Long-Term Bone Stability Assessment Around 1,187 Immediately Placed Implants with 1- to 22-Year Follow-up

Barry D. Wagenberg, DMD1/Stuart J. Froum, DDS2/Steven E. Eckert, DDS, MS3

Purpose: To evaluate the retention of bone around implants placed immediately following tooth extraction and used to support dental prostheses. Materials and Methods: Patients from a previous study of implants placed immediately following tooth extraction were recalled to the original practice to obtain dental radiographs, which were then used to compare bone levels after 1 to 22 years of clinical function supporting dental prostheses. All radiographs were evaluated by measuring the bone within the implant threads. Implant bone maintenance was correlated with smoking history, type of implant surface, antibiotics used in conjunction with surgery, bisphosphonate use, presence of splinted restorations, anatomical location (mandible or maxilla and anterior or posterior), sex, and past periodontal disease status. Statistical analysis was performed using the Mann-Whitney test for statistical significance of differences in mean bone loss. Results: A total of 1,187 implants were identified, with mean bone loss of 0.52 ± 0.79 mm. Overall bone loss was less than 1.5 mm in 90% of the implants studied. Bone loss was greater in women (0.61 ± 0.91 mm vs 0.44 ± 0.69 mm in men; P = .002). There was a correlation between bone loss and patient age at the time of tooth loss, with patients below the age of 50 experiencing significantly more loss (mean loss, 0.76 ± 1.07 mm at age < 50 and 0.46 ± 0.71 mm at age > 50; P = .008). Other significant differences were seen with implant surface (machined surface, 0.57 ± 0.77 mm; roughened surface, 0.44 ± 0.84 mm; P = .0049), maxilla vs mandible in molar areas (maxilla, 0.68 ± 0.83 mm; mandible, 0.43 ± 0.80 mm; P = .0001), and platform width (regular, 0.46 ± 0.77; wide, 0.83 ± 0.94 mm; P ≤ .0001). None of the other factors demonstrated significant differences. Conclusions: Bone loss of 1.5 mm or less was observed in 90% of the patients followed. Bone loss was correlated with age, sex, implant surface, anatomical location, and platform width. There was no statistical correlation between bone loss and any other factors evaluated. Int J Oral Maxillofac Implants 2013;28:605–612. doi: 10.11607/jomi.2809

Key words: clinical significance, immediate implants, long-term bone stability

Similar success rates have been described in literature reviews both for implants placed immediately following tooth removal and following a period of bone healing. The authors previously demonstrated a 96% implant survival rate over a period of 16 years with a sample size of 1,925 implants.1 Although the data in that study were assessed for factors that could have influenced implant survival, there was no specific analysis of bone retention when implants were used to support dental prostheses. With increasing use of the immediate implant protocol (IIP), it appears essential to evaluate the long-term stability of bone around implants placed immediately following tooth removal, as this is a criteria for implant success rather than survival.2–5 The purpose of this retrospective investigation was to evaluate marginal bone level responses to functional loading of implants placed immediately following tooth removal and to correlate these responses to factors that could influence bone retention.
MATERIALS AND METHODS

A research protocol was developed to include all patients treated with implants placed immediately following tooth extraction between the dates of January 1, 1988 and December 31, 2004. All patients were surgically treated in the same periodontal practice, providing a reference list that was used to contact patients. Patients were contacted by telephone with a request that they return for radiographic follow-up of previously placed implants during this time period. If patients did not respond to telephone contact, the referring dentist was contacted to determine if current radiographs were available. If the patients had changed residency, an attempt was made to contact their current dentist to obtain current radiographs. Reasons for not participating in the radiographic follow-up were recorded (Table 1). Patients were included in the study if consent was obtained for data associated with their care to be included in this research project. All patients in this study were treated consecutively.

Once consent was obtained and radiographs were made or provided a chart review was conducted of all patients enrolled in this study. Factors reviewed included the implant length, implant diameter, implant surface, patient age at the time of placement (≤ 50 or ≥ 50 years old), sex, type of antibiotics used following surgery, medical comorbidities, graft type, and anatomical location of the implant. These parameters were assessed relative to changes in bone height to determine any correlation between bone change and the aforementioned variables. In addition, several other variables were evaluated, including differences in results of patients who were smokers (≥ 1/2 pack per day) vs nonsmokers, patients taking bisphosphonates, and implants that were free standing vs splinted.

Radiographs were taken at the time of implant placement, and follow-up radiographs were obtained upon

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**Table 1  Implants Excluded from Study**

<table>
<thead>
<tr>
<th>Total (n)</th>
<th>Implants in patients that relocated (n)</th>
<th>Implants in nonresponsive patients (n)</th>
<th>Implants lost since previous study (n)</th>
<th>Implants in deceased patients (n)</th>
<th>Implants excluded (n)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1,841</td>
<td>220</td>
<td>312</td>
<td>2</td>
<td>92</td>
<td>624</td>
</tr>
</tbody>
</table>

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Fig 1  (left)  Radiologist calibrations demonstrating measurements of bone within the implant threads. + = Bone over the top thread that could not be measured.

Fig 2  Twenty-two-year postoperative radiograph of the immediately placed implant at a maxillary right first premolar site. (1988) demonstrating (+) bone over the top thread that could not be measured on both the mesial and distal sides. The restorative dentist was in the process of replacing the existing fixed partial denture.

Fig 3  Twelve-year postoperative radiograph of an immediately placed implant at the maxillary first and second premolar sites. The implant at the first premolar demonstrated loss of bone in 2.5 threads on the distal and 3.0 threads on the mesial aspects. Universal tooth numbering used.

Fig 4  Eleven-year postoperative radiograph demonstrating bone loss of seven threads both on the mesial and distal aspects. Universal tooth numbering used.
the patient’s return to the surgical practice. Final recorded measurements were made relative to the most coronal implant thread as the reference point. Changes in bone height relative to the reference position were calculated. All radiographs were evaluated by an independent oral and maxillofacial radiologist (PN). Bone change was measured as an absolute figure. In this study, these measurements are reported in millimeters based on the known distance between the thread peaks per the manufacturer’s specifications. Hence, a ratio was developed with the known peak-to-peak distance relative to the measured peak-to-peak distance. This is proportionate to the recorded bone change as viewed on the radiograph, allowing the actual bone change to be calculated (Fig 1). As in a previous study, using the known distance of 0.8 mm between the peaks of adjacent threads for wide-diameter implants (5.0 or 6.0 mm), and 0.6 mm for regular-diameter implants (3.75 or 4 mm), a determination was made of the magnitude of bone change that had occurred during the time of service of the implants. These known distances provided a measurement that allowed accurate assessment on each separate radiograph, regardless of differences in angulation or magnification (Figs 2 to 4). Bone above the first thread, was considered as being level with the first thread as the calculation for bone loss used in this study would not apply to bone gain.

The Mann-Whitney test was performed to test the statistical significance of differences in mean bone loss relative to the factors studied. Statistical analysis was performed using standard statistical software (SAS Institute), and a $P$ value of less than .05 was established as the threshold for statistical significance. All statistical analyses were performed by an independent statistician (YGC).

**RESULTS**

A total of 1,187 implants in 541 patients were followed from 1 to 22 years with a mean follow-up time of 10.18 years (standard deviation [SD], 3.18) and with an overall implant survival of 99.62% following the completion of the original study. The ages of the patient population at the time of implant placement ranged from 12 to 88 years, with a mean of 58.75 and a SD of 13.07. Approximately 95% of the implants were followed between 5 and 16 years (Table 2).

Average mean bone loss for all implants was 0.52 ± 0.79 mm. Bone loss was 1.5 mm or less for approximately 90% of implants. Of the 10% of implants that exhibited greater than 1.5 mm of bone loss, only 2% exhibited more than 3.0 mm of loss (Table 3). Loss of bone around each of the 1,187 implants placed with the IIP was initially determined by measuring bone loss within the implant threads (Fig 1) and then converted to millimeters utilizing the manufacturer’s specifications regarding peak-to-peak distance. Five hundred implants had 0 mm of bone loss. Of these 500, 197 implants had bone coronal to the first thread as the calculation for bone loss used in this study would not apply to bone gain.

There were a number of factors that showed a statistically significant correlation to bone level stability (Table 4). There was a statistically significant difference in bone retention around implants with differing surfaces (machined vs roughened). Machined implants ($n = 873$) demonstrated more bone loss at 0.57± 0.77 mm compared with roughened surfaced implants ($n = 314$) at 0.44 ± 0.84 mm, ($P = .0049$). Patients that lost teeth at an age of < 50 years had a tendency to lose more bone at 0.76 ± 1.07 mm than patients that had tooth loss at an age > 50 of 0.46 ± 0.71 mm ($P = .0001$).

<table>
<thead>
<tr>
<th>Table 2 Follow-up of Evaluated Implants</th>
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</thead>
<tbody>
<tr>
<td><strong>Period</strong></td>
</tr>
<tr>
<td>1–4 y</td>
</tr>
<tr>
<td>5–8 y</td>
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<tr>
<td>9–12 y</td>
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<tr>
<td>13–16 y</td>
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<tr>
<td>17–21 y</td>
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<tr>
<td>≥ 22 y</td>
</tr>
<tr>
<td><strong>Total</strong></td>
</tr>
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</table>

<table>
<thead>
<tr>
<th>Table 3 Bone Loss (mm) Within the Implant Threads</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Bone loss</strong></td>
</tr>
<tr>
<td>0.0</td>
</tr>
<tr>
<td>0.5</td>
</tr>
<tr>
<td>1.0</td>
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<tr>
<td>1.5</td>
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<tr>
<td>2.0</td>
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<tr>
<td>2.5</td>
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<tr>
<td>3.0</td>
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<tr>
<td>3.5</td>
</tr>
<tr>
<td>4.0</td>
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<tr>
<td>≥ 5.0</td>
</tr>
<tr>
<td><strong>Total</strong> 1,187</td>
</tr>
</tbody>
</table>

*197 implants demonstrated bone above the first thread and were therefore considered to show 0 bone loss.

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When comparing bone loss in men and women, there was more bone loss in women at 0.61 ± 0.91 than in men at 0.44 ± 0.69 mm (P = .0022). When comparing bone loss in regular-platform (n = 940) and wide-platform (n = 247) implants, there was a statistically significant greater bone loss with wider-platform implants at 0.83 ± 0.94 mm than with regular-platform implants at 0.46 ± 0.77 mm (P ≤ .0001). When evaluating the
bone loss in different tooth positions, it was determined there was more bone loss in maxillary molars (0.68 ± 0.83 mm) than the mandible (0.43 ± 0.80 mm, \( P = .0001 \)). However, the numerical differences in the magnitude of the measurement of these factors were so small that they may not be clinically significant (Table 5).

Several factors were evaluated that exhibited no statistically significant differences in the ability to maintain bone around the implants (Table 6). There was no difference in bone loss when evaluating loss related to implant position, whether anterior or posterior, maxillary canine to canine, or mandibular canine to canine, with the exception of bone maintenance in molars. Splinted implants demonstrated no difference in bone loss when compared to those restored as single units. When bone loss was compared in patients who smoked \( \geq 1/2 \) package per day with those who smoked < 1/2 package per day or did not smoke at all, there were no statistically significant differences in bone retention. This also held true when implants with roughened or machined surfaces in smokers were compared. There were no differences in bone maintenance in patients taking any specific type of antibiotic. Patients taking bisphosphonates showed no differences in bone loss when compared to patients not taking these drugs. Patients who lost teeth due to periodontal disease had a decreased success rate but did not lose more bone when compared to tooth loss due to other circumstances. The same was true for patients taking penicillin, which were shown in an earlier study to have a statistically significant greater implant success rate, but in the present study, showed no statistically significant correlation to bone loss. An evaluation of the protocol used for placement (immediate loading or immediate nonocclusally loading vs submerged [delayed loading]) implants revealed no differences in bone maintenance.

An analysis of all implants that demonstrated 2.5 mm or greater bone loss on either the mesial or distal aspects was done. No common factor could be found as a reason for the increased bone loss.

**DISCUSSION**

A previous study by the authors demonstrated that implants placed immediately following tooth removal showed a high implant survival rate of approximately 96%\(^1\). The strength of this study was related to the number of implants included \((n = 1,187)\) and the duration of the study, which extended over a 16-year period. It should be noted from the original study that many of the implants placed were in infected sites (Figs 6a to 6c), involved internal sinus lifts at the time of placement, involved fractured teeth, were immediately or nonocclusally loaded, and had other factors that contributed to compromised sites and added stress to the potential healing results. The original study assessed implant survival while also considering factors that could have influenced these outcomes. The current study followed this same group of patients to determine the performance of supporting bone.

Historically, dental implants were placed in healed alveolar bone months after tooth removal. The healed alveolar bone surrounding these implants demonstrated remarkable stability over time.\(^7\)\(^9\) The removal of a tooth followed by implant placement presents an...
entirely different environment that would likely perform differently than the traditional approach. For this reason, it is imperative that bone responses adjacent to immediately placed implants be evaluated.

This study assessed a group of patients who had previously undergone immediate implant placement. There are several concerns regarding the design of the present study. Issues such as the study design, radiographic technique, patient identification, and patient recruitment are somewhat unique to this specific study. This study was performed in a private practice setting without an institutional review board. All patients involved in the recall were verbally informed that it was the intention of the investigators to write a scientific paper and that their implants were to be evaluated regarding the amount of bone retention (loss) over the period of time since placement. The patients’ participation demonstrated their consent to be included in the study.

Radiographs were taken when the patients presented for assessment. This factor resulted in different time intervals between initial surgery and reassessment of bone. All patients who were evaluated were at risk for bone loss for a minimum of 6 years, and many were at risk for more than a decade. The radiographic technique was not one that utilized a standardized radiographic holding device but instead made calculations based on known measurements of the dental implants. Since the peak-to-peak ratio of the dental implant was a known factor, a simple proportion was used to assess bone loss. This approach may have been more accurate than would have been obtained through the use of a radiographic device. Twenty-eight implants were eliminated from the study (leaving 1,187) by the evaluating radiologist due to an inability to clearly measure the amount of bone within the threads.

Patient identification occurred through the list of patients who had previously been treated with dental implants placed immediately following tooth extraction. Every patient was contacted with the request that they present for radiographs. There was no systematic exclusion of any patient group. Every patient was given ample opportunity for participation, and failure to participate would represent a random event.

A critical finding of this study was that mean bone loss was 0.52 ± 0.79 mm. Furthermore, it is interesting to note that 90% of implants exhibited less than 1.5 mm of bone loss. Patients who demonstrated bone loss were considered, for the purposes of the study, to have had no bone change. The authors believed that this approach would be more conservative than attempting to estimate the magnitude of bone gain since the peak-to-peak radiographic reference would not have been applicable. This could have actually resulted in a lower average mean bone loss than the 0.52 mm reported in the study.

Although the earliest descriptions of dental implants suggested that osseointegration was dependent on a time period of undisturbed healing, this long-held tenet has come under question. The advent of single-stage implants demonstrated that implants need not be submerged beneath the oral mucosa to allow healing. The placement of implants immediately following tooth removal has provided further evidence that the integration process is possible even though a healed tooth socket is not present. This study assessed the magnitude of bone loss that occurred after functional loading of implants that had been placed immediately following natural tooth removal. Due to the limitations of periapical and bite wing radiographs, only mesial and distal bone retention could be calculated. Thus, any bone loss that occurred on the buccal or lingual surfaces was not taken into consideration. The effect of peri-implantitis was not evaluated specifically around each implant due to the large number of patients in the study and the inability to obtain buccal and lingual bone measurements as well as the fact that neither probing depths, bleeding on probing, or the inflammatory state of the mucosa was recorded.

This study demonstrates a number of factors that have statistically significant differences; however, the vast majority of these factors failed to demonstrate differences in bone loss patterns that would be considered clinically significant. From an academic standpoint, it is valuable to be aware of the factors that could contribute to increased severity of bone loss, but from a pragmatic standpoint, a differential loss of less than 1 mm may be considered to be clinically insignificant.

Using the Albrektsson criteria for implant success, it would appear that fewer than 2.5% of the implants in this study would be considered as failures secondary to bone loss, and even this amount of bone loss may fall within the range of “success” given the length of time from implant placement to assessment. Given the size of this study, with 1,187 implants being followed for a mean of 10 years, it appears that the information gathered in this study is fairly definitive.

Statistical significance depends on the sample size, the magnitude of difference, and the precision of measurement. Since the number of implants was large, small differences in some of the results showed statistical significance. However, in many cases, the clinical significance of these small differences may be of little consequence to the clinician (Table 5). What may be of interest to the clinician, however, is when a patient exhibits more than one factor that demonstrates a statistically significant increase in bone loss with the potential for an additive or synergistic effect. When examining
the differences of implant surfaces, there was a statistically significant but small difference in bone loss (0.13 mm). One must take into account that the machined-surface implants were in place significantly longer than the roughened-surface implants and therefore would have a much longer time at risk for bone loss.

Surgical placement of dental implants is a critical phase of implant therapy in that soft and hard tissue must be handled appropriately to achieve initial integration. Maintenance of integration is less dependent on surgery and more on restoration and maintenance. Furthermore, bone maintenance is likely the result of many cofactors. In this study, one surgeon placed all implants, utilizing the same immediate placement protocol. However, a variety of clinicians performed the prosthetic reconstruction and maintenance. This may have led to greater generalizability of the results as they pertain to loading. However, two clinical studies utilized immediate placement protocols with variations designed to reduce bone loss.14,15 A 10-case report investigation that employed different implant-abutment diameters (a platform-switching concept) followed bone levels for a mean of 22 months,14 and the other, a retrospective study, utilized a flapless implant insertion protocol with 165 single implants (followed for up to 36 months).15 Both studies reported bone loss (mean, 0.78 mm and ≤ 2 mm, respectively) that was equal to or exceeding that which occurred in the current study. Thus, the data in the current study demonstrated excellent levels of bone stability utilizing the IPP with 1- to 22-year postoperative follow-up without use of either a flapless or a platform-switching concept.

Perhaps the major consideration with bone loss is the relative predictability. Predictable loss of 0.5 to 1.5 mm would be preferable to mean bone loss of a smaller amount if that loss is associated with a larger standard deviation. Predictable loss allows technique modifications as a method of compensation, while large variability of loss makes compensatory techniques less effective. Of course, the ideal situation is one in which bone loss can be prevented, but at this time, the state of the science suggests this is not the case.16–20 Podium descriptions of no bone loss are likely hyperbole, a statement that is confirmed by presentations of data for which a mean bone loss of 0 mm is followed by a standard deviation of any number other than zero. If there is no bone loss in any study, there will be no standard deviation.

The logical suggestion is to assess bone loss using a randomized controlled clinical study in which a clear research question has been developed. The authors would propose a question such as: In patients receiving dental implants to support dental prostheses, does implant placement immediately following tooth removal provide superior bone maintenance when compared with implant placement following complete residual ridge healing? Although such a study would be welcome, it would be valuable only if it provided long-term results on large patient populations, as seen in the current article.

CONCLUSIONS

Based upon the outcomes of this retrospective study of 1,187 implants that have been in function 1 to 22 years (mean, 10.8 years), the following conclusions can be established:

- Mean bone loss was 0.52 ± 0.79 mm.
- Bone loss of 1.5 mm or less was observed for 90% of implants.
- Age, sex, location, implant surface, and implant width demonstrated statistically significant differences in bone loss, but no one factor was responsible for bone loss of more than 1.0 mm
- No significant differences in bone loss were seen for smoking, smoking with regard to implant surface, patients on antibiotics alternate to penicillin, bisphosphonates, singly restored vs splinted implants, tooth position (except molars), tooth loss due to periodontal disease, and loading protocol (delayed vs immediate) following implant placement.

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REFERENCES


