# Radiologic Study of Marginal Bone Loss Around 108 Dental Implants and Its Relationship to Smoking, Implant Location, and Morphology

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***Purpose:*** *To investigate peri-implant bone resorption around 108 ITI dental implants 1 year after prosthetic loading using extraoral panoramic, conventional intraoral periapical, and digital radiologic techniques.* ***Materials and Methods:*** *A total of 108 implants were placed (59 in the maxilla and 49 in the mandible) in 42 patients (16 men and 26 women) with a mean age of 44.2 years (range 14 to 68 years). Orthopantomographic, conventional periapical, and digital radiographs were obtained at loading and again 1 year later. Bone loss was calculated from the difference between the initial and final measurements.* ***Results:*** *Mean loss in alveolar bone height was determined to be 1.36 mm by extraoral panoramic radiography, 0.76 mm by intraoral periapical radiography, and 0.95 mm by digital radiography. The implants located in the maxilla and those placed in patients who smoked 11 to 20 cigarettes per day were associated with significantly greater bone loss.* ***Discussion:*** *The results in relation to peri-implant bone loss in the first year after loading were similar to those published by other authors.* ***Conclusion:*** *Conventional periapical films and digital radiographs were more accurate than orthopantomography in the assessment of peri-implant bone loss. Smoking and implant location in the maxilla were associated with increased peri-implant marginal bone resorption.* INT J ORAL MAXILLOFAC IMPLANTS 2004;19:861–867

**Key words:** *dental implants, dental radiography, digital dental radiography, panoramic radiography, peri-implant bone loss, smoking*

Two periods have been defined within the normal parameters of peri-implant bone loss: *(1)* a healing and remodeling period beginning at prosthesis delivery and lasting about 1 year, during which bone losses of 0.4 to 1.6 mm may be recorded, and *(2)* a follow-up period after the first year, in which marginal losses of 0.05 to 0.15 mm per year can be observed.[1–6] Different studies[2,3,5] have failed to clarify which radiologic technique (conventional periapical, digital periapical, or extraoral panoramic radiography) is best suited for quantifying peri-implant bone loss. Peri-implant bone loss has been related to factors such as patient age at the time of implantation, smoking, implant location, and morphology.[7,8]

The present study investigated peri-implant marginal bone loss in the first year after loading, using extraoral panoramic and conventional and digital intraoral periapical radiography to quantify bone loss to determine which technique was most reliable. In addition, parameters believed to influence peri-implant marginal resorption in the first year after prosthetic loading were assessed.

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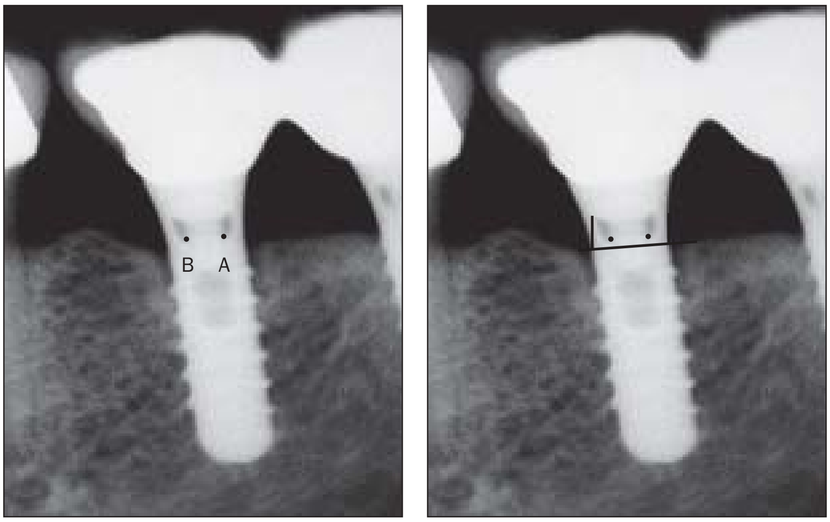


**Fig 1a** Location of points A (mesial) and B (distal).

**Fig 1b** Reference axis and mesial and distal measurement.

## MATERIALS AND METHODS

### Patients and Implants

The study included patients with single or partial tooth loss in the maxilla or mandible who were treated with solid, threaded, sandblasted, large grit, acid-etched ITI implants (Institut Straumann, Waldenburg, Switzerland).

Of the 108 implants studied, 59 were located in the maxilla and 49 in the mandible (4 additional implants initially considered for the study were later excluded because they failed during the osseointegration period, 2 because of apical peri-implantitis and 2 as a result of loss of osseointegration). Ninety-four implants were located in the posterior region (premolar and molar regions) versus 14 in the anterior region (incisor and canine regions). Eighty implants supported a single crown. Of the remaining 28, 22 supported restorations consisting of 3 crowns supported by 2 implants, and 6 supported fixed prostheses comprising 4 crowns supported by 3 implants.

The 108 implants were placed in 42 patients (16 males and 26 females) with a mean age of 44.2 years (range 14 to 68 years). Thirty-five implants were placed in patients 40 years old or younger, 62 in patients from 41 to 55 years old, and 11 in patients over the age of 55. Sixty-one implants were placed in nonsmokers versus 47 implants in smokers. In the latter group, 5 patients (with 18 implants) smoked 1 to 10 cigarettes/day (group 1), 7 (with 18 implants) smoked 11 to 20 cigarettes/day (group 2), and 4 (with 11 implants) smoked more than 20 cigarettes/day (group 3).

The implants were restored with single ceramometal crowns or cemented ceramometal fixed prostheses. The implants were placed from 1996 to 1998 by the same surgeon, and the prostheses were fabricated and placed by the same prosthodontists. Implant length was > 12 mm in 75 cases, 12 mm in 26 cases, and < 12 mm in 7 cases. Twelve implants measured 4.8 mm in diameter, 91 were 4.1 mm in diameter, and 5 were 3.3 mm in diameter.

To be included in the study, implants had to demonstrate primary stability after placement and could not have any exposed threads after placement or immersion of the polished neck within bone. Patients in whom bone regeneration techniques were carried out were not included in the study.

### Radiologic Data

In all cases, peri-implant bone loss was measured on conventional periapical, digital periapical, and extraoral panoramic radiographs at the time of prosthetic loading and after 1 year. The bone loss was calculated from the difference between the first and final measurements. The measurements were carried out as follows:

1. Two reference points were established within the implant head, 1 mesial *(A)* and 1 distal *(B)*. These points coincided with the vertex of the angle formed by the internal wall of the polished implant cone and the internal threading (Fig 1a). These points were chosen because they were permanently visible and easy to locate on all radiographs.[9]
2. A straight line was established between the 2 reference points; this represented the baseline height (Fig 1b). To determine bone loss, mesial and distal perpendicular lines were created, running from the line that represented baseline height to the most coronal point of bone contact. If the contact point was coronal to the reference axis the resulting value was positive; if it was apical, the value was negative.

3. After obtaining the 2 measurements, bone loss was calculated by subtraction. Both mesial bone loss and distal bone loss were determined; the larger of the 2 values was considered the bone loss for the implant in question.

The extraoral panoramic radiographs were obtained using orthopantomography (Panelipse II; Gendex Dental Systems, Des Plaines, IL); a magnification factor of 20% was taken into account when calculating bone loss.

Both the conventional and digital periapical radiographs were obtained with a retroalveolar radiology unit (Novelix 708 CCX; Trophy, Marne-la-Vallée, France) using the parallelization method with a Rinn XCP ring positioner (Dentsply, Constanz, Germany), allowing parallelization between the x-ray tube and film. This system consists of a plastic ring upon which the x-ray tube is supported at the time of imaging. The ring is joined by a stem to the x-ray film support and equipped with an indentation to allow the patient to bite and keep the system stable.[10]

The digital radiographs were obtained using a radiovisiographic system (Digora, Gendex Dental Systems) with software to allow precise measurements on the computer screen (0.1-mm intervals) after image scanning.[10]

### Statistical Analyses

A descriptive analysis was made for each variable. To determine intraobserver error, bone loss around 30 implants was measured using all 3 radiologic techniques. Each measurement was performed twice on consecutive days. An estimate of the intraobserver standard deviation (SD) was then determined using the following mathematical formula, where *d* is the difference between the 2 measurements and *n* is the number of measurements made (n = 30).

$$\text{Error} = \sqrt{\frac{(\Sigma^{d})^2}{2n}}$$

Repeated-measures analysis of variance (ANOVA) was performed to establish possible significant differences between the measurements obtained with each technique. The associations between the different quantitative variables were in turn assessed with the Student *t* test for independent samples. The ANOVA factor was used when comparing more than 2 groups, with verification in each case of variance homogeneity and determination of the corresponding *P* value. Given that 2 or more implants may come from the same patient, and that consequently measures could be statistically dependent, intraclass correlation coefficients (ICCs) were calculated. If the ICC indicated a lack of independence, corrections were used to ensure accurate statistical testing.[11] Finally, linear and curvilinear regressions were calculated.

## RESULTS

### Study of Error

Two possible sources of error were identified in the present study. Since all measurements were made by the same investigator, the determination of intraobserver error was particularly important. The other source was, of course, error associated with the technique. This was evaluated to determine whether the different radiologic techniques afforded a reliable assessment of the true situation.

With respect to intraobserver error, the estimate of the within-observer SD was applied to all 3 radiologic techniques, since it was anticipated that different errors could be generated according to the radiograph technique employed. Intraobserver error was greatest in the measurement of orthopantomographs (0.25 mm), followed by conventional periapical radiographs (0.15 mm) and digital periapical radiographs (0.11 mm).

To determine the error associated with the different radiologic techniques, the diameter of an implant measured with the 3 methods was compared with the known diameter of the implant as provided by the manufacturer.

A 4.1-mm-wide implant body (Fig 2) had a diameter (excluding the threads) of 3.5 mm. Thirty dental implants of the same diameter were measured using the 3 different radiologic techniques (Table 1). Two different measures of error were used. First, bias was calculated as the mean error produced by the technique. The amount of bias was the difference between the mean and the true diameter (3.5 mm). Second, the median absolute deviation (MAD) from the true diameter, a measure of variability of error, was calculated. With respect to bias, orthopantomography yielded the mean value furthest from the true diameter of the implant (3.783 mm), while the values recorded by the conventional and digital periapical radiographic techniques (3.503 and 3.501, respectively), were very close to the true diameter. With respect to variability, the orthopantomography had a mean MAD of 0.54 with respect to the true value, while both conventional and digital radiography were fairly consistent (0.02 and 0.01, respectively).

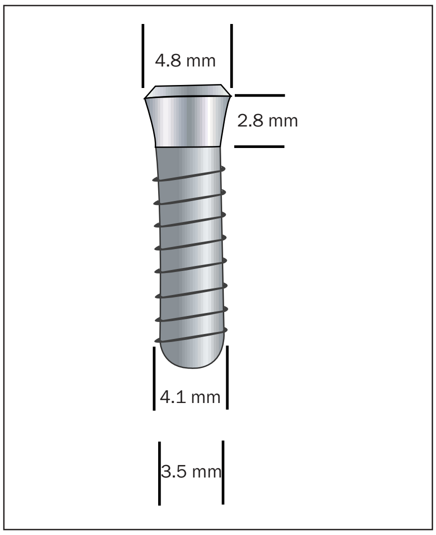


Fig 2 ITI implant measuring 4.1 mm in diameter.

**Table 1 Implant Diameter as Measured by the 3 Radiologic Techniques Used**

| Radiologic technique | Mean* (mm) | Variability | Maximum (mm) | Minimum (mm) |
|---|---|---|---|---|
| Orthopantomography | 3.783 | 0.541 | 4.40 | 2.75 |
| Conventional radiography | 3.508 | 0.028 | 3.60 | 3.40 |
| Digital radiography | 3.501 | 0.015 | 3.55 | 3.45 |

*A measure of bias is the difference between the means and 3.5.

To determine the possible existence of differences between the results obtained, the data were subjected to repeated-measures ANOVA. Both bias and variability were used as dependent variables. This inferential technique required compliance with theoretical assumptions regarding independence, variance homogeneity, and normality of the habitual scores. Before evaluating the results of the analysis, the so-called sphericity assumption had to be verified. This assumption was not tenable in this study; thus correction factors were used. An ANOVA on bias found a statistically significant difference between the techniques ($F_{1.01, 29.32} = 6.986$ and $P = .013$). Since significant differences were found between the means, paired a posteriori comparison tests were performed, and the results revealed significant differences between the measurements made with orthopantomography and both conventional and digital periapical radiography. No significant differences were observed between the conventional and digital periapical techniques ($P > .99$). The results afforded by the alternative nonparametric test (Friedman test) corroborated the differences found between the means for the 3 radiologic techniques ($P = .008$). An ANOVA on variability also found statistically significant differences between the techniques ($F_{1.02, 29.83} = 80.457$ and $P = .013$). Since significant differences were found between the means, paired a posteriori comparison tests were performed on variability, and the results again revealed significant differences between the measurements made with orthopantomography and those made with conventional and digital periapical radiography. No significant differences were observed between the conventional and digital periapical techniques. The results afforded by the alternative nonparametric test (Friedman test) corroborated the differences found between the means for the 3 radiologic techniques ($P < .001$).

## Bone Loss

Bone loss was measured on the mesial and distal side of each implant. The larger of the 2 measurements was considered the peri-implant bone loss for the implant. Average peri-implant bone loss was 1.36 mm as measured on the orthopantomograms, 0.76 mm as measured on the conventional periapical radiographs, and 0.95 mm as measured on the digital periapical radiographs (Table 2). The differences proved statistically significant between orthopantomography and the conventional ($P < .001$) and digital periapical radiographs ($P = .001$), as well as between the conventional and digital periapical imaging techniques ($P = .025$).

None of the radiologic techniques found peri-implant bone loss to be related to patient age, sex, position in the anterior or posterior region, or implant length or diameter (Table 3). No significant association (either linear or curvilinear) was found between bone loss and smoking when orthopantomography was used (Table 4). A positive linear association between bone loss and smoking was found when periapical radiographs were used. When digital radiographs were used, the pattern of association was significant but quadratic; the greatest bone loss corresponded to group 2 (Table 4). In relation to implant location, bone loss as determined by the conventional and digital periapical radiographs was greater in the maxilla than in the mandible (Table 5).

**Table 2 Mean Peri-implant Bone Loss with the 3 Radiologic Techniques**

| Radiologic technique | Mesial | Distal | Average |
|---|---|---|---|
| Orthopantomography | 1.12 | 1.06 | 1.36 |
| Conventional periapical radiography | 0.64 | 0.69 | 0.76 |
| Digital periapical radiography | 0.79 | 0.79 | 0.95 |

**Table 3 Factors in Relation to Peri-implant Bone Loss**

| Radiologic technique | *t* test | | ANOVA | | |
|---|---|---|---|---|---|
| | Sex | Position* | Age | Length | Diameter |
| Orthopantomography | 0.264 | 0.341 | 0.502 | 0.864 | 0.695 |
| Conventional periapical radiography | 0.584 | 0.399 | 0.708 | 0.520 | 0.807 |
| Digital periapical radiography | 0.634 | 0.581 | 0.325 | 0.709 | 0.950 |

**Table 4 Lineal and Curvilinear Regressions Between Bone Loss and Smoking with the 3 Radiologic Techniques**

| Radiologic technique/group | Mean (mm) | Linear | Quadratic |
|---|---|---|---|
| Orthopantomography | | | |
| 1 | 1.077 | | |
| 2 | 1.938 | $P > .05$ | $P > .05$ |
| 3 | 1.690 | | |
| Conventional periapical radiography | | | |
| 1 | 0.594 | | |
| 2 | 0.916 | $P < .01$ | $P > .05$ |
| 3 | 0.890 | | |
| Digital periapical radiography | | | |
| 1 | 0.822 | | |
| 2 | 1.027 | $P > .05$ | P < .05 |
| 3 | 0.900 | | |

Group 1 = patients who smoked 1 to 10 cigarettes per day (18 implants); group 2 = patients who smoked 11 to 20 cigarettes per day (18 implants); group 3 = patients who smoked > 20 cigarettes per day (11 implants).

## DISCUSSION

A finding worth noting with respect to the study of error is that when the accuracy of conventional and digital periapical radiography was assessed, maximum differences of 0.2 and 0.1 mm, respectively, were reported. However, when these techniques were used to measure bone loss, the measurements based on digital radiography were consistently larger than their conventional counterparts. Although this finding may be explained in a number of ways, including both viewing and measurement techniques, it is important to remember that no statistically significant differences were found between the digital and periapical techniques in terms of either bias or variability, and that it is therefore tenable to attribute the discrepancy to random differences.

**Table 5 Correlation Between Bone Loss and Implant Location with the 3 Radiologic Techniques**

| Radiologic technique/group | Mean (mm) | *P* |
|---|---|---|
| Orthopantomography | | |
| Maxillary implants | 1.364 | .968 |
| Mandibular implants | 1.357 | |
| Conventional periapical radiography | | |
| Maxillary implants | 0.835 | .003* |
| Mandibular implants | 0.669 | |
| Digital periapical radiography | | |
| Maxillary implants | 0.913 | .049* |
| Mandibular implants | 0.792 | |

**t* test.
There were 59 maxillary implants and 49 mandibular implants.

**Table 6 Mean Bone Loss According to the Literature**

| Authors | No. of patients | No. of implants | Mean bone loss first year after loading (mm) | Mean annual bone loss after first year (mm) | Radiographic technique |
|---|---|---|---|---|---|
| Behneke et al[1] | 109 | 320 | 0.8 | 0.1 | Conventional periapical |
| Levy et al[2] | 48 | 144 | 0.43 | 0.17 | Convential periapical |
| Becker et al[3] | 34 | 78 | 1.07 | 0.25 | Digital periapical |
| Strid[6] | — | 996 | 1.2 | 0.1 | Conventional periapical |

The results in relation to peri-implant bone loss in the first year after loading were similar to those published by other authors (Table 6).[1–3,6]

The inconvenience of extraoral panoramic radiographs, particularly in regard to measuring bone loss, is well known. Because of magnification and deformation associated with the technique, peri-implant marginal bone loss appears greater when measured on orthopantomograms than on intraoral radiographs.[12–16] Periapical radiographs (conventional or digital) offer a number of advantages when performing bone measurements, including clarity and sharpness[17] and the possibility of using parallelizers.[10] Digital periapical systems are particularly convenient; the computer can be used to define the 2 reference points and measure the bone loss automatically, thus increasing measurement accuracy. This could account for the differences observed between this radiologic technique and the other techniques used in this study.

According to Bryant and Zarb,[18] peri-implant bone loss is similar in elderly individuals and young adults. In coincidence with the present findings, most authors agree that patient age does not seem to be an important factor in peri-implant bone loss.[1–3,5]

Regarding patient sex, the studies of Fartash and associates[19] and Andersson and colleagues[20] coincided with the present findings and revealed no statistically significant differences between males and females.

Haber and colleagues[21] and Lindquist and associates[22] demonstrated a positive association between smoking and peri-implant bone loss and considered smoking to be an important risk factor in this sense. In a study of 540 patients and 2,194 implants, Bain and Moy[23] observed significant differences between smokers and nonsmokers and advised the elimination of smoking in patients undergoing dental implant therapy. Wilson and Nunn[24] showed that smoking increases peri-implant bone loss and raises the risk of implant failure by almost 250%. In contrast, in a series of 380 patients involving the placement of 1,263 implants, Minsk and associates[25] reported no significant differences between smokers and nonsmokers in regard to the percentage of peri-implant bone loss. In the present study, both conventional and digital radiography showed that heavier smokers were more likely to experience bone loss. As to implant location, the results of the present study agree with those of Wyatt and Zarb[26] and Meraw and coworkers,[27] who found no significant differences between the anterior and posterior regions.

In a prospective study of 102 implants, Kemppainen and coworkers[28] found marginal bone loss in the first year to be slightly greater for implants placed in the maxilla than for those in the mandible, although no statistically significant differences were recorded. This observation could have been the result of differences in the remodeling capacity and rate between maxillary and mandibular bone, since maxillary bone provides important vascularization and a great remodeling potential in the healing phase after implant placement. In contrast, the reaction of the mandible is slower; thus, more time is required to lose the same amount of bone around the implant. In the present study bone loss was found to be comparatively greater in the maxilla than in the mandible. The differences were statistically significant when bone loss was determined using conventional and digital periapical radiologic techniques.

Peri-implant bone loss has been related to implant length and diameter. In 1997, Ivanoff and coworkers[29] suggested that increased diameters could enhance stability by increasing the supporting cortical bone surface and reducing posterior peri-implant bone loss. However, in another article published by the same authors 2 years later,[8] on a study that involved 299 implants (141 3.75-mm-wide implants, 61 4-mm-wide implants, and 97 5-mm-wide implants), no statistically significant relationship was observed between peri-implant bone loss and implant diameter. Grunder and coworkers[30] evaluated 264 implants in 143 patients and reported increased peri-implant bone loss and a greater incidence of failures when short implants were placed; likewise van Steenberghe and colleagues[7] observed increased bone loss with shorter, narrower implants. In the present series, no relationship was found between implant dimensions and peri-implant bone loss.

## CONCLUSION

Conventional periapical films and digital radiographs were more accurate than orthopantomography in the assessment of peri-implant bone loss. Smoking and implant location in the maxilla were associated with increased peri-implant marginal bone resorption.

## ACKNOWLEDGMENTS

The authors are grateful to Rafael Gil (dental prosthetist), who prepared the prostheses, and to Charo Velarde (dental hygienist) for her help in the clinical care of the patients.

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