Association Between Peri-implant Bone Morphology and Marginal Bone Loss: A Retrospective Study on Implant-Supported Mandibular Overdentures

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Purpose: *The present study aimed to explore the association between marginal bone loss and type of peri-implant bony defect determined using a new peri-implant bony defect classification system.* ***Materials and Methods:*** *A total of 110 patients with implant-supported mandibular overdentures were involved. Clinical information was collected, including gender, age, smoking habit, and the overdenture attachment system used. Peri-implant bony defect types and marginal distances (ie, distance between the marginal bone level and the top of the implant shoulder) of all sites were identified on panoramic radiographs by a single experienced observer. The associations between marginal distance and peri-implant bony defect type, gender, age, smoking habit, attachment system, and time after implantation were investigated using marginal generalized linear models and regression analysis.* ***Results:*** *A total of 83 participants were included in the final sample with a total of 224 implants involving 3,124 implant sites. The mean observation time was 10.7 years. All peri-implant bony defect types except Type 5 (slit-like) were significantly related to marginal distance in all models ($P < .01$). Smoking and time after implantation were significantly related to marginal distance while gender, age, and the overdenture attachment system used were not.* ***Conclusions:*** *The peri-implant bony defect type, determined using the new classification system, is associated with the extent of marginal bone loss.* Int J Oral Maxillofac Implants 2017;32:147–155. doi: 10.11607/jomi.4922

Keywords: *bone morphology, dental implant, marginal bone loss, peri-implant bone defect*

Poor retention and stability of mandibular dentures and reduced chewing ability are common problems faced by edentulous denture wearers.[1,2] Implant-supported mandibular overdentures are generally accepted as an effective solution for edentulous patients with problems related to retention and function.[2,3] Many studies have reported that compared to mandibular complete dentures, implant-supported mandibular overdentures provide better stability, retention, masticatory efficiency, and patient satisfaction and quality of life.[4–6]

Peri-implant marginal bone loss has been regarded by many authors as one of the most important criteria in determining implant success,[7–9] since progressive marginal bone loss may lead to loss of implants. After prosthesis delivery, peri-implant marginal bone loss starts with a healing and remodeling period lasting about 1 year during which the marginal bone loss is around 0.27 to 1.36 mm; afterwards, a marginal bone loss of 0.05 to 0.15 mm per year may be observed.[10–12] Marginal bone loss provides indications about the success rates of implants expectable in the long term,[1,13] and early recognition of bone loss around implants might help improve implant survival and success rates.[14]

Periodontal bone morphology has been found to influence the clinical outcome in the treatment of periodontitis[15,16] and many authors have suggested that the outcome of a surgical regenerative treatment

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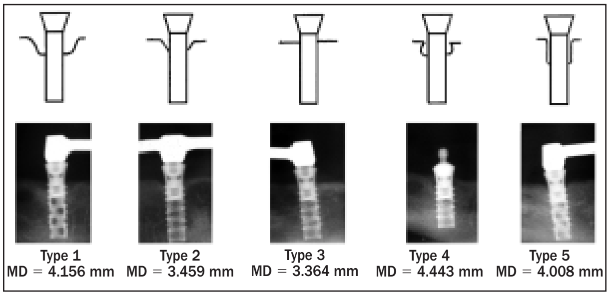

Fig 1 Classification of peri-implant bone defect: Type 1, saucer-shaped; Type 2, wedge-shaped; Type 3, flat or no pocket; Type 4, undercut; Type 5, slit-like. MD = marginal distance.

approach might be influenced by the peri-implant bone defect configuration.[17,18] Tonetti et al[19] showed that for guided tissue regeneration, the wider the radiographic defect angle, the lower the regenerated probing attachment level in intrabony defects. Furthermore, Schwarz et al[20] reported that the most frequently observed type of peri-implant bony defect configuration was circumferential bone loss without dehiscence of the adjacent alveolar crest, and the prognosis for this circumferential defect was found to be the most favorable with the bone regeneration procedure.[17]

Studies have often described the radiographic appearance of peri-implant bony pockets as saucer-shaped[21,22] or as "saucerization."[7,23] Dish-shaped,[24] crater-shaped (or "cervical cratering"[22,25]), and wedge-shaped[21] have also occasionally been mentioned. Oh et al[23] analyzed the possible causes of early implant bone loss and suggested that saucer-shaped peri-implant bony defects might be a result of stress concentration at the crestal bone level. Schwarz et al[20] suggested that the development of peri-implant inflammatory lesions might be related to the anatomy of the alveolar bone while Madi et al[26] suggested that the shape and size of peri-implant bony defects were influenced by the quantity of the available peri-implant bone along with implant surface properties.

Since peri-implant bony defect is an important aspect of bone loss, it is reasonable to assume that the type of peri-implant bony defect is also related to bone loss and may help assess the risk. To assist clinicians and researchers in characterizing peri-implant bony defects, a new classification system of peri-implant bony defects in patients with implant-supported mandibular overdentures was presented[27] that is based on radiographic appearance. Peri-implant bony defects were classified as follows (Fig 1):

- Type 1, saucer-shaped: Bone pocket characterized by a concave bottom (classified as type 4, if the undercut is below the alveolar bone crest)
- Type 2, wedge-shaped: Bone pocket characterized by a straight or convex wall
- Type 3, flat or no pocket: No pocket present or angle between flat alveolar crest and implant surface ≥ 90 degrees
- Type 4, undercut: Bone pocket characterized by a concave bottom, with obvious undercutting; ie, with an undercut > 0.5 mm and proportion of undercut > 50%
- Type 5, slit-like: Bone pocket is narrow and deep with a width of ≤ 0.5 mm and a depth equaling twice the width or more, or an undercut > 0.5 mm and proportion of undercut < 50%

Many studies have described peri-implant marginal bone loss after use of implant-supported mandibular overdentures with several possible influencing factors such as guided bone regeneration (GBR), the presence of a dehiscence, and loading protocols.[3,9,28,29] Previous studies analyzing the same objects as the present study have suggested associations between marginal bone loss and smoking, attachment systems, plaque and bleeding index score, and probing depth.[30–32] However, studies scarcely provide any information about the association between peri-implant bone morphology and marginal bone loss. Thus, the main objective of the present study was to explore the association between marginal bone loss and the peri-implant bony defect types classified using the new classification system. Factors that may also influence marginal bone loss, such as gender, age of patient, smoking habit, attachment system, and time after implantation, were set as control variables in this study.

MATERIALS AND METHODS

Subjects

This study involved 110 edentulous patients with atrophic mandibles who were referred by their dentists to the Amphia Teaching Hospital in Breda during the period from 1991 to 1993. These patients had been edentulous in both jaws for 5 years or more and had been wearing conventional complete dentures, but resorption of the mandibular alveolar ridges had made the fitting of new dentures difficult. The patients were treated with overdentures on one-stage titanium plasma-sprayed ITI dental implants (Straumann Bonefit, AG). This research was approved by the ethics committee of the Ignatius Teaching Hospital, Breda. All patients were informed about the potential benefits and risks of the treatment and agreed to undergo any of the three treatment options used in this study. A total of 36 patients received implant overdentures on two implants with ball attachments (2IBA) and Dalla Bona matrices; another 37 patients received implant overdentures on two implants with a single egg-shaped Dolder bar (2ISB); and another 37 patients received implant overdentures on four implants with a triple bar (4ITB).

Study Design

The design of the Breda Implant Overdenture Study has previously been described in detail.[33,34] The overdentures were delivered 3 months after implant surgery and lingualized occlusion was achieved. Panoramic radiographs were obtained to monitor the condition of the jaws and the bone surrounding the implants. Subsequent follow-up was performed annually or every 2 years. Patients with less than two post-implant panoramic radiographs were excluded from the current study because marginal bone loss could not be calculated for such patients.

Clinical information, namely gender, age, smoking habit, attachment system, and time after implantation, was collected. Patients who did not smoke during the evaluation period were regarded as nonsmokers irrespective of their smoking history.

Radiographs

All panoramic radiographs were obtained using the same machine and only those without obvious distortion and blurring were included. The panoramic radiographs were scanned with a flatbed scanner (Mikrotek ScanMaker 9800XL; Mikrotek International) at a resolution of 118 pixels/cm (300 dpi) on an 8-bit gray scale. For ease of evaluation, the digitized images were cropped around the part of the mandible containing the implants and attachments. This procedure was carried out on a 15-inch monitor with a resolution of 1920*1200 pixels.

Evaluating Peri-implant Bony Defect Categories

To control interobserver variability, a single experienced observer (L.Z.) who was blinded to patient information evaluated all panoramic radiographs in a random order. All images were viewed in a darkened and quiet room.

Marginal Distance Calculation

Marginal distance was calculated as the distance between the marginal bone level and the top of the implant shoulder. Additional points were used to locate the top and apex of the implant, whereby the central axis of the implant was located (Fig 2). Then, the marginal bone level for each implant was evaluated both mesially and distally from the panoramic radiographs. Each marginal bone level point was projected orthogonally on the central axis, after which the distance from the projected point to the top of the implant shoulder was calculated in pixels and converted to millimeters using the known length of the implant body. The length of the implant neck that had a smooth surface, which was 2.8 mm, was included in the marginal distance calculated. To increase the precision of the indicated points, all images were examined four times and marginal distances were measured by the same observer (L.Z.).

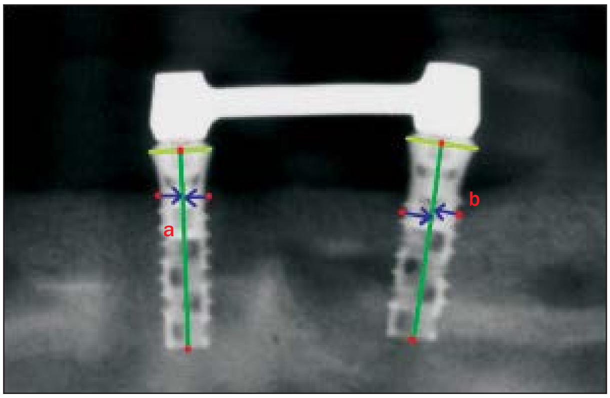

Fig 2 Marginal distance calculation. Two implants with a body of 12 mm and neck of 2.8 mm. *(a)* Implant body. *(b)* A peri-implant bone defect. Marginal bone levels, top, and apex of the implant are indicated by additional red points. Marginal bone levels are projected on the central axis of the implant (green line). The distance of the projected point to the top of the implant shoulder (yellow line) is calculated in mm using the known length of the implant body.

Statistical Analyses

Correlation data were analyzed using SAS Software Version EG5.1 (SAS Institute). Descriptive statistics were used to assess data related to marginal distances, peri-implant bony defects, and clinical information. Sequentially observed over time, the data were collected from observational experiments in which the response variables (marginal distance) pertained to reexamination records obtained at uncertain rediagnostic time points during research. Considering the time series data of the same implant and patient were not statistically independent, marginal generalized linear models, which can be used for regression analysis of dependent data in the form of multiple time series, were selected in this study. Marginal generalized linear models are an important class of regression models for correlated data that attempt to model the population average pattern of the data. These models only specify the first two moments of data distributions rather than the joint probability distribution of the data, and consequently the correlation is treated as a nuisance in the analysis.[35] Generalized method of moments and quadratic inference function (QIF) were used to estimate the marginal generalized linear models.

The marginal generalized linear models used in the present study are given as follows:

$$\text{MarginalDistance}_{i,j} = \alpha + \beta_1 \text{Type2}_{i,j} + \beta_2 \text{Type3}_{i,j} + \beta_3 \text{Type4}_{i,j} + \beta_4 \text{Type5}_{i,j} + \gamma_1 \text{Gender}_i + \gamma_2 \text{Smoking}_i + \gamma_3 \text{Treatment}_{2i} + \gamma_4 \text{Treatment}_{3i} + \gamma_5 \text{IdOfImplant}_{2i} + \gamma_6 \text{IdOfImplant}_{3i} + \gamma_7 \text{IdOfImplant}_{4i} + \gamma_8 \text{LocationOfImplant}_i + \gamma_9 \text{AgeOfImplant}_{i,j} + u_{i,j}, j = 1,2,\ldots, ni, i = 1,2,\ldots,83. \quad (I)$$

In the formula above, the response variable $\text{MarginalDistance}_{i,j}$, which is the proxy variable of the bone loss in patient i, was observed at the jth visit of patient i ($\text{AgeOfImplant}_{i,j}$); $\{_{ui,j}\}$ is a series of error items and has the correlation structure, while $\{_{ui,j}\}$ in common used linear models is independent or at least uncorrelated. The impacts of the following parameters were tested as control variables: gender, patient age, smoking habit, treatment strategy, and time after implantation. The level of statistical significance was set at $P < .05$.

RESULTS

Of the 110 patients included in the original study, 83 had radiographic evaluation adequate for inclusion in the present study. The age of the patients ranged from 34.7 to 80.9 years at the last examination (average, 61.5 years). The follow-up period ranged from 1 to 16 years and was more than 10 years in 59.0% of the patients (average, 10.7 years). Owing to blurring, large nonlinear distortion, or a metal necklace appearance, 8% of the panoramic radiographs were excluded. In the remaining 83 patients, 224 implants and 3,214 sites—including the mesial and distal sides of the implants on radiographs obtained in every follow-up—were included. Peri-implant bony defect types of 70 sites could not be determined because of blurring and obvious distortion; the corresponding data were deleted. One patient's smoking information was not obtained, which meant 20 more sites were excluded. Therefore, a total of 3,124 sites were included in the final sample.

Descriptive Statistics

Marginal Distance. The four marginal bone loss variables (MarginalDistance01, MarginalDistance02, MarginalDistance03, and MarginalDistance04) corresponded to the four times at which marginal distance was measured. These variables indicate changes in the marginal bone level.

The mean values of the marginal distance are listed according to peri-implant bony defect type in Table 1. If the length of the implant neck (2.8 mm) was excluded, the measurement results were similar to the data presented in earlier studies on implant-supported mandibular overdentures.[36–38] The results indicate that smallest marginal distance corresponds to Type 3 peri-implant bony defects, followed by Type 2 and Type 1. The marginal distance is the largest with Type 4. The marginal distance for Types 1 and 5 is similar, but it is unknown which is lower. This may suggest that Type 3 peri-implant bony defect is related to the least bone loss, followed by Types 2, 1, and 5, while Type 4 is related to the maximum bone loss.

Control Variables. The distribution of the control variables is summarized in Table 2. The frequencies of each index were significantly different, although these differences had little influence on the final result of marginal generalized linear model analysis.

Marginal Generalized Linear Model Analysis of Marginal Distance with Peri-implant Bony Defects. The results of the marginal generalized linear model analyses are shown in Table 3 with the significance levels of individual coefficients reported as two-tailed *P* values. Four models are reported, including four tests for marginal distance (two groups). Type 1 was the base type (benchmark group) of peri-implant bony defect, and its coefficient took the value 0. Similarly, 2IBA (Treatment 1) was the base type of treatment among the control variables.

Peri-implant Bony Defects and Marginal Distance. All peri-implant bony defect types except Type 5 were significantly related to the marginal distances in all models ($P < .01$). From the size and sign of the coefficient β, the result was as follows: in the marginal generalized linear model analyses, the smallest marginal distance was related to Type 3 peri-implant bony defect (followed by Types 2 and 1), the largest marginal distance corresponded to Type 4, and the association between Type 5 and marginal distance was not significant in any model. These results were consistent with the results of descriptive statistical analyses presented in Table 1.

Control Variables and Marginal Distance. According to the results shown in Table 3, the associations between the control variables and marginal distance can be described as follows:

- The association between gender and marginal distance was not significant in most models at the level of $P < .05$, but it was at $P < .10$. Female patients seem prone to a smaller marginal distance than male patients.
- Smoking significantly increased marginal distance at $P < .05$.
- As expected, the marginal distance was positively associated with the time after implant placement.

Table 1 Descriptive Statistics for Marginal Distance (n = 3,124)

Parameter		Group 1 (Marginal Distance 02/04)		Group 2 (Marginal Distance 01/03)	
Four tests for marginal distance		Test 2	Test 4	Test 1	Test 3
Type 1 (saucer shaped)	n Mean (mm)	1,337 4.157	1,337 4.183	1,337 4.152	1,337 4.159
Type 2 (wedge shaped)	n Mean (mm)	811 3.577	811 3.587	811 3.550	811 3.573
Type 3 (flat)	n Mean (mm)	553 3.282	553 3.326	553 3.274	553 3.304
Type 4 (undercut)	n Mean (mm)	275 4.434	275 4.489	275 4.389	275 4.508
Type 5 (slit like)	n Mean (mm)	148 4.200	148 4.198	148 4.040	148 4.109

Note: Intraobserver reliability of MarginalDistance01 and MarginalDistance03 was substantial (κ = 0.67), as was intraobserver reliability of MarginalDistance02 and MarginalDistance04 (k = 0.67). Four time tests of MarginalDistance can be distributed into two groups (Group 1 and Group 2). Each group includes two tests for marginal distance. The five dummy variables (Type 1, Type 2, Type 3, Type 4, and Type 5) corresponded to the five types of peri-implant bony defect, respectively. n = number of peri-implant sites.

- There was not adequate statistical evidence to support an association between marginal distance and treatment strategy.
- The association between patient age and marginal distance was not significant.

Examination of Result Robustness

To mitigate concerns that the working correlation structure in PROC GENMOD in SAS might bias the results, the sensitivity of the results was examined by selecting other common correlation structures. The regressions showed that the results of other correlation structures were adequately robust with the common correlation structures.

In order to ensure that the methods selected did not affect the results, the marginal generalized linear models were re-estimated by using another method, QIF. These results are also similar to those presented in Table 3 in terms of the sign and statistical significance of the test variables of interest.

To confirm the results regarding peri-implant bony defect types, another model was used in which the base type was undercut bony defects; ie, Type 4. The results were almost identical to those in Table 3 in terms of the sign and statistical significance of the variables of interest. The result tables of above robust tests were not listed.

Table 2 Distribution of Patient Features (Control Variables)

Variables	n	%
Gender		
Female	2,326	74.7
Male	798	25.3
Smoking habit		
Smoking	1,143	36.59
Nonsmoking	1,981	63.41
Treatment		
2IBA	571	18.28
2ISB	859	27.5
4ITB	1,694	54.23
Age (y)		
≤ 55	2,040	65.3
> 55	1,084	34.7

n = number of measurements; 2IBA = two implants with ball attachments;
2ISB = two implants with a single bar; 4ITB = four implants with a triple bar.

DISCUSSION

The present study demonstrated that the peri-implant bony defect type determined using a new classification system is associated with the extent of peri-implant marginal bone loss, measured on the panoramic radiographs of patients with implant-supported overdentures. Other associated factors identified were smoking habit and time after implant surgery. Although the results do not enable determination of causal relations between marginal bone loss and peri-implant bony defect types or other factors, the associations between them can be revealed to some extent. Since the length of the implant neck with a smooth surface was not excluded, the values of the marginal distances were definitely not equivalent to the extent of marginal bone loss. Considering the length of the implant neck was a constant, this measurement error had little influence on the study results.

Peri-implant inflammation is characterized by inflammation around the implant, including both plaque-induced progressive marginal bone loss and clinical signs of peri-implant soft tissue

Table 3 Marginal Generalized Linear Model Analysis of Bone Loss with Peri-implant Bony Defects

Parameter	Group 1 (MarginalDistance02/04)		Group 2 (MarginalDistance01/03)	
Four tests for marginal distance	Test 2	Test 4	Test 1	Test 3
Type 2 (wedge shaped)	−0.312*** (0.057)	−0.330*** (0.062)	−0.344*** (0.060)	−0.334*** (0.064)
Type 3 (flat)	−0.446*** (0.064)	−0.427*** (0.076)	−0.461*** (0.073)	−0.440*** (0.074)
Type 4 (undercut)	0.193** (0.090)	0.238*** (0.088)	0.155* (0.086)	0.266*** (0.084)
Type 5 (slit like)	0.107 (0.088)	0.067 (0.077)	−0.049 (0.085)	−0.012 (0.087)
Gender	0.233* (0.142)	0.279** (0.140)	0.275* (0.138)	0.231* (0.141)
Smoking	0.389** (0.158)	0.382** (0.154)	0.377** (0.154)	0.387** (0.156)
Treatment 2	0.167 (0.143)	0.246* (0.137)	0.180 (0.142)	0.159 (0.145)
Treatment 3	0.137 (0.168)	0.146 (0.163)	0.102 (0.165)	0.097 (0.172)
Age of patient (y)	0.119 (0.131)	0.102 (0.132)	0.109 (0.131)	0.154 (0.134)
Age of implant (	0.248*** (0.030)	0.245*** (0.030)	0.239*** (0.029)	0.235*** (0.029)
Intercept	2.786*** (0.160)	2.806*** (0.157)	2.816*** (0.156)	2.852*** (0.164)

Note: The quantities in parentheses below the coefficients are the standard errors. *Indicates statistical significance of asymptotic Z statistic at the 10% level; **Indicates statistical significance of asymptotic Z statistic at the 5% level; ***Indicates statistical significance of asymptotic Z statistic at the 1% level. Type 1 was the base type (benchmark group) of peri-implant bony defect and its coefficient took the value 0. Similarly, 2IBA (Treatment 1) was the base type of treatment among the control variables. Treatment 2 was 2ISB. Treatment 3 was 4ISB. If the coefficient was negative, MarginalDistance of the corresponding valuable was lower than that of the base type. Conversely, if the coefficient was positive, MarginalDistance of the corresponding value was higher than that of the base type. And the smaller the coefficient, the lower the MarginalDistance.

inflammation.[39,40] Plaque accumulation on the implant/abutment surface plays a fundamental role in the initiation and progression of peri-implant inflammation.[41–43] Moreover, peri-implant inflammation has been associated with Gram-negative anaerobic bacteria similar to those found around natural teeth in patients with severe chronic periodontitis.[42,43] Furthermore, angular bony defects have been reported to be associated with more periodontal bone loss than flat bony defects.[44] This indicates that vertical bone loss may increase the rate of bone loss over horizontal bone loss. Based on an experimental ligature model to induce peri-implant inflammation in dogs, there were experimental studies speculating that peri-implant bony defect was related to bacterial plaque accumulation and the spread of infection around the implant.[39,45] In the present study, Type 3 peri-implant bony defects, defined as flat or no pocket, were associated with the least bone loss. Type 3 is supposed to represent no bone loss or only horizontal bone loss and can be considered a healthy or relatively stable condition, indicating a low risk of bone loss. Types 1 (saucer shaped) and 2 (wedge shaped) defects showed more bone loss than Type 3. They are assumed to be associated with both horizontal and vertical bone pockets. In peri-implant inflammation, radiographic appearance of a bone defect was often in the shape of a saucer or crater,[21,22] which indicated that Type 1 defects may be related to more bone loss than Type 2. Type 4 peri-implant bony defects are undercut defects, and in such cases the inflammation can become progressive. This may be why they are associated with the maximum bone loss. Type 5 peri-implant bony defects, which are defined as slit-like defects, were reported to be the rarest among the five types.[27] In this study, Type 5 peri-implant bony defects were found to have a similar mean extent of bone loss to Type 1 and were associated with more bone loss than Type 3 and less bone loss than Type 4. However, it is uncertain whether this result is because of poor sampling or the lack of a difference in bone loss between Types 5 and 1 in practice. More samples are needed to obtain definite results regarding Type 5 peri-implant bony defects. The associations described above can be applied to the assessment of marginal bone loss risk and determination of prognosis. Early detection and characterization of marginal bone loss may be useful for properly timing the treatment for peri-implant inflammation and, if necessary, for deciding on the appropriate regenerative strategies.

The present study found that gender was not significantly related to marginal bone loss at a level of $P <$ .05. This finding is consistent with those of earlier studies, which reported similar extents of marginal bone loss between men and women.[11,46] However, at $P <$ .10, female patients seemed to be less prone to peri-implant bone loss than male patients; this finding may be related to differences in hormones and oral hygiene habits. For instance, it has been reported that compared to men, women use a toothbrush significantly more often and pay more attention to oral hygiene.[47]

As shown by the results, patient age seems to have little influence on marginal bone loss. Meijer et al[48] carried out a 3-year prospective study to determine the influence of age on peri-implant tissues in edentulous patients treated with mandibular implant-supported overdentures and also found no significant differences between the younger and the older groups. Most authors agree that patient age does not seem to be an important factor affecting peri-implant bone loss.[11,49] However, studies have also reported contradictory results; that is, that the marginal bone loss was higher in older patients, possibly because of lower bone vascularity and healing potential in these individuals.[50]

Time-dependent peri-implant bone loss after implant placement has been described in many studies.[2,3,51] By subtraction analysis of panoramic radiographs, Geraets et al[14] described gradual bone loss over 15 years after surgery. Just as shown by the results, after implant placement, marginal bone loss increases significantly over time.

The present results showed that smoking significantly increases the risk of peri-implant marginal bone loss. In agreement with these findings, Stoker et al[31] reported that smoking almost doubled marginal bone loss irrespective of the treatment strategy chosen, using almost the same data as the present study. Other authors[3,52] have also demonstrated a positive association between smoking and peri-implant bone loss in patients with mandibular implant-supported overdentures and consider smoking an important risk factor for bone loss.

According to previous research, the design of the overdenture attachment system may influence stress/strain magnitudes around implants.[53,54] Stoker et al[31] analyzed the same data as the present study and reported that the marginal bone loss in the 4ITB group was significantly higher than that in the two implant groups. However, several studies have found that different types of implant superstructures, such as bar, ball, and magnet attachments, are associated with marginal bone loss[28,55,56] to a similar extent as was found in the present study. The biomechanical behaviors of implants with different overdenture attachment systems were different, but there was not adequate statistical evidence to support an association between marginal bone loss and overdenture attachment system. The underlying reason may be attributed to the good primary and secondary implant stability provided by the dense bone present in the mandible.

In essence, these longitudinal data may be regarded as a collection of time series data for each patient. Considering the time series data of each patient were not statistically independent, marginal generalized linear models, which can be used for regression analysis of dependent data in the form of multiple time series, were selected in this study. Marginal generalized linear models are useful for conducting regression analysis of longitudinal data in the form of multiple short time series, where the serial correlation is treated as a nuisance. They arise from the formulation of quasi-likelihood modeling approach.

The present study has some limitations that need to be addressed. Measurements on panoramic radiographs are less consistent and reliable than those on intraoral periapical radiographs taken using the long-cone parallel technique, which has less image enlargement or distortion and better accuracy for peri-implant bone level measurements.[11,57] Nonetheless, panoramic radiographs have better patient acceptance than intraoral devices.[27] The present study showed that they offer valuable diagnostic information on trends in marginal bone loss. Secondly, some important parameters associated with crestal bone loss are not included in the data, such as level of plaque accumulation and mucosal inflammation, frequency and content of maintenance care during the follow-up period, width of keratinized tissue, systemic conditions, and so on. The main objective of this study was to explore the association between marginal bone loss and peri-implant bony defect types rather than exploring the causes of marginal bone loss. Factors mentioned above that are associated with crestal bone loss may have a comprehensive effect on peri-implant bony defect types as well. In the future, long-term studies can be carried out to examine the influence of these factors on marginal bone loss.

The results of this study, which examined the effect of peri-implant bony defect type and other influencing factors on marginal bone loss, may aid in the evaluation of the risk of marginal bone loss of implants in patients with implant-supported mandibular overdentures. From a clinical standpoint, these results could be beneficial to evaluate the status of marginal bone loss to some degree.

CONCLUSIONS

In patients with mandibular implant-supported overdentures, the peri-implant bony defect type determined using the new classification system is associated with the extent of marginal bone loss. Type 3 peri-implant bony defects (flat or no pocket) are associated with the minimum bone loss, followed by Type 2 (wedge shaped) and Type 1 (saucer shaped) while Type 4 peri-implant bony defects (undercut) are associated with the maximum marginal bone loss. Type 5 peri-implant bony defects (slit like) show bone loss similar to Type 1.

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