A Comparison of Peripheral Marginal Bone Loss at Dental Implants Measured With Conventional Intraoral Film and Digitized Radiographs

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The purpose of the present study was to examine the effects of conventional and bone-condensing implantation techniques and time (6 and 12 months after implantation) on levels of marginal bone surrounding implants and to assess the level of agreement between measurements made using digitized intraoral images and film. The study group consisted of 14 healthy patients (9 female, 5 male; age range, 23–59 years; mean age, 41.1 years) with 28 single-tooth dental implants. In each patient, an implant was placed on one side using a conventional technique and on the opposite side using a bone-condensing technique. Film radiographs were taken at 6 and 12 months following implant placement and were digitized at 300 dpi and 600 dpi using a laser scanner. All scanned images were stored as both TIFF and JPEG files. A single observer twice measured distal and mesial marginal bone loss from film and digitized images. At the mesial site, there was a significant main effect of time (6 and 12 months after implantation) on the measurement of bone loss, $F(1, 26) = 6.08, P = .02$, but no significant main effect of implantation technique, $F(1, 26) = 1.56, P = .223$, and no significant interaction between time and technique, $F(1, 26) = 2.09, P = .160$. Similarly, at the distal site, there was a significant main effect of time on the measurement of bone loss, $F(1, 26) = 14.1, P = .001$, but no significant main effect of implantation technique, $F(1, 26) = 1.21, P = .281$. However, in contrast to the mesial site, there was also significant interaction between technique and time on the distal site, $F(1, 26) = 4.974, P = .035$. Intraobserver intraclass correlation coefficients and repeatability measurements showed high agreement for all image types. The bone-condensing technique resulted in greater marginal bone loss. Marginal bone measurements made using digitized intraoral images and conventional film showed high levels of agreement.

Key Words: film radiography, digitized radiography, condensing technique, marginal bone measurement

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INTRODUCTION

Successful dental implant therapy requires long-term maintenance of the soft and hard tissue surrounding the implant. Studies have examined various parameters including mobility, pain, infection, inflammation, and marginal bone (also referred to as crestal bone) levels, with particular emphasis given to the use of standardized, serial radiographs to monitor changes in the amount of marginal bone surrounding the implant. Vertical bone loss at the surfaces facing implants should not exceed 1–2 mm during the first year of function and 0.2 mm thereafter. A decrease in bone level indicates a loss in the implant’s bony anchorage. To gain more insight into the factors affecting the success and failure of implant therapy, long-term clinical evaluation of dental implants and their superstructure is necessary. The bone-condensing technique was introduced to preserve all existing bone by minimizing or even eliminating the drilling sequence of the surgical protocol. The trabecular bone is compressed vertically with an implant-shaped instrument. The alveolar ridge is expanded, and the sinus floor is elevated through a crestal approach. In the bone-condensing technique, after the pilot drilling, implant bed preparation is continued with bone condensers. Because of the tapered shape of the instruments, the slow expansion of the site via the continuous use of condensers of different sizes is possible. Each enlargement of the site is followed by an additional expansion with an instrument of the next largest size. The implant is inserted after the final diameter of the implant bed is established.

Although film radiographs are still routinely used in dental practice, in the near future, direct digital radiography may replace conventional radiography. During the transition period, the digitization of existing records is of paramount importance for uniformity, space saving, and teleradiology. Film can be digitized using a high-grade digital CCD camera, a standard laser scanner, or a flatbed film/slide laser scanner. Digitized radiographs have been shown to display a narrower density range composed of higher density values and more image noise when compared with their film equivalents. As a result, a clinically important loss or decrease in subtle information may occur in dark image regions, such as marginal bone areas. Previous studies have focused on the diagnostic performance and quality of digitized radiographs, whereas information on quantitative measurements obtained from digitized intraoral radiographs is sparse. Although scanners and cameras are designed to allow numerous adjustments in order to optimize the visual quality of images during the digitization process, quantitative studies are normally concerned with extracting quantitative information from the digital image and rarely focus on producing “pretty pictures.”

In view of the importance of the level of marginal bone surrounding implants and the role of the digitization process in measuring these levels, the aims of this study were the following:

1. To determine the effects of implantation technique (conventional and bone condensing) and time (6 months and 12 months after implantation) on mesial and distal marginal bone levels measured from film radiographs.

2. To assess the agreement between digitized images and conventional film in the measurement of marginal bone levels surrounding implants inserted using conventional and bone-condensing techniques.

MATERIALS AND METHODS

This study is the second part of a previous study that evaluated radiographic bone density differences between conventional...
and bone-condensing techniques using dual-energy X-ray absorptiometry and radiography. The study group consisted of 14 healthy patients (9 female, 5 male; age range, 23–59 years; mean age, 41.1 years) who had been treated at the Ankara University Faculty of Dentistry for bilateral missing teeth in the maxillary premolar region. Each patient had 2 single-tooth 2-stage dental implants (Frialit-2; Friadent, Dentsply, Mannheim, Germany) inserted, with a conventional technique used on one side and a bone-condensing technique on the other. The sites of the bone-condensing and conventional techniques were randomly selected. All patients received a local anesthetic before implant placement. In the conventional technique, the implant was placed in accordance with the manufacturer’s recommended protocol. In the bone-condensing technique, following pilot drilling, bone condensers (Frialit-2 Bone Condenser Kit; Friadent, Dentsply) were used to prepare the implant bed. Metal-ceramic restorations were placed 6 months after implant placement.

Standardized periapical radiographs were taken preoperatively and at 6 and 12 months after implant placement using Kodak Ultraspeed film (Eastman Kodak, Rochester, NY) with an XCP film holder (Rinn Corporation, Elgin, Ill) and acrylic bite blocks. All radiographs were obtained using the same x-ray unit (Sirona Dental Systems, Bensheim, Germany) and developed in the same automatic processor (DL 24; Durr Dental, Bietigheim-Bissingen, Germany). Radiographs taken at 6 and 12 months postimplantation were digitized at 300 dpi and 600 dpi using an Epson Expression 1680 Pro laser scanner, and all scanned images were stored as both TIFF and JPEG files.

Marginal bone loss was measured at the distal and mesial aspects using digital calipers for the film radiographs and the dental software ImageTool (UTHSCSA, Image Tool [IT] version 3.0, Department of Dental Diagnostic Science at the Texas University Health Science Center, San Antonio, Tex) for the digitized images. Measurements were taken from 56 film radiographs (14 conventional technique and 14 bone-condensing technique at 6 months and 12 months postimplantation) and from 112 scanned digital images each of conventional and of condensing implantation techniques (fourteen 300-dpi JPEG, fourteen 600-dpi JPEG, fourteen 300-dpi TIFF, and fourteen 600-dpi TIFF at 6 months and 12 months postimplantation). Measurements were recorded twice by a single observer, an oral radiologist, at 1-week intervals. The top of the marginal bone and the bottom of the bone loss margin were identified as reference points and marked on the film radiographs using a felt-tip pen for the measurements. For the digitized images, the distance between the same points was measured using the ImageTool software. Calibration was performed using the known lengths of the inserted implants. Conventional film radiographs were viewed on a light box, and scanned digital images were viewed on a 15-in. Toshiba Satellite laptop monitor with a 1024×768-pixel screen resolution and 32-bit color depth. The observer was allowed to use the brightness and contrast tools.

A two-way mixed analysis of variance (ANOVA) was used to determine the effects of implantation technique (conventional and bone condensing) and time (6 months and 12 months after implantation) on mesial and distal measurements of marginal bone obtained from film radiographs. Bland-Altman limits of agreement were calculated to assess agreement between film and digitized image measurements. Intraclass correlation coefficients (ICCs) as well as 2-way ANOVA were used to assess intraobserver reliability. All statistical analysis was performed using the Statistical Package for Social Sciences (SPSS, Windows version 11.0).

**Results**

Mean mesial and distal measurements for conventional and bone-condensing im-
plantation techniques obtained from film radiography are given in Table 1. Two-way mixed ANOVA conducted for mesial bone loss measurements found no significant main effect of implantation technique, $F(1, 26) = 1.56, P = .223$, but a significant main effect of time, $F(1, 26) = 6.08, P = .021$. There was no significant interaction between time and technique, $F(1, 26) = 2.09, P = .160$, for the mesial bone measurements. Mean mesial measurements for 6 months and 12 months postimplantation are shown in Figure 1. Two-way mixed ANOVA conducted for distal bone loss measurements found a significant main effect of time, $F(1, 26) = 14.1, P = .001$, but no significant main effect of implantation technique, $F(1, 26) = 1.21, P = .281$. However, in contrast to the mesial site, there was also a significant interaction between time and technique, $F(1, 26) = 4.974, P = .035$. Mean distal measurements for 6 months and 12 months postimplantation are given in Figure 2.

Marginal bone loss levels increased over time with both the conventional and bone-condensing implantation techniques, but the rate of increase was higher when the bone-condensing technique was used. However, this difference was not statistically significant (conventional technique, $t = 1.785, P = .098$; bone-condensing technique, $t = 3.296, P = .006$). With the conventional technique, mean marginal bone loss on the distal site was $1.59 \pm 0.46$ at 6 months postimplantation and $1.73 \pm 0.47$ at 12 months postimplantation (mean increase, 8.81%), whereas mean marginal bone loss on the mesial site was $1.61 \pm 0.48$ at 6 months postimplantation and $1.72 \pm 0.47$ at 12 months postimplantation (mean increase, 6.8%). With the condensing technique, mean marginal bone loss on the distal site was $1.66 \pm 0.83$ at 6 months postimplantation and $2.23 \pm 1$ at 12 months postimplantation (mean increase, 34.34%), whereas mean marginal bone loss on the mesial site was $1.79 \pm 0.97$ at 6 months postimplantation and $2.23 \pm 1$ at 12 months postimplantation.

### Table 1

<table>
<thead>
<tr>
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<th>Mesial (mm)</th>
<th>Distal (mm)</th>
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<tbody>
<tr>
<td></td>
<td>6th mo Mean ± SD</td>
<td>12th mo Mean ± SD</td>
</tr>
<tr>
<td>Conventional technique</td>
<td>1.61 ± 0.48</td>
<td>1.72 ± 0.47</td>
</tr>
<tr>
<td>Condensing technique</td>
<td>1.79 ± 0.97</td>
<td>2.23 ± 1.03</td>
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</table>

**Figure 1.** Mean mesial measurements at 6 months and 12 months after implantation using 2 different techniques.

**Figure 2.** Mean distal measurements at 6 months and 12 months after implantation using 2 different techniques.
and 2.23 ± 1.03 at 12 months postimplantation (mean increase, 24.68%).

The levels of agreement among bone loss measurements from film and digitized images were examined using the Bland-Altman method. A comparison of mean differences and 95% limits of agreement among digitized image and film measurements is given in Table 2. All image types resulted in similar measurements for both the distal and mesial sites. The mean differences in measurements among film and digitized radiographs scanned at 300 dpi or 600 dpi and stored as JPEG or TIFF files at 6 months postimplantation and 12 months postimplantation, respectively, ranged from −0.005 to −0.013 and from −0.009 to −0.013 for the mesial site and from −0.005 to −0.010 and from 0.000 to −0.002 for the distal site.

Intraclass correlation coefficients and repeatability values for film and digitized image measurements are given in Table 3. Intraobserver measurements for all image types showed high agreement, ranging from 0.99 to 1 at 6 months postimplantation and from 0.89 to 0.99 at 12 months postimplantation for the mesial site and from 0.99 to 1 at 6 months postimplantation and from 0.88 to 1 at 12 months postimplantation for the distal site. Intraobserver repeatability for the different

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**Table 2**

Mean differences and 95% limits of agreement measured by different digitized film image types compared with film measurements

<table>
<thead>
<tr>
<th></th>
<th>Mesial Mean Difference</th>
<th>95% Limits of Agreement</th>
<th>Distal Mean Difference</th>
<th>95% Limits of Agreement</th>
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<tr>
<td></td>
<td>Lower</td>
<td>Upper</td>
<td>Lower</td>
<td>Upper</td>
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<tr>
<td>6 mo</td>
<td></td>
<td></td>
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<tr>
<td>Film-TIFF 300 dpi</td>
<td>−0.005</td>
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<td>0.053</td>
<td>−0.005</td>
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<td>Film-JPEG 300 dpi</td>
<td>−0.008</td>
<td>−0.067</td>
<td>0.050</td>
<td>−0.010</td>
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<tr>
<td>Film-TIFF 600 dpi</td>
<td>−0.013</td>
<td>−0.101</td>
<td>0.075</td>
<td>−0.002</td>
</tr>
<tr>
<td>Film-JPEG 600 dpi</td>
<td>−0.012</td>
<td>−0.073</td>
<td>0.049</td>
<td>−0.002</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>12 mo</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Film-TIFF 300 dpi</td>
<td>−0.010</td>
<td>−0.108</td>
<td>0.088</td>
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<tr>
<td>Film-JPEG 600 dpi</td>
<td>−0.009</td>
<td>−0.106</td>
<td>0.084</td>
<td>−0.002</td>
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<tr>
<td>Film-JPEG 600 dpi</td>
<td>−0.013</td>
<td>−0.087</td>
<td>0.061</td>
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</tbody>
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**Table 3**

Intraclass correlation coefficients (ICC) and repeatability values for film and different types of digitized image measurements

<table>
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<th>Mesial</th>
<th>Distal</th>
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<tr>
<td></td>
<td>Intraobserver ICC</td>
<td>Intraobserver Repeatability</td>
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<td>6 mo</td>
<td></td>
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<tr>
<td>Film</td>
<td>.99</td>
<td>.05</td>
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<tr>
<td>JPEG 300 dpi</td>
<td>1.00</td>
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<tr>
<td>TIFF 300 dpi</td>
<td>.99</td>
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<tr>
<td>TIFF 600 dpi</td>
<td>1.00</td>
<td>.04</td>
</tr>
<tr>
<td>12 mo</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Film</td>
<td>.89</td>
<td>.16</td>
</tr>
<tr>
<td>JPEG 300 dpi</td>
<td>.99</td>
<td>.10</td>
</tr>
<tr>
<td>JPEG 600 dpi</td>
<td>.99</td>
<td>.07</td>
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<tr>
<td>TIFF 300 dpi</td>
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<td>.06</td>
</tr>
<tr>
<td>TIFF 600 dpi</td>
<td>.95</td>
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</table>
image types ranged from 0.04 mm to 0.06 mm at 6 months postimplantation and from 0.06 mm to 0.16 mm at 12 months postimplantation for the mesial site and from 0.03 mm to 0.08 mm at 6 months postimplantation and from 0.03 mm to 0.10 mm at 12 months postimplantation for the distal site.

**DISCUSSION**

This study found measurements of marginal bone loss surrounding implants at 6 months and 12 months postimplantation made on different digitized images to be comparable to those of measurements obtained from film radiographs, thereby confirming the clinical usefulness of digitized intraoral radiographs in the evaluation of implant success. Intraobserver measurements also showed high agreement in terms of ICC and repeatability. In addition, the increase in marginal bone loss over time was greater with the use of the bone-condensing technique than with conventional implantation. Gulsahi et al.\(^\text{11}\) also found a higher success rate for the conventional technique when compared with the bone-condensing technique, and they suggested that the differences in rates could be due to trabecular fracture associated with the bone-condensing technique.

In this in vivo study, it was neither possible nor practical to determine the actual marginal alveolar bone loss at the distal and mesial sites. As a result, the diagnostic accuracy of the methods evaluated was not assessed. Calibration of conventional radiographs was performed mathematically based on the known lengths of the implants, whereas calibration of digitized images was performed using the ImageTool software’s built-in calibration tool.

An in vivo study\(^\text{19}\) that assessed the diagnostic potential of computer-assisted measurement of bone height around endosseous implants found significantly higher values (\(P < .05\)) for interobserver variability with digitized radiographs than with all 3 digital subtraction imaging methods tested. Interobserver variability was found irrespective of the method used to evaluate marginal bone level, with a mean overall difference between observers of approximately 0.4 mm. Clinically, these differences can be considered significant. In addition, measurements of bone height around endosseous implants were lower using digital subtraction images than using digitized radiographs.

In a study in which 6 oral radiologists measured the distance between a reference point on the fixture and the proximal marginal bone on conventional radiographs, findings showed a small interobserver variation (0.14 mm), with intraobserver variation (0.08 mm) as its largest component. Confidence values showed that the reliability of measurement improved when one or preferably more than one observer was allowed to make several, independent readings, which compensated for minor differences in bone height over time or between implant systems. Factors that have been shown to influence observer variability include the quality of the radiograph, the degree of bone loss, the jaw in which fixtures have been inserted, the time elapsed after fixture loading, and the number of radiographs in which each fixture is displayed.\(^\text{20}\) In the present study, to eliminate interobserver bias, a single oral radiologist acted as observer. Our findings showed high intraobserver ICCs and repeatability for the different image types assessed.

Both digital and conventional radiographs have been shown to yield reliable and reproducible measurements of alveolar bone. Intraexaminer reproducibility was found to be higher than interexaminer agreement, and there was no improvement in examiner agreement when direct digital radiographs were used instead of conventional radiographs.\(^\text{21}\) In another study, measurements made from digital radiographs were found to be more accurate than measurements made from conventional radiographs.
F-speed film radiographs when assessing marginal bone levels. The authors concluded that measurement accuracy improved when digital radiographs were processed with correction for attenuation and visual response but that additional shifts in gray levels did not improve accuracy.22

In a previous study, the success rate of implants placed using the immediate placement, immediate load protocol has been shown to be equivalent to that of traditional methods in terms of adjacent bone loss.23 At 6 months postimplantation, bone loss adjacent to implants placed in fresh extraction sockets (ES) was less than that of implants placed in native bone (NB). At 12 months, adjacent bone loss for NB implants and ES implants were similar. The mean bone loss for all implants (ES + NB) was 0.60 ± 0.71 mm at 6 months, 1.17 ± 0.59 mm at 18 months, 0.87 ± 0.76 mm at 36 months, and 1.35 ± 0.42 mm at 60 months postimplantation. When NB and ES implants were evaluated separately, mean bone loss for NB implants was 0.75 ± 0.21 mm at 6 months, 1.31 ± 0.91 mm at 12 months, 1.07 ± 0.21 mm at 36 months, and 1.45 ± 0.49 mm at 54 months postimplantation. For ES implants, mean bone loss was 0.14 ± 0.33 mm at 6 months, 1.02 ± 0.27 mm at 12 months, 0.86 ± 0.42 mm at 36 months, and 1.30 ± 0.48 mm at 54 months postimplantation.23 In the present study, mean marginal bone loss scores ranged between 1.59 ± 0.46 and 2.23 ± 1.03 for different sites, time periods, and techniques.

When changes in interimplant marginal bone heights were compared for dental implants placed in the anterior maxillary region using immediate and nonimmediate placement techniques, mean marginal bone loss for patients was found to be higher with immediate placement (0.83 mm) when compared with delayed placement (0.48 mm).24 In the present study, immediate placement techniques and immediate loading were not preferred.

A study evaluating 1-piece implants in terms of marginal bone levels found mean levels to be 0.33 mm (SD, 1.20; n = 141) superior to the reference point (lower edge of the implant collar) at implant placement, −0.77 mm (SD, 1.33; n = 138) at 6 months, −0.98 mm (SD, 1.38; n = 123) at 12 months, and 0.17 mm (SD, 1.20; n = 26) at 24 months after loading. At 12 months of loading, maxillary bone was more apical than mandibular bone (P = .05). Moreover, a positive correlation was found between bone level at placement and at 12 months (P = .008), with deep implant positioning resulting in greater marginal bone remodeling than shallow positioning.25

In a study comparing implant assessment from intraoral direct digital radiographs and conventional film, 10 viewers separately assessed 8 different details of 59 implants on 50 pairs of radiographs with similar projection and exposure. The viewers showed very high agreement in their assessments of radiographs of each technique separately, and there were no statistically significant differences.26

In a study that examined the accuracy and quality of both 2D and 3D measurement techniques, simulated peri-implant defects were measured using 2D intraoral radiography and panoramic radiography as well as 3D computerized tomography (CT) and digital volumetric tomography. With both CT and dental volumetric tomography scans, bone defects could be measured in all 3 planes and showed only slight mean deviations when compared with direct measurement (CT, 0.17 ± 0.11 mm; dental volumetric tomography, 0.18 ± 0.12 mm). With intraoral radiographic and panoramic radiographic images, the defects could be detected in only the mesiodistal and craniocaudal planes and showed greater mean deviations when compared with direct measurement (intraoral radiography, 0.34 ± 0.30 mm; panoramic radiography, 0.41 ± 0.35 mm). Although dental volumetric tomography provides images in 3 planes without distortion, it is not always appropriate or possible to use in routine clinical practice.
Conclusions

The increase in marginal bone loss over time was found to be higher on both mesial and distal sides with the bone-condensing implantation technique when compared with the conventional technique. On the distal side, this difference was statistically significant. In addition, marginal bone level measurements made using digitized intraoral and film radiographs were similar, thereby confirming the clinical usefulness of digitized intraoral radiographs in the evaluation of implant success.

Abbreviations

CT: computerized tomography
ICC: intraclass correlation coefficient

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