Clinical Evaluation of Short, Machined-Surface Implants Followed for 12 to 92 Months

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Purpose: *Bone resorption following tooth loss often limits the quantity of bone available for implant placement. The purpose of the present study was to evaluate the clinical outcome of 10-mm or shorter machined-surface implants when used exclusively in the treatment of various forms of edentulism.* ***Materials and Methods:*** *Two hundred sixty-nine screw-type Brånemark System implants (Nobel Biocare), 10 mm or shorter, were placed in 111 consecutively treated patients. Of the total, 88.8% were placed in the mandible and 11.2% were placed in the maxilla; 95.2% were used to treat partially edentulous situations, including single-tooth losses, of which 96.6% were in the premolar and molar regions. The patients were followed for periods of 12 to 92 months.* ***Results:*** *Of the 269 placed implants, 12 were lost. The overall survival rate was 95.5%. Bone quality 2 and 3 (Lekholm-Zarb classification of 1985) was found in 88.8% of the treated sites. There was no statistical difference in the survival rate of the 10-mm implants when compared to the shorter series ($P > .05$) or between the various implant diameters. The mean marginal bone loss was 0.71 ± 0.65 mm.* ***Discussion:*** *The failure rate of 4.5% compares favorably with that of implants of different shape, surface characteristics, and length. Bone quality appeared to be the critical factor in implant survival, rather than bone quantity, in this patient series.* ***Conclusions:*** *This study supports the survival of short, machined-surface implants when used for the treatment of partial edentulism in bone of good quality.* INT J ORAL MAXILLOFAC IMPLANTS 2003;18:894–901

Key words: *clinical outcomes, dental implants, edentulism, osseointegration, surface properties*

The high clinical success rate of endosseous implants in the treatment of different forms of edentulism has been well documented. Several short- and long-term studies have clearly demonstrated the efficacy of implants in the replacement of missing teeth.[1–3] Bone resorption following tooth loss often limits the quantity of bone available for implant placement. When resorption occurs in areas of poor bone quality and strong masticatory forces, treatment options may include augmentation procedures or the exclusive use of short implants. Clinical strategies to improve the success rate of implants placed in sites with reduced bone quantity have included the use of large-diameter implants,[4] rough-surfaced implants for greater bone-to-implant contact,[5] or simply a greater number of implants.

It is difficult to ascertain precisely the number of implants that is needed to meet a patient's functional demands. It is directly related to several anatomic and functional factors that may greatly influence the outcome of therapy.[6] The number is often overestimated to meet the possible changes in function and later manifestation of parafunctional habits that may jeopardize osseointegration or cause metal fatigue and biomechanical failure. The treatment strategy often favors providing the patient with the maximum amount of supporting units within anatomic limitations.

Several factors may influence the outcome of therapy and therefore the decision-making process in treatment planning. Most of them have yet to be quantified and mathematically related. Functional factors include the magnitude of the occlusal forces in function and parafunction and the point of application of these forces relative to the long axes of the implants. Prosthetic factors include the crown-to-implant ratio and the dimension and morphology of the prosthetic crown. Anatomic and occlusal factors are related to bone quality and quantity, the

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Fig 1a Replacement of missing mandibular molars by 3 short implants (4 × 8.5 mm, 4 × 7 mm, and 5 × 6 mm). Radiograph taken after 2 years of loading.

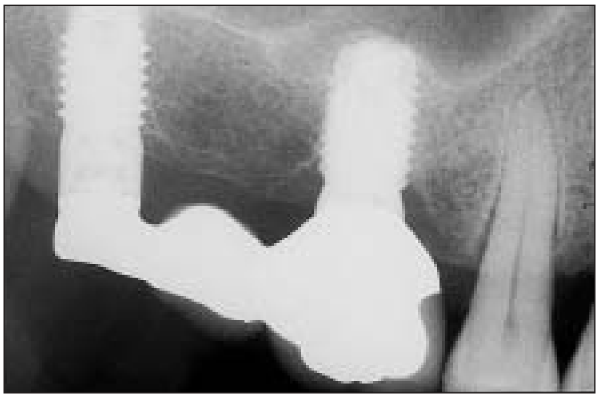

Fig 1b Replacement of missing maxillary molars by 2 short implants (both 5 × 8 mm). Radiograph taken 6 years after loading.

mesiodistal length of the edentulous space, and the maxillomandibular jaw relationship. Factors related to the hardware include the configuration and size of the implants and their surface characteristics. However, more comparative studies are needed to determine the influence of these parameters on the outcome of therapy.

Technical factors may also influence the treatment results. Variations in bone site preparation will affect the initial stability of the implant and its congruency with the host bed. Better results can be achieved when the surgical placement of the implant is under greater control.[7] All of these factors will dictate the number, size, and distribution of the implants in the arch and provide an estimate of the implants needed, although the final decision is often based on clinical perception rather than objective figures.

The purpose of the present study was to determine the long-term fate of 10-mm or shorter machined-surface implants when placed in anatomic sites of limited bone height.

MATERIALS AND METHODS

A total of 111 patients—45 men and 66 women with a mean age of 53.6 years (range, 22 to 80)—were consecutively treated and followed beginning in June 1994. All had limited bone height, mostly in the posterior parts of their jaws, and required implant-supported fixed restorations to treat various stages of edentulism according to the Applegate-Kennedy classification.[8] All presented with bone loss that required the exclusive placement of 10-mm or shorter implants (Figs 1a to 1c). Each was reluctant to undergo advanced surgical treatment and accepted short implants as the only alternative for the replacement of their missing teeth by fixed restorations. However, in the posterior maxilla, where bone height in the subsinus area was less than 8 mm and width of the crest did not permit the placement of a wide-diameter implant, patients were advised of the greater failure rate associated with 7-mm regular-platform (RP) implants, and therapeutic decisions were made accordingly. This clinical situation represented an exclusion criterion.

Fig 1c Replacement of a missing mandibular first molar by a 5.5 × 8.5-mm wide-platform implant. Radiograph taken 2 years after loading.

Pretreatment records included a medical history, a full-mouth long-cone series of periapical radiographs, and a panoramic radiograph. Computerized tomography (CT) was prescribed when vital anatomic structures could not be determined precisely with conventional radiographs. A complete dental and periodontal evaluation was done during planning of the treatment. Patients with periodontal disease were treated and controlled before implant treatment was started.

A total of 269 machined-surface implants (Nobel Biocare, Göteborg, Sweden), all 10 mm or shorter, were used in this study. Patients who were treated during the same period with short implants mixed

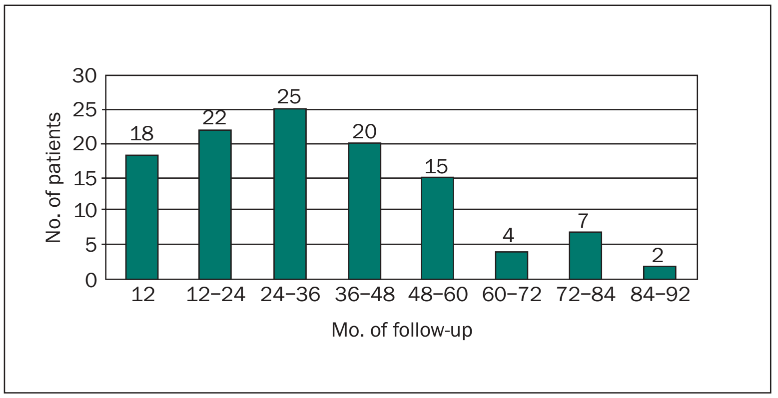

Fig 2 Distribution of patients according to months of follow-up. Two patients were operated on at different times in different quadrants, making the total number of observation periods 113.

Table 1 Loss of Patients to Follow-up, Postoperative Interval

Year	No. of patients	No. of implants	Severe illness or death
1	2	9	—
2	3	8	—
3	6	21	3
4	2	2	1
5	0	0	—
6	2	6	—
7	0	0	—
8	0	0	—

with longer implants in the same prosthetic restoration were excluded from the study. Two hundred fifty-six implants were placed following a standard surgical protocol (2-stage surgical approach) and 13 were placed using a 1-stage procedure. In the latter situation, implants were directly connected to a healing abutment at the time of placement. Surgical site preparation, particularly the drilling sequence, was altered when poor bone quality was encountered to ensure greater primary stability and better congruency between the implant and the surrounding bone. After a healing period of 4 months in the mandible and 4 to 6 months in the maxilla (healing duration was based on bone quality), abutments were connected. The prosthetic treatment was initiated following soft tissue healing. Porcelain-fused-to-metal crowns were fabricated for all partially edentulous patients; 78 restorations were screw-retained and 33 were cemented.

The patients were followed for a period ranging from 12 to 92 months (Fig 2). They were seen every 6 to 12 months for examination and maintenance. Fifteen patients, accounting for 46 implants, were lost to follow-up at different postoperative intervals (Table 1). None of the restorations was retrieved for evaluation of the outcome of the individual implant. The implant was considered as surviving when no clinical or radiographic signs of failure could be detected.

Radiographic Evaluation

Periapical radiographs were obtained using a long-cone technique and a noncustomized paralleling device (XCP positioner; Rinn, Elgin, IL) at abutment connection and at the last follow-up examination and were analyzed for peri-implant bone loss. The radiographs were considered for analysis when the threads on the mesial and distal side of the implants were distinctly visible. The reference point for evaluation of bone loss was the edge between the conical and the cylindric parts of the implant head. For the 5-mm RP implant, the abutment-implant connection was used as reference point. All measurements were made under a magnifying loupe (×8) using a Digimatic caliper (Mitutoyo, Tokyo, Japan) by a calibrated operator.

Statistical Analysis

The chi-square test and contingency tables were used for statistical analysis. Implants of different diameters and lengths were compared. All significance tests were 2-tailed and conducted at the 95% significance level.

RESULTS

Patient distribution according to months of follow-up is reported in Fig 2; 81.4% of patients had at least 24 months of postoperative loading at the time the study was concluded.

Implant distribution according to type of edentulism is reported in Table 2: 12.3% of implants were used for single-tooth replacement, 4.8% for completely edentulous patients, and 82.9% for partially edentulous situations. (Three patients presented with 2 different types of edentulism in the same or opposite jaw.) The total number of clinical situations treated was 114. Implant distribution by arch and site is shown in Table 3: 88.8% of implants were placed in the mandible and 11.2% were placed in the maxilla; 96.6% were placed in premolar and molar sites and only 3.4% replaced incisors or canines.

Distribution of the implants according to length and diameter is shown in Table 4. Five different lengths (6, 7, 8, 8.5, and 10 mm) and 4 different diameters (3.3, 3.75, 4, and 5 mm) were used. One hundred fifty-three implants were 10 mm long, 46 were 8.5 mm, 27 were 8 mm, 27 were 7 mm, and 16 were 6 mm long.

Implant distribution according to bone quality (Lekholm-Zarb classification and Applegate-Kennedy classification) is reported in Table 5.[8,9] Type 1 bone was found in 1.1% of the mandibular sites treated, type 2 bone in 29.4% of the mandibular sites treated, type 3 in 59.5% of the treated sites in both jaws, and type 4 in 10% of the treated sites in both jaws. The final tightening force at which the implants were finally seated is reported in Table 6; 93.25% of the implants were placed at 40 Ncm. No implant was left in place if it was found to be unstable at the time of placement.

Table 2 Implant Distribution and No. of Failed Implants According to the Type of Edentulism

Type of edentulism*	No. of patients	Implants Placed	Implants Failed
Class I	35	110	7
Class II	41	95	2
Class III	7	18	0
Complete	3	13	0
Single-tooth	28	33	3
Total	114	269	12

*Applegate-Kennedy classification.
Note: Three patients presented with 2 types of edentulism.

Table 3 Implant Distribution and No. of Failures by Arch and Site

	No. (%) placed					
	Incisors	Canines	Premolars	Molars	Total	No. failed
Maxilla	1 (0.4)	0	4 (1.5)	25 (9.3)	30 (11.2)	2
Mandible	5 (1.9)	3 (1.1)	46 (17.1)	185 (68.7)	239 (88.8)	10
No. placed	6 (2.3)	3 (1.1)	50 (18.6)	210 (78)	269 (100)	—
No. failed	0	0	1	11	—	12

Table 4 Distribution of Implants According to Length and Diameter (n = 269)

Implant diameter	Implant length				
	6 mm	7 mm	8 mm	8.5 mm	10 mm
3.3 mm					
Maxilla					
Mandible					1 (0.4%)
3.75 mm					
Maxilla				1 (0.4%)	2 (0.7%)
Mandible		14 (5.2%)		25 (9.3%)	67 (24.9%)
4 mm					
Maxilla					5 (1.9%)
Mandible		10 (3.7%)		12 (4.5%)	23 (8.5%)
5 mm					
Maxilla RP			7 (2.6%)		4 (1.5%)
Maxilla WP				1 (0.4%)	10 (3.7%)
Mandible RP	16 (5.9%)		20 (7.4%)	1 (0.4%)	27 (10%)
Mandible WP		3 (1.1%)		6 (2.2%)	14 (5.2%)
Total	16	27	27	46	153

RP = regular-platform; WP = wide-platform.

Of the 269 implants placed, 12 were lost (Table 7). Five were 7 mm long, one was 8 mm long, two were 8.5 mm long, and four were 10 mm long. Two were placed in type 2 bone, 8 in type 3 bone, and 2 in type 4 bone. Two implants were lost because of early loading, 3 were lost in a patient suffering from osteoporosis, and 1 fractured in a severe bruxer, whose adjacent 7-mm-long implant connected to a 2-unit prosthesis was apparently lost because of functional overload. Two implants were placed in very dense bone and failed as a result of overheating of the site at the time of preparation, and in 3 sites, the cause of failure could not be identified. Six implants were lost at the time of abutment connection, and 6 were lost at various postoperative intervals.

Four late-failing implants were lost 1 to 3 years after loading. In one case (1 implant), the cause could not be identified. In one case totaling 3 implants, the patient suffered from severe osteoporosis as a consequence of renal failure. Altogether, 8 implants were successfully replaced by implants of equal or shorter length. The initial survival rate was 95.5%. The final survival rate following replacement of the 8 initially lost implants was 98.5%. When the survival rate of 10-mm implants was compared to that of the shorter implants, no statistical difference was found ($P > .05$) (Table 8). With respect to the different implant diameters, no statistical difference was found between the survival rate of 3.75-mm, 4-mm, and 5-mm implants ($P > .05$) (Table 8).

Bone loss was measured on the mesial and distal side of each implant using the edge between the conical and the cylindric part of the implant as a reference point.

The mean marginal bone loss over the observation period was 0.71 ± 0.65 mm; 8.9% of the sites lost more than 1.5 mm, ranging from 1.60 to 3.18 mm.

Table 5 Implant Distribution According to Bone Quality

	Bone quality*			
Location	1	2	3	4
Maxilla	0	0	21 (7.80%)	9 (3.34%)
Mandible	3 (1.10%)	79 (29.36%)	139 (51.70%)	18 (6.70%)

*According to Lekholm and Zarb.

DISCUSSION

The present study suggests the predictability of short, machined-surface implants used predominantly in the

Table 6 Implant Distribution According to Final Tightening Force

	Tightening force				
Location	10 Ncm	20 Ncm	30 Ncm	40 Ncm	45 Ncm
Maxilla	1 (0.40%)	5 (1.85%)	5 (1.85%)	19 (7.00%)	—
Mandible	1 (0.40%)	—	1 (0.40%)	232 (86.25%)	5 (1.85%)

Table 7 Distribution of Failed and Replaced Implants

Site	Bone quality*	Type of edentulism†	Implant dimensions (mm)	Torque (Ncm)	Dimensions of replacement implants (mm)	Torque (Ncm)	Failed (n = 12)	Replaced (n = 8)	Cause of failure
36	2	I	3.75 × 10	40	5 × 7 (WP)	40	2	2	Fracture
37	2		3.75 × 7	40	5 × 6 (RP)	40			
37	3	Single	5 × 10 (WP)	40	5 × 10 (WP)	40	2	2	Unknown
47	3		5 × 10 (WP)	40	5 × 10 (WP)	40			
47	3	Single	5 × 8.5 (WP)	40	—	—	1	—	Unknown
26	4	I	5 × 10 (WP)	40	5 × 8.5 (WP)		2	2	Early loading
27	4		5 × 8 (RP)	40	5 × 7 (WP)				
35	3	I	4 × 7	40	—	—	3	—	Osteoporosis
36	3		4 × 7	40	—	—			
37	3		5 × 8.5 (RP)	40	—	—			
46	3	II	3.75 × 7		4 × 7	40	2	2	Dense bone
47	3		3.75 × 7		5 × 6 (RP)	45			overheating

*Lekholm and Zarb classification.
†Applegate-Kennedy classification.
Tooth numbers: 35 = Mandibular left second premolar; 36 = mandibular left first molar; 37 = mandibular left second molar; 46 = mandibular right first molar; 47 = mandibular right second molar; 26 = maxillary left first molar; 27 = maxillary left second molar.
WP = wide platform; RP = regular platform.

treatment of posterior partial edentulism. An overall initial failure rate of 4.5% was found, which compares favorably with other reports in which implants of greater length were used.[10,11] However, it is important to determine the precise clinical situations in which the implants were used and the inclusion/exclusion criteria that were selected. Only 11.2% of the implants in the present series were placed in the maxilla, predominantly in the posterior segments. Of the 30 maxillary implants placed, 9 were 8.5 mm or shorter and 21 were 10 mm long (Table 4). Also, 73.3% of the implants were of the large-diameter series. In situations of limited bone height (less than 8 mm), limited bone width (less than 7 mm), and poor bone quality (type 4), short implants were used more cautiously in the maxilla (11.2%) as compared to the mandible (88.8%), and large-diameter implants were preferred whenever the bone site width permitted. Only 10% of the sites were type 4 bone. It is interesting to note that the 2 maxillary failures occurred in bone of very low density, but all the mandibular failures were placed in acceptably dense bone. No statistical difference could be determined between the maxillary and mandibular implants because of the unmatched size of the 2 groups.

It has been observed repeatedly that short, threaded implants are more likely to fail in clinical situations where limited bone height and poor bone quality are present.[12–15] In a study by Becker and coworkers[16] of 282 implants placed in molar positions, 184 were 10 mm or shorter. Eleven of 132 mandibular implants were lost, resulting in a survival rate of 91.7%, and 9 of 52 maxillary implants failed, for an overall survival rate of 82.7%. The failures were attributed to poor bone quality and lack of bicortical stabilization in the molar position.

A higher failure rate has been reported for short implants versus longer implants.[17–19] Buser and associates[18] found a trend for better results with increasing implant length. Bahat[7] also found a higher failure rate for 7-mm implants (9.5%, compared to 3.8% for longer implants), but no differences were found between implants placed in type 4 bone as compared to type 3 or 2 bone, or between implants placed in molar as compared to premolar positions.

An increase in the failure rate has been observed in the maxilla when compared to the mandible,[19–23] regardless of the implant surface quality. In a study conducted by Jemt[19] of 449 implants placed in totally edentulous maxillae, 108 machined-surface implants were 7 mm in length. An overall survival rate of 92.1% was reported after 5 years. However, 15 of the 7-mm implants were lost during the first 3 years of loading, as compared to 16 of 341 implants that were 10 mm or longer during the same period

Table 8 Survival Rate According to Implant Dimensions

Implant dimensions	No. placed	No. failed	Survival rate (%)
Length			
< 10 mm	116	8	93.1
10 mm	153	4	97.4
Diameter			
3.75 mm	109	4	96.3
4 mm	50	2	96.0
5 mm	109	6	94.5

$P > .05$; chi-squared test.

of observation. Friberg and colleagues[20] reported a 7.1% failure rate of 7-mm machined-surface implants placed in the edentulous maxilla, as compared to a 3.1% failure rate in the mandible, and attributed the difference to poor bone quality in the maxilla and early loading induced by wear of a removable prosthesis. Block and coworkers,[21] who investigated hydroxyapatite-coated cylinders, concluded that 8-mm-long implants should be avoided in posterior mandibles and that mechanical and inflammatory factors were the main causes of failure. Short, rough-surfaced implants, particularly the 8-mm length, had the lowest survival rate when compared to a longer length group.[24] This rate showed a rapid decline after 4 to 6 years in function, reaching 79.5% at 8 years for the hydroxyapatite-coated implants. A significant difference in the survival rate was found between implants placed in the maxilla (80.3%) and those placed in the mandible (90.8%).

To compensate for the reduced support of short, machined-surface implants, rough surfaces have been recommended because of the apparently greater bone-to-implant contact and higher removal torque.[25–28] Ten Bruggenkate and associates[29] reported a 93.8% cumulative survival rate after 6 years using 6-mm implants in different areas of the jaw. However, of 253 implants placed, only 45 (17.6%) were placed in the maxilla, and many were placed in combination with longer implants to support full-arch prostheses. Most of the failures occurred in the maxilla. The authors attributed the higher success rate to the implant design and surface quality. However, the combination of short implants with longer implants was recommended for better biomechanical resistance to stress and strain. Deporter and coworkers,[30] using 7- to 9-mm implants with a sintered porous surface to replace mandibular premolars and molars, obtained a 100% survival rate after a mean functional time of 32.6 months. The sintered surface increased the bone-to-implant contact by 3 to 4 times, along with mechanical interlock at the implant-bone interface; this was believed to be the main reason for the high survival rate.

Conversely, in severely atrophic mandibles, short machined-surface implants supporting predominantly fixed prostheses were placed and achieved a survival rate of 92.3% at 10 years.[31] In a meta-analysis by Cochran,[32] failures of smooth-surfaced implants were more numerous than those of rough-surfaced implants. However, more randomized clinical trials are needed to clearly define the indications for implant surface and configuration in specific clinical situations.

The survival rate found in the present series using machined-surface implants is comparable to those of previous reports. It may be attributed to bone quality (90% of the sites were of type 2 or 3), the precise preoperative evaluation, and meticulous surgical and prosthetic treatment. Each missing tooth was individually replaced by the longest and widest implant possible, given the available bone at the implant site. However, prosthetic restorations with unfavorable parameters are often fabricated to complete the treatment.[33,34] It is not possible to conclude from this study that the survival rate would have been equally high in bone of very poor density, although the maxillary implants in the present series were mostly of large diameter, were placed in type 3 or 4 bone, and showed a survival rate of 93.3%. In assessing the implant survival rate, it is important to take into account multiple factors that intervene in the establishment and maintenance of osseointegration, with implant length and surface being only 2 of the variables.

Stability of the standard 3.75-mm implants over time was compared to that of 4-mm implants in a 3-year follow-up study by Henry and coworkers.[35] More short 3.75-mm implants were lost over time, raising the failure rate from 4.9% to 7.3%, whereas only 1 of 33 4-mm implants was lost after 3 years of function. The failure rate was also higher for 3.75-mm implants when compared to those with 4-mm diameter.[14] In the present series, the failure rate of 3.75-mm implants was 1.8%, as compared to 4% for the 4-mm group and 4.1% for the 5-mm group. These differences were not statistically significant ($P > .05$). When the survival rate of 10-mm implants was compared to that of the shorter implants, no statistical difference was found ($P > .05$).

Peri-implant marginal bone loss has been reported at between 0.4 and 0.96 mm during the first year after loading. In the present study, the mean marginal bone loss over the observation period was 0.71 ± 0.65 mm.

Paresthesia of the lower lip has been mentioned as one of the significant complications following implant placement in the posterior mandible.[36] It is interesting to note that in spite of the limited bone height in the present series, the need to benefit from all the bone volume available to anchor short implants, and the subsequently higher risk of damaging the dentoalveolar nerve, no neurovascular complications were observed. The placement of short implants in limited bone height will not induce greater nerve damage if the necessary surgical precautions are taken and careful preoperative assessment of the situation is performed.

CONCLUSIONS

The results of the present study support the use of short, machined-surface implants in the treatment of partial edentulism. Bone quality appears to be a critical factor in planning the treatment of partial posterior edentulism, as compared to bone quantity. In situations of good bone quality but limited quantity, predictable results can still be obtained with implants that are 10 mm or shorter. Occlusal forces on the posterior implants are variable and will also affect implant survival.

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REFERENCES

1. Nevins M, Langer B. The successful application of osseointegrated implants to the posterior jaw: A long-term retrospective study. Int J Oral Maxillofac Implants 1993;8:428–432.
2. Lazzara R, Siddiqui AA, Binon P, et al. Retrospective multicenter analysis of 3i endosseous dental implants placed over a five-year period. Clin Oral Implants Res 1996;7:73–83.
3. Grunder U, Goene R, Hatano H, et al. A 3-year prospective multicenter follow-up reports on the immediate and delayed-immediate placement of implants. Int J Oral Maxillofac Implants 1999;14:210–221.
4. 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.
5. Deporter DA, Todescan R, Watson PA, et al. Use of the endospore dental implant to restore single teeth in the maxilla: Protocol and early results. Int J Oral Maxillofac Implants 1998;13:263–272.
6. Rangert B, Jemt T, Jorneus L. Forces and moments on Brånemark implants. Int J Oral Maxillofac Implants 1989;4:241–247.

7. 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.
8. Applegate OC. Essentials of Removable Partial Denture Prosthesis. Philadelphia: W.B. Saunders, 1960.
9. Lekholm U, Zarb GA, Albrektsson T (eds). Tissue-Integrated Prostheses: Osseointegration in Clinical Dentistry. Chicago: Quintessence, 1985:199–220.
10. Lekholm U, van Steenberghe D, Herrmann I, et al. Osseointegrated implants in the treatment of partially edentulous jaws: A prospective 5-year multicenter study. Int J Maxillofac Implants 1994;9:627–635.
11. Jemt T, Lekholm U. Oral implant treatment in posterior partially edentulous jaws: A 5-year follow-up study. Int J Oral Maxillofac Implants 1993;8:635–640.
12. Naert I, Quirynen M, van Steenberghe D, Darius P. A six-year prosthetic study of 509 consecutively inserted implants for the treatment of partial edentulism. J Prosthetic Dent 1992;67:236–245.
13. Jaffin RA, Berman CI. The excessive loss of Brånemark fixtures in type IV bone. J Periodontol 1991;62:2–4.
14. Van Steenberghe D, Lekholm U, Bolender C, et al. The applicability of osseotintegrated oral implants in the rehabilitation of partial edentulism: A prospective multicenter study on 558 fixtures. Int J Oral Maxillofac Implants 1990;5:272–281.
15. Scurria MS, Morgan V, Guckes AD, Li S, Koch G. Prognostic variables associated with implant failure: A retrospective effectiveness study. Int J Oral Maxillofac Implants 1998;13:400–406.
16. Becker W, Becker BE, Alsuwyed A, Al-Mubarak S. Long-term evaluation of 282 implants in maxillary and mandibular molar positions: A prospective study. J Periodontol 1999;70:896–901.
17. Roos J, Sennerby L, Lekholm U, Jemt T, Grondahl K, Albrektsson T. A qualitative and quantitative method for evaluating implants success: A 5-year retrospective analysis of the Brånemark implant. Int J Oral Maxillofac Implants 1997;12:504–514.
18. Buser D, Mericske-Stern R, Bernard JP, et al. Long-term evaluation of non-submerged ITI implants. Clin Oral Implants Res 1997;8:161–172.
19. Jemt T. Fixed implant-supported prostheses in the edentulous maxilla. A 5-year follow-up report. Clin Oral Implants Res 1994;5:142–147.
20. Friberg B, Jemt T, Lekholm U. Early failures in 4,641 consecutively placed Brånemark dental implants: A study from stage 1 surgery to the connection of completed prostheses. Int J Oral Maxillofac Implants 1991;6:142–146.
21. Block M, Gardiner D, Kent JN, Misiek DJ, Finger IM, Guerra L. Hydroxyapatite-coated cylindrical implants in the posterior mandible: 10-year observations. Int J Oral Maxillofac Implants 1996;11:626–633.
22. Babbush C, Shimura M. Five-year statistical and clinical observations with the IMZ two-stage osteointegrated implant system. Int J Oral Maxillofac Implants 1993;8:245–253.
23. Friberg B, Nilson H, Olsson M, Palmquist C. Mk II: The self-tapping Brånemark implant: 5-year results of a prospective 3-center study. Clin Oral Implants Res 1997;8:279–285.
24. Wheeler S. Eight-year clinical retrospective study of titanium plasma-sprayed and hydroxyapatite-coated cylinder implants. Int J Oral Maxillofac Implants 1996;11:340–350.
25. Buser D, Schenk RK, Steimann S, Fiorellini J, Fox C, Stich H. Influence of surface characteristics on bone integration of titanium implants. A histomorphometric study on miniature pigs. J Biomed Mater Res 1991;25:889–902.
26. Deporter DA, Watson PA, Pillar RM, et al. A prospective clinical study in humans of an endosseous dental implant partially covered with a powder-sintered porous coating: 3- to 4-year results. Int J Oral Maxillofac Implants 1996;11:87–95.
27. Sullivan DY, Sherwood RL, Mai TN. Preliminary results of a multicenter study evaluating a chemically enhanced surface for machined commercially pure titanium implants. J Prosthet Dent 1997;78:379–386.
28. Evian CI. A comparison of hydroxyapatite-coated Micro-vent and pure titanium Swede-Vent implants. Int J Oral Maxillofac Implants 1996;11:639–644.
29. Ten Bruggenkate CM, Asikainen P, Foitzik C, Krekeler G, Sutter F. Short (6-mm) nonsubmerged dental implants: Results of a multicenter clinical trial of 1 to 7 years. Int J Oral Maxillofac Implants 1998;13:791–798.
30. Deporter D, Pilliar RM, Todescan R, Watson P, Pharoah M. Managing the posterior mandible of partially edentulous patients with short, porous-surfaced dental implants: Early data from a clinical trial. Int J Oral Maxillofac Implants 2001;16:653–658.
31. Friberg B, Grondahl K, Lekholm U, Brånemark P-I. Long-term follow-up of severely atrophic edentulous mandibles reconstructed with short Brånemark implants. Clin Implant Dent Relat Res 2000;2:184–189.
32. Cochran D. A comparison of endosseous dental implant surfaces. J Periodontol 1999;70:1523–1539.
33. Rangert B, Eng M, Krogh PHJ, Langer B, Van Roekel N. Bending overloads and implant fracture: A retrospective clinical analysis. Int J Oral Maxillofac Implants 1995;10:326–334.
34. Meijer HJA, Kuiper JH, Starmans FJM, Bosman F. Stress distribution around dental implants: Influence of superstructure, length of implants, and height of mandible. J Prosthet Dent 1992;68:96–102.
35. Henry PJ, Tolman DE, Bolender C. The applicability of osseointegrated implants in the treatment of partially edentulous patients: Three-year results of a prospective multicenter study. Quintessence Int 1993;24:123–129.
36. Ellies L, Hawker P. The prevalence of altered sensation associated with implant surgery. Int J Oral Maxillofac Implants 1993;8:674–679.