The Effect of Vertical Implant Position in Relation to Adjacent Teeth on Marginal Bone Loss in Posterior Arches: A Retrospective Study

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Purpose: The aim of this retrospective study was to investigate the possible association between peri-implant marginal bone loss and the apico-coronal (vertical) positioning of dental implants placed adjacent to a tooth.

Materials and Methods: Dental records at the University of Michigan, School of Dentistry, were screened. To be included in the study, the patient had to have at least one implant in the premolar or molar region, unilaterally or bilaterally, in either arch, with an immediately mesial adjacent tooth. The implant had to have been functioningally loaded for at least 3 years after crown insertion, and clear, nondistorted periapical films had to be available. Several landmarks were identified: the cementoenamel junction (CEJ) and crestal bone (CB) of the tooth adjacent to the implant, the implant platform (PL), and the first radiographic implant-bone contact (BL). The following parameters were measured: CEJ-PL, CEJ-CB, CB-PL, horizontal distance between the adjacent tooth and PL (HD), and vertical distance between BL and the first implant thread at the mesial (BL-m) and distal (BL-d) implant surfaces.

Results: A total of 139 patients with a mean age of 62.1 ± 9.3 years were included. The mean follow-up period was 4.42 ± 2.5 years. When the implant was placed more than 3 mm apical to the CEJ of the adjacent tooth, significantly greater peri-implant bone loss occurred at the mesial (difference of means = 0.57 mm) and distal (difference of means = 0.83 mm) implant surfaces.

Conclusion: In this study population, implants placed in the posterior area with a vertical distance greater than 3 mm from the CEJ of the adjacent tooth displayed more peri-implant bone loss. Further investigation is required to determine whether this increased peri-implant bone loss predisposes a site to peri-implantitis.

Key words: alveolar bone loss, dental implants, peri-implantitis, retrospective study

Marginal bone loss around implants may be categorized as early or late.1,2 In both single-stage and two-stage implant placement surgeries, early bone remodeling begins immediately after connection of the healing abutment3 and may continue through the first year of function. Possible causes of this phenomenon include surgical trauma, occlusal overload, peri-implantitis, the microgap between the implant and abutment, biologic width re-formation, and design of the implant crest module.1 Crestal bone was found to remodel to the first implant thread, or 1.5 to 2.0 mm apical to the implant-abutment junction, to create space for the biologic soft tissue seal.4,5 This initial peri-implant bone remodeling has been widely discussed. Some termed it a physiologic process,6 whereas others attributed it to a foreign-body reaction or implant adaptation.7,8 Late implant bone loss, on the other hand, is often referred to as peri-implantitis. It generally occurs after 1 year of loading and is primarily caused by bacteria or residual cement.9–12 Both early and late implant bone loss can compromise the function and esthetics of dental implants; therefore, it is important to identify and control the factors that contribute to bone loss.

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Fig 1 Diagram of the selected reference points. The CEJ and crestal bone (CB) of the tooth adjacent to the implant, the implant platform (PL), and the first radiographic implant-bone contact (BL) were identified. HD represents the horizontal distance between the adjacent tooth and PL, and BL-m-1TD and BL-d-1TD represent the vertical distance between BL and the first implant thread at the mesial (BL-m) and distal (BL-d) implant surfaces, respectively, at the most recent follow-up appointment.

The position of the dental implant in relation to adjacent teeth and the alveolar crest has been correlated with peri-implant marginal bone loss. It was reported that both vertical and horizontal differences in implant positions might influence the interimplant marginal bone level. A lower proximal bone crest was also observed between implant units when implants were placed at different apicocoronal levels. In addition, a loss of interimplant bone was reported when adjacent implants were ≤ 3 mm apart.

In general, implants are placed 3 to 4 mm apical to the restorative cementoenamel junction (CEJ). However, when there is a loss of ridge height, or if bone levels are uneven, implants may be placed in different apicocoronal positions. This is evident when implants are placed adjacent to a tooth. Because of postextraction ridge remodeling, the distal bone crest of the tooth is generally higher than the rest of the ridge. As such, the mesial surface of the implant has to be placed deeper than the distal surface, which is equicrestal. It is not clear whether these implants experience a greater amount of marginal bone loss after functional loading. Therefore, the aim of this retrospective study was to investigate the possible influence of the vertical positioning of implants in relation to the CEJ of adjacent teeth on peri-implant marginal bone loss.

MATERIALS AND METHODS

Patient Sample
This retrospective study was approved by the institutional review board of the University of Michigan (HUM00072390). All dental records and intraoral radiographs from the implant patient database at the University of Michigan School of Dentistry were screened by three examiners (JM, VK, JL). Patients selected for this study had at least one implant placed in a healed maxillary or mandibular posterior site. The implants were placed distal to the most posterior tooth, and a delayed loading approach was adopted. They were restored with fixed prostheses and had been functionally loaded for at least 3 years. Implants with an internal or external connection, one or two components, and a rough or smooth collar were included in this study. In addition, implants placed crestally, supracrestally, or subcrestally were also included. Radiographs of the implant and surrounding bone at implant placement and the most recent follow-up appointment had to be sharp and undistorted. Implants that were placed immediately after extraction or immediately loaded, implants without follow-up radiographs, and implants with unclear and/or distorted radiographs were excluded.

Measurements
The periapical radiographs taken immediately after implant placement and at the most recent follow-up visit were digitized at a resolution of 600 dpi. The digital images were evaluated using an open source software package (ImageJ, U.S. National Institutes of Health) on a 15-inch laptop with NVIDIA GeForce FX Go5200 graphics cards. The images were magnified and viewed in full-screen mode for better visualization. Known implant lengths were used to calibrate all measurements. A built-in digital caliper in the software was used for all measurements. Pixel values of a given linear measurement were converted to an international system to obtain all measurements in millimeters.

Several landmarks were identified: the CEJ and crestal bone (CB) of the tooth adjacent to the implant, the implant platform (PL), and the first radiographic implant-bone contact (BL-m on the mesial surface and BL-d on the distal surfaces). The following parameters were measured: CEJ-PL, CEJ-CB, CB-PL, horizontal distance between the adjacent tooth and PL (HD), and the vertical distance between BL and the first implant thread on the mesial (BLm-1TD) and distal (BLd-1TD) implant surfaces (Fig 1). All parameters, except for BL-m and BL-d, were measured immediately after implant placement. BL-m and BL-d (and thus BLm-1TD and BLd-1TD) were measured off the radiographs taken at the most recent follow-up appointment.
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Fig 2 The differences in BL-m and BL-d between implants placed in the mandible and the maxilla. There were no significant differences (mean BL-m difference = 0.21 mm, \( P = .47 \); mean BL-d difference = 0.08 mm, \( P = .77 \)) between implants placed in the mandible and the maxilla.

A single calibrated examiner (JM) performed all radiographic measurements. Intraexaminer reliability was evaluated by measuring the radiographs on two separate occasions 5 days apart. The intraexaminer reliability obtained had a kappa value of 95%, as the differences in linear measurements were within 0.5 mm.

Statistical Analysis
To determine the effect of vertical implant position on marginal bone level, the data were categorized into two groups: CEJ-PL ≤ 3 mm and CEJ-PL > 3 mm. A two-tailed independent Student t test with alpha value of .05 was used to evaluate the difference in mean marginal bone level between the two groups. All statistical analyses were performed with a software program (SPSS Statistics for Windows, Version 21.0, IBM). The results were presented as mean values ± standard deviations.

RESULTS
A total of 139 rough-surface implants that fulfilled the inclusion criteria were inserted into 139 patients at the Department of Periodontics and Oral Medicine, University of Michigan, between June 2002 and April 2012. The patient population consisted of 75 women (53.9%) and 64 men (46.1%) with a mean age of 62.1 ± 9.3 years. Within this population, 24.5% were smokers and 10.8% had diabetes mellitus. Simultaneous bone augmentation with implant placement was performed in 19.4% of patients.

The majority of the implants were placed in the mandible (66.9%), and 33.1% were placed in the maxilla. All implants were placed in healed sites without immediate loading and restored with fixed dental prostheses. Eight different implant systems were used (Table 1). The mean follow-up period since loading was 4.42 ± 2.5 years. At baseline, the mean CEJ-PL was 4.13 ± 2.27 mm, mean CEJ-CB was 2.63 ± 1.32 mm, mean CB-PL was 1.54 ± 1.75 mm, and mean HD was 3.04 ± 1.18 mm. The positive CB-PL value indicated that most implants had been placed apical to the bone crest. The latest follow-up radiographs showed that 31 implants had bone levels apical to the first thread at the mesial surface; likewise, 34 implants had the bone levels apical to the first thread at the distal surface. The mean BL-m and BL-d were –0.73 ± 1.59 mm and –0.46 ± 1.51 mm, respectively, indicating that the first point of bone contact was coronal to the first implant thread.

There were no significant differences in BL-m (mean difference = 0.21 mm; \( P = .47 \)) and BL-d (mean difference = 0.08 mm; \( P = .77 \)) between implants placed in the mandible and maxilla (Fig 2). Patients with a vertical implant distance (CEJ-PL) greater than 3 mm had significantly more mesial (0.57 mm, \( P = .044 \)) and distal (0.83 mm, \( P = .002 \)) peri-implant bone loss.

Table 1 Distribution of the Implant Systems Used

<table>
<thead>
<tr>
<th>Implant type</th>
<th>Manufacturer</th>
<th>No.</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brånemark</td>
<td>Nobel Biocare</td>
<td>36</td>
<td>25.9</td>
</tr>
<tr>
<td>Straumann</td>
<td>Institut Straumann</td>
<td>33</td>
<td>23.7</td>
</tr>
<tr>
<td>Zimmer</td>
<td>Zimmer Dental</td>
<td>12</td>
<td>8.6</td>
</tr>
<tr>
<td>Nobel Replace Select</td>
<td>Nobel Biocare</td>
<td>45</td>
<td>32.4</td>
</tr>
<tr>
<td>BioHorizons</td>
<td>BioHorizons</td>
<td>3</td>
<td>2.2</td>
</tr>
<tr>
<td>Nobel Speedy</td>
<td>Nobel Biocare</td>
<td>6</td>
<td>4.3</td>
</tr>
<tr>
<td>3i</td>
<td>Biomet/3i</td>
<td>2</td>
<td>1.4</td>
</tr>
<tr>
<td>Astra Tech</td>
<td>Astra Tech</td>
<td>2</td>
<td>1.4</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>100</td>
<td></td>
</tr>
</tbody>
</table>

Fig 3 Peri-implant bone loss on patients with CEJ-PL > 3 mm.

Patients with vertical implant distance (CEJ-PL) greater than 3 mm had significantly more mesial (0.57 mm, \( P = .044 \)) and distal (0.83 mm, \( P = .002 \)) peri-implant bone loss.
DISCUSSION

The present study evaluated interproximal marginal bone loss around implants placed in the posterior regions. The incidence of marginal bone loss beyond the first thread was 28.8% in this cohort. This is in accordance with the reported prevalence of peri-implantitis (reported incidence, 3.7% to 28.7%). In that study by Roos-Jansaker et al, the first implant thread was used as the reference level, whereby bone loss beyond the first thread was taken as peri-implantitis.21 In the current study, clinical measurements were not taken; therefore, any implants with bone loss beyond physiologic bone remodeling could not be diagnosed with peri-implantitis.

Several factors might further influence crestal bone level in relation to the adjacent CEJ and depth of placement, including the use of an external- or internal-connection implant design, a one- or two-piece implant, a machined or roughened implant collar, and subcrestal implant placement. In an animal study, Huang et al22 attempted to assess the influence of the depth of placement of tapered internal-connection implants on bone remodeling. Their findings demonstrated that, on average, the distance between the implant-abutment interface and the first bone-implant contact in subcrestally placed implants was significantly smaller than for the implants placed at the crest in posterior areas. The authors explained that this result might be caused by the sealing ability of the tapered internal connection, which minimizes bacterial penetration at the implant-abutment interface.22

Furthermore, one- and two-piece implants were shown to distribute the peaks of bone stresses differently. A one-component implant was shown to have the highest peak bone stresses at the level of the most coronal thread, whereas the two-component implant had the highest peak bone stresses at the levels of the fifth to ninth threads from the coronal end of the implant. Increased implant wall thickness and modulus of elasticity in two-component implants led to increased bone stresses at the coronal thread.23 In addition, implants with a conical and roughened neck were also reported to be able to maintain marginal bone level around implants above the first thread after 4 years of loading.24

The results of this retrospective study revealed corresponding relationships for bone changes at the proximal area between the implant and the neighboring tooth. The data demonstrated that a posterior implant that was placed more than 3 mm (vertically) from the CEJ of the adjacent tooth showed more mesial and distal peri-implant bone loss. This finding concurs with a recent clinical trial, in which the authors reported more mean bone loss at implant-facing surfaces than at tooth-facing surfaces.25 More recently, a clinical trial15 evaluating 28 patients with 35 fixed partial prostheses also showed that implants positioned 6 mm apical to the CEJ of the adjacent tooth showed mean marginal bone loss of 0.5 mm on the implant side during the 3-year follow-up period. However, multiple regression analysis failed to reveal a statistically significant influence of vertical implant-tooth distances.15

Significant amounts of crestal bone loss have also been reported to occur around implants that were placed in more apical positions.26,27 One study27 demonstrated that the first bone-to-implant contact was positioned more apically in implants inserted below the crestal bone level compared to implants placed at the crestal bone level. However, the authors reported that the apical positioning of the implants did not influence bone loss.27 In contrast with this report, a more recent study28 showed that crestal bone resorption (0.5 to 1.5 mm) was present around equicrestal implants, whereas in subcrestally placed implants, preexisting and newly formed bone was found coronal to the implant shoulder. Therefore, it could not be neglected that the different levels of implant placement might have affected the results in the present investigation.

Another factor that might influence marginal bone resorption is the height of the supported prosthesis. A recent systematic review evaluating the influence of crown-implant ratio on marginal bone loss around dental implants showed a significant association between crown-implant ratio and peri-implant marginal bone loss, suggesting that a higher crown-implant ratio may provide a protective effect on peri-implant marginal bone, leading to less peri-implant marginal bone loss.29 Nonetheless, excessive occlusal forces have been demonstrated to cause higher remodeling activity in the peri-implant bone,30 and this may be prevented by placing implants in ideal prosthetic positions as well as by controlling parafunctional habits prior to implant treatment.31 This may in turn prevent peri-implant marginal bone loss. Moreover, it is essential to fabricate a definitive prosthesis with light occlusal contacts, minimal lateral forces, and an ability to distribute the occlusal load to the adjacent natural teeth.31 Naert et al32 failed to find an association between occlusal overload and peri-implant marginal bone loss, but they did indicate that supraocclusal loading worsened plaque-induced bone loss when peri-implant inflammation was present.

A recent prospective study16 reported results that were incongruous with the current outcomes. The authors showed stable proximal bone levels at tooth/implant units after 3 years. It is difficult to compare these two studies because the reference points for the measurements were different. In the prospective study,16 vertical bone resorption was measured from
the implant/abutment connection level to the most coronal bone level in the proximal area. On the other hand, the current study recorded hard tissue resorption as the vertical distance between the first implant thread and the first implant-bone contact. In addition, all patients in the prospective study were instructed to use interproximal brushes for daily cleaning, which might have contributed to maintenance of the interproximal bone.16

Cigarette smoking has also been associated with significantly greater marginal bone loss33 and an increased risk of postoperative infection, implant loss, peri-implant mucositis, and peri-implantitis.34 Moreover, former smokers continue to experience more peri-implant marginal bone loss than nonsmokers.35 However, in this study, smokers did not appear to experience an increased amount of marginal bone loss. This could be attributed to the enrollment of these patients in a regular periodontal maintenance program, which might have attenuated the effect of smoking on bone loss.36 In addition, a review of existing records might not have fully reflected the actual smoking habits of this cohort.

There were several inherent limitations in this study: (1) radiographs were not standardized; (2) clinical data that might confound the results, eg, oral hygiene status and periodontal status, were not collected; and (3) bone loss was assessed at different time points. Future studies could be designed to overcome these inherent limitations.

CONCLUSION

Within the limitation of this study, the results demonstrated that implants placed in the posterior area at a vertical distance greater than 3 mm from the cementoenamel junction of the adjacent tooth showed more peri-implant bone loss than those placed at less than 3 mm from the cementoenamel junction.

ACKNOWLEDGMENTS

The authors would like to thank Corey Powell, Department of Statistics, University of Michigan, for assistance with statistics, and the American Academy of Implant Dentistry Foundation, Chicago, Illinois, for supporting the study with a grant. The authors express their gratitude to Emily Richardson and Lori Jackson, Department of Periodontics & Oral Medicine, University of Michigan, for their help in obtaining patient charts. The authors would also like to thank Andrea Cranston, study coordinator, for her assistance. The authors do not have any financial interests, either directly or indirectly, in the products or information listed in the paper.

REFERENCES


