Influence of Variations in Implant Diameters: A 3- to 5-Year Retrospective Clinical Report

Carl-Johan Ivanoff, DDS*/Kerstin Gröndahl, DDS, PhD**/Lars Sennerby, DDS, PhD***/
Christina Bergström, MSc****/Ulf Lekholm, DDS, PhD*****

Sixty-seven patients ranging in age from 16 to 86 years were included in this 3- to 5-year retrospective report focusing on implant survival and marginal bone remodeling in relation to implant diameter. A total of 299 Brånemark implants (3.75-mm diameter: 141; 4.0-mm diameter: 61; 5.0-mm diameter: 97) were placed in 16 completely and 51 partially edentulous arches. Seven of the 141 implants in the 3.75-mm-diameter group failed (5%). The corresponding value for the 4.0-mm-wide implants was 2 of 61 (3%). The highest failure rate, 18% (17/97), was seen for the 5.0-mm-diameter implants. The least favorable cumulative survival rates were seen in mandibles after 5 years and involving 4.0-mm- and 5.0-mm-diameter implants (84.8% and 73.0%, respectively). The marginal bone loss was generally low over the 5-year period. When the data were evaluated by the Cox regression analysis, a relationship was found between implant failure and implant diameter ($P < .05$), with a higher failure rate for the 5.0-mm-diameter implant. However, no relationship could be seen between implant failure and jaw type, or bone quality and quantity ($P > .05$). Neither was any relationship seen between marginal bone loss and bone quality and quantity, implant diameter, or jaw type when tested by multiple linear regression analysis ($P > .05$). A learning curve, poor bone quality, and changed implant design were suggested as possible reasons for the less positive outcome seen for the 5.0-mm-diameter implant. The fact that this implant was often used as a rescue implant when the standard ones were not considered suitable or did not reach initial stability was another plausible explanation.
(Int J Oral Maxillofac Implants 1999;14:173–180)

Key words: Brånemark system, diameter, titanium oral implant, treatment result

*Consulting Oral and Maxillofacial Surgeon, Department of Oral and Maxillofacial Surgery, Mölndal Hospital, Mölndal, Sweden; and Department of Biomaterials/Handicap Research and Institute for Surgical Sciences, Göteborg University, Faculty of Medicine, Göteborg, Sweden.
**Associate Professor, Department of Oral Diagnostic Radiology, Göteborg University, Faculty of Odontology, Göteborg, Sweden.
***Associate Professor, Department of Biomaterials/Handicap Research and Institute for Surgical Sciences, Göteborg University, Faculty of Medicine, Göteborg, Sweden; and The Brånemark Clinic, Public Dental Health Service and Faculty of Odontology, Göteborg University, Göteborg, Sweden.
****Clinical Research Associate, Department of Clinical Research, Nobel Biocare AB, Göteborg, Sweden.
*****Professor, Department of Biomaterials/Handicap Research and Institute for Surgical Sciences, Göteborg University, Faculty of Medicine, Göteborg, Sweden; and The Brånemark Clinic, Public Dental Health Service and Faculty of Odontology, Göteborg University, Göteborg, Sweden.

Reprint requests: Dr Carl-Johan Ivanoff, Department of Oral and Maxillofacial Surgery, Mölndal Hospital, S-431 80 Mölndal, Sweden. Fax: +46 31 861501. E-mail: carl-johan.ivanoff@ms.se

During the last 30 years, endosseous oral implants have become a reliable treatment modality for patients with lost or compromised dentitions. The technique developed by Brånemark et al[1,2] has shown that bone-to-implant integration can be achieved with the use of commercially pure titanium implants, a phenomenon known as osseointegration. Predictable long-term results have been reported for treatment of complete and partial edentulism using the Brånemark system (Nobel Biocare, Göteborg, Sweden).[3–8] Despite high success rates, failures may occur, usually as a result of poor bone quality and/or reduced bone volume.[2,9–11] Initial implant stability has been pointed out as another parameter of importance for establishing osseointegration,[12] and initial stability can be accomplished with a precise drilling technique and bicortical anchorage of the implant.[13–16] However, in posterior partially edentulous arches it is often difficult to achieve

implant stability because of both compromised bone quality and/or quantity.

One method for circumventing this problem has been suggested: the use of wide-diameter implants.[17–19] An increased implant surface area can engage more cortical bone. It has also been shown in a recent experimental study in rabbit tibia that wider implant diameters resulted in increased removal torque values.[20] Furthermore, Matsushita et al[21] employed a two-dimensional finite element method to analyze the effect of different implant diameters on stress distribution within the alveolar bone using hydroxyapatite-coated implants. They found that stress in cortical bone decreased with increased implant diameter. Earlier clinical studies have indicated higher success rates for 4-mm-diameter implants than for standard 3.75-mm-diameter implants in soft quality bone.[19,22] As a result, Langer et al[17] introduced the use of 5.0-mm- and 5.5-mm-diameter implants, but thus far no longer-term results have been presented. Instead, mainly technical data have been published regarding how to apply 5.0-mm- and 6.0-mm-diameter implants,[17,23,24] so that there is still a lack of clinical knowledge regarding the benefits of wide implants.

The aims of this study were to present 3- to 5-year follow-up results using wide-diameter implants, and to study the influence of implant diameter on implant survival and marginal bone loss.

Table 1 No. of Patients at Start of Each Period Followed Throughout the Study

Time period	No. of patients followed
Placement to loading	67
Loading to 1 y	66
1 to 2 y	63
2 to 3 y	60
3 to 4 y	47
4 to 5 y	25
5 y	19

Materials and Methods

Sixty-seven consecutively treated patients were followed; between March 1990 and May 1993 each had been provided with at least one 5.0-mm-diameter implant at the Brånemark Clinic, Public Dental Health Service, Göteborg, Sweden (Table 1). The group comprised 37 women and 30 men, having a mean age of 59 years (range 16 to 86). Altogether, 47 maxillae and 20 mandibles were treated. Bone quantity and quality (Table 2) were classified according to Lekholm and Zarb.[25] Altogether, 229 Brånemark implants of different diameter and length (Table 3) were placed in 32 partially and 15 totally edentulous maxillae and in 1 completely and 19 partially edentulous mandibles. A majority of the implants had been placed into arch shape groups B, C, or D and into Type 3 or 4 bone quality (Table 2). A standardized surgical technique was used when placing the regular implants,[13] and an adapted one was used to place the 5.0-mm implants.[17] The majority of the implants were placed in posterior areas of the jaws, except for the 3.75-mm-diameter maxillary implants, which were more equally distributed (Table 4). After healing, the implants supported 68 partial prostheses (40 maxillary and 28 mandibular), 14 complete arch prostheses (13 maxillary and 1 mandibular), 2 maxillary overdentures, and 2 single crowns (1 maxillary and 1 mandibular). One patient, who was bilaterally partially edentulous in the mandible and received 6 implants, did not complete second-stage surgery because of economic reasons and was, consequently, not provided with fixed restorations.

The prosthodontic procedure followed standards of the Brånemark system,[26–28] and all restorations were designed as free-standing units except in one patient, who received a prosthesis that was supported by one implant and connected to the natural dentition. All patients were examined at

Table 2 Frequency of 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 (0)	0 (0)	182 (39)	32 (8)	3 (1)	50 (9)	118 (27)	42 (9)	1 (1)
Failed	—	—	11 (8)	3 (2)	0 (0)	1 (1)	8 (5)	5 (4)	0 (0)
Mandible									
Placed	0 (0)	23 (6)	39 (9)	23 (5)	7 (2)	32 (8)	32 (7)	14 (3)	0 (0)
Failed	—	1 (1)	10 (4)	1 (1)	0 (0)	3 (2)	5 (3)	4 (1)	—

*Grading according to Lekholm and Zarb.[25]
Parentheses indicate no. of arches.

the time of prosthesis placement and annually thereafter, according to a standardized recall program.[3] Of the parameters assessed, the following were included in the present report: indications for using 5.0-mm-diameter implants when mentioned, control of prosthesis stability, recording of complications including implant failures, and radiographic assessments of marginal bone level and state of osseointegration. The radiographic examinations, consisting of intraoral radiographs and performed at the Department of Oral Diagnostic Radiology at Göteborg University, commenced at the time of prosthesis placement (+ 3 months) and were thereafter repeated at 1 year (± 6 months), 3 years (± 6 months), and 5 years (± 6 months). The suprastructures were not removed routinely, unless there were clinical and/or radiographic indications of loss of integration. Because of the chosen inclusion period, all patients could not be followed for 5 years. However, no subject was considered a drop-out unless the intended clinical and radiographic examinations were not performed.

The marginal bone level was assessed with respect to a fixed point on the implant. Regarding the 3.75-mm- and 4.0-mm-diameter implants, the reference point was defined as the edge between the conical and cylindric parts of the implant head (0.8 mm below the abutment-implant junction). Because of lack of a corresponding reference point on the 5.0-mm-diameter implant, the abutment-implant connection level was used as a reference point. Measurements were taken to the nearest 0.1 mm by one observer with a magnifying lens (× 7) at the mesial and distal surfaces and a mean value was calculated per implant. All 5.0-mm-diameter implants were radiographically assessed with regard to changes in marginal bone level. In patients who had more than one 3.75-mm- and/or 4.0-mm-diameter implant placed in the same jaw, only one implant of each of these diameters was randomly chosen for the marginal bone evaluation.

Table 3 Distribution Per Arch of Placed and Failed Implants According to Implant Diameter and Length

	Maxilla		Mandible	
Implant size	Placed	Failed	Placed	Failed
3.75-mm diameter				
7 mm long	6	1	10	0
10 mm long	36	2	9	2
13 mm long	28	1	1	0
15 mm long	14	0	0	—
18 mm long	17	1	13	0
20 mm long	1	0	6	0
Total	102	5	39	2
4-mm diameter				
7 mm long	19	0	12	2
10 mm long	16	0	3	0
13 mm long	7	0	0	—
15 mm long	2	0	0	—
18 mm long	2	0	0	—
Total	46	0	15	2
5-mm diameter				
6 mm long	41	4	21	7
8 mm long	15	4	3	1
10 mm long	3	0	3	0
12 mm long	7	1	4	0
Total	66	9	31	8

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

Implant location	Implant type—maxilla			Implant type—mandible		
	3.75 mm	4 mm	5 mm	3.75 mm	4 mm	5 mm
Right third molar	0/0	0/0	0/0	0/0	0/0	0/0
Right second molar	0/0	0/0	2/0	0/0	1/0	0/0
Right first molar	0/0	2/0	10/4	3/0	5/0	6/2
Right second premolar	5/0	4/0	10/0	5/0	2/0	7/1
Right first premolar	15/1	6/0	8/0	11/0	1/0	0/0
Right canine	14/1	3/0	3/0	1/0	0/0	0/0
Right lateral incisor	7/0	0/0	0/0	2/0	0/0	0/0
Right central incisor	14/1	3/0	2/1	1/0	0/0	0/0
Left central incisor	14/0	1/0	1/0	0/0	0/0	0/0
Left lateral incisor	5/0	2/0	2/1	0/0	0/0	0/0
Left canine	17/1	3/0	3/0	1/1	0/0	0/0
Left first premolar	8/0	15/0	3/0	6/0	1/0	1/1
Left second premolar	2/0	5/0	11/1	5/1	4/1	5/1
Left first molar	1/1	1/0	8/0	3/0	1/1	9/3
Left second molar	0/0	0/0	3/2	1/0	0/0	3/0
Left third molar	0/0	1/0	0/0	0/0	0/0	0/0

Statistics

Mean values, standard deviations, and frequency distributions were calculated for recorded data. Implant cumulative survival rates (CSR) were separately evaluated for the 3 implant diameter groups, divided by jaw, using a life table analysis and based on all implants placed.[29]

Multiple linear regression and Cox regression analyses were performed to study the influence of jaw type, bone quality and quantity, and implant diameter on the marginal bone loss and implant survival rate, respectively. For each patient, one implant was thereby randomized by the use of a table of random numbers to avoid dependence between implants. No stratification was used.

Results

Implant Failures. Initially, 67 patients were included for analysis. Over the 5-year follow-up period, based on radiographic examination, 48 patients dropped out, leaving 47 patients after 3 years and 19 patients for the 5-year examination (Table 1). However, based on clinical follow-ups, 59 patients were followed over the 3-year period and 50 patients over 5 years. The reasons for drop-outs were death, moving out of the area, or lack of interest in attending the examinations. Of the 67 originally treated patients, 16 (24%) were affected by 26 implant failures (Table 2). Of the 299 implants placed, this constituted 9% (Table 3). All failures except one took place either at abutment surgery (n = 14) or within the first 2 years in function (n = 11) (Table 5). A tendency for an increased number of failures was related to decreasing jaw volume. The highest individual failure rate, based on the total number of implants lost, was observed in patients with Type C bone quantity (13/26; Table 2) and with Type 3 bone quality (21/26), respectively. However, most implants had also been placed in these 2 groups.

The distribution of placed and failed implants with regard to location (maxilla or mandible), implant length, and diameter, is presented in Table 3, and regarding implant position in Table 4. As seen in Table 3, 7 of the 141 implants in the 3.75-mm-diameter group failed (5%). The corresponding value for the 4.0-mm-diameter implants was 2 of 61 (3%). The highest failure rate, 18% (17/97), was seen for 5.0-mm-diameter implants. In the latter group, 2 patients accounted for 6 of the failed implants. The cumulative implant survival rates showed variations between the different implant diameters (Table 5), and the lowest cumulative survival rates after 5 years were seen with 4.0-mm- and 5.0-mm-diameter implants placed in mandibles (84.8% and 73.0%, respectively) (Table 5). In the maxilla, the 5.0-mm-diameter implants also showed low CSR. However, indications for using the widest diameter implant were, in 38% of the implant sites, extremely poor bone quality and, in 7% of sites, immediate replacement of a primarily unstable standard implant (ie, in 45% of implant sites the 5.0-mm-diameter implants had been used as a rescue implant).

In the maxilla, 14 of the 214 implants placed failed (7%) (Table 3). The corresponding mandibular number was 12 failed implants (14%) of the 85 placed. Shorter implants showed higher failure rates, specifically within the 5-mm-diameter implant group (Table 3). Seven implants were kept "sleeping," ie, covered by mucosa during the follow-up period. Six of these were classified as withdrawals after placement and the remaining implant was classified as a withdrawal after 3 years. The Cox regression analysis ($P < .05$) revealed a relationship between implant failure and implant diameter, with a higher failure rate for the 5.0-mm-diameter implant. No relationship could be observed, though, between implant failure and jaw type or bone quality and quantity ($P > .05$).

Radiographic Findings. Seven implants in 5 patients that had been radiographically judged as nonintegrated were clinically tested with regard to stability. They were all mobile and were therefore removed (included in data above).

The mean marginal bone loss during the 5-year period is presented in Table 6. Since radiographs were not available for all implants at all time intervals, the number of observations did not match the total number of implants investigated. In general, small changes were noted over time, and most of the bone loss occurred during the first year of function (Table 6). However, the 5.0-mm-diameter implants tended toward greater total marginal bone loss than did the other implant widths. No relationship between the marginal bone loss and bone quality and quantity, implant diameter, or jaw type was seen during the first year of loading, when tested by multiple linear regression analysis ($P > .05$). Further analyses were not possible, since there were too few observations during later periods.

Prosthesis Stability. During the observation period, 4 mandibular partial prostheses (one patient with bilateral restorations supported by 2 and 3 implants and two patients with 1 prosthesis each, supported by 2 implants) were lost. A single crown in the position of the mandibular left sec-

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

	Maxilla					Mandible				
	No. of implants followed	No. of implants failed	No. of implants withdrawn	Time not passed	CSR (%)	No. of implants followed	No. of implants failed	No. of implants withdrawn	Time not passed	CSR (%)
3.75-mm diameter										
Placement to loading	102	4	0	0	96.1	39	0	1	0	100
Loading to 1 y	98	1	2	0	95.1	38	1	0	0	97.4
1 to 2 y	95	0	5	0	95.1	37	0	1	0	97.4
2 to 3 y	90	0	19	0	95.1	36	1*	4	0	94.7
3 to 4 y	71	0	38	0	95.1	31	0	11	0	94.7
4 to 5 y	33	0	7	2	95.1	20	0	4	0	94.7
5 y	24	—	—	—	—	16	—	—	—	—
4-mm diameter										
Placement to loading	46	0	0	0	100	15	1	3	0	93.3
Loading to 1 y	46	0	2	0	100	11	0	0	0	93.3
1 to 2 y	44	0	4	0	100	11	1	0	0	84.8
2 to 3 y	40	0	6	0	100	10	0	2	0	84.8
3 to 4 y	34	0	22	0	100	8	0	3	0	84.8
4 to 5 y	12	0	0	1	100	5	0	1	0	84.8
5 y	11	—	—	—	—	4	—	—	—	—
5-mm diameter										
Placement to loading	66	6	0	0	90.9	31	3	2	0	90.3
Loading to 1 y	60	2	1	0	87.9	26	1	0	0	86.8
1 to 2 y	57	1	2	0	86.3	25	4	1	0	73.0
2 to 3 y	54	0	11	0	86.3	20	0	7	0	73.0
3 to 4 y	43	0	20	0	86.3	13	0	4	0	73.0
4 to 5 y	23	0	6	2	86.3	9	0	1	0	73.0
5 y	15	—	—	—	—	8	—	—	—	—

*Implant fracture.
CSR = cumulative survival rate.

Table 6 Mean Marginal Bone Loss and Standard Deviation for Arches, Implant Diameters, and Different Time Periods Per Implant

	Implant diameter		
Time	3.75 mm	4 mm	5 mm
Maxilla			
Loading to 1 y	0.3 (0.6); n = 30	0.2 (0.4); n = 24	0.2 (0.6); n = 49
1 to 3 y	–0.1 (0.4); n = 19	–0.1 (0.4); n = 18	0.2 (0.5); n = 33
3 to 5 y	–0.1 (0.3); n = 7	0.0 (0.5); n = 6	0.1 (0.4); n = 12
Loading to 5 y	0.2 (0.5); n = 8	0.1 (0.5); n = 6	0.5 (0.7); n = 12
Mandible			
Loading to 1 y	0.8 (0.8); n = 10	0.4 (0.7); n = 6	0.4 (0.4); n = 16
1 to 3 y	0.2 (1.3); n = 7	0.2 (0.4); n = 5	0.0 (0.3); n = 5
3 to 5 y	–0.1 (0.2); n = 4	–0.3 (0.3); n = 3	0.0 (0.3); n = 4
Loading to 5 y	0.1 (0.4); n = 5	0.1 (0.1); n = 3	0.4 (0.5); n = 8

Negative values indicate bone gain. Standard deviation indicated in parentheses.

ond premolar was lost as the result of a fracture of its supporting implant. Consequently, this implant was also regarded a failure.

Complications. During the 5-year period, the following complications were encountered: fistulas (n = 4), porcelain veneer fractures (n = 3), postoperative infections (n = 2), implant fracture (n = 1), and loosened gold screw (n = 1). Two patients, each with a complete maxillary prosthesis, were not satisfied with the esthetic result of their restorations. One patient, whose surgery was in the posterior area of the mandible, reported persistent altered nerve sensation of the left mental nerve up to 2 years after implant placement. However, no specific implant diameter group experienced more complications than the others.

Discussion

The present study evaluated the outcome of various implant diameters after 3 to 5 years in function with regard to implant survival and marginal bone loss. The results showed a lower CSR and a tendency for higher bone loss for 5.0-mm-diameter implants, as compared to 3.75-mm- or 4.0-mm-diameter implants. This outcome was unexpected, since earlier clinical studies have indicated more favorable results for wide-diameter implants,[19,22] particularly for the 5.0-mm implant, although the clinical follow-up periods have been shorter.[17,23,24] Furthermore, Ivanoff et al[20] have shown, in an experimental study of the rabbit tibia, that removal torque values for unloaded implants increased with increasing implant diameter. However, it is important to understand that the clinical situation is quite different from an experimental protocol. More uncontrolled variables are present, a situation that most likely influenced the current outcome. This report is based on retrospective material, and the result must be interpreted with caution. Based on radiographic follow-ups, the number of drop-outs seems to be rather high, and consequently there might be a risk of selection bias. However, no specific pattern could be observed in the drop-out group compared to those who completed the study.

In contrast to other studies involving implant treatment for edentulous patients and using standard implants 3.75 mm in diameter,[3,4] higher failure rates were seen in the current report for mandibular implants than for maxillary implants. However, most implants in the present study were placed in the posterior areas of partially edentulous jaws, where most of the mandibular losses were seen (Table 4). Similar findings were previously reported by Graves et al,[24] who also reported lower success rates in the mandible than the maxilla. However, in the study by Bahat and Handelsman,[23] a low failure rate (2.3%) was reported for 5.0-mm-diameter Brånemark implants that replaced molars (46 maxillary and 95 mandibular). All failures still occurred in mandibles after a mean loading period of approximately 1 year. Consequently, the posterior region of the mandible seems to give rise to more failures than the corresponding area of the maxilla. One reason might be that in most instances the implant is supported by only one cortical layer, because of the presence of the inferior alveolar nerve, even if sometimes it might be possible to also use the compact bone of the buccal and/or lingual plates. However, in situations involving unfavorable arch shape and bone quality, ie, Type 4 bone quality with excessive buccolingual dimension, the initial stability of the implant will depend on the marginal compact bone only. This may, at least to some extent, explain the higher losses seen in these regions of the current report. In further support of such an assumption, an experimental study in rabbit tibia found that bicortical fixation of titanium screw implants resulted in higher removal torque values than did monocortical fixation.[16]

The low success rate found for the 5.0-mm-diameter implants may also be explained by the fact that 45% of these implants were used for rescue purposes. Consequently, they may have been placed in poor quantities of low-quality bone. Previously, other studies also ascribed implant failures to poor bone quality.[2,9–11] Such a relationship did not clearly exist from the quality grading of this report (Table 2), as only 19% of arches were classified as Type 4 bone quality. However, the Lekholm and Zarb index[25] gives only a mean value for the entire arch, and thus individual sites were not reported. The lack of a relationship between implant failure, jaw type, and bone quality and quantity may be explained by the fact that the number of failed implants was low, which results in a low power.

Since many of the implant losses were identified at second-stage surgery, the failures may to some extent be surgically related and/or dependent on implant design. It has been reported that new procedures, which require changed instrumentation and new technical skill, may often be associated with a learning curve. It has been shown that inexperienced surgeons profit from a definite learning curve and have a significantly higher rate of treatment failures than experienced surgeons, who have a flatter curve.[3,30–32] However, in the current study, all patients were treated by surgeons with long clinical experience in implant surgery, although not with the new wide-diameter implant. At the time the implants were placed, no adapted surgical techniques were used for poor bone situations, ie, smaller diameter twist drills as presented by Friberg[33] and Bahat and Handelsman[23] and increased healing time as indicated by Sennerby et al.[34] Furthermore, the 5.0-mm-diameter implant lacks a neck and has a differently threaded profile, compared to standard and 4.0-mm-diameter implants. Certainly, this might also have had an impact on the treatment results, both with regard to implant survival and marginal bone loss. The implant neck may play an important role in stabilizing the implant during its final tightening when placed, especially in poor quality bone and in combination with a thin marginal compact bone layer.

The mean marginal bone loss for the 3 implant diameter groups was generally low over the 5-year period and was in accordance with earlier studies.[4,7,35] The 5.0-mm-diameter implants indicated, however, slightly higher marginal bone loss than did the 2 other diameters. This result was unexpected and not in accordance with previous experimental findings using finite element method analysis, in which lower stress in the marginal compact bone around hydroxyapatite-coated implants was found with increasing implant diameters.[21] Thus, design of the 5.0-mm-diameter implant might have altered the load distribution of the marginal compact layer. The selection of a reference point might also have had an influence on the difference between the 3 implant types noted. For the 5.0-mm-diameter implant, any change in bone level over time was recorded as bone loss, since the abutment-implant junction was chosen as reference point, while only bone level changes occurring 0.8 mm apical to the abutment-implant junction were registered as a change in bone level for the 2 other implant diameters. However, implant design has previously been reported to alter marginal bone remodeling, as shown for the conical implant design,[36] and this could also be a contributing factor in this study.

In this report, multiple regression analyses were used to study relationships between marginal bone loss, implant diameters, and clinical parameters. To do this appropriately, it is necessary to have an equal distribution of the material, which was not the case in the current report. Clinical studies based on limited numbers of patients do not provide this easily. However, the statistical methods used were still considered acceptable for the purposes.

Conclusions

The 5.0-mm-diameter implant showed less favorable results than 3.75-mm- and 4.0-mm-diameter implants with regard to stability and marginal bone loss. However, the different implant diameters were not placed in comparable anatomic situations in identical indications. Therefore, a strict comparison could not be performed. However, the different outcomes might still be related to a learning curve involving a new implant design, or even the changed implant design itself, factors that could not be properly elucidated by the present study protocol. Although the results with the 5.0-mm-diameter implant were not as good as those with the standard implants, there still seem to be obvious benefits for using 5.0-mm-diameter implants in certain clinical situations.[17,24] Further development of implant design and surgical technique may be necessary to achieve optimal treatment results. A prospective study by Polizzi[37] indicates that higher success rates can be expected for a new generation of 5.0-mm-diameter implants, which have been designed more like the standard Brånemark implant.

References

1. Brånemark P-I, Breine U, Adell R, Hansson BO, Lindström J, Ohlsson Å. Intra-osseous anchorage of dental prostheses. I. Experimental studies. Scand J Plast Reconstr Surg 1969;3:81–100.
2. Brånemark P-I, Hansson BO, Adell R, Breine U, Lindström J, Hallén O, Öhman A. Osseointegrated implants in the treatment of the edentulous jaw. Experience from a 10-year period. Scand Reconstr Surg 1977;11(suppl 16):1–132.
3. Adell R, Eriksson B, Lekholm U, Brånemark P-I, Jemt T. A long-term follow-up study of osseointegrated implants in the treatment of the totally edentulous jaw. Int J Oral Maxillofac Implants 1990;5:347–359.
4. Friberg B, Nilson H, Olsson M, Palmquist C. Mk II: The self-tapping Brånemark implant. 5-year result of a prospective 3-center study. Clin Oral Implants Res 1997;8:279–285.
5. Henry P, Laney WR, Jemt T, Harris D, Krogh P, Polizzi G, et al. Osseointegrated implants for single-tooth replacement: A prospective 5-year multicenter study. Int J Oral Maxillofac Implants 1996;11:450–455.
6. Jemt T, Chai J, Harnett J, Heath R, Hutton J, Johns R, et al. A 5-year prospective multicenter follow-up report on overdentures supported by osseointegrated implants. Int J Oral Maxillofac Implants 1996;11:291–298.
7. Lekholm U, van Steenberghe D, Herrmann I, Bolender C, Folmer T, Gunne J, et al. Osseointegrated implants in the treatment of partially edentulous jaws: A prospective 5-year multicenter study. Int J Oral Maxillofac Implants 1994;9:627–635.
8. Zarb GA, Schmitt A. The longitudinal effectiveness of osseointegrated dental implants: The Toronto study. Part 1: Surgical results. J Prosthet Dent 1990;63:451–457.
9. Engquist B, Bergendal T, Kallus T, Linden U. A retrospective multicenter evaluation of osseointegrated implants supporting overdentures. Int J Oral Maxillofac Implants 1988;3:129–134.
10. Friberg B, Jemt T, Lekholm U. Early failures in 4641 consecutively placed Brånemark dental implants. A study from stage I surgery to the connection of completed prostheses. Int J Oral Maxillofac Implants 1991;6:142–146.
11. Jaffin RA, Berman CL. The excessive loss of Brånemark fixtures in type IV bone. A 5-year analysis. J Periodontol 1991;62:2–4.
12. Albrektsson T, Brånemark P-I, Hansson H-A, Lindström J. Osseointegrated titanium implants. Requirements for ensuring long-lasting, direct bone-to-implant anchorage in man. Acta Orthop Scand 1981;52:155–170.
13. Adell R, Lekholm U, Brånemark P-I. Surgical procedures. In: Brånemark P-I, Zarb GA, Albrektsson T (eds). Tissue-Integrated Prostheses: Osseointegration in Clinical Dentistry. Chicago: Quintessence, 1985:211–232.

14. Carlsson L, Röstlund T, Albrektsson B, Albrektsson T. Implant fixation improved by close fit. Cylindrical implant-bone interface studied in rabbits. Acta Orthop Scand 1988;59:272–275.
15. Ivanoff C-J, Sennerby L, Lekholm U. Influence of initial implant mobility on the integration of titanium implants. An experimental study in rabbits. Clin Oral Implants Res 1996;7:120–127.
16. Ivanoff C-J, 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.
17. Langer B, Langer L, Herrmann I, Jörnéus L. The wide fixture. A solution for special bone situations and a rescue for the compromised implant. Part I. Int J Oral Maxillofac Implants 1993;8:400–408.
18. Lekholm U, Adell R, Brånemark P-I. Complications. In: Brånemark P-I, Zarb GA, Albrektsson T (eds). Tissue-Integrated Prostheses: Osseointegration in Clinical Dentistry. Chicago: Quintessence, 1985:233–240.
19. Lekholm U. The Brånemark implant technique. A standardized procedure under continuous development. In: Laney WR, Tolman DE (eds). Tissue Integration in Oral, Orthopedic and Maxillofacial Reconstruction. Chicago: Quintessence, 1992:194–199.
20. Ivanoff C-J, Sennerby L, Johansson C, Rangert B, Lekholm U. Influence of implant diameters on the integration of screw implants. An experimental study in rabbits. Int J Oral Maxillofac Surg 1997;26:141–148.
21. Matsushita Y, Kitoh M, Mizuta K, Ikeda H, Suetsugu T. Two-dimensional FEM analysis of hydroxyapatite implants: Diameter effects on stress distribution. J Oral Implantol 1990;16:6–11.
22. Van Steenberghe D, Lekholm U, Bolender C, Folmer T, Henry P, Herrmann I, et al. The applicability of osseointegrated 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. 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.
24. Graves SL, Jansen CE, Siddiqui AA, Beaty KD. Wide diameter implants: Indications, considerations and preliminary results over a two-year period. Aust Prosthodont J 1994;8:31–37.
25. Lekholm U, Zarb GA. Patient selection and preparation. In: Brånemark P-I, Zarb GA, Albrektsson T (eds). Tissue-Integrated Prostheses: Osseointegration in Clinical Dentistry. Chicago: Quintessence, 1985:199–209.
26. Jemt T. Modified single and short span restorations supported by osseointegrated fixtures in the partially edentulous jaw. J Prosthet Dent 1986;55:243–246.
27. Zarb GA, Jansson T. Prosthodontic procedures. In: Brånemark P-I, Zarb GA, Albrektsson T (eds). Tissue-Integrated Prostheses: Osseointegration in Clinical Dentistry. Chicago: Quintessence, 1985:241–282.
28. Zarb GA, Jansson T, Jemt T. Other prosthodontic applications. In: Brånemark P-I, Zarb GA, Albrektsson T (eds). Tissue-Integrated Prostheses: Osseointegration in Clinical Dentistry. Chicago: Quintessence, 1985:283–292.
29. Colton T. Longitudinal studies and the use of the life table. In: Colton T. Statistics in Medicine. Boston: Little, Brown and Company, 1974:237–250.
30. Block MS, Kent JN. Factors associated with soft and hard tissue compromise of endosseous implants. J Oral Maxillofac Surg 1990;48:1,153–1,160.
31. Esposito M, Hirsch JM, Lekholm U, Thomsen P. Biological factors contributing to failures of osseointegrated oral implants. II. Etiopathogenesis. Eur J Oral Sci 1998;106:721–764.
32. Lambert P, Morris H, Shigeru O. Positive effect of surgical experience with implants on second-stage implant survival. J Oral Maxillofac Surg 1997;55(suppl 5):12–18.
33. Friberg B. Bone Quality Evaluation During Implant Placement [thesis]. Göteborg: Univ of Göteborg, 1994.
34. Sennerby L, Thomsen P, Ericsson L. A morphometric and biomechanic comparison of titanium implants inserted in rabbit cortical and cancellous bone. Int J Oral Maxillofac Implants 1992;7:62–71.
35. 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.
36. Jemt T, Lekholm U, Gröndahl K. A 3-year follow-up study of early single implant restorations ad modum Brånemark. Int J Periodontics Restorative Dent 1990;5:341–349.
37. Polizzi G. Clinical experiences with the Mark II wide platform. Talk of the Times 1998;3:24–26.