# Clinical and Radiographic Evaluation of the 5-mm Diameter Regular-Platform Brånemark Fixture: 2- to 5-Year Follow-up

Georges Tawil, DDS, DSc Odont;* Muhieddine Mawla, DCD, DES;† Jan Gottlow, DDS, PhD‡

## ABSTRACT

*Purpose:* The purpose of this study was to report the clinical results obtained with 5-mm diameter regular-platform Brånemark implants after 2 to 5 years of follow-up. A secondary aim was to compare the clinical outcome to that of adjacently placed standard 3.75-mm fixtures in the same patients under the same operative condition and in the same prosthetic construction.

*Materials and Methods:* Sixty patients, with a mean age of 54 years, received a total of 97 5-mm diameter regular-platform fixtures. The majority of the implants were placed at molar sites. In 41 of the patients, 53 5-mm diameter implants were placed adjacent to 62 standard 3.75-mm diameter fixtures in the same prosthetic reconstruction. All implants were submerged for an average period of 4 to 6 months. Abutment connection was done according to standard protocol. The prosthetic treatment consisted of freestanding fixed bridges.

*Results:* The cumulative survival rate of the 5-mm diameter implants loaded for a period of 2 to 5 years was 96.9%. Only three implants failed. They were placed in type 4 bone in the posterior maxilla. Bone loss over the first year was 0.70 mm and over a 3-year period 0.81 mm. Implants placed in type 4 bone showed significantly higher bone loss. No difference in the resorption rate could be found between the maxillary and the mandibular implants or between the various implant lengths. There was no significant difference between the bone loss around the 5-mm diameter fixtures and the adjacent 3.75-mm diameter standard fixtures.

*Conclusion:* The present study demonstrated a high predictability of 5-mm diameter regular-platform implants when placed in the posterior maxilla and mandible.

KEY WORDS: Brånemark System, diameter, titanium oral implant, treatment result

Until the late 1980s, the most widely used dental implant for osseointegration was the 3.75-mm diameter Brånemark standard implant (Nobel Biocare AB, Gothenburg, Sweden). The implant was initially designed for the treatment of total edentulism and placed in the anterior part of the jaw.[1] Because of the resorption pattern following tooth extraction leading to a severe reduction in bone width,[2,3] implants were sized to fit the bone site yet provide enough mechanical strength to sustain function. The need for larger-diameter implants came from clinical requisites to overcome specific problems.[4] In situations of limited bone height, below the maxillary sinus or above the mandibular canal, a 5-mm diameter fixture provides 35% more surface area for fixture-to-bone contact compared with the standard fixture. It is also possible, when bone anatomy is favorable, to engage the lateral cortex to improve the anchorage and the stability of the fixture.[4] The 5-mm diameter implant can also serve as a rescue in case of weak initial stability because of either poor bone quality or imprecise drilling of the bone site. It can be used to replace a fractured or a nonintegrated implant, saving healing time and reducing the overall treatment period. It can be used for immediate implantation when the dimension of the dental socket fits better to a larger-diameter implant. Better emergence profiles and improved biomechanical

*St. Joseph University, Beirut, Lebanon; †Private Practice, Beirut, Lebanon; ‡University of Gothenburg, Sweden

Reprint requests: Georges Tawil, DDS, DSc Odont, Elias Sarkis Avenue, Abou Arbig Bldg, Achrafieh, Beirut, Lebanon; e-mail: gtawil@inco.com.lb

stability can also be obtained with larger implants, which have three times greater resistance to fracture,[5] better masticatory force distribution in the posterior areas, and less strain on the prosthetic components, resulting in less screw loosening or fracture.[6,7]

Langer and colleagues developed the first generation of 5-mm diameter regular platform (RP) Brånemark implants in 1988.[4] The implants were delivered in four lengths (6, 8, 10, and 12 mm). They were used as self-tapping and had no cervical smooth collar or marginal flange with threads reaching up to the marginal platform. Countersinking was not necessary, because the threads reached the marginal platform of the fixture. Countersinking in the standard surgical protocol was developed to allow for the seating of the implant head in the marginal bone cortex.

The indications and clinical results of the 5-mm diameter RP Brånemark implants had been reported in a number of clinical studies,[8–12] with a success rate varying between 82% and 96.6%.[13]

The purpose of this study was to report the clinical results obtained with 5-mm diameter RP implants. A secondary aim was to compare the clinical outcome to that of adjacently placed standard 3.75-mm fixtures in the same patients under the same operative conditions and included in the same prosthetic construction.

## MATERIALS AND METHODS

Sixty patients (32 male, 28 female; mean age, 54 yr; range, 24–81 yr) received a total of 97 5-mm diameter RP fixtures (Nobel Biocare AB, Gothenburg, Sweden) for the treatment of various forms of edentulism (Table 1). The patients were consecutively treated between February 1994 and November 1996. They were all systemically healthy at the time they entered the study. Ten of the patients were heavy smokers (more than 10 cigarettes per day).

The surgical placement of the implants was done according to the standard protocol recommended by Nobel Biocare AB. However, it was altered in cases of type 4 bone to increase primary implant stability. The standard protocol recommends the use of a 3.0-mm twist drill, a 4.3-mm pilot drill, and a 4.3-mm twist drill to the full length for the placement of a 5-mm diameter fixture. The altered protocol bypassed, in a few cases, the pilot drill and the 4.3-mm twist drill. In others, the 4.3-mm twist drill was used to half its length. Countersinking was not performed. Bone tapping was done when bone density at the implant site did not allow for direct placement of the implant. In all cases, the final torque used to stabilize the implants was recorded. In case of poor bone quality, the torque was set at 20 Ncm on the drilling equipment (DEC 500, Nobel Biocare) and progressively increased if the implant was blocked before reaching its final position. If the implant was close to its final position (less than 2 mm) and yet no blocking was reached at 20 Ncm, the manual wrench was used to drive the implant to its final position and the final torque was rated as 10 Ncm (two implant sites). Implant stability was a prerequisite to maintain the implant in place.

The majority of the patients had adequate bone volume to accommodate 5-mm diameter implants. However, in 11 patients, an augmentation procedure (sinus floor elevation or a monocortical inlay graft) was performed.

All implants were submerged for an average period of 4 to 6 months. Abutment connection was done according to standard protocol. A healing abutment was connected for 3 to 4 weeks. A proper abutment selection was done at this stage and placed at the recommended torque.

The prosthetic treatment consisted of freestanding fixed bridges in all cases except one in which the adjacent natural teeth were connected to one distally placed implant. In four cases, the implants were considered at risk because of a poor bone quality and low final torque during placement. A temporary full-resin fixed prosthesis was fabricated and placed for an evaluation period of 6 to 12 months. The prosthesis was then removed and the implants individually tested for stability, pain, or discomfort. After that, the final bridge was provided to the patient.

In 41 patients and 45 quadrants, 53 5-mm diameter implants were placed adjacent to 62 standard 3.75-

**TABLE 1. Patient Distribution According to Class of Edentulism (Kennedy's Classification)**

| Class | Number of Patients (N = 60) |
|---|---|
| I | 12 |
| II | 36 |
| III | 3 |
| IV | — |
| Single tooth | 5 |
| Total edentulism | 4 |

mm diameter fixtures, under the same surgical conditions using the standard protocol. They were mixed in the same prosthetic reconstruction and loaded under the same conditions. They serve as a reference group to evaluate the clinical performance and the marginal bone loss of the 5-mm diameter fixtures.

All patients were recalled every 6 to 12 months for a radiographic examination of marginal bone loss and a clinical evaluation of osseointegration, prosthetic stability, and possible complications.

Since the final prostheses were not routinely removed and the implants individually tested for stability unless there was a clinical or radiographic reason to suspect a loss of integration, the cases were classified in the survival category even when the clinical and radiographic signs were within normal range.[14,15]

### Radiographic Evaluation

The radiographic examination was done, at least, at three postoperative periods: at abutment connection, at 1-year post loading, and at the final examination. A minimum of a 2-year period post loading was set for the final evaluation of a case. A noncustomized paralleling device (XCP positioner, Rinn, Elgin, Illinois, USA) was used. The radiographs were considered for evaluation only when the threads on the mesial and distal sides of the implants were clearly discernible.[14] The reference point for the evaluation of bone loss of the standard 3.75-mm diameter implants was the edge between the conical and the cylindrical part of the implant head.[12] For the 5-mm diameter implants, the abutment implant connection was used as a reference point.

### Statistics

Implant cumulative survival rate (CSR) was evaluated using a life-table analysis based on all implants placed. All other statistical tests were based on the patient as the unit (i.e., not on prosthesis or on implants).

For comparison between type of jaw, the Mann-Whitney U-test was used. Changes over time between the matched groups were analyzed with the Wilcoxon signed rank test for paired analysis.

Nonparametric Spearman's rank correlation test was used in the correlation analysis with the relation illustrated with Pearson's correlation coefficient (r).

All significance tests were two-tailed and conducted at the 5% significance level.

**TABLE 2. Distribution of 5.0-mm Implants by Arch and Site**

| Site | Maxilla (n = 41) | Mandible (n = 56) |
|---|---|---|
| Incisor | — | — |
| Canine | — | — |
| Premolar | 5 | 3 |
| Molar | 36 | 53 |

## RESULTS

Sixty patients were consecutively treated. One patient was lost to follow-up, representing two implants. All others were checked at a minimum of 2 years post loading. Some patients missed the 2-year control visit but were checked at the 3-year recall visit. One patient exited the study at the 3-year visit because of severe renal failure.

Most patients had partial edentulism (see Table 1). Altogether 97 5-mm diameter implants were placed: 41 in the maxilla and 56 in the mandible. The majority of the implants were placed at molar sites (Table 2) and in soft bone (type 3 and type 4) (Table 3). Implant distribution according to length and location is shown in Table 4. The most frequently used length was 10 mm. Forty-nine patients had adequate bone volume to accommodate 81 5-mm diameter implants. Eleven patients needed augmentation procedures (10 sinus floor elevations and one monocortical inlay graft) and received 16 implants. Most of the implants (n = 70) had an insertion torque of 40 Ncm, even though 84 of the treated sites had bone quality 3 or 4. Bone tapping was done at only 20 sites.

A life table demonstrating the implant CSR of all 5-mm diameter implants is shown in Table 5. Only

**TABLE 3. Distribution of 5.0-mm Implants According to Bone Quality***

| | Bone Quality Type | | | |
|---|---|---|---|---|
| Jaw | 1 | 2 | 3 | 4 |
| Maxilla | | | | |
| Placed (n = 41) | — | — | 17 | 24 |
| Failed (n = 3) | | — | 0 | 3 |
| Mandible | | | | |
| Placed (n = 56) | | 13 | 36 | 7 |
| Failed | — | 0 | 0 | 0 |

*Classification of Lekholm and Zarb.

**TABLE 4. Distribution of 5-mm Implants According to Implant Length**

| Implant Length | Maxilla | Mandible |
|---|---|---|
| 6 mm | | |
| Placed (n = 6) | 1 | 5 |
| Failed (n = 0) | 0 | 0 |
| 8 mm | | |
| Placed (n = 23) | 13 | 10 |
| Failed (n = 1) | 1 | 0 |
| 10 mm | | |
| Placed (n = 35) | 17 | 18 |
| Failed (n = 2) | 2 | 0 |
| 12 mm | | |
| Placed (n = 33) | 10 | 23 |
| Failed (n = 0) | 0 | 0 |
| Total | | |
| Placed (n = 97) | 41 | 56 |
| Failed (n = 3) | 3 | 0 |

three implants failed, resulting in a CSR of 96.9%. The failures were all placed in a type 4 bone (see Table 3).

Two of the failures were placed in one patient along with a sinus floor elevation procedure. One of the implants was mobile at the time of abutment connection, and the other was connected to two periodontally involved teeth. Eighteen months post loading, the implant lost its osseointegration. It was removed with the severely compromised adjacent teeth. Three implants were placed to restore the quadrant. One year post loading they were all stable.

The other failure occurred in a posterior maxilla in which a depth of only 8 mm below the sinus was available for implant placement in type 4 bone. Poor initial stability was obtained in spite of an altered surgical protocol. At the time of abutment connection, the implant was found to be mobile and was removed. A sinus floor elevation and an autogenous, monocortical bone graft were done to improve the bone quality and quantity. Two 13 × 4-mm implants were successfully placed 6 months later in the newly regenerated bone.

Life tables demonstrating the implant CSR of the 5-mm diameter implants and the standard implant in the reference group are shown in Tables 6 and 7. One of 62 standard fixtures placed adjacent to 55 5-mm diameter fixtures was lost. However, this is not indicative of

**TABLE 5. Life Table: All 5-mm Diameter Implants**

| | Number of Implants | | | | |
|---|---|---|---|---|---|
| Time Period | Followed | Failed | Withdrawn | Time Not Passed | CSR (%) |
| Placement–loading | n = 97 | n = 2 | n = 0 | n = 0 | 97.9 |
| Maxillary | 41 | 2 | 0 | 0 | 95.1 |
| Mandibular | 56 | 0 | 0 | 0 | 100.0 |
| Loading–1 yr | n = 95 | n = 0 | n = 2 | n = 0 | 97.9 |
| Maxillary | 39 | 0 | 0 | 0 | 95.1 |
| Mandibular | 45 | 0 | 2 | 0 | 100.0 |
| 1–2 yr | n = 93 | n = 1 | n = 1 | n = 0 | 96.9 |
| Maxillary | 39 | 1 | 0 | 0 | 92.7 |
| Mandibular | 54 | 0 | 1 | 0 | 100.0 |
| 2–3 yr | n = 91 | n = 0 | n = 2 | n = 17 | 96.9 |
| Maxillary | 38 | 0 | 0 | 9 | 92.7 |
| Mandibular | 53 | 0 | 2 | 8 | 100.0 |
| 3–4 yr | n = 72 | n = 0 | n = 0 | n = 51 | 96.9 |
| Maxillary | 29 | 0 | 0 | 18 | 92.7 |
| Mandibular | 43 | 0 | 0 | 43 | 100.0 |
| 4–5 yr | n = 21 | n = 0 | n = 0 | n = 16 | 96.9 |
| Maxillary | 11 | 0 | 0 | 11 | 92.7 |
| Mandibular | 10 | 0 | 0 | 5 | 100.0 |
| 5 yr | n = 5 | n = 0 | — | — | — |
| Maxillary | 0 | 0 | — | — | — |
| Mandibular | 5 | 0 | — | — | — |

CSR = cumulative survival rate.

**TABLE 6. Life Table: Reference Group Implants, 5-mm Diameter**

| Treatment Period | Number of Implants | | | Time Not Passed | CSR (%) |
|---|---|---|---|---|---|
| | Followed | Failed | Withdrawn | | |
| Placement–loading | n = 53 | n = 1 | n = 0 | n = 0 | 98.1 |
| Maxillary | 30 | 1 | 0 | 0 | 96.7 |
| Mandibular | 23 | 0 | 0 | 0 | 100.0 |
| Loading–1 yr | n = 52 | n = 0 | n = 0 | n = 0 | 98.1 |
| Maxillary | 29 | 0 | 0 | 0 | 98.1 |
| Mandibular | 23 | 0 | 0 | 0 | 100.0 |
| 1–2 yr | n = 52 | n = 0 | n = 1 | n = 0 | 98.1 |
| Maxillary | 29 | 0 | 0 | 0 | 96.7 |
| Mandibular | 23 | 0 | 1 | 0 | 100.0 |
| 2–3 yr | n = 51 | n = 0 | n = 2 | n = 10 | 98.1 |
| Maxillary | 29 | 0 | 0 | 7 | 96.7 |
| Mandibular | 22 | 0 | 2 | 3 | 100.0 |
| 3–4 yr | n = 39 | n = 0 | n = 0 | n = 30 | 98.1 |
| Maxillary | 22 | 0 | 0 | 16 | 96.7 |
| Mandibular | 17 | 0 | 0 | 14 | 100.0 |
| 4–5 yr | n = 9 | n = 0 | n = 0 | n = 8 | 98.1 |
| Maxillary | 6 | 0 | 0 | 6 | 96.7 |
| Mandibular | 3 | 0 | 0 | 2 | 100.0 |
| 5 yr | n = 1 | n = 0 | — | — | — |
| Maxillary | 0 | — | — | — | — |
| Mandibular | 1 | 0 | — | — | — |

CSR = cumulative survival rate.

the overall failure rate among the patients treated, because only those implants that were placed in the same quadrants adjacent to a 5-mm diameter fixture were considered for analysis. Seven of 60 patients experienced implant losses in other quadrants, but they were not included in the present study. Nine of the 137 placed standard fixtures were lost, giving an overall failure rate of 6.5%.

## Radiographic Evaluation of Marginal Bone

Figure 1 shows the bone height level of all 5-mm diameter implants that had readable radiographs at the baseline and follow-up time points. Radiographs for 59 implants were readable at the baseline and at the 1- and 3-year follow-up examinations (Figure 2, *A*). The bone loss over the first year was 0.70 mm and over the 3-year period 0.81 mm. Similarly, readable radiographs for 18 implants with 4 years of follow-up showed a total bone loss of 0.95 mm (Figure 2, *B*). Figures 3, 4, 5, and 6 show examples of long-term radiographic follow-up.

Only five implants had bone loss exceeding 2 mm after 3 years of loading (Figure 7). There was no difference in bone loss between the maxilla and the mandible (Table 8). However, implants placed in type 4 bone sites showed significantly more bone loss (Table 9).

In 23 patients (26 prostheses) from the reference group, a matched-pair analysis found no significant difference between the bone loss at the 5-mm diameter fixture and the adjacent standard fixture (Table 10). The standard fixture showed a mean bone loss of 1.2 mm over 3 years. Four sites had a bone loss of more than 2 mm. Sites with full countersinking had significantly less bone loss than sites with minimal or no countersinking (Table 11).

## Complications

A few marginal soft-tissue irritations were handled with regular oral hygiene reinforcement measures and plaque control. No peri-implant infection occurred. Some prosthetic complications occurred, such as screw loosening and loss of the resin material in early cases in which resin bridges were used.

**TABLE 7. Life Table: Reference Group Implants, 3.75-mm Diameter**

| Treatment Period | Number of Implants | | | Time Not Passed | CSR (%) |
|---|---|---|---|---|---|
| | Followed | Failed | Withdrawn | | |
| Placement–loading | n = 62 | n = 1 | n = 0 | n = 0 | 98.4 |
| Maxillary | 32 | 0 | 0 | 0 | 100.0 |
| Mandibular | 30 | 1 | 0 | 0 | 96.7 |
| Loading–1 yr | n = 61 | n = 0 | n = 0 | n = 0 | 98.4 |
| Maxillary | 32 | 0 | 0 | 0 | 100.0 |
| Mandibular | 29 | 0 | 0 | 0 | 96.7 |
| 1–2 yr | n = 61 | n = 0 | n = 1 | n = 0 | 98.4 |
| Maxillary | 32 | 0 | 0 | 0 | 100.0 |
| Mandibular | 29 | 0 | 1 | 0 | 96.7 |
| 2–3 yr | n = 60 | n = 0 | n = 4 | n = 13 | 98.4 |
| Maxillary | 32 | 0 | 0 | 10 | 100.0 |
| Mandibular | 28 | 0 | 4 | 3 | 96.7 |
| 3–4 yr | n = 43 | n = 0 | n = 0 | n = 32 | 98.4 |
| Maxillary | 22 | 0 | 0 | 15 | 100.0 |
| Mandibular | 21 | 0 | 0 | 17 | 96.7 |
| 4–5 yr | n = 11 | n = 0 | n = 0 | n = 10 | 98.4 |
| Maxillary | 7 | 0 | 0 | 7 | 100.0 |
| Mandibular | 4 | 0 | 0 | 3 | 96.7 |
| 5 yr | n = 1 | n = 0 | — | — | — |
| Maxillary | 0 | 0 | — | — | — |
| Mandibular | 1 | 0 | — | — | — |

CSR = cumulative survival rate.

## DISCUSSION

The objective of this study was to determine treatment outcome following the use of 5-mm diameter RP implants loaded for 2 to 5 years and the effect of the modified implant geometry on the marginal bone resorption. The CSR was 96.9%. Only three implants failed. They were placed in maxillary molar sites with type 4 bone. The results are in accordance with Bahat and Handelsman, who reported an overall 2.3% failure rate for the 5-mm RP implants.[9]

The mean bone resorption was 0.70 mm after 1 year, which compares favorably with the results reported by Renouard and colleagues.[11] After 3 years of loading, the bone loss amounted to 0.81 mm. This means that bone loss occurred mainly during the first year in function and remained stable in subsequent years. Three maxillary implants and two mandibular implants had lost more than 2 mm of bone during 3 years post loading but with no evidence of soft-tissue irritation or peri-implant infection. Implants placed in type 4 bone showed significantly higher bone loss (see Table 9). No difference in resorption rate could be found between the maxillary and the mandibular implants or between the various lengths of implant.

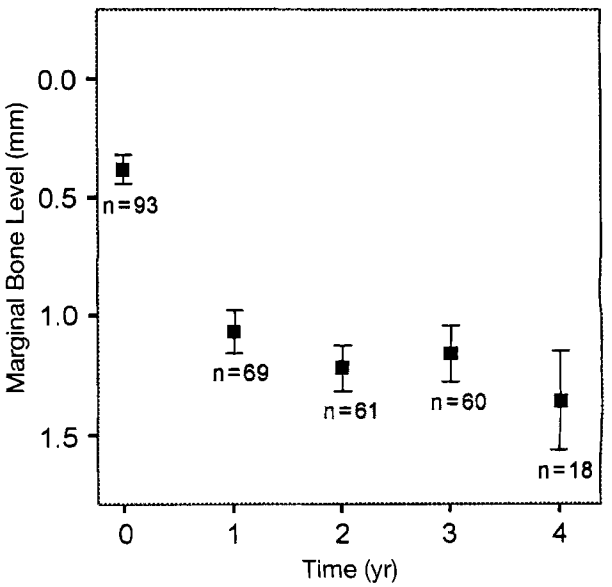


**Figure 1.** Radiographic evaluation of bone levels of 5-mm diameter implants at the 0- to 4-year examination time points.

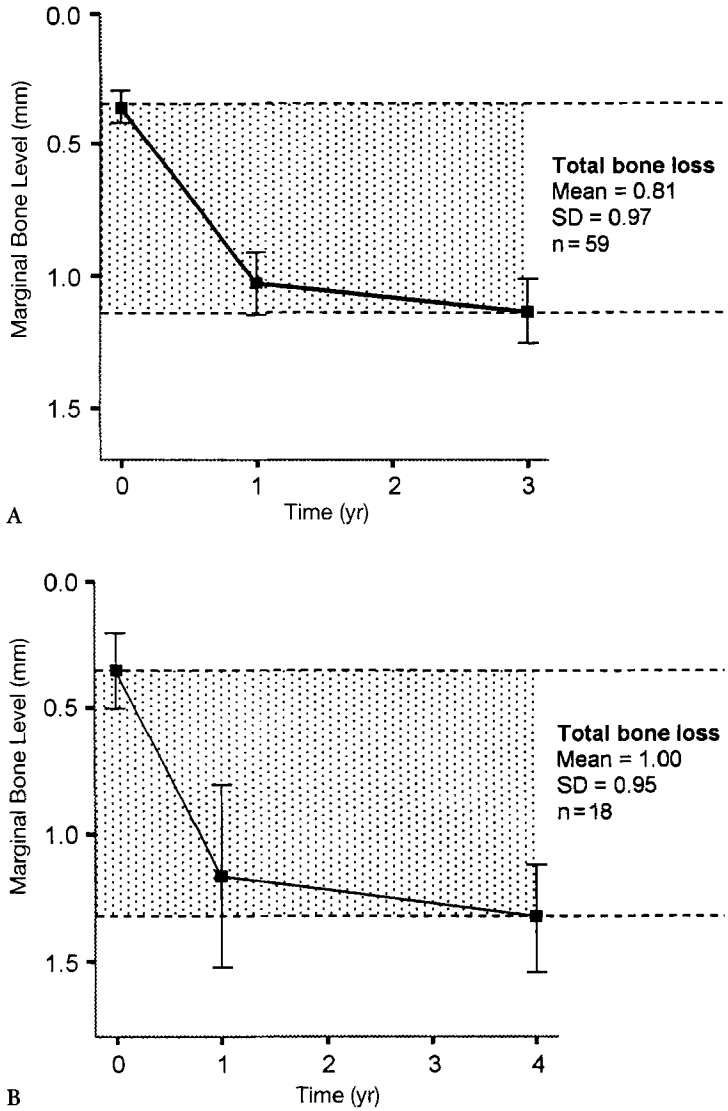


**Figure 2.** Radiographic evaluation of bone loss: *A*, year 1 to year 3; *B*, year 1 to year 4.

In a subpopulation of the present study, the reference group, it was possible to compare bone loss with that of adjacent standard 3.75-mm diameter implants included in the same prosthetic construction. No difference was found. Hence, changing the configuration of the implant by removing the smooth marginal collar did not affect the marginal bone resorption. In an experimental study in dogs, Abrahamsson and colleagues found bone resorption for three differently designed implants to be similar.[16]

Implant stability has been defined as a prerequisite for the establishment of osseointegration.[17] How firmly should the implant be anchored at the time of insertion for the process of osseointegration to occur and remain functional after loading? In the present investigation, 15 of the 97 implants were finally seated at 20 Ncm or less, yet only 1 of these implants ultimately failed. This indicates that stability, but not necessarily a high insertion torque, is a sufficient condition for implant long-term survival, provided that proper criteria for insertion technique and time allowed for osseointegration have been met.

The vast majority of implants in the present series (i.e., 89/97, 92%) were placed in the molar area. Sixty percent of these were placed in the mandible and 40% in the maxilla. None of the mandibular implants were lost, whereas three of the maxillary implants failed. The CSR was 96.9% after 5 years, although 31% of these implants were placed in type 4 bone. These results conflict with those of other reports[12] that describe implants

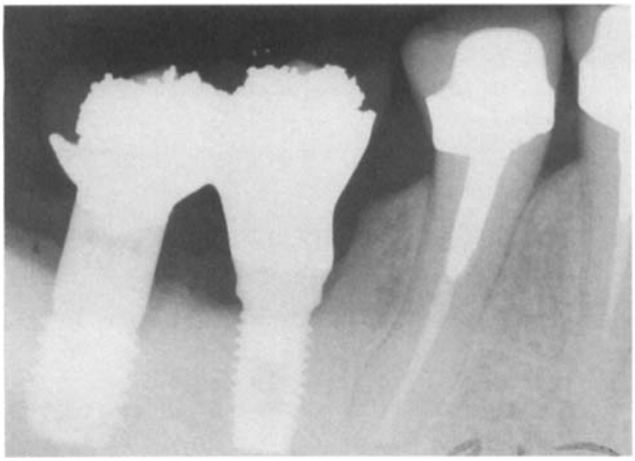

**Figure 3.** Two implants (8.5 × 4 and 5 × 6 mm RP) replaced two missing molars. Radiograph taken 5 years post loading. No difference in the marginal bone behavior is seen between the two differently designed fixtures placed side by side and loaded under the same conditions.

that were placed in the posterior mandible to be more at risk than those placed in the corresponding area of the maxilla because of their monocortical anchorage. Unloaded monocortically anchored implants were found to have less removal torque values than bicortically anchored implants in experimental animals, and the untraumatized apical periosteum responded more favorably to surgical implant placement than the coronal periosteum deprived of its full vascular supply post surgery.[18] In the present investigation, all the implants placed in the posterior mandible and loaded for 2 to 5 years were successful. It can only be speculated that the lack of bicortical anchorage in the present study was compensated for by an anchorage to the lateral cortical walls when 5.0-mm diameter implants were used.[19] No difference in survival rate was found between the standard fixture and the 5.0-mm diameter implants placed side by side.

Bone quality has been considered to be one of the most critical factors of success when machined surface implants are used.[20] Yet, the success rate varied between 50% and 94% in a score of published studies.[20–27] Barrachina and co-workers obtained a failure index of 36.4% in poor bone quality and did not find an improvement of the success rate by using implants of larger diameter.[27] In the present study the failure rate in type 4 bone amounted to 9.7%. Differences might be attributable to the subjective evaluation of diagnosing type 4 bone or to the surgical handling of the implant site.[26] The prerequisites for improving the success rate in the posterior maxilla include proper treatment planning, appropriate healing time, and altered surgical pro-

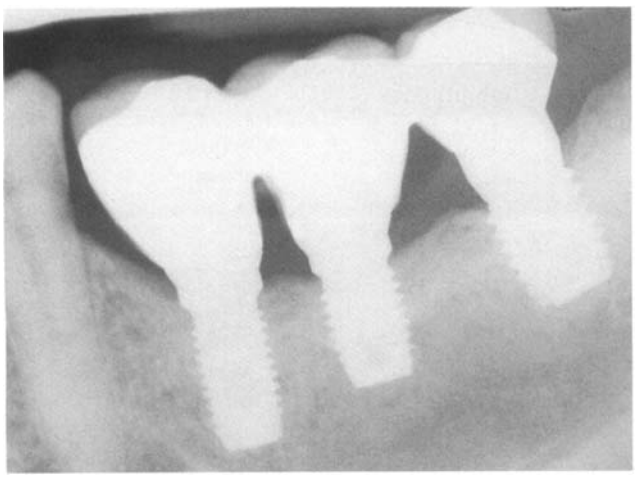

**Figure 4.** Three short fixtures replacing missing molars in the right mandible with limited residual bone above the dental alveolar nerve, 52 months post loading.

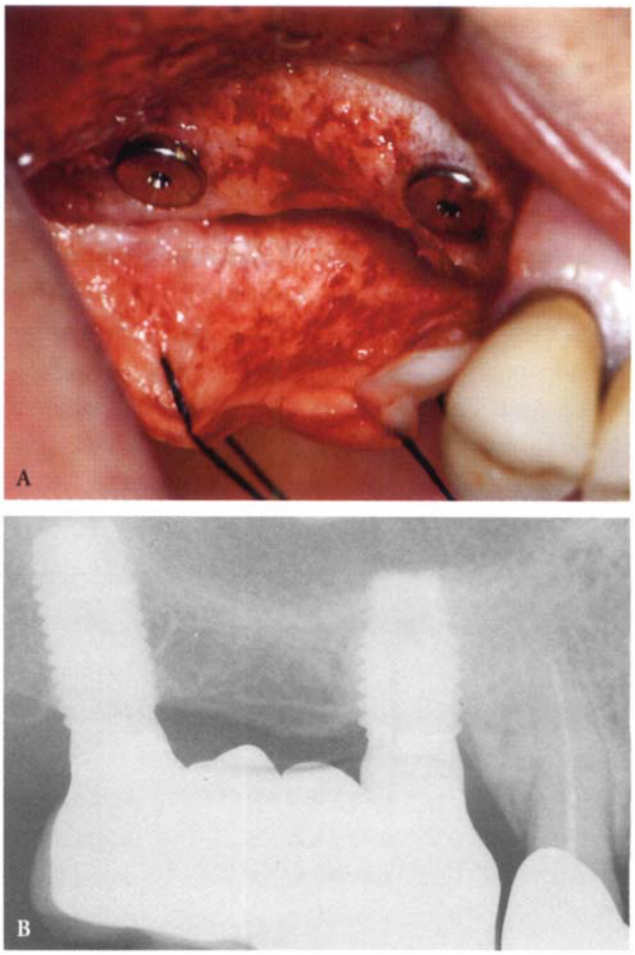


**Figure 5.** *A*, Peroperative view of two 5-mm diameter implants replacing missing molars in the maxilla. *B*, Radiograph taken 4 years post loading. A 5 × 8 and 5 × 10 mm RP fixture replaced missing maxillary molars.

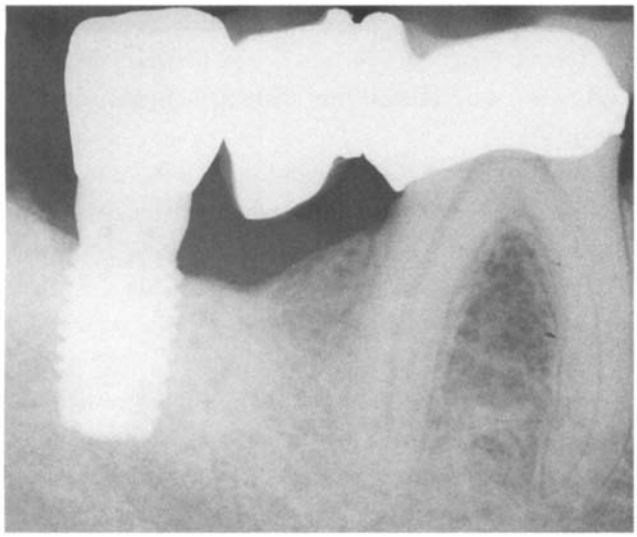

Figure 6. A 5 × 8 mm RP fixture replacing the mandibular left second molar connected to the adjacent first molar by a semi-precision attachment. Radiograph taken 2 years post loading.

tocol as defined by Bahat.[26] Congruency of the implant to the surgically prepared site enhances bone contact and primary stability of the implant. This becomes critical in bone of soft quality. Also, in the present study, tapping was never done at sites with type 4 bone. One of the failed implants was placed in low-density bone where primary stability could barely be reached in spite of an altered surgical approach and delicate handling of the surgical site. In the other 29 sites classified as type 4 quality, primary stability could be obtained with a proper surgical approach. The other two failures in the present study might be attributable to early loading following sinus floor elevation or to improper treatment planning resulting in unfavorable loading and, ultimately, loss of a previously integrated implant.

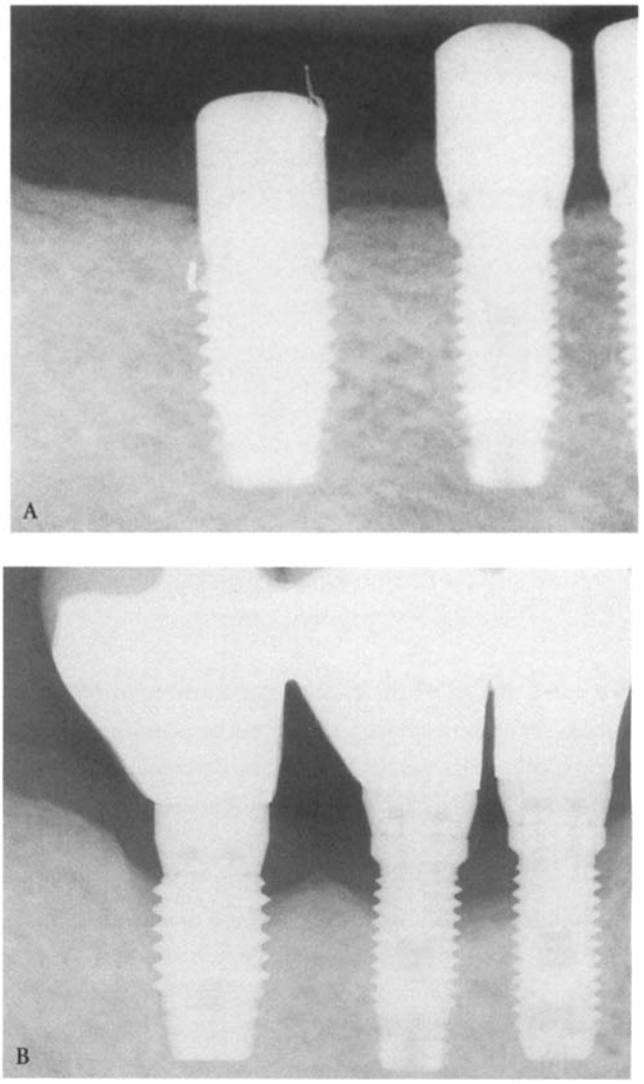


Figure 7. *A*, A 5 × 10 mm and two 3.75-mm fixtures replacing missing left mandibular molars. Radiograph taken at abutment connection. *B*, Radiograph taken 3 years post loading. Bone loss that occurred 3 months after abutment connection has remained stable over the observation period with no clinical signs of infection or soft-tissue inflammation.

**TABLE 8. Marginal Bone Loss at 5.0-mm Diameter Implants According to Jaw Site**

| Time Period (yr) | Bone Loss (mm) in Jaw Site | | | Difference between Jaws (mm) | *p*-Value |
|---|---|---|---|---|---|
| | All Mean ± SD (n) | Maxilla Mean ± SD (n) | Mandible Mean ± SD (n) | | |
| All fixtures | | | | | |
| 0–1 | 0.70 ± 0.72 (66) | 0.97 ± 0.87 (26) | 0.53 ± 0.56 (40) | 0.44 | — |
| 0–2 | 0.75 ± 0.77 (58) | 0.91 ± 0.88 (26) | 0.63 ± 0.65 (32) | 0.28 | — |
| 0–3 | 0.81 ± 0.97 (59) | 1.05 ± 1.00 (21) | 0.67 ± 0.93 (38) | 0.38 | — |
| All patients | | | | | |
| 0–1 | 0.73 ± 0.65 (43) | 0.89 ± 0.74 (17) | 0.62 ± 0.56 (26) | 0.27 | .208 |
| 0–2 | 0.77 ± 0.75 (37) | 0.89 ± 0.81 (19) | 0.65 ± 0.68 (18) | 0.24 | .378 |
| 0–3 | 0.83 ± 1.01 (36) | 0.96 ± 0.82 (12) | 0.76 ± 1.10 (24) | 0.20 | .261 |

**TABLE 9. Marginal Bone Loss at 5.0-mm Diameter Implants According to Bone Quality**

| Time Period (yr) | Bone Loss (mm) in Bone Quality Type 2 Mean ± SD (n) | 3 Mean ± SD (n) | 4 Mean ± SD (n) | Difference Between Types 2 + 3 and 4 (mm) | *p*-Value |
|---|---|---|---|---|---|
| All fixtures | | | | | |
| 0–1 | 0.76 ± 0.73 (9) | 0.49 ± 0.56 (36) | 1.04 ± 0.85 (21) | | — |
| 0–2 | 0.93 ± 0.69 (7) | 0.50 ± 0.66 (32) | 1.11 ± 0.83 (19) | | — |
| 0–3 | 0.68 ± 0.77 (9) | 0.50 ± 0.54 (31) | 1.36 ± 1.33 (19) | | — |
| All patients | | | | | |
| 0–1 | 0.83 ± 0.73 (8) | 0.48 ± 0.61 (19) | 1.03 ± 0.58 (13) | –0.45 | .014 |
| 0–2 | 1.00 ± 0.73 (6) | 0.34 ± 0.54 (18) | 1.16 ± 0.68 (13) | –0.66 | .010 |
| 0–3 | 0.78 ± 0.84 (7) | 0.45 ± 0.53 (18) | 1.47 ± 1.39 (11) | –0.93 | .013 |

Several retrospective and prospective studies have reported that short implants fail more frequently than longer implants and more so in the maxilla, where the cortical bone is thin.[22,24,26,28] A failure rate of 10.7% for 7-mm implants placed in the maxilla was reported by van Steenberghe and colleagues.[22] According to Friberg and co-workers,[24] 6.9% of maxillary and 3.1% of mandibular 7-mm implants fail, and more precisely, they fail when placed in severely resorbed maxillae and poor quality bone. Yet a high percentage of them are integrated and can be used efficiently to support a restoration. In the present series, 29 of 97 5-mm diameter implants placed had a length of 8 mm or less (see Table 4). Only one 8-mm implant failed. No 6-mm implant failed. According to these figures, the short 5-mm diameter implants do not have a less favorable prognosis than the longer implants and can be used predictably when limited bone volume is available above the dental alveolar nerve or below the maxillary sinus. The prognosis, however, remains guarded when bone of low density is present.

**TABLE 10. Matched-Pair Analysis of Marginal Bone Loss***

| Implant Diameter | Bone Loss (mm) over 3 Years (Mean ± SD) | Difference (mm) between Fixture Types | *p*-Value |
|---|---|---|---|
| All prostheses (n = 26) | | | |
| 5.00 mm | 0.99 ± 1.14 | –0.16 | — |
| 3.75 mm | 1.15 ± 0.97 | | |
| All patients (n = 23) | | | |
| 5.00 mm | 1.07 ± 1.18 | –0.13 | .223 |
| 3.75 mm | 1.20 ± 0.95 | | |

*Only paired fixtures included.

**TABLE 11. Marginal Bone Loss and Use of Countersink in 3.75-mm Diameter Fixtures: Reference Group**

| Time Period (yr) | Bone Loss (mm) per CS Method Full Mean ± SD (n) | Minimal or No Mean ± SD (n) | Difference between CS Methods | *p*-Value |
|---|---|---|---|---|
| 0–1 | 0.97 ± 0.79 (34) | 2.05 ± 1.11 (10) | –1.08 | .004 |
| 0–2 | 0.96 ± 0.75 (27) | 1.85 ± 1.30 (11) | –0.89 | .039 |
| 0–3 | 0.90 ± 0.84 (26) | 1.92 ± 1.37 (8) | –1.02 | .044 |

CS = countersink.

## CONCLUSION

The present study describes successful outcome following the use of 5-mm diameter RP implants in the posterior maxilla and mandible. There was no significant difference between bone loss at the 5-mm diameter fixture and that at adjacently placed standard 3.75-mm fixtures.

## ACKNOWLEDGMENTS

The authors thank Kerstin Gröndahl, DDS, PhD, Department of Radiology, University of Gothenburg, Sweden, for performing the radiographic evaluation, Inger Wendelhag, PhD, Clinical Research, Nobel Biocare AB, Gothenburg, Sweden, for performing the statistical analyses, and Åsa Taylor, DDS, Clinical Research, Nobel Biocare AB, Gothenburg, Sweden, for data compilations and creation of tables.

## REFERENCES

1. Adell R, Lekholm U, Rockler B, Brånemark P-I. A 15-year study of osseointegrated implants in the treatment of the edentulous jaw. Int J Oral Surg 1981; 10:387–416.
2. Johnson K. A study of the dimensional changes occurring in the maxilla following tooth extraction. Aust Dent J 1969; 14:241–244.
3. Lekovic V, Kenney EB, Weinlander M, et al. A bone regenerative approach to alveolar ridge maintenance following tooth extraction. Report of 10 cases. J Periodontol 1997; 68: 563–570.
4. Langer B, Langer L, Herrmann I, Jörneus L. The wide fixture: a solution for special bone situations and a rescue for the compromised implant. Part 1. Int J Oral Maxillofac Implants 1993; 4:400–408.
5. Sullivan DY. Wide implant for wide teeth. Dent Econ 1994; 84:82–83.
6. Becker W, Becker BE. Replacement of maxillary and mandibular molars with single endosseous implant restorations: a retrospective study. J Prosthet Dent 1995; 74:51–55.
7. Jansen CE, Graves SL, Siddiqui AA, Beaty KD. Les implants de large diamètre. Resultats prothétiques à 2 ans. Implant 1995; 1:303–313.
8. Davarpanah M, Martinez H, Tecucianu JF, Etienne D, Askari N, Kebir M. Les implants de large diamètre. Implant 1995; 1:289–300.
9. Bahat O, Handelsman M. Use of wide implants and double implants in the posterior jaw: a clinical report. Int J Oral Maxillofac Implants 1996; 11:379–386.
10. Aparicio C, Orozco P. Use of 5-mm diameter implants: Periotest values related to a clinical and radiographic evaluation. Clin Oral Implants Res 1998; 9:398–406.
11. Renouard F, Arnoux JP, Sarment D. Five-mm-diameter implants without smooth surface collar: report on 98 consecutive placements. Int J Oral Maxillofac Implants 1999; 14:101–107.
12. Ivanoff CJ, Gröndahl K, Sennerby L, Bergström C, Lekholm U. Influence of variations in implant diameters: a 3- to 5-year retrospective clinical report. Int J Oral Maxillofac Implants 1999; 14:173–180.
13. Davarpanah M, Martinez H, Kebir M, Etienne D, Tecucianu JF. Wide-diameter implants: new concepts. Int J Periodontics Restorative Dent 2001; 21:149–159.
14. Gröndahl K, Ekestubbe A, Gröndahl HG. Technical considerations for intraoral radiography in postoperative examination. Nobel Biocare Global Forum 1996; 10:10–11.
15. Gröndahl K, Lekholm U. The predictive value of radiographic diagnosis of implant instability. Int J Oral Maxillofac Implants 1997; 12:59–64.
16. Abrahamsson I, Berglundh T, Wennström J, Lindhe J. The peri-implant hard and soft tissues at different implant systems: a comparative study in the dog. Clin Oral Implants Res 1996; 7:212–219.
17. Albrektsson T, Zarb G, Worchington P, Eriksson RA. The long-term efficacy of currently used dental implants: a review and proposed criteria of success. Int J Oral Maxillofac Implants 1986; 1:11–25.
18. Ivanoff CJ, Sennerby L, Lekholm U. Influence of mono- and bicortical anchorage on the integration of titanium implants: a study in the rabbit tibia. Int J Oral Maxillofac Surg 1996; 25:229–235.
19. Ivanoff CJ, Sennerby L, Johansson CB, Rangert B, Lekholm U. Influence of implant diameters on the integration of screw implants: an experimental study in rabbits. Int J Oral Maxillofac Implants 1997; 26:141–148.
20. Jaffin RA, Berman CL. The excessive loss of Brånemark fixtures in type IV bone: a 5-year analysis. J Periodontol 1991; 62:2–4.
21. Engquist B, Bergendal T, Kallus T, Linden UA. Retrospective multicenter evaluation of osseointegrated implants supporting overdentures. Int J Oral Maxillofac Implants 1988; 3:129–134.
22. van Steenberghe D, Lekholm U, Bolender C, et al. Applicability of osseointegerated oral implants in the rehabilitation of partial edentulism: A prospective multicenter study on 558 fixtures. Int J Oral Maxillofac Implants 1990; 5:272–281.
23. Jemt T, Lekholm U, Adell R. Osseointegrated implants in the treatment of partially edentulous patients: a preliminary study on 876 consecutively placed fixtures. Int J Oral Maxillofac Implants 1989; 4:211–217.
24. Friberg B, Jemt T, Lekholm U. Early failures in 4641 consecutively placed Brånemark dental implants: a study from stage 1 surgery to the connection of the completed prostheses. Int J Oral Maxillofac Implants 1991; 6:142–146.
25. Bahat O. Osseointegrated implants in the maxillary tuberosity: report in 45 consecutive patients. Int J Oral Maxillofac Implants 1992; 7:459–467.
26. Bahat O. Treatment planning and placement of implants in the posterior maxillae: report of 732 consecutive Nobelpharma implants. Int J Oral Maxillofac Implants 1993; 8:151–161.
27. Barrachina Mataix M, Calvo Azpeitia G, Calvo Azpeitia J. Implantes de 5 milimetres: a proposito de 84 implantes. Avances en Odontoestomatologie 1994; 10:633–640.
28. Minsk L, Polson A, Weisgold A, etal. Outcome failures of endosseous implants from a clinical training center. Compend Contin Educ Dent 1996; 17:848–856.