Brånemark System Implants in the Posterior Maxilla: Clinical Study of 660 Implants Followed for 5 to 12 Years

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Originally, osseointegrated implants were used principally in the anterior region of the mandible and maxilla, but use in the posterior segments of both arches is common today. The long-term success of implants placed in the posterior region, an environment of stronger forces and poorer bone quality, has not been thoroughly reviewed. The purpose of the present study was to review a large series of Brånemark System implants placed in posterior maxillae (660 implants in 202 patients) that have been restored with fixed partial ceramometal restorations and followed for as long as 12 years after loading. Thirteen of the implants (2%) failed between placement and loading, 12 implants were lost between loading and the end of the first year, and 10 failed thereafter, 2 as the result of fractures at 3 and 4 years. The cumulative success rate is therefore 94.4% at 5 to 6 years and 93.4% after 10 years. The quality and quantity of bone appeared to have little influence on the success rate. Surgical techniques are particularly important to the success of osseointegrated implants placed in the posterior maxilla. With careful surgical planning and execution, a success rate of approximately 95% at 5 years can be achieved. (Int J Oral Maxillofac Implants 2000;15:646–653)

Key words: *dental implants, posterior maxilla, osseointegration*

Treatment with osseointegrated implants continues to evolve, although many questions remain unanswered. Initially, implants were used principally in the anterior segments of the edentulous maxilla and mandible. Subsequently, endosseous implant use was extended to include partial edentulism, particularly in the posterior arches. However, the long-term success of implants placed in the posterior regions has been less extensively documented. Factors such as length of the implants, bicortical fixation, and extended healing periods seem to contribute to a good long-term success rate. Because of the lack of well-documented clinical data, it is currently impossible to determine whether one particular implant microdesign is superior to another. The purpose of the present study was to review a large series of Brånemark System implants (Nobel Biocare, Göteborg, Sweden) placed in the posterior maxilla and restored with fixed partial ceramometal reconstructions, with follow-up for as long as 12 years. The results are analyzed according to implant diameter, length, and position, as well as the quality and quantity of the bone, using life table analysis methods.

MATERIALS AND METHODS

Patients

Between November 1986 and December 1994, 202 patients received a total of 660 posterior maxillary implants. Anterior implants placed for complete maxillary reconstruction are not included here. The patients' ages ranged from 18 to 81 years, with the largest number (72%) between the ages of 51 and 80 years (Table 1). No implants were left unloaded as "sleepers." The follow-up period extended for as long as 12 years (Table 2).

Surgical Techniques

The technique of implant placement in bone of compromised quality and quantity has been described elsewhere.[1] The quality and quantity of bone at each site was assessed on the basis of reformatted computed tomographic (CT) scans. The

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Table 1 Patient Data

	No. of patients
Male	78
Female	124
Age (y)	
18 to 30	1
31 to 40	16
41 to 50	34
51 to 60	70
61 to 70	53
71 to 80	27
81+	1

Table 2 Follow-Up Status of 203 Patients and 660 Implants

	Patients			Implants			
	Followed	Withdrawn	TNE*	Followed	Failed	Withdrawn	TNE*
Placement	202	1	—	660	13	1	—
Load to 1 y	192	11	—	646	12	34	—
1 to 2 y	187	15	1	600	3	8	2
2 to 3 y	164	19	20	587	2	13	70
3 to 4 y	144	23	36	502	1	8	51
4 to 5 y	121	32	50	442	4	33	42

*Time not yet elapsed.

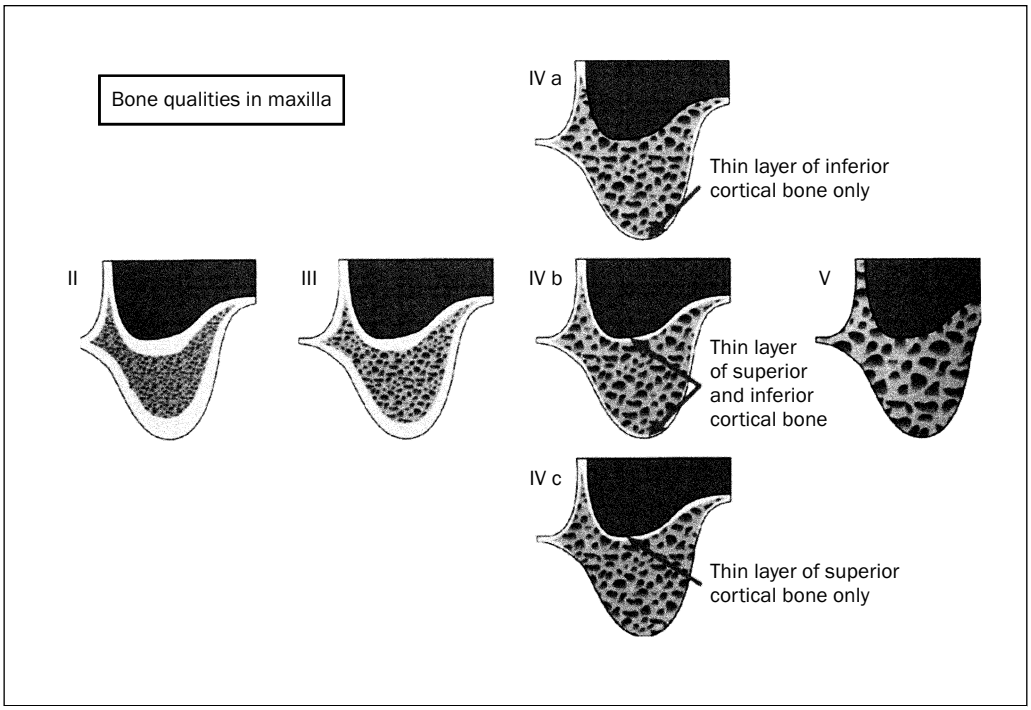


Fig 1 Modification (Bahat, 1998) of bone classification system of Lekholm and Zarb.[2] Type IV has been divided into 3 subtypes: inferior cortical bone only (a), inferior and superior cortical bone (b), and superior cortical bone only (c). Type V (no cortical bone superiorly or inferiorly) has been added.

Lekholm and Zarb system of bone classification[2] was modified to include additional variations (Fig 1). Preparation of sites was guided by the objectives of minimizing the osteotomy diameter while maintaining optimal implant direction. Other basic procedural concepts include:

- Identification of all deviations from the normal anatomy
- Treatment of all pathologic processes
- Presurgical planning of the final restoration (including all reconstructive procedures) with a clear idea of the desired restorative outcome
- Placement of sufficient implants to withstand the high occlusal forces in the posterior maxilla
- Use of wider (≥ 4 mm) implants rather than the 3.75-mm standard design when possible[3]
- Retention of some teeth or tooth roots, at least temporarily, when possible to support the fixed partial provisional restoration, thus avoiding transmucosal loading of the implants

If there was any deviation from the protocol, or if the implant did not arrest at full length under a force of 40 Ncm, the implant was removed immediately.

Bone regeneration with an exclusion membrane was used for 7 implants in 4 patients because of exposed threads. None of these implants failed. To improve esthetics and orofacial support, grafts of autogenous bone obtained from the osteotomies with surgical filters were placed at 7 implant sites in 3 patients. If a greater volume was needed, Osteograft N100 (CeraMed Dental Products, Lakewood, CO) was added to the bone coagulum. No sinus, veneer, or onlay grafts with corticocancellous bone were used. Six implants in 5 patients were left positioned supracrestally because the vertical distance to the sinus floor was not identical in length to any of the commercially available implants. In general, however, an attempt was made to position the top of the implant only slightly (< 0.5 mm) below the bony crest to reduce transmucosal loading. The minimal submergence of the implant preserves the thin cortical bone and will increase access for oral hygiene while protecting the soft tissues. Thirty implants were angulated 10 degrees lingually, 4 were angulated 10 degrees mesially, and 642 were angulated 20 degrees mesially. In most patients (n = 139), the number of implants placed was the same as the number of teeth lost. In 14 patients, there were more implants than lost teeth, and in 36, there were fewer.

Patients were seen weekly or biweekly for the first 2 months after implant placement and then monthly for 4 months. Soft tissue changes such as bleeding or suppuration were evaluated by circular probing during regular appointments. Any pressure exerted by the temporary prosthesis was immediately relieved. When soft tissue irritation persisted in spite of good oral hygiene, radiographs were obtained to assess the fit of the cover screws, and any loose screws were tightened. If these potential causes of the problem were not present, a flap was raised to rule out foreign body entrapment and other pathologic processes. At 6 months, the implants were uncovered, and a provisional restoration was placed for 3 to 8 months. During that time, implant stability, soft tissue health, occlusal relationships, and crown emergence profiles were monitored every 2 months.

After the final restoration had been placed, an attempt was made to see the patients at least every 3 months (implant surgeon) and every 6 months (restoring dentist). All patients were instructed in the use of a maxillary nightguard, which usually was fabricated to allow bilateral canine rise and wide canine-to-canine protrusive guidance in occlusion. At each visit, the patient was examined for gingival health, adequate oral hygiene, occlusal relationships, implant stability, integrity and stability of the prosthesis, and areas of excessive wear. If negative changes were found, the superstructure was removed and the integration of each implant was evaluated. The integrity and tightness of the prosthetic screws was ascertained; the prosthesis was then repositioned. If pocket depth exceeded 4 mm after second-stage surgery, flap surgery was performed, with the flaps being positioned apically, internally thinned, and sutured to improve access for maintenance.

Radiologic Follow-up

A defined protocol for radiography was followed. Intraoperative periapical radiographs were obtained using the long-cone technique whenever variations were detected between the oral radiographs and CT scans or when implants were placed near a vital structure such as the maxillary sinus or a dental unit. A periapical radiograph was obtained routinely at the conclusion of implant placement before the patient was dismissed. During the healing period, a follow-up periapical radiograph was obtained any time the patient reported unexpected pain or discomfort or if soft tissue health worsened. Radiographs also were obtained after second-stage surgery, after prosthesis placement, and every 1 to 2 years thereafter. The images were evaluated for periimplant radiolucency and vertical bone loss.

For further evaluation of implant stability, 55 paired periapical radiographs were obtained using the parallel long-cone technique at abutment connection and follow-up examinations. The average time between the 2 examinations was 86.2 months. An independent investigator digitized these radiographs at 300 dpi on a flatbed scanner connected to a transparency adapter (Hewlett Packard Scan Jet 3c/t). To avoid dependence, a randomization table was used to select 1 implant in each posterior segment for measurement, and NIH Image-based software (Scion Corp, Bethesda, MD) was used to measure crestal bone levels in millimeters (11.81 pixels/mm). With the measurement tool, a vertical line was drawn from the top of the implant cylinder to the first bone to contact the implant. Mesial and distal measurements were made from each randomly chosen implant. The mesial and distal measurements were then combined, and changes in crestal bone levels were evaluated using NIH Image (Minitab, College Station, PA). The paired *t* test for related samples was used to evaluate the significance of any changes.

Definition of Success

In general, implant success was defined as suggested by Albrektsson et al.[4] That is, the implants had to be surrounded by compact or trabecular bone without radiolucency and with bone loss of no more than 2 mm on calibrated radiographs at the most recent follow-up in comparison with the condition at the time

Table 3 Failures According to Type and Length of Implants

Implant type and length (mm)	No. placed	No. lost
Standard (3.75 mm)		
7	49	10
8.5	3	0
10	118	5*
13	109	5*
15	86	3
18	23	0
20	8	0
4 mm		
7	35	2
10	66	3
13	59	5
15	30	0
18	3	0
5 mm		
6	8	0
8	8	1
10	11	1
12	6	0
Self-tapping (3.75 mm)		
10	13	0
13	7	0
15	11	0
18	3	0
Self-tapping conical (3.75 mm)		
10	2	0
13	2	0

*One of these failures was the result of implant fracture.

Table 4 Cumulative Success Rate of Posterior Maxillary Implants

Time (n)	Failed (total)	WD (total)	TNE (total)	CSR (%)
Place/load (660)	13 (13)	1 (1)	0	98.0
Load/1 yr (646)	12 (25)	34 (35)	0	96.2
1 to 2 yr (600)	3 (28)	8 (43)	2 (2)	95.7
2 to 3 yr (587)	2 (30)	13 (56)	70 (72)	95.4
3 to 4 yr (502)	1 (31)	8 (64)	51 (123)	95.2
4 to 5 yr (442)	4 (35)	33 (97)	42 (165)	94.4

WD = withdrawn; TNE = time not elapsed; CSR = cumulative success rate.

of loading. Although the 2-dimensional nature of these images and the difficulty of standardization detract from the utility of radiographs as a means of monitoring implant stability,[5] they are a widely accepted follow-up technique. In contrast to the protocol suggested by earlier authors, the restorations were not routinely removed to test the implants for mobility after loading, as this measure would be difficult with cemented restorations. Although quality-of-life evaluations were not done, patients were asked about pain and chewing function.

RESULTS

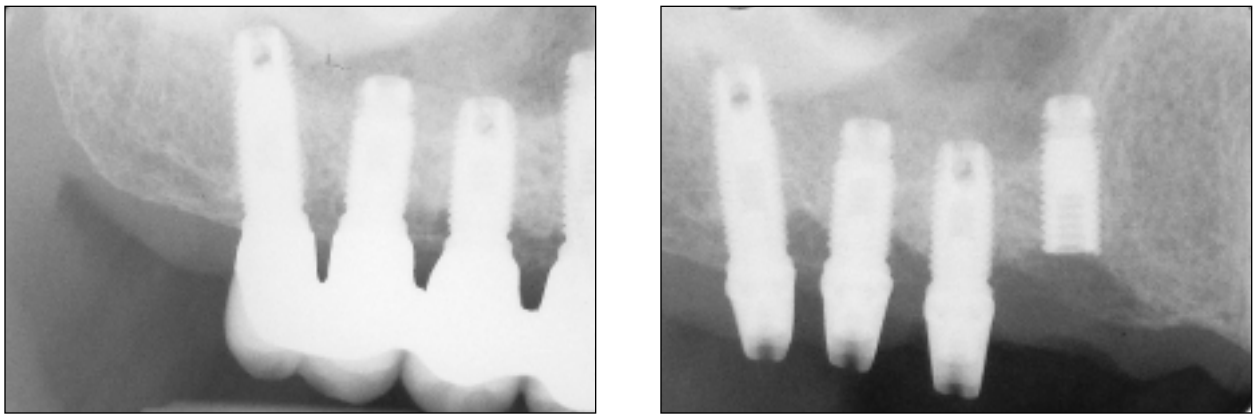
Of the 660 implants placed, 13 (2%) failed between placement and loading. Twelve more of the 647 evaluable implants (3%) were lost between loading and the end of the first year, 3 implants failed between 1 and 2 years after placement, and 7 failed thereafter, 2 as the result of fracture (Table 3). Thus, 71% of the failures occurred within a year of implant placement. A life table analysis is presented in Table 4 showing a 93% cumulative success rate at 10 years.

As noted, 2 of the failures (5% of all failures; < 1% of the total number of implants placed) were the result of implant fracture (Figs 2a and 2b), one during the third year and the other during the fourth. Both implants were of the standard 3.75-mm type; one was 10 mm long and the other was 13 mm, and they had been placed at the sites of the maxillary right first premolar and the left second premolar, respectively. Two other fractures, of a first molar and a premolar implant, occurred at 8 years. These 2 failures were not included in the calculations of the 5-year success rate.

As expected, the longer implants were more likely to survive than the shorter ones. Among the 3.75-mm implants, the non-fracture failure rates for implants of 7 and 8.5 mm, 10 to 15 mm, and 18 and 20 mm were 17%, 5%, and 0%, respectively. However, the failure rate of the 7-mm-long implants was similar to that of longer ones when the 7-mm implant was not the most distal in a series. The failure rate of wider implants (4-mm and 5-mm) was 5%, versus 7% for the 3.75-mm implants. All of the 38 self-tapping implants survived (Table 3).

The quality of bone did not have a clear influence on the success rate, although the lowest failure rate was seen in Type IV bone (Table 5). The quantity of bone likewise did not appear to be significant, with failure being seen in 6% of the implants placed in bone graded 1 through 3 versus 7% of those placed in bone graded 4 (Table 5). Although the failure rate was high in bone graded 5 for quality or quantity, it is difficult to interpret the numbers, since so few implants were placed in such bone.

Implants placed in the molar area had essentially the same failure rate as those placed in the premolar region (Table 6). At 5 years, the cumulative success rate for the premolar implants, including the fractured implants, was 95.2%, and the rate in the molar area was 93.1%.



Figs 2a and 2b Radiographs of a patient who experienced an implant fracture. *(Left)* Radiograph of patient 2 years after loading. *(Right)* Radiograph shows fracture of mesial implant despite optimal fit clinically and radiographically.

Table 5 Failures According to Bone Quality and Quantity

Grade	Quality (% failed)	Quantity (% failed)
I	0	1/23 (4.0)
II	8/78 (10.3)	16/285 (5.6)*
III	18/345 (5.2)*	9/202 (4.5)
IV	6/194 (3.1)	6/104 (5.8)
V	1/3 (33.0)†	1/6 (17.0)
Other or unknown	2/40	2/40

*Two of these failures were the result of implant fracture.
†Coarse trabeculation and absence of cortical bone were observed.

Table 6 Failure Rate According to Site of Placement

Site	No. placed	No. (%) failed
R and L first premolars	204	6 (2.9)
R and L second premolars	196	12 (6.1)*
R and L first molars	151	6 (4.0)
R and L second molars	58	7 (12.1)
R and L third molars	51	4 (7.8)

*Two of these failures were the result of implant fracture.

Table 7 Crestal Bone Loss Associated with 55 Implants over 86.2 Months

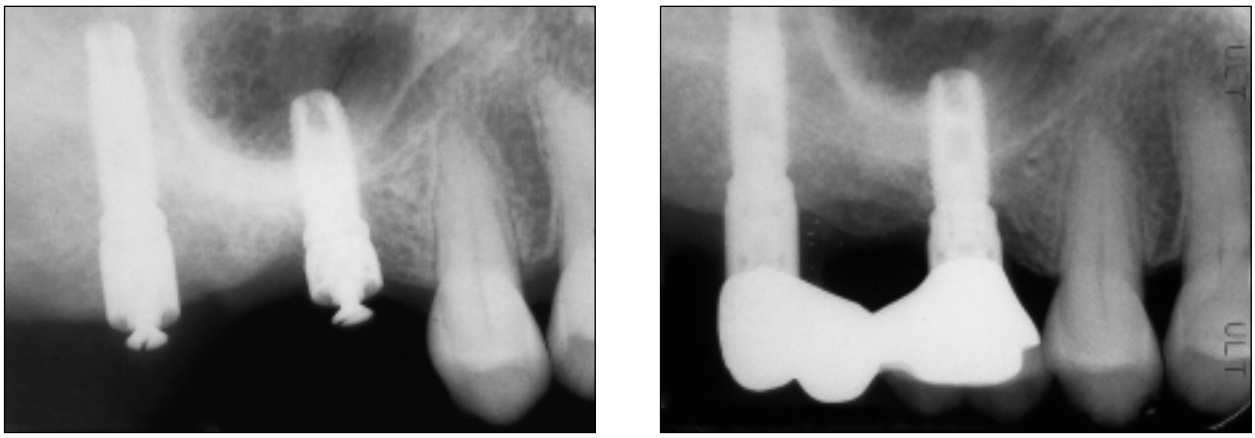
	Mean	SD	SEM
Distal + mesial, examination 1	1.31	0.73	0.06
Distal + mesial, examination 2	1.95	0.74	0.07
Difference	–0.64*	0.91	0.08

**t* value 7.39; *P* = .000.

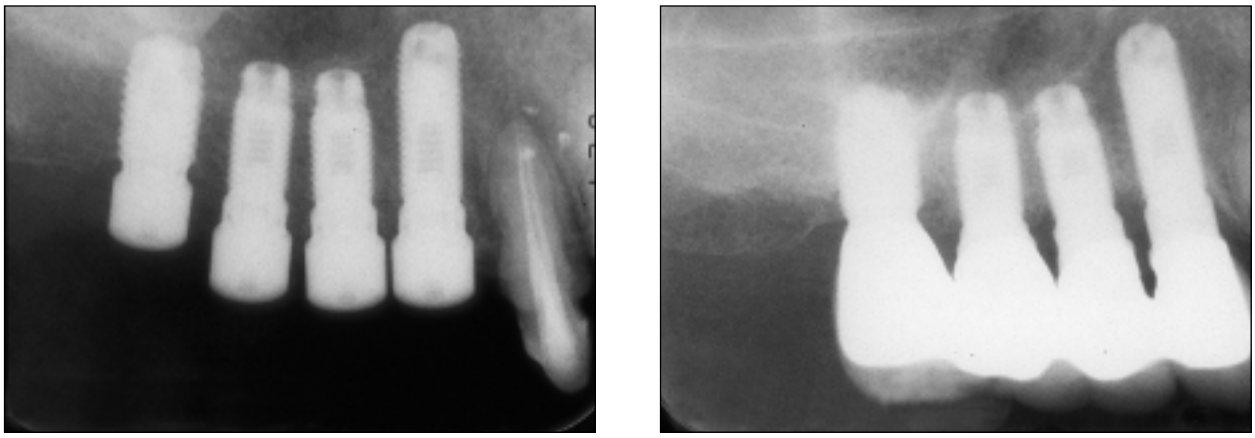
The data suggest that some patients have a greater propensity to lose implants. For example, among the 30 patients who lost implants, 3 lost 2 implants, 1 lost 3, and 1 lost 5. None of these 14 failures was the result of implant fracture. Together, these 5 patients with multiple failures lost 58% of their posterior implants and accounted for 36% of the total implant losses. Moreover, 5 of the patients who lost 1 or more posterior implants also lost an anterior implant.

There was a slight tendency toward an increase in gingival pocket depth with increasing time after surgery. However, nearly all of the patients were instructed repeatedly in oral hygiene, and few had pocket depths exceeding 4 mm. Approximately 5% of the patients with ceramometal restorations demonstrated gingival recession, usually buccally, over 5 to 12 years. This change is not infrequent in patients who have a thin periodontium. The gingiva around the adjacent teeth usually shows various degrees of recession as well. Further evaluation of the long-term stability of the gingival margin in patients with ceramometal reconstructions is advisable.

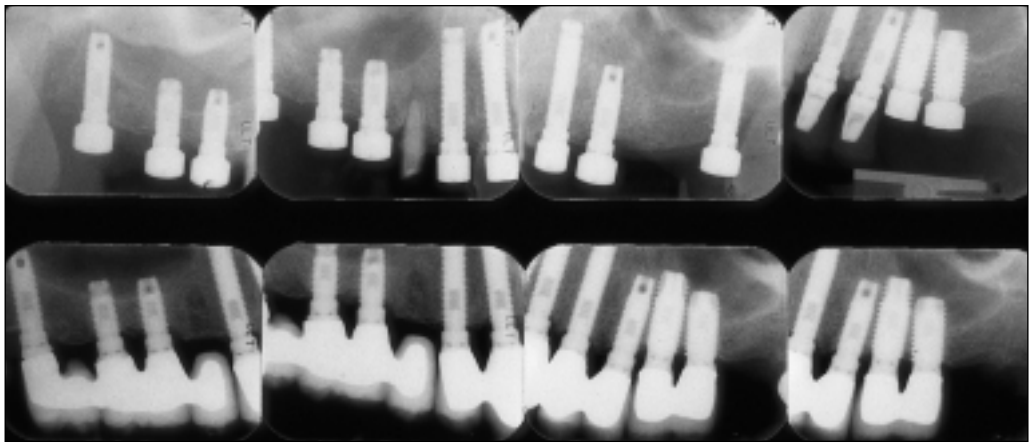
Analysis of the paired radiographs showed an average loss of 0.64 mm of crestal bone (Table 7, Figs 3 to 5). Although this loss is statistically significant ($P = .000$), it was not considered clinically significant. It represents less than 1.5 mm bone loss after 1 year of loading, the value suggested as acceptable by Albrektsson and associates.[4] It is slightly greater than the change reported from a comparison of AstraTech (Lexington, MA) and Brånemark System implants after 1 year of loading (0.22 mm and 0.03 mm, respectively).[6] However, such comparisons are complicated by the considerable variability inherent in measuring bone levels from nonstandardized radiographs and differences in the landmarks and measurement methods used.



Figs 3a and 3b Long-term stability of bone after placement of multiple implants in the posterior maxilla. (*Left*) Radiograph obtained at uncovering of short and long implants in molar and second molar positions, skipping a descended sinus. Note placement of implant in tuberosity area. (*Right*) The 10-year follow-up radiograph shows no bone loss on implants in function. (Restoration by Dr Lawrence Brucker, Beverly Hills, California.)



Figs 4a and 4b Use of implants of various lengths and widths to support the occlusal load. (*Left*) Multiple implants, ranging from 13 mm to 5 × 8 mm in the right posterior sextant, shown at uncovering. (*Right*) No bone loss is apparent at 5 years. (Restoration by Dr Robert Rifkin, Beverly Hills, California.)



Figs 5a and 5b Multiple implants placed in bone of poor quality in the posterior and anterior sextant, seen at (*above*) second-stage surgery and (*below*) 7-year follow-up. The increased number of implants has helped support the occlusal load, and there has been minimal bone loss. (Restoration by Dr Lawrence Brucker.)

DISCUSSION

Several recent compilations of long-term outcomes of various types of endosseous implants have been published. Some papers provide data on success rates by site, whereas others simply distinguish maxillary from mandibular implants; several provide few or no data on success/survival rates according to location.

Buchs and colleagues[7] reported site-specific data from a multicenter trial of threaded HA-coated implants, including 416 placed in the posterior maxillae. The 5-year success rate (life table analysis) was said to be 96.6%. Block and Kent reviewed the experience with hydroxyapatite-coated implants followed for as long as 8 years.[8] The cumulative success rate in the posterior maxilla was 93.7% in patients treated early in the series and 97.7% in later patients. Stultz and associates[9] placed 2,371 Integral implants in the maxilla. Only 6% of the patients were followed for the entire 6-year period of the report. Of the implants placed, 146 failed; 29% of these had been placed in the posterior maxilla. Implant length appeared to be more important to a successful outcome than implant diameter.

Jemt and Lekholm[10] described 701 Brånemark System implants placed in edentulous maxillae with 5 years of follow-up. The cumulative failure rate was 28.7% for implants placed in severely resorbed bone, versus 7.9% for those placed in bone of better quality. In patients who required bone grafting before implant placement, the cumulative failure rate was virtually the same as that in the patients with an intermediate degree of resorption. With the same type of implant, a success rate of 95.2% was reported with an average follow-up of 30.3 months for 732 implants placed in the posterior maxilla.[1] The success rate was slightly lower in Type IV bone, in the molar region, and with 7-mm-long implants. An area that is considered to be a particularly poor site for implant placement is the maxillary tuberosity. Nevertheless, several authors have described acceptable success rates.[11–13]

Five groups of authors provided data on implants in various sites in the maxilla. Fugazzotto and colleagues[14] placed 2,023 IMZ implants in 974 patients, with a cumulative success rate of 92.9% in the maxilla. In the series described by Haas and associates,[15] the Kaplan-Meier success rate for 167 IMZ implants placed in the posterior maxilla was 96.9% after 80 months. An unusual finding was a steady decline in the success rate with continued follow-up, rather than a concentration of the failures in the first few years. Babbush and Shimura,[16] who placed 1,059 IMZ implants at all sites, found that shorter implants (8 mm) and narrower implants (3.3 mm) had higher failure rates regardless of their position. One implant was lost by fracture. Lazzara and coworkers,[17] who placed 529 implants in posterior maxillae, reported a success rate of 93.8%, although only a few implants had been followed for a full 5 years.

The factors that determine the long-term success or failure of osseointegrated implants remain unclear, despite many years of research, but certain tentative conclusions can be drawn from published reports. Some patient characteristics (although not age or sex) and behavior, implant design and microstructure, and surgical planning and technique may all be important.[18] Implants placed in bone of poor quality have been considered less likely to integrate[19] and more likely to fail after loading.[20] The same is true of implants placed in patients who smoke.[21] Nevertheless, even significantly resorbed bone can maintain implants. Poor oral hygiene practice may be a common precursor to implant loss.[22,23] Bicortical fixation may improve osseointegration and reduce bone resorption,[24,25] whereas subcrestal placement appears to reduce the success rate.[26] Minimization of site preparation and precision of the restoration appear to improve the potential for success.[1]

A critical aspect of the technique, especially in the posterior region, is the placement of a sufficient number of implants to support the occlusal load in a way that avoids nonaxial loading. The average surface area of the roots of a maxillary first molar is 533 mm^2, whereas that of a threaded 18-mm Nobel Biocare implant is only 256 mm^2 (R. Sullivan, personal communication). Moreover, the occlusal table of a molar crown is approximately 96 mm^2,[27] whereas that of a 3.75-mm implant is just 44 mm^2. The disparity in anchorage ability is magnified in poorer-quality bone. A one-to-one substitution of implants for teeth is thus likely to lead to overloading. Support for this hypothesis can be seen in the present series, in which 29% of the patients who lost implants had received fewer implants than there were missing teeth. It may be possible to reduce the failure rate of posterior implants through judicious use of wide or double implants.[2,28–30]

The use of wide and double implants posteriorly is one aspect of a general rule of successful implant placement. Each site must be treated individually and an implant of the appropriate type, length, and diameter selected.

SUMMARY

It appears that a success rate of approximately 95% at 5 years is a reasonable expectation for endosseous implants placed in the posterior maxilla. This figure is

encouraging, as the posterior jaw region has the greatest occlusal need as well as the greatest surgical difficulty. Precise treatment planning and manipulation are critical to success. More studies are required to determine whether the success rate can be improved even further and to gain a better understanding of the reasons for success and failure.

ACKNOWLEDGMENT

William Becker, DDS, MS, Tucson, AZ, performed the computer analysis of the changes in crestal bone after implant loading.

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