Clinical Outcome of Brånemark System Implants of Various Diameters: A Retrospective Study

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Purpose: *The purpose of this study was to evaluate the outcome of the 3 different diameters of Brånemark System implants, with special focus on the 5.0-mm-diameter implant.* ***Materials and Methods:*** *Ninety-eight patients (99 jaws) with a mean age of 62 years were included in this retrospective report. The mean follow-up period was 2 years and 8 months. A total of 379 Brånemark System implants (3.75 mm diameter, n = 146; 4.0 mm diameter, n = 76; 5.0 mm diameter, n = 157) were placed in 29 edentulous and 70 partially edentulous jaws.* ***Results:*** *Eight of the 146 implants in the 3.75-mm-diameter group failed (5.5%). The corresponding figures for the 4.0- and 5.0-mm-diameter implants were 3 of 76 (3.9%) and 7 of 157 (4.5%), respectively.* ***Discussion:*** *All failures were recorded in maxillae, ie, 18 of the 298 placed, and the majority of these were found in bone quantity group B and quality group 2. Only 3 implants of 131 failed in bone judged as quality 4. The marginal bone loss was low for the 3 implant diameter groups.* ***Conclusion:*** *The favorable outcome in bone of poor quality is ascribed partly to the use of an adapted preparation technique and extended healing periods for achievement of the best primary and secondary implant stability possible.* (Int J Oral Maxillofac Implants 2002;17: 671–677)

Key words: *dental implants, endosseous dental implantation, implant diameter, treatment outcome*

Oral implant treatment ad modum Brånemark has been in clinical use for more than 35 years. Predictable results with high rates of survival and success have been presented in numerous prospective multicenter studies.[1–5] The original standard Brånemark System implant was 3.75 mm in diameter, but owing to treatment needs, the 4.0-mm[6] and 5.0-mm-diameter implants[7] were introduced (Nobel Biocare, Göteborg, Sweden) as well.

Clinical reports are available describing the clinical performance and the short-term results of the 5.0-mm implants.[8–11] Although good results have been presented, some studies involving implants of various diameters reach the conclusion that failure is more common for the 5.0-mm implant as compared to the 3.75-mm and 4.0-mm standard design.[9,11] In a study by Ivanoff and coworkers[9] conducted at the Brånemark Clinic, Göteborg, Sweden, failure rates of 13.7% and 27% were seen at 3 years for the 5.0-mm-diameter implant in maxillae and mandibles, respectively. The authors discussed possible causes for the outcome, such as changing the instrumentation to accommodate a new implant design. Furthermore, the 5.0-mm implant was frequently placed as a rescue implant in bone of poor texture without utilizing an adapted surgical technique and without extended healing time. In a multicenter

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report, Polizzi and associates[12] presented the outcome at 3 years for single wide-platform (5.0-mm-diameter, designed for molar regions) Brånemark System implants in posterior jaw regions. The healing time was randomized to be either 4 or 8 months in mandibles and 6 or 9 months in maxillae. All implants with extended healing periods were successful at the end of the study period. With reference to other implant systems (Osseotite, Implant Innovations, West Palm Beach, FL), Sullivan and colleagues[13] showed similar success after 3 years for 5.0-mm-wide implants with chemically enhanced surfaces.

The aim of the present retrospective study was to evaluate the outcome of the 3 Brånemark System implant diameter groups (all with machined surfaces), with special focus on the 5.0-mm-diameter implant,[7] when using an adapted preparation technique and extended healing periods in bone of poor texture.

MATERIALS AND METHODS

Patients

The present study included 98 patients (63 women/35 men, mean age 62 years) representing 99 jaws consecutively treated at the Brånemark Clinic, Public Dental Health Service, Göteborg, Sweden, between January 1994 and December 1998 (Table 1). Eight edentulous mandibles, 21 edentulous maxillae, 19 partially edentulous mandibles, and 51 partially edentulous maxillae, including 2 single-tooth applications (premolar regions), were treated. Eleven of the 99 jaws had been treated previously with implants. Owing to earlier implant failures (16 implants in 9 patients) or additional tooth losses (2 patients), these patients needed additional implants.

Radiographic assessments of jawbone quality and quantity were performed preoperatively according to the classification of Lekholm and Zarb[14] (Table 2). Bone quality scores 1 to 4 were evenly distributed among the mandibles and scores 2 to 4 among the maxillae. Bone quantity scores B, C, and D were represented in maxillae, while in the mandibles, B and E predominated.

Table 1 No. of Patients Followed in Study

Time period	No. of patients
Placement to loading	98
Loading to 1 y	98
1 to 2 y	94
2 to 3 y	76
3 to 4 y	50
4 to 5 y	33
5 y	7

Implant Surgery and Prosthetic Treatment

Implants (Brånemark System, Nobel Biocare) were placed by one surgeon. Each patient received at least one 5.0-mm implant[7]; a total of 379 implants of various diameters were placed (Table 3). The wider implants (4.0-mm and 5.0-mm) were placed predominantly in the premolar and molar regions of both maxillae and mandibles, whereas the 3.75-mm implants in maxillae were distributed more evenly (Table 4).

Implant placement in bone of poor texture was executed utilizing an adapted bone site preparation technique.[15] Thus, 3.75-mm implants were placed in bone sites prepared to a final diameter of 2.7 to 2.85 mm, rather than to 3.0 mm, which was the recommendation given by the implant manufacturer. The 3.0-mm twist drill and the short-peg countersink were the final drills used when placing 4.0-mm and 5.0-mm implants. The short-peg countersink allowed for a widening of the implant site entrance to provide accommodation for the 5.0-mm-diameter implant. In dense bone, the implants were placed as self-tapping ones after a final preparation of 3.0 to 3.15 mm for 3.75-mm and 4.0-mm

Table 2 Placed and Failed Implants with Regard to Bone Quality and Quantity

	Bone quality*				Bone quantity*				
	1	2	3	4	A	B	C	D	E
Maxilla									
Placed	0	76 (17)	113 (29)	109 (26)	0	160 (34)	109 (27)	29 (11)	0
Failed	0	14 (6)	1 (1)	3 (3)	0	12 (5)	4 (3)	2 (2)	0
Mandible									
Placed	17 (5)	25 (9)	17 (7)	22 (6)	0	64 (22)	2 (1)	0	15 (4)
Failed	0	0	0	0	0	0	0	0	0

*Classification according to Lekholm and Zarb.[14]
Parentheses indicate no. of arches.

implants and after preparation of 3.7 to 4.3 mm for 5.0-mm implants.

All implant placement procedures were performed according to the 2-stage surgical technique,[16] although in bone of poor texture the mean healing period was extended to 9 and 4 months in maxillae and mandibles, respectively.[15] Two weeks following abutment connection surgery, prosthetic treatment was commenced, and implant-supported fixed prostheses were fabricated either in gold alloy[17] or in titanium.[18]

Radiographic Follow-up

The radiographic examinations, consisting of intraoral radiographs taken with a standardized long-cone paralleling technique,[19] were performed at the abutment operation, at prosthesis connection, and at the 1-year checkup. At longer follow-up periods, radiographs were obtained at the 3-year and/or 5-year visits (Fig 1). Radiographs, obtained at the abutment operation and at the 1-year visit, were used to assess the distance from the implant/abutment junction to the marginal bone crest at the mesial and distal surfaces of each implant. Measurements were performed to the closest 0.1 mm by one observer, a specialist in oral radiology with long experience from implant radiography, using a magnifying lens (×7), and a mean value was calculated per implant. The marginal bone loss was determined during the first year of function. In addition, signs of radiographic changes at the bone-implant interface zone indicating loss of osseointegration, as well as complications related to the implant system, were registered.

Table 3 Distribution of Placed and Failed Implants with Regard to Implant Diameter and Length

Implant diameter/length	Maxilla		Mandible	
	Placed	Failed	Placed	Failed
3.75 mm				
7 mm	0	0	4	0
8.5 mm	2	0	4	0
10 mm	12	0	8	0
11.5 mm	1	0	1	0
13 mm	29	6	1	0
15 mm	37	1	1	0
18 mm	34	1	10	0
20 mm	2	0	0	0
Total	117	8	29	0
4 mm				
7 mm	4	1	0	0
8.5 mm	3	1	1	0
10 mm	10	0	2	0
11.5 mm	0	0	0	0
13 mm	19	1	0	0
15 mm	26	0	0	0
18 mm	11	0	0	0
Total	73	3	3	0
5 mm				
6 mm	32	4	14	0
7 mm	2	0	0	0
8 mm	23	0	7	0
10 mm	27	3	19	0
12 mm	24	0	9	0
Total	108	7	49	0

Table 4 Placed and Failed Implants with Respect to Implant Type and Location

	Maxillary implants			Mandibular implants		
	3.75 mm	4 mm	5 mm	3.75 mm	4 mm	5 mm
Molar region	1 (0)	7 (0)	29 (3)	2 (0)	1 (0)	16 (0)
Premolar region	51 (2)	50 (3)	69 (3)	19 (0)	2 (0)	25 (0)
Canine region	29 (3)	9 (0)	6 (1)	3 (0)	0 (0)	2 (0)
Incisor region	36 (3)	7 (0)	4 (0)	5 (0)	0 (0)	6 (0)

Implant failures are shown in parentheses.

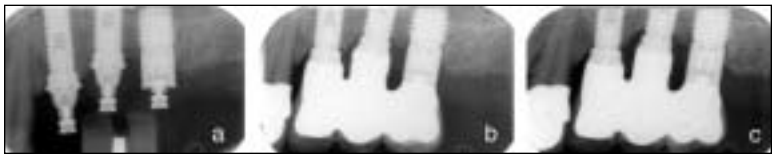

Fig 1 Radiographs from one of the patients obtained at abutment connection (a), 1 year (b), and 3 year (c) follow-ups. Implants (3.7 mm, 4 mm, and 5 mm) placed in maxillary left premolar and molar regions.

Clinical Follow-up

The mean follow-up period was 2 years and 8 months (range 0.5 to 5.5 years). The number of withdrawn patients over time is shown in Table 1. Apart from those patients who were treated more recently, ie, with limited follow-up periods, 2 patients withdrew because of severe illness, 2 patients moved, and 1 patient had a complete failure. Fifty patients attended the 3-year follow-up visit.

Statistics

Recorded data were used for calculations of mean values, standard deviations, and frequency distributions. Based on all implants placed, cumulative survival rates (CSRs) were evaluated separately for the 3 implant diameter groups, presented by jaw, using a life table analysis.[20]

The statistical significance of differences in marginal bone level changes between implants with different diameters was tested with the *t* test, and a *P* value < .05 was chosen as the level for significant differences.

RESULTS

Implant Failures

Ten of the 98 patients (10.2%) were afflicted with 18 implant losses (Table 3), corresponding to a total failure rate of 4.7% (18/379). All failures were recorded in maxillae, ie, 18 of the 298 implants placed (6.0%), while no losses were recorded in mandibles. Table 3 shows the distribution of placed and failed implants with regard to implant diameter, length, and location (maxilla or mandible). A failure rate of 5.5% (8/146) was seen for the 3.75-mm-diameter group; the corresponding figures for the 4.0-mm- and 5.0 mm-diameter groups were 3.9% (3/76) and 4.5% (7/157), respectively. In the 3.75-mm-diameter group, only long implants failed (13 to 18 mm), while shorter implants (6 to 10 mm) predominated among the failures of the wider-diameter groups. With regard to implant location, the failures in maxillae were recorded in 3 incisor, 4 canine, 8 premolar, and 3 molar positions (Table 4).

The CSRs for the various implant groups are presented in Table 5. Six implants in 6 patients were lost at the abutment operation. One patient represented a complete failure and lost his first implant after 6 months of function, while the remaining 7 implants were found to be mobile at the 1-year check-up. Another 4 implants were lost in 3 patients during the second and third year of function.

When referring implant failures to the assessed bone quality and quantity,[14] scores 2 (14/18) and B (12/18) predominated, respectively (Table 2). Only 3 of the 131 implants placed in quality 4 bone were lost during the study period (2.3%).

Radiographic Findings

The mean marginal bone loss is presented for each of the various implant diameter groups in Table 6. Only small bone changes were seen over time, and most of the bone loss was seen during the first year of function. There was a significant difference in marginal bone loss between the 5.0-mm group and the 3.75-mm and 4.0-mm groups ($P = .0006$ and $P = .0004$, respectively) during the first year. The difference in marginal bone loss between the implants in the 5.0-mm group and the 3.75-mm group with the longest follow-up time (abutment connection to 5 years) was also statistically significant ($P = .0027$), although few observations were recorded at 5 years. All other differences between groups were not statistically significant. No signs of loss of integration, apart from those implants being removed, or problems correlated to the components of the implant system were noted in the radiographs.

Prosthesis Stability

One patient, who received 1 complementary implant, continuously lost earlier placed implants as well as the new one and had to return to a conventional removable prosthesis. The patient, representing a complete failure, was reoperated after 1 year with 6 new implants (data not included). All remaining patients wore their original prostheses throughout the observation period.

DISCUSSION

The present study showed similar low failure rates, ie, 5.5%, 3.9%, and 4.5% for the various implant diameters of 3.75, 4.0, and 5.0 mm, respectively. In an earlier report by Ivanoff and coworkers[9] comprising 67 patients treated between 1990 and 1993 at the Brånemark Clinic, Göteborg, Sweden, low failure rates for the 3.75-mm (5.0%) and 4.0-mm (3.0%) implants were noted. With regard to the 5.0-mm implants, however, an overall failure rate of 18% was seen. The authors speculated on possible causes for this outcome, and suggested that it may have been related to a learning curve involving a new implant design. Furthermore, it was stated that 45% of these 5.0-mm-diameter implants were used as rescue implants, ie, they replaced narrower implants placed with insufficient initial stability. Ivanoff and coworkers[9] claimed that the 5.0-mm implants were placed with an adapted surgical technique, using the associated

Table 5 Life Table Analysis Showing Cumulative Survival Rates (CSR) for the 3 Implant Diameters

	Maxilla				Mandible		
Implant diameter/time	No. followed	No. failed	No. withdrawn	CSR (%)	No. followed	No. failed	No. withdrawn
3.75 mm							
Placement to loading	117	2	0	98.3	29	0	0
Loading to 1 y	115	6	1	93.2	29	0	0
1 to 2 y	108	0	18	93.2	29	0	1
2 to 3 y	90	0	45	93.2	28	0	7
3 to 4 y	45	0	10	93.2	21	0	4
4 to 5 y	35	0	26	93.2	17	0	12
5 y	9	–	–	–	5	–	–
4.0 mm							
Placement to loading	73	1	0	98.6	3	0	0
Loading to 1 y	72	1	6	97.3	3	0	0
1 to 2 y	65	1	11	95.8	3	0	0
2 to 3 y	53	0	13	95.8	3	0	2
3 to 4 y	40	0	11	95.8	1	0	1
4 to 5 y	29	0	22	95.8	0	–	–
5 y	7	–	–	–	–	–	–
5.0 mm							
Placement to loading	108	3	0	97.2	49	0	0
Loading to 1 y	105	1	5	96.3	49	0	0
1 to 2 y	99	2	23	94.4	49	0	11
2 to 3 y	74	1	31	93.1	38	0	9
3 to 4 y	42	0	14	93.1	29	0	14
4 to 5 y	28	0	20	93.1	15	0	13
5 y	8	–	–	–	2	–	–

Table 6 Mean Marginal Bone Loss for Implants with Different Diameters and at Different Time Periods

	Implant diameter					
	3.75 mm		4 mm		5 mm	
Time	Bone loss (SD)	n	Bone loss (SD)	n	Bone loss (SD)	n
Abutment to 1 y	1.2 (0.8)	118	1.3 (0.8)	60	0.8 (0.8)	103
1 to 3 y	0.2 (0.5)	45	0.1 (0.4)	26	0.1 (0.3)	43
3 to 5 y	0.1 (0.5)	14	–0.1 (0.2)	5	–0.1 (0.4)	8
Incisor region	1.8 (1.0)	15	1.0 (0.9)	4	0.6 (0.6)	5

Negative values indicate bone gain; n = number of implants.

drilling equipment with twist drills 3.7 to 4.3 mm in diameter and a screw tap diameter of 5.0 mm, in bone of poor texture. In the present study, the adapted bone site preparation technique used refers to one suggested by Friberg,[15] ie, 23 molar and 52 premolar maxillary sites were prepared to a final diameter of 3.0 mm in bone of poor texture to harbor 5.0-mm-diameter implants. When comparing the 2 surgical techniques, one might assume that the initial implant stability was greater when using the technique of the present study. Sjöström and coworkers (Resonance Frequency Analysis Symposium, Göteborg, Sweden, July 6, 2000) were able to demonstrate higher initial implant stability, as measured with resonance frequency,[21] in grafted than in non-grafted maxillae, when using final twist drills of 2.85 mm diameter in

grafted and 3.0 mm diameter in non-grafted bone. They also showed that failed implants, on average, had lower primary stability than the successful implants, a finding supported by laboratory results on rabbits, where poor initial implant stability resulted in inferior integration.[22]

When considering the duration of healing for posterior maxillae, the current study also varied from that of Ivanoff and associates,[9] ie, 8 to 10 months were used instead of 6 months, a procedure based on the outcome of several animal and clinical studies. Earlier reports on rabbits have shown increased bone-to-metal contact and increased removal torque of implants over time.[23,24] Implants placed in osteoporotic rabbits showed similar amounts of bone-to-implant contact as compared to controls, but only after an extended healing period of 50%, ie, at 12 and 8 weeks for test and control animals, respectively.[25] In human maxillae with bone of poor, medium, and dense textures, implants were demonstrated to approach similar resonance frequency values, ie, stability values, but only after a postoperative period of more than 1 year.[26]

Another difference between the present report and that of Ivanoff and associates[9] is the outcome in mandibles. While no mandibular implant losses were reported in the current study, Ivanoff and associates[9] found low CSRs, ie, 84.8% and 73.0% for the 4.0-mm- and 5.0-mm-diameter implants, respectively, in mandibles. The latter outcome is in agreement with the study by Aparicio and coworkers,[8] who showed a similar tendency to more failures in mandibles than maxillae when using the 5.0-mm-diameter Brånemark System implant. The deviation between the present report and the one by Ivanoff and associates[9] is difficult to explain, since the number and locations of mandibular implants, as well as the duration of healing, were similar for the 2 studies. Furthermore, in the denser mandibular bone the same preparation technique was executed; thus, in both studies the 5.0-mm implants were placed after using final twist drills with diameters ranging from 3.7 to 4.3 mm. However, Ivanoff and associates[9] frequently used the 5.0-mm implant as a rescue implant, while in the present study that implant was preoperatively planned for.

All implants that failed were placed in maxillae, which is in agreement with the overall majority of clinical follow-up studies on machined screw-type implants.[27] The "clustering effect"—ie, a majority of implant failures are seen in a few patients—was also evident in the current study. Ten of the 18 failures were recorded in 2 patients, a finding in accordance with earlier reports.[28–30] Both patients exhibited severe bruxism, which was considered a major cause for the implant losses. With regard to bone sites assessed as quality 4,[13] only 3 of 131 implants placed in such sites failed during the study period. While high failure rates have been reported for implants in bone of poor texture,[31–34] encouraging results have been presented by others.[30,35,36] When considering implant length, short implants (6 to 10 mm) failed only among the wider-diameter groups. One explanation may be the relatively high number of such implants placed, while only a few short implants were used in the 3.75-mm-diameter group.

The mean marginal bone loss during the first year of function must be considered low, although it was greater than that reported by Ivanoff and associates.[9] The 5.0-mm-diameter implant group in the present study showed significantly less marginal bone loss over time than the 3.75-mm and 4.0-mm groups, a finding in contrast to those of Ivanoff and associates,[9] who demonstrated that the wide implant tended toward greater total marginal bone loss. All differences in marginal bone loss between the present study and the report by Ivanoff and associates[9] may, to a great extent, find their explanation in the different radiographic reference points used in the latter study. For the 3.75-mm and the 4.0-mm implants, bone loss was measured 0.8 mm apical from the implant/abutment junction. In the current report, the marginal bone loss around all implants was measured from the implant/abutment junction, regardless of diameter.

CONCLUSIONS

In a report by Ivanoff and associates,[9] a higher failure rate was demonstrated for 5.0-mm-diameter implants. Similar conditions were at hand, as compared to the present study, with regard to patient material, clinical setup, and experience of the performing surgeons, although the 5.0-mm-diameter implant was of a new design at the time of the study by Ivanoff and associates. An improved outcome for the 5.0-mm-diameter implants was demonstrated in the present study. This may have been achieved by creating the best primary and secondary implant stability possible, and by using an adapted preparation technique and extended healing periods, respectively.

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