A 1-Year Radiographic Evaluation of Marginal Bone Around Dental Implants

Young-Chul Jung, DDS, MSD/Chong-Hyun Han, DDS, MSD, PhD/Keun-Woo Lee, DDS, MSD, PhD

The aim of this study was to report alveolar bone loss during the first 12 months after implant abutment connection. Marginal bone loss around 62 endosseous root-form implants in 62 patients was measured on periapical radiographs. Changes in bone density were measured by the digital subtraction image radiographic method. At 3-month intervals for 1 year, bone loss around the four types of implants used (standard series, mini series, and hex-lock implants of the Steri-Oss system; and 3i standard implants) was investigated. Rapid bone loss around all four implant types occurred in the first 3 months. Most of the implants showed resorption of alveolar bone beyond the polished neck at 12 months. The bone level stabilized at the first thread of the implants with no correlation to either the time of exposure of the polished neck or the type of implant. Bone density decreased at the marginal bone and increased at the newly formed alveolar crest. (INT J ORAL MAXILLOFAC IMPLANTS 1996;11:811–818)

Key words: alveolar bone resorption, bone density change, dental implant, digital subtraction image method

Numerous studies have been conducted to establish criteria for the success and failure of osseointegration. One of the first objective attempts to assess osseointegrated dental implants came from the Swedish National Board of Health and Welfare in 1975. The report measured Gingival Index, Plaque Index, and pocket depths, as well as the evaluation of the prosthetic phase of implant therapy in terms of occlusion and esthetics. Radiographic assessment was limited to the observation of space between implants and osseous tissues around the implants.

The first National Institutes of Health (NIH) consensus was held in 1978 to establish criteria for the success of implant therapy for all types of implant systems. The consensus involved a wide-range discussion of the subject. James suggested that the absence of a clinical index that could effectively define success or failure of the implant therapy discouraged many clinicians from accepting implants in dentistry. Not until 1988 when the second NIH consensus conference discussed detailed criteria did implants have an established place in dentistry.

Currently, clinical examination methods such as those used in periodontology have been widely applied in implant dentistry. However, there have been ongoing
controversies related to the application of conventional periodontal examination methods without modifications to the assessment of implants.\textsuperscript{5-9}

Radiographic examination has proved to be useful despite its limitations and has been studied extensively. Radiographs may be helpful in assessing stress concentration around implants, thereby obviating excessive alveolar bone loss.\textsuperscript{8} Smith and Zarb\textsuperscript{10} suggested that one of the criteria for implant success was that less than 0.2 mm of alveolar bone loss occurred per year after the first year. Adell\textsuperscript{11} proposed that the success of implant therapy should be judged after 1 year of service because most of the bone loss occurred during the 12 months following abutment connection. A 15-year study reported by Adell et al\textsuperscript{12} indicated that alveolar bone loss during the first year after abutment connection averaged 1.2 mm, and annual bone loss thereafter remained at approximately 0.1 mm for both the maxilla and the mandible. The study concluded that the rapid initial bone loss might be the result of periosteal elevation, surgical trauma from preparation of the recipient bed, and stress concentration from excessive tightening of the implant. Subsequent studies\textsuperscript{13-21} of alveolar bone loss drew similar conclusions.

Subtraction radiography has enabled clinicians and researchers to detect minute changes in peri-implant bone tissue. This method was developed by Ziedses des Plantes\textsuperscript{22} to observe vascular structures. As seen in Fig 1, the reference image is subtracted from subsequent images with minute changes, eliminating structural noises that mask other changes.\textsuperscript{23} This technique was applied in dentistry by Grondahl et al\textsuperscript{23} Jeffcoat\textsuperscript{24} and Wenzel et al\textsuperscript{25} used this method to observe osseous changes in progressive alveolar bone resorption and in guided tissue regeneration therapy. The photographic subtraction method, which juxtaposes positive and negative images, has limitations in the number of images that can be processed. The digital subtraction method using computers had been developed for that reason, and it had the advantages of controlling and equalizing the concentration differences that could result from exposure and development discrepancies.\textsuperscript{26} It could also provide pseudocolor converting easily on a particular area so that a subtle change could be visualized.\textsuperscript{27} Jeffcoat et al\textsuperscript{28} and Reddy et al\textsuperscript{29} are a few of many investigators who have used digital subtraction radiography in implant dentistry. Brägger et al\textsuperscript{30} even stressed that the digital subtraction method could be the most precise and noninvasive tool for the diagnosis of osseous changes around the implant during regular checkups.

Although the authors of the present study agree with previous reports that alveolar bone loss generally amounts to an average of 1.2 mm during the first year and stabilizes at 0.1 mm per year thereafter, the most active phase of bone loss during the first 12 months has not been studied extensively. Therefore, peri-implant alveolar bone was observed through standard intraoral radiographs every 3 months and analyzed with digital subtraction imaging for the present study.

Materials and Methods
**Subjects.** Sixty-two implants in 62 partially edentulous patients, aged 17 to 62 years, with abutments connected from January 1993 to April 1994, were selected. The subjects included 37 males and 25 females with 24 implants in maxillae and 38 in mandibles. Types of implants used included 17 mini series, 11 standard series, and 18 hex-lock series from the Steri-Oss Implant System (Steri-Oss, Yorba Linda, CA), as well as 16 3i standard implants (Implant Innovations, West Palm Beach, FL) (Table 1, Fig 2).

**Radiographic Recordings.** Standard intraoral radiographs were taken at 3-month intervals starting from the time of implant abutment connection. Alveolar bone loss was measured at the mesial and distal sites of the implants from the implant-abutment interface to the crest of the alveolar bone using the Micrometer (Mitutoyo, Tokyo, Japan), which is capable of measuring 0.001-mm increments. Ratios obtained from the actual and radiographic measurements between each thread on the implants compensated for radiographic distortions (Fig 3). The extent of alveolar bone loss along the polished necks of the implants was recorded at 1-month intervals in the first 3 months (Fig 3[A]). Alveolar bone loss from the polished necks was measured during the 12-month follow-ups as well (Fig 3[B]).

In six of the subjects, impressions were made at the time of preliminary fixation of the prosthesis, and using the stone casts and Biostar (vacuum-forming machine for resin stent, Scheu-Dental, Iserlohn, Germany), 2-mm-thick radiographic resin templates were made. Standard intraoral radiographs were taken with the template every 3 months with identical exposure conditions: 70 kV(p); 15 mA; 0.5 seconds of exposure time. Standard intraoral radiographs taken after 6 months and 12 months were digitally scanned (300 dots/inch, 256-gray scale) to obtain the subtracted images. The radiographs taken immediately after abutment connection were used as reference images. Subtraction radiography was performed using a personal computer and graphic processing software (Adobe Photoshop, Adobe Systems, San Jose, CA). Increases and decreases in bone density were shown as green and red areas, respectively, after pseudocolor conversion.

**Statistical Analysis.** The amount of alveolar bone loss during the 12-month period, the time in which the bone loss progressed along the polished neck, and the amount of bone loss beyond the neck were statistically analyzed with the Kruskal-Wallis test and Mann-Whitney U test ($P < .05$) using SPSS/PC+ software (SPSS, Chicago, IL). Preliminary statistical analysis with the Mann-Whitney U test indicated that no statistically significant difference existed with regard to sex, site, or implant length. Age was not found to be a statistically significant factor according to a correlation test; therefore, no attempt was made to discriminate the data by those criteria.

**Results**

**Amount of Alveolar Bone Loss.** The amount of alveolar bone loss after 12 months...
indicated statistically significant differences between the four groups according to the Kruskal-Wallis test ($P = .001$). Statistical significance was analyzed via the Mann-Whitney $U$ test, and statistically significant differences were found between the standard series and the mini series implants ($P = .0363$), the standard series and the 3i implants ($P = .0000$), the mini series and the 3i implants ($P = .0052$), and the hex-lock system and the standard series implants ($P = .0006$) (Table 2, Fig 4).

**Progression of Alveolar Bone Loss to the Polished Neck Area.** The time it took for the alveolar bone loss to progress to the polished neck showed statistically significant differences between the four groups as evaluated using the Kruskal-Wallis test ($P = .0019$). Statistical significance analyzed by the Mann-Whitney $U$ test was found between the mini series and the hex-lock system implants ($P = .0000$), the mini series and the 3i implants ($P = .0001$), the hex-lock system and the standard series implants ($P = .0000$), and the standard series and the mini series implants ($P = .0000$) (Table 3, Fig 5).

**Amount of Alveolar Bone Loss Beyond the Polished Neck.** The amount of alveolar bone loss beyond the polished neck during the 12-month period showed statistically significant differences between maxillae and mandibles. No statistically significant differences were observed between the various implant systems, according to the Kruskal-Wallis test ($P = .0892$) (Table 4).

**Changes in Bone Density on the Digital Subtraction Images.** The digital subtraction imaging method showed that during the first 6 months after abutment connection, only a decrease in bone density occurred (Fig 6). During the next 6 months, additional bone density decreases occurred, and some increases in bone density occurred near the bone crest (Fig 7).

**Discussion**
The amount of alveolar bone loss during the 12-month period following abutment connection for various implant systems ranged from 1.320 to 2.020 mm, which is consistent with numbers from other studies. Correlations were found between the amount of bone loss for 12 months and the lengths of polished neck for various implant systems. The standard series implants of the Steri-Oss System, which had the longest polished neck, showed statistically significant differences in bone loss compared to the other systems.

It took longer for the alveolar bone resorption to progress to the polished neck in the groups with longer polished neck portions, but this generally occurred within the 12-month period. Significant differences in the time were observed in the standard series implants, which had a longer polished neck section of 4.5 mm compared to the hex-lock system implants (1.2 mm) and the 3i implants (1.0 mm). These two results suggest that factors related to polished neck portions and bone loss may be relevant. Earlier studies have shown that alveolar bone resorption inevitably progressed to the polished neck, whether a result of stress on the implants or bacteria-induced...
peri-implant destruction.\textsuperscript{39,40} It was stabilized when the bone loss reached the threaded areas. The present study showed similar results.

Another factor related to initial bone loss is the damage from the initial surgical procedure. Adell et al\textsuperscript{12} claimed that surgical trauma, such as that evolving from periosteal elevation and alveolar bone removal, could speed up bone loss. The present study showed that more than 50\% of total bone loss recorded in a 12-month period occurred during the first 3 months. This suggests that trauma at the time of abutment connection could be an important factor in the initial bone loss.

Adell\textsuperscript{41} and Brånemark et al\textsuperscript{42} observed successfully osseointegrated implants and found increases in bone density with horizontal orientation of peri-implant trabeculae from the threads. Albrektsson et al\textsuperscript{43} reported that the horizontal laminalization started at the implant edges in radiographic and in histologic observations. They suggested that the threads could distribute the stress to a large area.

In digital subtraction imaging in the present study, a decrease in bone density occurred only during the first 6 months; the following 6 months showed further bone loss, as well as some increases in bone density near the bone crest. Pylant et al\textsuperscript{20} reported that 6 to 49 months of observation seemed insufficient to observe peri-implant corticalization. The present study showed no changes in bone density at the midportion of the implants, and more than 12 months of observation seemed to be necessary for remodeling to be evident.

Jeffcoat\textsuperscript{44} claimed that digital subtraction could detect minute changes of 0.1 mm, but the actual images in the present study had not shown clear changes. This may be because the tendency for stress concentration might have occurred at the buccal and lingual areas, rather than at the mesial and distal areas as Clelland et al\textsuperscript{45} suggested. Misch\textsuperscript{8} also mentioned that initial bone loss started at the buccal area, and only interproximal bone loss could be measured on radiographs. Therefore, it can be speculated that the changes were unclear because the buccolingual bone changes were indistinguishable on the two-dimensional radiographs.

The present study showed that alveolar bone loss was rapid during the first 12 months and stabilized thereafter, but detection of the changes in bone density required longer observation.

Summary
The present study measured marginal bone loss on periapical radiographs and changes in bone density through the digital subtraction image radiographic method around four types of endosseous root-form dental implants. The results were as follows:

1. Rapid bone loss occurred in the first 3 months for all four types of implants. The bone level stabilized at the first thread of the implants. The amount of bone loss
for 12 months showed a correlation with the length of the polished neck.

2. Most of the implant systems showed resorption of alveolar bone up to the polished neck, although a long polished neck could delay the resorption.

3. Alveolar bone loss apical to the polished neck stabilized at the first thread of the implants, with no correlation to either the time of exposure of the polished neck or types of implant systems.

4. No changes in bone density around the implant threads were observed throughout the experimental period. Marginal bone density decreased, and bone density of the newly formed alveolar crest increased.


15. Henry PJ, Bower RC, Woolridge JA. Radiographic evaluation of marginal bone


Table 1: Number of Implants Studied

<table>
<thead>
<tr>
<th>Patient sex</th>
<th>Implant location</th>
</tr>
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<tbody>
<tr>
<td>Male</td>
<td>Female</td>
</tr>
<tr>
<td>Maxilla</td>
<td>Mandible</td>
</tr>
<tr>
<td>Hex-lock system</td>
<td>12</td>
</tr>
<tr>
<td>Standard series</td>
<td>7</td>
</tr>
<tr>
<td>Mini series</td>
<td>9</td>
</tr>
<tr>
<td>3i system</td>
<td>9</td>
</tr>
<tr>
<td>Total</td>
<td>37</td>
</tr>
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</table>

Table 2: Alveolar Bone Loss (mm) for Each Implant at Different Follow-up Examinations

<table>
<thead>
<tr>
<th></th>
<th>3 months</th>
<th></th>
<th>6 months</th>
<th></th>
<th>9 months</th>
<th></th>
<th>12 months</th>
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<tbody>
<tr>
<td></td>
<td>Median</td>
<td>Range</td>
<td>Median</td>
<td>Range</td>
<td>Median</td>
<td>Range</td>
<td>Median</td>
<td>Range</td>
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<tr>
<td>Hex-lock system</td>
<td>1.043</td>
<td>0.130-1.625</td>
<td>1.145</td>
<td>0.265-2.550</td>
<td>1.270</td>
<td>0.300-2.950</td>
<td>1.320</td>
<td>0.315-2.965</td>
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<tr>
<td>Standard series</td>
<td>1.705</td>
<td>0.200-1.795</td>
<td>1.670</td>
<td>0.965-1.645</td>
<td>1.625</td>
<td>1.350-2.130</td>
<td>2.020</td>
<td>1.455-2.445</td>
</tr>
<tr>
<td>Mini series</td>
<td>0.980</td>
<td>0.240-1.780</td>
<td>1.500</td>
<td>0.660-1.880</td>
<td>1.625</td>
<td>0.930-2.940</td>
<td>1.660</td>
<td>0.955-2.945</td>
</tr>
<tr>
<td>3i implants</td>
<td>0.980</td>
<td>0.100-1.290</td>
<td>1.172</td>
<td>0.260-1.520</td>
<td>1.238</td>
<td>0.265-1.530</td>
<td>1.260</td>
<td>0.285-1.540</td>
</tr>
</tbody>
</table>

*Systems that have matching letters are statistically significantly different from each other (P < .05; Mann-Whitney U test).

Table 3: Time (months) Taken for Alveolar Bone Loss to Progress to the Polished Neck

<table>
<thead>
<tr>
<th></th>
<th>Median</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hex-lock system</td>
<td>1.250</td>
<td>0.000-4.500</td>
</tr>
<tr>
<td>Standard series</td>
<td>9.000</td>
<td>6.500-9.500</td>
</tr>
<tr>
<td>Mini series</td>
<td>4.000</td>
<td>2.000-6.000</td>
</tr>
<tr>
<td>3i implants</td>
<td>2.000</td>
<td>1.000-4.000</td>
</tr>
</tbody>
</table>

*Systems that have matching letters are statistically significantly different from each other (P < .05; Mann-Whitney U test).
### Table 4  Alveolar Bone Loss (mm) Beyond the Polished Neck After 12 Months

<table>
<thead>
<tr>
<th>System</th>
<th>Median</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hex-lock system</td>
<td>0.478</td>
<td>0.205–0.960</td>
</tr>
<tr>
<td>Standard series</td>
<td>0.460</td>
<td>0.220–0.965</td>
</tr>
<tr>
<td>Mini series</td>
<td>0.400</td>
<td>0.040–0.795</td>
</tr>
<tr>
<td>3i implants</td>
<td>0.435</td>
<td>0.140–0.495</td>
</tr>
</tbody>
</table>

P > .05 (Kruskal-Wallis test)
Fig. 1 In subtraction radiography, the reference image is subtracted from subsequent images with minute changes. Structural noises that mask changes are eliminated.

Fig. 2 Implant types and the corresponding lengths of polished necks: hex-lock system (H), 1.2 mm; standard series (S), 4.5 mm; mini series (M), 2.0 mm; and 3i standard (B), 1.0 mm.
**Fig. 3** Measuring protocols for alveolar bone loss (A = alveolar bone crest to bone-implant interface; B = apical border of polished neck to bone-implant interface).

**Fig. 4** Alveolar bone loss of each implant system.
bone loss to progress to the polished neck. 

Fig. 5 Time needed for the alveolar
Fig. 6 Digital subtraction images at 6 months (left) and 12 months (right). Decreases in bone density were evident at 6 months. Increases in bone density around the newly formed alveolar bone crest after 12 months were observed.
Fig. 7 Pseudocolor-converted images at 6 months (left) and at 12 months (right), with red for decreases in bone density and green for increases. Only marginal bone was affected; no changes occurred around the implant trunks.