Survival of the Brånemark Implant in Partially Edentulous Jaws: A 10-Year Prospective Multicenter Study

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A total of 127 partially edentulous patients, treated according to the Brånemark protocol, was followed for 10 years after completion of prosthetic treatment. The patients ranged in age from 18 to 70 years, and 57% were female. Four hundred sixty-one implants were placed in 56 maxillae and 71 mandibles. In 125 patients, 163 fixed partial prostheses were attached to the implants; a majority of the prostheses (83%) were located in posterior regions. At the end of the 10-year period, 73% of the implants could be traced either as failed or in function, providing cumulative implant survival rates of 90.2% and 93.7% for the maxilla and mandible, respectively. Of the original fixed prostheses, 63% (cumulatively 86.5%) were still in use, whereas the level of continuous cumulative prosthesis function, including primary and remade restorations, was 94.3% at the end of the evaluation period. Marginal bone resorption at the implants was low (mean = 0.7 mm), and mucosal health was good. No severe complications apart from the above-mentioned implant and prosthetic failures were reported. The Brånemark Implant System is a safe and predictable method for restoring partially edentulous patients, as demonstrated by this 10-year follow-up investigation.
(INT J ORAL MAXILLOFAC IMPLANTS 1999;14:639–645)

Key words: Brånemark System, osseointegration, partial edentulism, titanium implants

The use of oral implants in the treatment of partially edentulous jaws has become a well-established and accepted contemporary clinical method.[1] When proposing this treatment, however, it is important to also inform patients about long-term outcome. This information should be based on reports of results found in international, peer-reviewed journals. With regard to partial edentulism, there is ample documentation that the Brånemark System has predictable medium-term success.[2–8]

Shortcomings can easily be found in most previously reported investigations. The studies may be based on individual clinics or clinicians, which limits the value of the analysis, since the studies may be retrospective rather than prospective, meaning that research parameters and follow-up periods have not been decided from the start of the study. Prospective studies, however, assess all patients for the same length of time and examine the same parameters. Criteria for success and failure are other important aspects and matters of ongoing debate. Follow-up parameters should include at least testing of implant mobility and/or bone loss using standardized radiographs.[9,10] It is also important to limit the results to one implant

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design at a time, as well as to well-defined surgical protocols. The outcome of implant treatment for partial edentulism has been evaluated mainly after less than 5 years of function.[2,3,4,8,11] Only a few reports present 5-year or longer results.[5,7,12–14] Consequently, there is still a need for more information regarding the long-term outcome of implant treatment of partial edentulism.

The aim of the present prospective investigation was to report the 10-year outcome of a multicenter trial, using Brånemark implants to restore partially edentulous arches. The outcome was evaluated using well-defined success criteria.

Table 1 Placed and Failed Implants with Respect to Bone Quality and Quantity*

	Maxilla		Mandible	
	Placed	Failed	Placed	Failed
Bone quality				
1	0	—	6	0
2	24	3	46	3
3	138	11	182	11
4	23	3	42	3
Total	185	17	276	17
Bone quantity				
A	7	2	8	0
B	103	9	136	11
C	68	6	115	5
D	5	0	17	1
E	2	0	0	—
Total	185	17	276	17

*Based on Lekholm and Zarb.[15]

Materials and Methods

The present investigation is an update on a prospective multicenter trial that examined outcomes after 5 years.[14] At the completion of the study, the clinical teams were invited to extend the follow-up for another 5 years. Six of the initial 9 centers, representing Australia, Belgium, Sweden, and the United States, accepted the proposal.

A total of 127 patients was treated by the 6 teams between July 1985 and April 1987. The mean age of these patients was 50 years (range 18 to 70 yrs). Fifty-four of the patients were males, and 56 maxillae and 71 mandibles were restored. A majority of arches were designated Applegate-Kennedy Class I or II (maxillary 73%; mandibular 92%), ie, represented posterior regions. All arches were classified regarding shape and quality according to Lekholm and Zarb.[15] It appeared that most arches were type B in shape and type 3 in quality (Table 1).

In treated jaws, a total of 461 Brånemark implants (Nobel Biocare AB, Göteborg, Sweden) of various lengths and diameters was placed (Table 2), using a well-defined standard surgical protocol.[16] Following second-stage surgery, 163 fixed partial prostheses (65 maxillary and 98 mandibular) in 125 patients were fabricated according to the conventional protocol described elsewhere.[17] Treated patients were followed annually using clinical and radiographic parameters. The results have been published at 1-, 3-, and 5-year intervals.[14,18–22] In

Table 2 Distribution of Placed and Failed Implants with Regard to Implant Size and Location

	Maxillae		Mandibles		Total	
Implant size	Placed	Failed	Placed	Failed	Placed	Failed
3.75 mm diameter						
7 mm long	22	4	70	2	92	6
10 mm long	74	10	119	13	193	23
13 mm long	35	3	24	2	59	5
15 mm long	45	0	23	0	68	0
18 mm long	4	0	13	0	17	0
20 mm long	2	0	4	0	6	0
4.00 mm diameter						
7 mm long	0	0	9	0	9	0
10 mm long	2	0	12	0	14	0
13 mm long	1	0	2	0	3	0
15 mm long	0	0	0	0	0	0
18 mm long	0	0	0	0	0	0
Total	185	17	276	17	461	34

the present report, implant survival, prosthesis stability, marginal health conditions at implants, and complications were evaluated.

At the 10-year examination, the prostheses were not removed to evaluate individual implant stability. Therefore, implant survival was defined according to Albrektsson et al.[23] Prosthesis stability was measured using a percentage grading system based on 3 functional levels: *(1)* original restorations in function; *(2)* continuous prosthesis function, including original and remade prostheses; and *(3)* impaired or failed prosthetic function, ie, the patient temporarily or permanently returned to tooth-supported fixed restorations or removable partial dentures. Bone conditions around the implants were evaluated using intraoral radiographs.[24] These were taken at the time of prosthesis placement and as a baseline for measurements. Gingival health was evaluated using a modified Sulcus Bleeding Index (grades 0, 1, and 2), according to Mühlemann and Son[25]; grade 0 denoted no bleeding on probing, 1 indicated bleeding on probing up to 1 mm subgingivally, and 2 indicated unknown conditions. Observed complications were counted and reported for each patient once a year.

Drop-outs. During the 10-year follow-up period, 38 of the 127 patients (30%) dropped out (24 during the later 5-year period; Table 3) because of death (n = 5), severe illness (n = 2), migration (n = 15), noncompliance (n = 9), implant failure (n = 5), and unknown reasons (n = 2). This left 89 patients for the final examination. The withdrawn patients represented a total of 123 implants (27%) (Table 4).

Statistics. Calculations of implant survival and prosthesis stability rates were based on the life table principle described by Colton,[26] taking into account the drop-outs. Cox regression analyses regarding parameters influencing implant survival were performed according to Altman.[27] Chi-square tests were used to evaluate the difference between implant failure in prostheses supported by 2 or 3 implants and implant failure in prostheses supported by 4 implants.[27] To avoid possible influences of patient dependence, 1 implant per patient was selected according to Pocock.[28] The implants

Table 3 Status of Followed and Withdrawn Patients over the 10-Year Study Period

Time	No. of patients followed	No. of patients withdrawn
Baseline		
No. of implants	127	—
No. of abutments	127	—
No. of prostheses	125	2
1 y	120	7
2 y	118	9
3 y	116	11
4 y	114	13
5 y	113	14
10 y	89	38

Table 4 Life Table Analysis of Placed and Followed Implants

Time	Implants	Failed	Withdrawn	CSR (%)
Maxilla				
Placement to loading	185	5	0	97.3
Loading to 1 y	180	2	14	96.2
1 to 2 y	164	4	2	93.9
2 to 3 y	158	1	1	93.3
3 to 4 y	156	0	3	93.3
4 to 5 y	153	1	0	92.7
5 to 10 y	152	4	26	90.2
10 y	122	—	—	—
Mandible				
Placement to loading	276	11	1	96.0
Loading to 1 y	264	1	7	95.7
1 to 2 y	256	3	4	94.5
2 to 3 y	249	0	10	94.5
3 to 4 y	239	0	1	94.5
4 to 5 y	238	2	2	93.7
5 to 10 y	234	0	52	93.7
10 y	182	—	—	—

CSR = cumulative survival rate.

Table 5 Distribution of Implant Failures within Patients

No. of implants placed per patient	No. of patients	No. of patients with 1 implant failure	No. of patients with more than 1 implant failure
2	26	1	1*
3	50	10	1*
4	16	2	1*
5	15	3	0
6	20	4	3†

*The patient lost 2 implants.
†Two patients lost 2 implants and 1 patient lost 4 implants.

in each patient were thereby calculated from quadrant 1 to 4, following the SIS tooth numbering system, until the number from the randomized chart was reached. In connection with statistical evaluations, a *P* value of .05 (5%) was considered clinically relevant.

Results

Of the 461 implants placed, 34 (17 maxillary and 17 mandibular; Tables 1, 2, and 4) were reported as failed after 10 years of follow-up, resulting in an overall implant survival rate of 92.6%. The cumulative implant survival rates were 90.2% and 93.7% for maxillae and mandibles, respectively (Table 4). Shorter standard-diameter implants were lost more often than longer ones, whereas no wider-diameter implants whatsoever were lost (Table 2). Furthermore, a majority of lost implants (n = 26) failed before prosthesis connection and during the first 1 to 2 years in function (Table 4), whereas only 4 implants, placed in the maxillae of 3 patients, were lost during the last 5-year period. The 4 lost implants failed because of fracture (n = 2), nonrepairable abutment screw fracture (n = 1), and unknown reasons (n = 1). Cox regression analyses showed that implant loss varied with decreasing implant length ($P \leq .05$; regression coefficient = –.62).

With regard to the distribution of implant failures as a function of the number of implants placed within each patient, the outcome is presented in Table 5. It appeared that the number of lost implants was low and independent of the number of implants placed (7.4% vs 7.3%; 2 to 3 vs 4 to 6 implants). If prosthetic units were used as a basis for the same calculation, the failure rate was 3.9% when a smaller number of implants (2 to 3) supported the prosthetic restorations and was 5.9% when 4 or more implants supported the restorations. No significant difference was seen between the groups ($P > .05$).

Of the 163 prostheses, 40 (24.5%) were withdrawn from the study and 102 were followed and still in function 10 years later (63%). The cumulative survival rate for original prostheses was 86.5%. Nine prostheses failed (5.5%), whereas 12 (7.4%) had to be refabricated because of various clinical and/or mechanical reasons. This resulted in a continuous cumulative prosthesis function level of 94.3% after 10 years of follow-up, including withdrawn patients. No differences were seen between maxillae and mandibles with respect to this outcome.

The average loss of marginal bone height was 0.7 mm in maxillae and mandibles (Table 6). Measurements were made on 538 surfaces (88%) of the available records from the first and last examinations. Bone loss was less than 1.0 mm in most cases (70%), and only 7% showed more than 2.0 mm of bone resorption.

The Gingival Bleeding Index was 0 at 80% of the sites and grade 1 or 2 in 9% (Table 7). Values were missing in 18 instances (2%). During the last 5-year follow-up period (from 5 to 10 years), 18 patients had unscheduled visits (16 patients 1 to 5 times, one patient 6 to 10 times, and one patient more than 10 visits). In addition to visits to specialists or restorative dentists, 26 patients reported visits to oral hygienists (mostly 1 to 5 visits).

All complications occurring during the last 5-year period are reported in Table 8. Persistent paresthesia was observed in 2 patients. One gold screw fractured in 1 patient, gold screws loosened in 1 patient, abutment screws fractured in 2 patients, and a loose abutment screw was seen in 1 patient. Three prostheses were mobile at the 10-year follow-up visit; these were stabilized by tight-

Table 6 Marginal Bone Resorption After 10 Years of Function*

	Maxillae		Mandibles	
	Mesial	Distal	Mesial	Distal
< 0 mm	15	19	23	16
0 mm	18	16	22	34
0.1 to 0.5 mm	19	20	30	35
0.6 to 1.0 mm	23	25	38	26
1.1 to 2.0 mm	32	24	31	35
> 2 mm	7	10	10	10
Mean (mm)	0.7	0.7	0.7	0.7
SD (mm)	0.9	0.9	0.9	0.8

*As measured in intraoral radiographs using a paralleling technique. No. of sites measured: 114 mesial and distal in maxillae, 154 mesial and 156 distal in mandibles.

Table 7 Gingival Bleeding on Probing Measured at 4 Sites around Implants/ Abutments at the 10-Year Follow-up Visit*

Index	DB	MB	DL	ML
0	248	237	244	248
1	22	33	31	27
2	27	27	27	27
Missing	7	7	2	2
Total	304	304	304	304

*According to Mühlemann and Son.[25]
DB = distobuccal; MB = mesiobuccal; DL = distolingual; ML = mesiolingual.

ening the prosthesis-locking screws. The prostheses were temporarily removed in 7 patients for therapeutic reasons, and new prostheses were fabricated for 9 patients because of fractures of the veneering material, need for additional implants (1 patient), soft tissue problems, tooth extractions, or esthetic reasons. A detailed account of the complications that occurred during the first 5-year period has previously been presented.[14]

Table 8 Reported Complications Occurring During the Latest 5-Year Period*

Complication	No. of patients	(%)
Persistent paresthesia	2	1.8
Implant fractures/failures	3	2.7
Gold screw loosening/fracture	2	1.8
Abutment screw loosening/fracture	3	2.7
Temporary removal of prostheses	7	6.2
Fabrication of new prostheses	9	8.0
Reoperation/additional implants	3	2.7

*Based on 113 patients followed for 5 to 10 years.

Discussion

The present study reports the follow-up of implant reconstruction of partially edentulous arches, using the Brånemark System in a prospective multicenter trial. The overall outcome showed an implant survival rate of 92.6% and a continuous cumulative prosthetic stability of 94.3% after 10 years in clinical function. No other studies have thus far examined implant reconstruction of partially edentulous patients for 10 years. The outcome compares well with other studies of partial edentulism using the Brånemark System.[5–7,12,14] The outcome also compares well and even exceeds those for edentulous arches followed for the same length of time.[29]

The cumulative implant survival rates (Table 4) were 90.2% and 93.7% for maxillae and mandibles, respectively. It should be pointed out that a majority of treated arches (83%) involved posterior regions. Compared to the previous 5-year follow-up results,[14] only minor changes had taken place (4 new implant failures in 5 years, all concentrated in maxillae). It is important, however, to observe that the current study presented only survival and not success rates, since the prostheses were not removed at 10 years (patients were very reluctant to do so) to assess individual implant stability. On the other hand, the discriminative power of standardized intraoral radiographs obtained using a parallelling technique has been found to be high for identifying loose implants.[30]

Of the losses reported during the 5- to 10-year period, 3 proved to be mechanical failures, which suggests that overloading of the anchorage units, rather than marginal tissue inflammation, may be the long-term limited problem to be expected in partially edentulous patients treated with Brånemark System implants. According to Cox regression analysis, the only relationship between failures and implant characteristics was seen with regard to implant length, in that shorter implants failed more often than longer ones. Similar findings have already been reported after 5 years of function.[14] However, all implant lengths exceeded the 85% survival rate stipulated by Albrektsson and Zarb.[31]

Of the 163 originally attached prostheses, 102 were still in function 10 years later (63%). A tendency for a higher failure rate was seen for those restorations supported by 4 or more implants than

for those supported by 2 to 3 units, in contrast to previous reports.[12] However, the small number of prostheses supported by more than 3 implants does not permit a definitive conclusion. When taking into account the remade prostheses (n = 12), a total continuous prosthesis function level of 94.3% was seen over the 10-year period. The limited prosthetic failure rate of 5.5% (n = 9) observed at the same time is also well in line with previous reports.[5,12,14] Regarding the prosthetic outcome, the current use of 3 levels of evaluation helps indicate to what extent new prostheses had to be fabricated, which is relevant information for both clinicians and patients. Besides, the fact that 84% of the patients followed the conventional treatment protocol[17] indicated the cost-effectiveness of the prosthetic treatment provided.

Marginal bone loss (Table 6) was extremely low after 10 years (mean = 0.7 mm). The bone was stable around these implants in spite of the concern about a microgap being present between the implant and the abutment components.[32] The bone resorption compares favorably with reports for completely edentulous situations.[29] In 80% of the sites, no bleeding on probing was noted, and only 20% of the patients had to attend additional hygiene appointments with dentists or dental hygienists. This indicates that these partially edentulous patients were capable of maintaining good oral hygiene around their implants during the entire 10-year follow-up period.

In the current report, complications observed only during the last 5-year period were presented (for the first 5-year period, see Lekholm et al[14]). Observed complications were evaluated on a per-patient basis (Table 8), ie, the number of patients affected instead of the actual number of complications that occurred. Apart from implant and prosthetic failures, temporary removal of prostheses (6.2%) was the most commonly reported problem. Soft tissue and mechanically related problems were very infrequent (2 to 3% for each type). Consequently, this implant system seems to be well-maintained and does not require extensive retreatment of patients.

During the 10-year follow-up period, 33 patients (26%; Table 3), corresponding to 27% of the implants originally placed, were lost to follow-up because of various reasons, and this is not an uncommon occurrence in long-term studies. All withdrawals have been accounted for in cumulative survival rate presentations, as the life table principle of Colton[26] was used in their calculation.

Conclusions

The Brånemark Implant System, used to treat partial edentulism, provided excellent survival rates over a 10-year follow-up period. Good mucosal health and little marginal bone loss were observed. There were also no severe complications reported.

Acknowledgments

The authors are indebted to all colleagues who have made this study possible. In particular the following persons are recognized: Björn Klinge, Malmö, Sweden; Justine Leavy, Perth, Australia; Ruth Billings, Spokane, Washington; Torsten Jemt and Bengt Lindén, Göteborg, Sweden; and Ignance Naert and Marc Quirynen, Leuven, Belgium.

References

1. Esposito M, Hirsch J-M, Lekholm U, Thomsen P. Biological factors contributing to failures of osseointegrated oral implants. (I) Success criteria and epidemiology. Eur J Oral Sci 1998;106:527–551.
2. Jemt T, Lekholm U, Adell R. Osseointegrated implants in the treatment of partially edentulous patients. A preliminary study on 876 consecutively placed implants. Int J Oral Maxillofac Implants 1989;4:211–217.
3. Van Steenberghe D. A retrospective multicenter evaluation of the survival rate of osseointegrated fixtures supporting fixed partial prostheses in the treatment of partial edentulism. J Prosthet Dent 1989;61:217–224.
4. Tolman DE, Laney WR. Tissue-integrated prosthesis complications. Int J Oral Maxillofac Implants 1992;7:477–484.
5. 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.
6. Zarb GA, Schmitt A. The longitudinal clinical effectiveness of osseointegrated dental implants in posterior partially edentulous patients. Int J Prosthodont 1993;6:189–196.
7. Olsson M, Gunne J, Åstrand P, Borg K. Bridges supported by free-standing implants versus bridges supported by teeth and implants. A 5-year prospective study. Clin Oral Implants Res 1995;6:114–121.
8. 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.
9. Roos J, Sennerby L, Lekholm U, Jemt T, Gröndahl K, Albrektsson T. A quantitative and qualitative method for evaluating implant success: A 5-year retrospective study of the Brånemark Implant. Int J Oral Maxillofac Implants 1997;12:504–514.
10. Van Steenberghe D. Outcomes and their measurements in clinical trials of endosseous oral implants. Ann Periodontol 1997;2:291–298.
11. Balshi TJ, Hernandez RE, Pryszlak MC, Rangert B. A comparative study of one implant versus two replacing a single molar. Int J Oral Maxillofac Implants 1996;11:372–378.
12. Jemt T, Lekholm U. Oral implant treatment in posterior partially edentulous jaws: A 5-year follow-up report. Int J Oral Maxillofac Implants 1993;8:635–640.

13. Ericsson I, Brånemark P-I, Glantz P-O. Partial edentulism. In: Worthington P, Brånemark P-I (eds). Advanced Osseointegration Surgery. Applications in the Maxillofacial Region. Chicago: Quintessence, 1992:194–209.
14. 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.
15. 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.
16. 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.
17. 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.
18. 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.
19. Gunne J, Jemt T, Lindén U. Implant treatment in partially edentulous patients: A prospective report after 3 years. Int J Prosthodont 1993;7:143–148.
20. Henry P, Tolman D, 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.
21. Van Steenberghe D, Klinge B, Lindén U, Quirynen M, Herrmann I, Garpland C. Periodontal indexes around natural and titanium abutments: A longitudinal multicenter study. J Periodontol 1993;64:538–541.
22. Higuchi KW, Folmer T, Kultje C. Implant survival rate in partially edentulous patients: A 3-year prospective multicenter study. J Oral Maxillofac Surg 1995;53:264–268.
23. Albrektsson T, Zarb GA, Worthington P, Eriksson AR. The long-term efficacy of currently used dental implants. A review and proposed criteria of success. Int J Oral Maxillofac Implants 1986;1:11–25.
24. Hollender L, Rockler B. Radiographic evaluation of osseointegrated implants of the jaws. Dentomaxillofac Radiol 1980;9:91–95.
25. Mühlemann HR, Son S. Gingival sulcus bleeding: A leading symptom in initial gingivitis. Helv Odontol Acta 1971;15:107–113.
26. Colton T. Longitudinal studies and the use of the life table. In: Colton T. Statistics in Medicine. Boston: Little, Brown, 1974:241–249.
27. Altman DG. Practical Statistics for Medical Research. London: Chapman and Hall, 1991:241–265, 387–395.
28. Pocock SJ. Clinical Trials. A Practical Approach. Whichester: John Wiley and Sons, 1984:66–89.
29. Adell R, Eriksson B, Lekholm U, Brånemark P-I, Jemt T. A long-term follow-up study of osseointegrated implants in the treatment of totally edentulous jaws. Int J Oral Maxillofac Implants 1990;5:347–359.
30. Gröndahl K, Lekholm U. The predictive value of radiographic diagnosis of implant stability. Int J Oral Maxillofac Implants 1997;11:179–185.
31. Albrektsson T, Zarb GA. Current interpretations of the osseointegrated response: Clinical significance. Int J Prosthodont 1993;6:95–105.
32. Hermann JS, Cochran DL, Nummikoski PV, Buser D. Crestal bone changes around titanium implants. A radiographic evaluation of unloaded nonsubmerged and submerged implants in the canine mandible. J Periodontol 1997;68:1117–1130.