Inc. Photo Scanner (Tokyo, Japan) and transferred to the computer as digital media. The implants were marked according to their position in the mandible. The most distal implant—Implant I; the most mesial implant—Implant II. The medial implant in the 3-implant group, Implant III (Fig. 1A–B).

The analysis was performed by the NIH ImageJ software (MD), developed by the American National Institute of Health especially for medical research measurements.[22] All images were normalized and calibrated according to the known length of the implant, as specified in the patient's medical records.

The level of bone resorption in the vertical axis was calculated using a formula that refers to the bone measures performed over periapical radiographs after the implant placement versus the follow-up images. The height of the marginal bone around the implant relative to the implant's coronary end (the neck of the implant) at $t = 0$ is the reference point used to calculate the absorption.[20]

The total marginal bone loss was calculated by Excel (Microsoft 2016, Redmond, WA) using the following formula:

Equation 1: The total marginal bone loss

Linear measurements from the implant abutment interface to the highest crestal bone level were obtained at mesial and distal interface (Fig. 2). The average change in mesio-distal peri-implant bone levels was obtained for each implant. A positive number implied peri-implant bone loss.

Statistical Analysis

The results were statistically processed by IBM SPSS Statistics software (Stanford University), with the consultation and guidance of the Statistical Consulting Lab, the School of Mathematics,

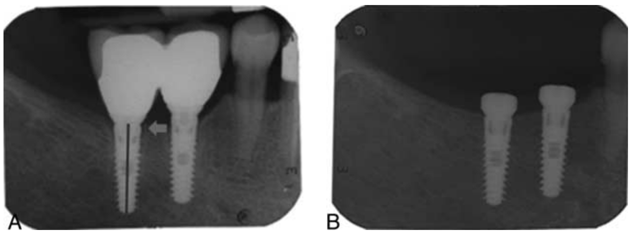

FIGURE 2. Marginal bone loss measurement. (A) The follow-up radiograph; (B) radiograph after implant placement. Dark gray arrows indicate the level of marginal bone loss; light gray line: calibration according to the known implant's length.

Tel-Aviv University. The correlation between parameters was tested using Simple Linear Regression and Student *t* test.

RESULTS

This retrospective study included 41 patients, 23 males and 18 females. The average age was 67 ± 7.46 years. All the patients underwent implant placement and FPP of the posterior mandible between the years 2006 and 2015. Radiological follow-up was conducted 2 to 10 years after implantation, with an average follow-up time of 6.375 years. Patients were divided in 2 groups: 1-implant group that included 24 patients (total of 48 implants), and 3-implant group that included 17 patients (total of 51 implants). In total 99 implants were tested. The demographic and clinical parameters are shown in Table 1.

The mean marginal bone loss around the *mesial* implant in 2-implant group was higher than that of the mesial implant in the 3-implant group with borderline significance correlation ($P = 0.055$) (Table 2).

When comparing the average bone loss around the *distal* implant of both groups, there was no significant difference ($P > 0.09$) in the mean marginal bone loss between the groups, and no significant difference ($P = 0.112$) between the *total* mean marginal bone loss of the 2-implant group (0.738 mm) versus the 3-implant group (0.348 mm) (Fig. 3).

No correlation was found between age, sex, diabetes, smoking, restoration type, fractures, parafunction, night guard, and mean marginal bone loss in the 2 groups.

DISCUSSION AND CONCLUSIONS

Biomechanical factors are one of the most common causes for complications and implant failure of an implant-supported prostheses. The number of implants supporting a PFF should be sufficient, and the choice between using 2 or 3 implants for the restoration of 2 missing molars depends on biomechanical function of the prostheses and is affected by the stress distribution during function. However, this also greatly depends on the volume and density of the available bone.[1] Loss of marginal bone around implants is an important parameter when evaluating the prognosis and success rate of dental implants.[21] Albrektsson presented in 1986 the "gold standard" criteria for success rate of the dental implants. The Marginal Bone Loss (MBL) index was used to define success, "vertical bone loss less than 1 mm during the first year of the loaded implant and continuing resorption up to 0.2 mm/y." Today, however, doubts regarding the accuracy level of this criteria are raised.[22,23] Laural et al performed a literature review and inspected the studies which radiologically examined the changes in marginal bone level over a 5-year period, and found that the annual decrease in bone height was even <0.1 mm.[23]

Bone loss can occur due to BIC infection, thus causing peri-implantitis. However, under optimal clinical conditions, <5% of the implants will exhibit failure due to peri-implantitis.[24]

Today, the common approach is that bone loss around implants is multifactorial, such as patient genetics, bacterial proliferation, poor surgery, adverse loading, cement excess, titanium ionic leakage, broken components, and smoking. A combination of these factors with immune reaction may cause a cellular response and breach the balance between osteoblast and osteoclast activity, thus causing bone resorption around the implants. However, most implants maintain equilibrium with a foreign body (titanium), exhibiting very high survivability percentages in long-term follow-up periods.[12]

TABLE 1. Demographic and Clinical Parameters Among Study Groups

	2-Implants Group	3-Implants Group	Total Patients
Mean age	7.336±67.92	7.587 ± 67.06	7.46 ± 67.49
Male	13 (%54.2)	10 (%58.8)	23 (%56.1)
Female	11 (%45.8)	7 (%41.2)	18 (%43.9)
Smoker	5 (%20.8)	2 (%11.8)	7 (%17.1)
Nonsmoker	19 (%79.2)	15 (%88.2)	34 (%82.9)
Diabetic	4 (%16.7)	2 (%11.8)	6 (%14.6)
Screw retained	4 (%16.7)	4 (%23.5)	8 (%19.5)
Cemented retained	20 (%83.3)	13 (%76.5)	33 (%80.5)
Fractures	5 (%12.1)	7 (%17.07)	12 (%29.2)
Parafunction	12 (%29.2)	12 (%29.2)	24 (%58.5)
Night-guard	2 (%4.8)	3 (%7.3)	5 (%12.1)
No night-guard	22 (%53.6)	14 (%34.1)	36 (%87.8)
Total	24 (%100)	17 (%100)	41 (%100)

TABLE 2. Mean Marginal Bone Loss Around Implant II in the 2- and 3-implant groups

	MBL (mm)		MBL (mm)		MBL (mm)	
Implant II	Mesial	SD	Distal	SD	Total	SD
Two-implants group	0.714	0.67	0.951	0.76	**0.833**	0.66
Three-implants group	0.382	0.73	0.479	0.77	**0.431**	0.60

Mean marginal bone loss of the mesial implant in 2-implants group (0.833 mm) was higher than that of the 3-implants group (0.431). $P = 0.055$.

Mean marginal bone loss of the distal side of the mesial implant in the 2-implants group (0.951 mm) was higher than that of the 3-implants group (0.479). $P = 0.06$.

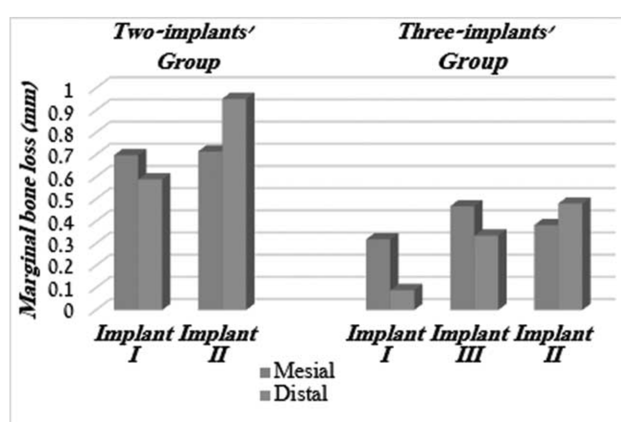

FIGURE 3. Marginal bone loss around implants I, II, and III in 2- and 3-implant groups.

During the first weeks after implant loading, the bone replacement process may lead to the loss of marginal bone. This bone loss is not considered peri-implantitis but a physiological bone loss necessary to create the biological width. Crestal bone loss during the first year may still undergo spontaneous healing processes. Nevertheless, continuous bone loss that persists in progression after the first year is usually related to complications during the insertion of the implant and is affected by the immunological response and other risk factors, for example, nonoptimal components of the implant, restoration overload, compromised patient, treatment quality, and follow-up.[24]

To evaluate the bone level around the implants, a series of X-ray images should be taken during periodic follow-up. It is important to determine whether the implant undergoes a continuous bone loss process or not.[12,24] Several studies found that the radiological measuring method using periapical imaging had the highest level of accuracy and credibility; therefore, periapical images are especially appropriate for radiological evaluation of the bone height around the implants.[25,26]

In our study, the patients were invited for a single follow-up visit. Clinical and radiological examinations of the patients were conducted at a single time point during the study. We found no significant differences ($P > 0.05$) in the mean marginal bone loss (MBL) between the 2-implant group (0.738 mm) and the 3-implant group (0.348 mm). However, we did find that there is greater bone resorption around the mesial implant in the 2-implant group (0.833 mm) compared with the 3-implant group (0.431 mm), a result which nearly reaches statistical significance ($P = 0.055$). The lack of statistical significance may stem from the small size of our sample.

It can be explained by the fact that the resistance of 2-implant-supported prostheses to lateral forces is reduced compared with that of 3-implant-supported prostheses. Moreover, the design of the crown in the buccolingual dimension has a greater influence on the level of load exerted on the implant; thus, when there is buccolingual over-contour a greater load is exerted on the implant due to the bending momentum.[20] Our findings support previous studies.

Eliasson et al in their study, comparing 2-implant-supported prostheses versus 3-implant-supported prostheses, also found no differences in marginal bone loss between the 2 groups. They found that the mean bone loss after a 5-year follow-up was 0.3 mm in both groups, suggesting that after the first year the percentage of absorption stabilizes. Nevertheless, they found that in cases of 3-implant-supported group, more mechanical failures of porcelain fractures were found compared with cases with 2-implant-supported group, where the failures were more often caused by loose abutment screws. The researchers tried to explain this by arguing that excessive occlusal forces are exerted, leading to screw loosening and fracturing.[20] In our preliminary study we found no correlation between the number of implants and mechanical complications such as screw loosening, porcelain fracture, or cement wash.

On the contrary, 3-dimensional finite element model (3-D FEM) studies have shown that a decrease in the number of supporting pillars caused exertion of greater loads on the ridges and that insertion of 3 implants contributed to the increased resistance to lateral forces. Hence, decreasing the number of implants may risk long-term survivability of restorations.[27,28]

The literature debates the definition of peri-implantitis as a disease. The body maintains equilibrium with the foreign body (the implant), which leads to an existing inflammatory response, albeit slight, around all implants. Furthermore, the body's aging processes lead, among other things, to jaw bone absorption.[12] In our study, the absorption appeared with no clinical inflammatory symptoms around the implants (eg, color changes, edema, bleeding, and recurrent abscess). In cases of continuous loss of the bone around the implants, when combined with lack of prominent clinical signs of inflammation, an overload may be a suspected cause of the phenomenon.[17]

Parafunctional habits such as bruxism and clenching cause a massive overload on the surface of the implant.[13] Studies performed on monkeys and dogs show that parafunctional activity leads to bone loss. Other studies performed with dogs show that when a good oral hygiene is maintained around the implant, an overload over the implants for 8 months did not cause excessive loss of OI or marginal bone loss compared with implants that did not suffer any load.[17] Retrospective studies on humans found no correlation between parafunctional activity and bone loss. However, parafunctional activity is still considered a significant risk factor when planning implant-based therapy. The long-term survivability of the implants is greatly affected by the scope of the force and the quality of the bone. Therefore, a low-quality bone is more vulnerable to occlusal overloads and extends the time of the treatment.[13]

In our study, fractures and grinding marks on the implant-supported reconstruction were demonstrated in 29.2% of the patients. Only 7 patients suffered from parafunctional habits and they too demonstrated fractures in their reconstructions. No significant difference was found between these parameters and bone loss in neither the 2-implant group nor 3-implant group ($P = 0.133$). Only 5 (20.8%) patients were found to demonstrate parafunctional activity and wear a night guard. No significant difference was found between the use of a night splint and the prevalence of fractures versus bone loss in either group ($P = 0.393$).

In this present study, we also examined the influence of parameters such as age, sex, smoking, diabetes, and restoration type on bone loss around 2 implants versus 3 implants. There was no statistical difference between the age of the patient and the bone loss around implants ($P = 0.718$), so old age is not a limiting factor of the process. This contradicts the retrospective study by Jang, who examined the effects of different risk factors on the survivability of implants. Jang found a significant correlation between survivability rate and patient's age, showing that bone resorption increased in correlation with the patient's age due to reduced bone density. The cortical bone becomes thinner and the spongey bone more porous.[3]

We also found no statistical correlation was found between the patient's sex and bone loss around the implants. This finding is in line with Jang's findings.[3]

In this study, only 17.1% of the entire sample population were smoking patients that got implants. According to our findings there was no significant influence of smoking on bone loss in either group $P = 0.679$. According to many studies, smoking can cause an aberrant immune response and have adverse effects on wound healing processes and considered as the number-one risk factor for peri-implantitis and predicts implant failure. Smoking also increases the annual bone loss around implants by 0.16 mm/y and constitutes the most significant systemic risk factor.[10,29]

The diabetic patients were selected from a preselected group according to a protocol of the school. Only 14.6% of the patients were diabetic but balanced with drugs. Our work found no correlation between diabetes and bone absorption in either group. According to Fiorellini, there is an 86% chance of implant success in diabetic patients for a 5-year period (compared with 95% in the general population). Failure to balance one's diabetes is considered one of the risk factors that may influence healing around the implants. Although there is a slight bias toward implant failure in diabetic patients, in balanced patients the risk is insignificant.[30]

In our study, we found no significant correlation between the types of the restoration, screw retained or cemented bridge, and bone loss in either group. This contradicts Sailer's study, where more biological complications were found in a cement retained, including complications such as implant failure and bone loss of

>2 mm, whereas screw retained implants suffered less biological complications and more technical problems. Bone loss of an implant-supported partial prostheses was significantly lower in screw retained compared to cement retained ($P = 0.01$).[31]

In summary, insertion of implants in the posterior mandible forms a surgical challenge due to anatomical and occlusal limitations. The mandibular canal is an important structure that could limit the installation of dental implants, the presence of the mental foramen, and the decreased bone volume on edentulous ridges of the mandible—all affect the number of implants that can be inserted. Sometimes the number of implants must be reduced and/or short and narrow implant must suffice. Nevertheless, the posterior mandible is designated for chewing and undergoes excessive biting load which increases the need for wide, long, and sufficiently number of implants.[1,32]

1. The most mesial implant in the ridge is more susceptible to marginal bone loss compared with distal implants. The mean marginal bone absorption around the mesial implant in the 2-implant group is higher than the 3-implant group ($P = 0.055$). In light of this data, if one of the implants in a 3-implant-supported FPP is lost, the prostheses can still be maintained. If the mesial implant is lost, one can use the restoration in a cantilever form.[1,20]
2. There was no influence of various parameters such as age, sex, smoking, diabetes, restoration type, restoration fractures, parafunctional activity, and use of night guard on the bone loss in either 2- or 3-implant-supported prostheses.
3. There was no significant difference between the total mean marginal bone losses around 2 implants compared to 3 implants.
4. Our study was a preliminary study with only 99 implants. Further research is required to investigate the phenomenon of bone resorption around 2 or 3 implants and its correlation with additional parameters.

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