Fixed Implant-Supported Prostheses in Elderly Patients: A 5-Year Retrospective Study of 133 Edentulous Patients Older than 79 Years

Ingela Engfors, DDS;* Anders Örtorp, DDS;* Torsten Jemt, DDS, PhD†‡

ABSTRACT

Background: An increasing number of elderly patients are treated with implants, but results for the elderly patient in terms of implant success and adaptation to implant prostheses are contradictory.

Objective: To retrospectively study the 5-year clinical and radiologic performances of fixed implant-supported prostheses placed in edentulous elderly patients and to compare those results with the results of using similar prostheses in a control group of younger patients.

Materials and Methods: The study group comprised 133 edentulous patients who were 80 or more years of age and who were consecutively treated with fixed implant-supported prostheses between January 1986 and August 1998. Altogether 761 Brånemark System® implants (Nobel Biocare AB, Göteborg, Sweden) were placed in 139 edentulous jaws. The control group comprised 115 edentulous patients who were younger than 80 years and who were treated consecutively from March 1996 to November 1997 with similar prostheses. In this group 670 implants were placed in 118 edentulous jaws. Information was collected from all postinsertion visits, including the fifth annual checkup, and changes of marginal bone levels were analyzed from intraoral radiographs.

Results: The 5-year cumulative survival rate (CSR) for implants in the maxilla was 93.0% in the study group and 92.6% in the control group; the corresponding CSRs for implants in the mandible were 99.5% and 99.7%. The most common complications for patients in the study group were soft tissue inflammation (mucositis) and cheek and lip biting ($p < .05$) whereas resin veneer fractures were the most common complications for the control group. Overall 5-year marginal bone loss for the study group was 0.7 mm (standard deviation [SD], 0.45) in the upper jaw and 0.6 mm (SD, 0.50) in the lower jaw. Differences in bone levels and bone loss between the two groups did not reach significant levels ($p > .05$).

Conclusions: Implant treatment in the elderly patients showed treatment results comparable to those observed in younger age groups. However, indications of more problems with adaptation could be observed and were reflected in more postinsertion problems. Cleaning problems and associated soft tissue inflammation (mucositis) as well as tongue, lip, and cheek biting were significantly more often observed among the elderly patients ($p < .05$).

KEY WORDS: adaptation, age, complications, edentulism, elderly, implants

According to population data, the number of persons older than 80 years has increased continuously in Sweden during the last decades,[1–3] a trend that also has been observed in the rest of the Western world. It has also been reported that people with complete dentures are less common today than they were 5 to 10 years ago,[4,5] which implies that more people of higher age will maintain their teeth and ask for dental treatment in the future. Accordingly, in the future, patients in higher age groups will have more remaining teeth, and it is reasonable to assume that edentulism may appear first in elderly patients who are having problems adapting to their first removable dentures.[6,7]

*Consultant in prosthodontics, The Brånemark Clinic, Public Dental Health Service, Göteborg, Sweden; †chairman, The Brånemark Clinic, Public Dental Health Service, Göteborg, Sweden; ‡professor, Department of Prosthetic Dentistry/Dental Material Science, Faculty of Odontology, University of Göteborg, Göteborg, Sweden

Reprint requests: Dr. Torsten Jemt, The Brånemark Clinic, Public Dental Health Service, Medicinaregatan 12C, S–413 90 Göteborg, Sweden; e-mail: torsten.jemt@vgregion.se

When this happens elderly people can be expected to make higher demands on dental treatment and to be more receptive to new restorative techniques.

Many studies have shown evidence of good long-term success for implant treatment in edentulous patients.[8–13] However, results in terms of implant success for the elderly patient are contradictory. Some studies indicate that age alone is not a contraindication for implant treatment[14–20] whereas other studies suggest that age may be associated with a higher implant failure rate, more marginal bone loss,[21–23] and more problems in adapting to the new prosthesis.[7,24]

The objective of this retrospective study was to examine the 5-year clinical and radiologic performances of fixed implant-supported prostheses placed in edentulous patients 80 or more years of age and to compare the results with the results of using similar prostheses in a control group of younger patients.

MATERIALS AND METHODS

Study Group

The present study was designed as a retrospective 5-year follow-up study on elderly edentulous patients consecutively treated with fixed implant-supported prostheses at one clinic (The Brånemark Clinic, Göteborg, Sweden) between January 1986 and August 1998. During the inclusion period a total of 1,240 and 1,802 edentulous patients were treated with fixed implant-supported prostheses in the upper jaw and lower jaw, respectively (Table 1). For inclusion in the study group, patients had to be 80 or more years of age at the time of implant surgery. Patients with bone grafts were excluded.

The study group comprised 133 patients (79 females and 54 males). The mean age was 83.1 years (standard deviation [SD], 2.9; range, 80–93 years) at the time of implant surgery (Table 2; see also Table 1).

Forty-eight (36%) of the patients were taking no medication and reported good general health at the time of implant surgery. Records with regard to smoking habits were available for 101 patients (76%) and indicated that 12 patients (12%) were smokers and 89 (88%) were nonsmokers.

Altogether patients were provided with 761 Brånemark System® implants (Nobel Biocare AB, Göteborg, Sweden); 479 implants were placed in the mandible, and 282 implants were placed in the maxilla. The implants were placed according to a routine two-stage surgical

Table 1 Distribution of Treated Edentulous Jaws in the Elderly Study Group and Total Number of Treated Edentulous Jaws during the Inclusion Period

	Maxilla				Mandible			
	Elderly				Elderly			
Year	Males	Females	Total Clinic*	% Elderly†	Males	Females	Total Clinic*	% Elderly†
1986	0	0	52	0.0	1	0	108	0.9
1987	0	0	69	0.0	3	2	147	3.4
1988	0	0	99	0.0	3	5	222	3.6
1989	0	2	114	1.8	2	5	195	3.6
1990	2	2	93	4.3	4	4	193	4.1
1991	3	1	126	3.2	4	7	174	6.3
1992	3	0	117	2.6	1	5	123	4.9
1993	0	1	101	1.0	1	5	139	4.3
1994	2	6	108	7.4	2	4	122	4.9
1995	1	2	118	2.5	4	5	115	7.8
1996	1	7	107	7.5	6	6	123	9.8
1997	0	5	81	6.2	2	2	91	4.4
1998	6	0	55	10.9	6	6	50	24.0
Total	18	26	1,240		39	56	1,802	—
Mean	—	—	—	3.5	—	—	—	5.3

*Total number of treated edentulous jaws at the clinic.
†Distribution of elderly patients as a percentage of the total number of treated jaws.

Table 2 Distribution of Treated Jaws in the Study Group by Age and Gender at Time of Inclusion, Number of Total Failures, Number of Deceased Patients, and Number of Patients Declining Recall

Age (yr)	No. of Jaws	Males	Females	Total Failures	Deceased Patients	Patients Declining Recall
80	29	17	12	1	8	—
81	22	9	13	1	3	7
82	19	9	10	—	5	4
83	20	6	14	—	3	6
84	13	5	8	—	8	2
85	10	4	6	—	2	2
86	8	4	4	—	4	—
87	5	2	3	1	1	1
88	7	1	6	—	4	1
89	2	0	2	—	—	—
91	1	0	1	—	—	—
92	2	0	2	—	—	1
93	1	0	1	—	1	—
Total	139	57	82	3	39	24

protocol[25] in all but the lower jaws of two patients, for whom a one-stage surgical protocol was followed.[26] The patients were on average provided with 6.4 (SD, 1.0) implants in the upper jaw and 5.0 implants (SD, 0.4) in the lower jaw. Altogether 44 fixed prostheses were placed in upper jaws and 95 prostheses were placed in lower jaws after abutment connection surgery. Six patients were treated in both jaws. The patients were treated with fixed prostheses in gold alloy[27] or titanium frameworks provided with resin teeth.[28–31]

Control Group

The control group consisted of patients younger than 80 years who were consecutively treated with fixed prostheses in the edentulous jaw from March 1996 to November 1997. Patients with bone grafts in the maxilla were excluded.

Altogether 115 patients were included (57 women and 58 men). Their ages ranged from 41 to 79 years; mean age at the time of first surgery was 65 years (SD, 9.6). Twenty-eight patients (24%) were taking no medication and reported no general health problems, and 43 patients (37%) were smokers.

The patients were provided with 670 Brånemark System implants; 336 implants were placed in the maxilla, and 334 implants were placed in the mandible. The implants were placed according to a routine two-stage surgical protocol[25] in all but seven lower jaws, in which a one-stage surgical protocol was followed.[26] The patients received 4 to 6 implants (mean, 5.0 implants; SD, 0.3) in the edentulous mandible and 4 to 8 implants (mean, 6.6 implants; SD, 1.1) in the edentulous upper jaw. After abutment connection surgery, 51 prostheses were placed in upper jaws and 67 prostheses were placed in mandibles; three patients were treated in both jaws. As with the control group, the patients were treated with fixed prostheses in gold alloy[27] or titanium frameworks provided with resin teeth.[28–31]

Registrations

All data were retrieved from the patients' records, and information on age, gender, medications, general health, smoking habits, time of implant surgery, and numbers of implants was collected. After placement of the prostheses, all visits for maintenance and annual checkups were counted, including the fifth annual checkup. Information on clinical complications and adjustments related to the treated jaw was also recorded. Obvious clinical signs of inflammation and hyperplasia were referred to as "mucositis" in the records. Patients were followed up for 5 years, and data collection ended in August 2003.

On a routine basis all patients were scheduled for radiographic examinations. These examinations

were performed at the time of prosthesis delivery (loading) and after 1 and 5 years. On an individual-based program, radiography could also be performed at shorter time intervals (mostly for the upper jaws, where radiography could be performed after 3 years). The routine protocol was intraoral apical radiography performed with the long-cone technique. The radiographs were analyzed with regard to mechanical and biologic complications at the implants and also with regard to changes of marginal bone level. Bone level was measured in relation to the implant reference point,[32,33] which was placed 0.8 mm below the implant/abutment junction.

Statistics

Descriptive statistics have been used for the present material. Criteria for success and survival are those suggested by Roos and colleagues[34] (ie, because the prostheses were not removed to determine the stability of individual implants, the term *survival* is used in regard to implants, and the term *success* is used in regard to prostheses that can be confirmed on an individual level). Life table analysis[35] was used to calculate implant cumulative survival rate (CSR) as well as prosthesis cumulative success rate. The chi-square test was used for comparing the two groups' data on complications.

RESULTS

Patients Lost to Follow-Up

During the study period 61 patients (45%) (339 implants in 63 jaws) in the study group were lost to follow-up. The distribution of the elderly patients who died, who declined recall because of general health, or whose restorations failed for other reasons is presented in Table 2. In the control group 23 patients (19.5%) (118 implants in 23 jaws) were lost to follow-up; 13 of these patients died, and the remaining 10 patients were lost for other reasons.

Implants and Prostheses

Initially 761 implants were in patients in the study group. Six implants in 6 different patients were lost at abutment surgery (5 implants in the maxilla and 1 implant in the mandible). During the first year of

Table 3 Life Table Analysis of Implants Placed and Lost during 5 Years

	Study Group							
	Maxilla				Mandible			
	No. of Implants				No. of Implants			
Time Period	Followed	Failed	Withdrawn	Implant CSR (%)	Followed	Failed	Withdrawn	Implant CSR(%)
Placement	282	—	—	100.0	479	—	—	100.0
Loading	277	5	—	98.2	478	1	—	99.8
1st year	253	5	19	96.4	454	—	24	99.8
2nd year	223	4	26	94.8	395	—	59	99.8
3rd year	216	1	6	94.4	357	1	38	99.5
4th year	192	3	21	93.0	280	—	76	99.5
5th year	162	—	30	93.0	240	—	40	99.5
Total		18	102			2	237	
				Control Group				
Placement	336	—	—	100.0	334	—	—	100.0
Loading	331	5	—	98.5	333	1	—	99.7
1st year	312	8	11	95.9	323	—	10	99.7
2nd year	290	6	16	94.0	299	—	24	99.7
3rd year	279	3	8	93.0	289	—	10	99.7
4th year	262	—	17	93.0	279	—	10	99.7
5th year	249	1	12	92.6	279	—	—	99.7
Total		23	64			1	54	

CSR = cumulative survival rate.

Table 4 Life Table Analysis of Prostheses during 5 years

	Study Group							
	Maxilla				Mandible			
	No. of Prostheses				No. of Prostheses			
Time Period	Followed	Failed	Withdrawn	Prosthesis CSR (%)	Followed	Failed	Withdrawn	Prosthesis CSR (%)
Placement	44	—	—	100.0	95	—	—	100
1st year	40	1	3	97.6	90	—	5	100
2nd year	35	1	4	95.1	78	—	12	100
3rd year	34	—	1	95.1	70	—	8	100
4th year	30	1	3	92.2	55	—	15	100
5th year	26	—	4	92.2	47	—	8	100
Total	26	3	15	92.2	47	—	48	100
				Control Group				
Placement	51	—	—	100.0	67	—	—	100
1st year	49	—	2	100.0	65	—	2	100
2nd year	45	1	3	97.9	60	—	5	100
3rd year	43	—	2	97.9	58	—	2	100
4th year	40	—	3	97.9	56	—	2	100
5th year	38	—	2	97.9	56	—	—	100
Total		1	12			—	11	

CSR = cumulative success rate.

function, another 5 implants were lost in one upper jaw. Thereafter another 8 implants were lost in the upper jaw, and 1 implant was lost in the lower jaw (Table 3). Altogether 24 implants were removed from patients in the control group, 23 implants from the maxilla and 1 from the mandible (see Table 3). The 5-year CSRs for implants in the maxilla and mandible for the two groups are given in Table 3; there are no significant differences with regard to implant failures in any of the jaws ($p > .05$).

In the study group one prosthesis was lost owing to the failure of all implants after 8 months; the patient resumed wearing a complete denture in the maxilla. Another two fixed prostheses in upper jaws were lost after 1 and 3 years of function because of implant failures in this group (Table 4). One of these patients

Table 5 Complications during the 5-Year Follow-Up Period

	Maxilla		Mandible		Both Jaws	
Complication	Study Group	Control Group	Study Group	Control Group	Study Group	Control Group
Mucositis	10	3	12	4	22	7
Cheek, lip, tongue biting	6	1	9	3	15	4
Decubitus	4	—	8	—	12	—
Resin veneer fracture	7	16	7	3	14	19
Loose gold screw	1	—	—	—	1	—
Loose abutment screw	1	—	—	—	1	—
Abutment screw fracture	—	—	1	—	1	—
Aesthetic problem	1	4	1	1	2	5
Speech problem	5	2	2	—	7	2
Adaptation problem	1	—	4	—	5	—
Framework fracture	—	2	—	—	—	2
Other	—	1	2	4	2	5

resumed using a complete denture whereas the other patient was provided with a removable overdenture supported by three remaining implants.

In the control group one prosthesis failed owing to the loss of all six inserted implants during the second year; the patient resumed wearing a complete denture in the maxilla. The 5-year cumulative success rates of fixed prostheses for the two groups are given in Table 4. Again no significant differences between the groups are indicated.

Follow-Up, Maintenance, and Complications

In the study group the most common complications were cheek, lip, and tongue biting and oral hygiene problems with associated mucositis (Table 5). These problems were significantly more frequent for the study group ($p < .05$). Speech problems also were more frequent in the elderly patients but did not reach a significant level ($p > .05$). Resin veneer fracture was the most common complication in the control group (see Table 5).

During the first year of follow-up, few of the elderly patients achieved straightforward maintenance with only one appointment after final placement of the prosthesis whereas one appointment was most common for patients in the control group (Table 6). For the following years, a maximum of one visit per year was predominant for both groups. The most common problem for control group patients who made several visits was veneer fracture.

Radiography

In the study group 84 implants in the maxilla and 150 implants in the mandible were followed up with radiography after 5 years. Mean marginal bone level and mean marginal bone loss at the implants are shown in Table 7 for the two groups. In the study group 6 implants in the maxilla and 5 implants in the mandible showed a bone loss of 2 mm or more (Table 8). Comparable findings can be seen in the radiographs for the two groups, and differences in bone level and bone loss did not reach significant levels ($p > .05$).

Table 6 Distribution of Clinical Appointments per Year for Study and Control Group Patients with Implants and Prostheses in the Maxilla and Mandible

No. of Visits	1st Year	2nd Year	3rd Year	4th Year	5th Year
	% of Elderly Patients for Maxilla				
0*	—	25	15	43	—
1	2	58	70	37	92
2–4	94	17	15	17	4
5–7	2	—	—	3	4
8–10	—	—	—	—	—
> 10	2	—	—	—	—
Total	100	100	100	100	100
	% of Control Patients for Maxilla				
0*	2	26	2	68	—
1	59	55	70	25	87
2–4	27	7	16	7	10
5–7	6	4	5	—	3
8–10	4	4	7	—	—
> 10	2	4	—	—	—
Total	100	100	100	100	100
	% of Elderly Patients for Mandible				
0*	—	32	17	42	9
1	4	62	77	45	85
2–4	87	6	6	13	4
5–7	5	—	—	—	2
8–10	1	—	—	—	—
> 10	3	—	—	—	—
Total	100	100	100	100	100
	% of Control Patients for Mandible				
0*	—	43	7	73	—
1	74	50	79	22	93
2–4	25	7	11	5	5
5–7	—	—	3	—	2
8–10	1	—	—	—	—
> 10	—	—	—	—	—
Total	100	100	100	100	100

*Not all patients were checked every year.

DISCUSSION

Earlier studies on implant treatment in edentulous elderly patients have been contradictory. Some studies indicated that age alone is not a contraindication for implant treatment[14–20] whereas other studies suggested that age may be associated with a higher implant failure rate and greater marginal bone loss.[21–23] The clinical performances of implant treatment in the two groups of patients in the present study were very similar, and the results coincide well with other reports on implant treatment.[29,36,37] Furthermore, in accordance with other reports, both groups in the present study had more implant failures in the maxilla.[8–11,16,17] This study also showed that some of the patients who were

Table 7 Mean Marginal Bone Levels and Mean Marginal Bone Loss in Maxillas and Mandibles during the 5-year Follow-Up Period

	Mean Marginal Bone Level (mm)*†			
	Control Group		Study Group	
Time Period	Maxilla	Mandible	Maxilla	Mandible
Prosthesis placement	0.9 (0.60), $n = 50$	0.4 (0.40), $n = 67$	0.5 (0.39), $n = 43$	0.3 (0.29), $n = 95$
After 1 yr	1.2 (0.66), $n = 46$	0.8 (0.48), $n = 64$	0.9 (0.88), $n = 38$	0.6 (0.40), $n = 85$
After 5 yr	1.2 (0.52), $n = 37$	1.0 (0.60), $n = 56$	1.1 (0.56), $n = 14$	0.8 (0.57), $n = 29$
	Mean Marginal Bone Loss (mm)†			
	Control Group		Study Group	
Time Period	Maxilla	Mandible	Maxilla	Mandible
Loading to 1 yr	0.3 (0.33), $n = 46$	0.4 (0.37), $n = 64$	0.5 (0.86), $n = 38$	0.4 (0.38), $n = 85$
Loading to 5 yr	0.4 (0.44), $n = 37$	0.6 (0.57), $n = 56$	0.7 (0.45), $n = 14$	0.6 (0.50), $n = 29$

*Calculated from a reference point 0.8 mm below the implant/abutment junction and with the patient as the unit (n).
†Values in parentheses represent standard deviations.

treated in the maxilla have ''cluster problems'' and lost all implants during the first few years of function. This ''cluster problem'' has been reported in other studies.[29,38] Accordingly both the pattern and frequency of lost implants as well as the degree of bone loss were comparable for the two groups in both upper and lower jaws, indicating that implant treatment can be expected to function as well in older patients as it does in younger individuals. The present findings thus strongly support the observation that age alone is not a contraindication for implant treatment.[14–20]

Table 8 Distribution of Implants according to Bone Loss during the Follow-Up Period

Mean Marginal Bone Loss* during 5 years (mm)	Control Group Implants		Study Group Implants	
	Maxilla	Mandible	Maxilla	Mandible
0	71	87	18	45
> 0 to < 0.5	65	77	10	25
0.5 to < 1.0	50	47	21	38
1.0 to < 1.5	38	62	25	29
1.5 to < 2.0	18	13	4	8
2.0 to < 2.5	1	10	2	4
2.5 to < 3.0	—	3	4	1
3.0 to < 4.0	—	1	—	—
Total	243	300	84	150

*Calculated by means of intra-individual measurements (paired observations).

Follow-up studies always involve the problem of patients who are lost to follow-up. The longer the follow-up period is and the older the patients are at inclusion, the higher is the risk that patients will be lost. In the present study 20% of the patients in the control group were lost during 5 years, which is well in accordance with other 5-year follow-up studies.[28–30,36,37] However, the study group lost altogether 45% of its patients during the follow-up period. This is significantly more than the control group lost ($p < .001$) and reaches the levels of withdrawal reported for studies with very long follow-up periods.[12] Certainly this higher level of withdrawal for the study group is not a surprise and can be related to the high age of the patients at the time of inclusion. Patients treated at higher ages do not have the same long life expectancy that younger individuals have, and the observation therefore further implies that problems of a slow-progressing character as well as more time-dependent fatigue problems are of less significance in the maintenance of these patients. Elderly patients thus do not necessarily need treatment protocols that are similar in long-term safety and strength to those needed by younger patients, and chronic changes or problems of a very slow progression can be approached in a different way.

It was observed in the present study that elderly patients needed more postinsertion appointments

during the first year than patients in the control group needed (see Table 6). Elderly patients also had significantly more problems with cheek and lip biting and with oral hygiene problems and associated mucosal inflammation than younger patients had (see Table 5). More speech problems, decubitus, and overall problems with adaptation were also noticed, and the general impression must be that elderly patients have more problems to adapt to and must learn new muscle patterns for chewing as well as for speaking and toothbrushing. This finding of delayed adaptation and muscular function in elderly patients coincides with findings in earlier reports[7,24,38] and may explain why elderly patients may prefer removable prostheses to fixed implant prostheses, claiming easier cleaning as the reason for their choice.[39] Accordingly the elderly patients reported problems that were related more to adaptation than were the problems reported by the younger patients. In the control group the problems were predominantly veneer fractures, which are more related to load, which might be higher for younger patients than for elderly patients. Other studies have reported acrylic resin fractures as a common complication.[40–42]

Average marginal bone loss was similar for the two groups during the 5 years of follow-up. The overall marginal bone loss was about 0.6 mm for the entire group of edentulous patients and was well in accordance with other reports.[28–30,36,37] The distribution of bone loss for individual implants in both groups also showed a similar pattern for the lower jaw (see Table 8), indicating implants with 2 mm or more of bone loss during 5 years and frequencies of 3.3% for the study group and 4.7% for the control group. Upper-jaw implants with bone loss (> 2 mm) were not so evenly distributed between the groups as were lower-jaw implants with bone loss, indicating more implants with a bone loss of ≥ 2 mm in the study group (7.1%) than in the control group (0.4%) (see Table 8). Whether this difference is due to age or to difference in inclusion period or whether it is merely a result of chance is an open question that was impossible to answer in the present study.

CONCLUSIONS

Implant treatment in the elderly patients yielded results that were comparable to those observed in younger age groups. Differences between the groups in regard to implant and prosthesis survival as well as to changes in marginal bone did not reach significant levels. However, indications of more problems with adaptation could be observed, reflected in more early postinsertion problems. Furthermore, cleaning problems and associated soft tissue inflammation as well as tongue, lip, and cheek biting were significantly more often observed in the elderly patients ($p < .05$) whereas the younger patients had relatively more problems related to load, which were expressed in this study as problems with fractures of veneering materials.

REFERENCES

1. Statistics Sweden. Population statistics 1986. Part 4. Vital statistic. Örebro: Official Statistics of Sweden, Statistics Sweden, 1987; 4:112–113.
2. Statistics Sweden. Population statistics 1990. Part 4. Vital statistic. Örebro: Official Statistics of Sweden, Statistics Sweden, 1991; 4:114–115.
3. Statistics Sweden. Population statistics 1995. Part 4. Vital statistic. Örebro: Official Statistics of Sweden, Statistics Sweden, 1996; 4:88–89.
4. Österberg T, Carlsson GE, Sundh V, Fyhrlund A. Prognosis of and factors associated with dental status in the adult Swedish population 1975–1989. Community Dent Epidemiol 1995; 23:232–236.
5. Österberg T, Carlsson GE, Sundh V. Trends and prognoses of dental status in the Swedish population: analysis based on interviews in 1975 to 1997 by Statistics Sweden. Acta Odontol Scand 2000; 58:177–182.
6. Landt H. Oral stereognosis and oral muscular coordination ability. Front Oral Physiol 1983; 4:55–79.
7. Nordenram Å, Landt H. Oral implants in aged patients. In: Holm-Pedersen P, Löe H, eds. Geriatric dentistry. Copenhagen: Munksgaard, 1986:353–361.
8. 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.
9. 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.
10. Albrektsson T, Zarb G, 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.
11. Brånemark P-I, Hansson BC, Adell R, et al. Osseointegrated implants in the treatment of the edentulous jaw. Experience from a 10-year period. Scand J Plast Reconstr Surg 1977; 11(Suppl 16):40–47.
12. Ekelund JA, Lindquist LW, Carlsson GE, Jemt T. Implant treatment in the edentulous mandible: a prospective study

on Brånemark System implants over more than 20 years. Int J Prosthodont 2003; 6:602–607.
13. Lindqvist LW, Carlsson GE, Jemt T. A prospective 15-year follow-up study of mandibular fixed prostheses supported by osseointegrated implants. Clinical results and marginal bone loss. Clin Oral Implants Res 1996; 7:329–336.
14. Bryant SR. The effects of age, jaw site, and bone condition on oral implant outcomes. Int J Prosthodont 1998; 11:470–490.
15. Bryant SR, Zarb GA. Osseointegration of oral implants in older and younger adults. Int J Oral Maxillofac Implants 1998; 3:492–499.
16. Bryant SR, Zarb GA. Outcome of implant prosthodontic treatment in older adults. J Can Dent Assoc 2002; 2:97–102.
17. Köndell PÅ, Nordenram A, Landt H. Titanium implants in the treatment of edentulousness: influence of patient's age on prognosis. Gerodontics 1988; 4:280–284.
18. Ochi S, Morris HF, Winkler S. Patient demographics and implant survival at uncovering: Dental Implant Clinical Research Group Interim Report No. 6. Implant Dent 1994; 3:247–251.
19. Zarb GA, Schmitt A. Implant therapy alternatives for geriatric edentulous patients. Gerodontology 1993; 10:28–32.
20. Zarb GA, Schmitt A. Osseointegration for elderly patients: the Toronto study. J Prosthet Dent 1994; 2:559–568.
21. Dao TT, Andersson JD, Zarb GA. Is osteoporosis a risk factor for osseointegration of dental implants? Int J Oral Maxillofac Implants 1993; 8:133–144.
22. Holm-Pedersen P. Studies on healing capacity in young and old individuals (thesis). Copenhagen: Munksgaard, 1973.
23. Roberts E, Gonsalves M. Aging of bone tissue. In: Holm-Pedersen P, Loe H, eds. Geriatric dentistry. Copenhagen: Munksgaard, 1986:83–94.
24. Jemt T. Implant treatment in elderly patients. Int J Prosthodont 1993; 6:456–461.
25. Adell R, Lekholm U, Brånemark P-I. Surgical procedure. In: Brånemark P-I, Zarb G, Albrektsson T, eds. Tissue-integrated prosthesis: osseointegration in clinical dentistry. Chicago: Quintessence, 1985:211–232.
26. Randow K, Ericsson I, Nilner K, Petersson A, Glantz P-O. Immediate functional loading of Brånemark dental implants. An 18-month clinical follow-up study. Clin Oral Implants Res 1999; 10:8–15.
27. Zarb GA, Jansson T. Prosthodontic procedures. In: Brånemark P-I, Zarb G, Albrektsson T, eds. Tissue-integrated prosthesis: osseointegration in clinical dentistry. Chicago: Quintessence, 1985:241–282.
28. Bergendahl B, Palmqvist S. Laser-welded titanium framework for implant-supported fixed prostheses: a 5-year report. Int J Oral Maxillofac Implants 1999; 14:69–71.
29. Jemt T, Bergendal B, Arvidsson K, et al. Implant-supported welded titanium frameworks in the edentulous maxilla. A 5-year prospective multi-centre study. Int J Prosthodont 2002; 15:544–548.
30. Örtorp A, Linden B, Jemt T. Clinical experiences of laser-welded titanium frameworks supported by implants in the edentulous mandible. A 5-year follow-up study. Int J Prosthodont 1999; 12:65–72.
31. Örtorp A, Jemt T. Clinical experience of CNC-milled titanium frameworks supported by implants in the edentulous jaw: a 3-year interim report. Clin Implant Dent Relat Res 2002; 2:52–58.
32. Hollender L, Rockler B. Radiographic evaluation of osseointegrated implants of the jaws. Dent Maxillofac Radiol 1980; 9:91–95.
33. Strid KC. Radiographic results and radiographic procedures. In: Brånemark P-I, Zarb GA, Albrektsson T, eds. Tissue-integrated prostheses: osseointegration in clinical dentistry. Chicago: Quintessence, 1985:187–198, 317–327.
34. Roos J, Sennerby L, Lekholm U, Jemt T, Gröndahl K, Albrektsson T. A qualitative and quantitative method for evaluating implant success: a 5-year retrospective analysis of the Brånemark implant. Int J Oral Maxillofac Implants 1997; 12:504–514.
35. Colton T. Statistics in medicine. Boston: Little, Brown, 1974:241–50.
36. Jemt T. Fixed implant-supported prostheses in the edentulous maxilla. A five-year follow-up report. Clin Oral Implants Res 1994; 5:142–147.
37. Jemt T, Lekholm U. Implant treatment in the edentulous maxillae: a 5-year follow-up report on patients with different degrees of jaw resorption. Int J Oral Maxillofac Implants 1995; 10:303–311.
38. Book K, Karlsson S, Jemt T. Functional adaptation to full-arch fixed prosthesis supported by osseointegrated implants in the edentulous mandible. Clin Oral Implants Res 1992; 3:17–21.
39. Feine JS, de Grandmont P, Boudrias P, et al. Within-subjects comparisons on implant-supported mandibular prostheses: choice of prosthesis. J Dent Res 1994; 73:1105–1111.
40. Göthberg C, Bergendahl T, Magnusson T. Complications after treatment with implant-supported fixed prostheses: a retrospective study. Int J Prosthodont 2003; 16:201–207.
41. Hemmings KW, Schmitt A, Zarb GA. Complications and maintenance requirements for fixed prostheses and overdentures in the edentulous mandible: a 5-year report. Int J Oral Maxillofac Implants 1994; 9:191–196.
42. Jemt T. Failures and complications in 391 consecutively inserted fixed prostheses supported by Brånemark implants in edentulous jaws: a study of treatment from the time of prosthesis placement to the first annual checkup. Int J Oral Maxillofac Implants 1991; 6:270–276.