Rehabilitation of Edentulous Mandibles by Means of Osseointegrated Implants: A 5-Year Follow-Up Study on One or Two-Stage Surgery, Number of Implants, Implant Surfaces, and Age at Surgery

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ABSTRACT

Background: In three former reports, the present team has presented the 1-year outcome of four different treatment procedures handling the edentulous mandible; that is, two-stage and one-stage surgery with turned Brånemark System® (Nobel Biocare AB, Gothenburg, Sweden) implants (Group 1 and 2) and one-stage surgery using either 5 or 4 TiUnite™ (Nobel Biocare AB, Gothenburg, Sweden) implants (Group 3 and 4).

Purpose: The aim of the present investigation was to follow up these patients for a period of 5 years with regard to implant/prosthesis cumulative survival rates, marginal bone loss calculations, clinical complications, and results related to age at surgery.

Materials and Methods: A total of 385 patients, provided with 1,838 implants, were originally included in the four patient groups. All patients received fixed prostheses. The overall majority of patients had each five implants placed. Radiographs were obtained at prosthesis delivery, at the 1 and 5-year follow-up.

Results: A total of 1,230 implants in 259 patients (67%) were possible to follow up for 5 years. Implant Cumulative Survival Rates (CSR) in 5 years for Groups 1–4 were 99.7, 97.0, 98.5, and 98.6%. The corresponding prosthesis treatment CSR was 100, 99.3, 98.5, and 98.6%, respectively. Significantly, more patients ($p < .05$) lost turned implants after one-stage surgery (Group 2). Frequency distributions of implants revealed that >1.2 mm bone loss was observed around 75 implants (6.4%). The moderately rough central (midline) implant showed more bone loss than other placed implants (Group 3; $p < .05$). The youngest half of included patients at surgery (Youngest$^{50\%}$; $n = 193$) presented significantly higher mortality than older patients as well as compared to normal population ($p < .05$). Patients in the Younger$^{50\%}$ group showed also an association to patients with complete loss of all implants and patients with most implants with obvious bone loss after 5 years.

Conclusions: All four treatment procedures served well during the 5 years of follow-up and only eight patients (2.1%) were complete failures or showed obvious bone loss (>1.8 mm) at several implants (>2 implants), mostly observed in younger patients. The few complications in relation to implant failure and/or obvious bone loss could be associated to both *local impact* factors (surface, implant site, surgical protocol) as well as to *host response* factors (systemic health).

KEY WORDS: 5-year study, early loading, edentulous mandibles, implant site, implant surface, local impact, one-stage surgery, oxidized oral implants, patient mortality, systemic health

INTRODUCTION

Edentulism is the ultimate clinical situation that reflects the failure of the patient and the dental profession to maintain an intact dentition. Edentulism is associated with psychological vulnerability,[1,2] but also linked to general health factors and increased mortality.[3,4]

Prosthetic rehabilitation of the edentulous patient was earlier a challenge, especially in the lower jaw, where lack of retention and stability of the removable denture

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DOI 10.1111/cid.12116

is most obvious. The very first patient provided with osseointegrated implants received four implants in the edentulous lower jaw in 1965.[5] Brånemark and colleagues[6] showed early that four implants presented comparable clinical results as when more implants were placed in either jaw, albeit a higher implant number is still today favored by many clinicians for the routine edentulous patient. With the introduction of modified implant surfaces, a significantly faster integration was observed,[7] which allowed for earlier loading and more predictable osseointegration.[8–10]

In a series of publications comprising a total of 385 patients, the present authors have described the 1-year outcome of four groups of patients (Groups 1–4) when handling edentulous mandibles.[11–13] The studies compared turned Brånemark System® implants (Nobel Biocare AB, Gothenburg, Sweden) in one and two-stage surgery with early and delayed loading,[11] compared turned and oxidized Brånemark System® implants in one-stage surgery with early loading,[12] and compared four or five oxidized Brånemark System® implants in one-stage surgery with early loading,[13] all to support fixed prostheses. The various procedures showed similarly good implant cumulative survival rates (97.5–100%) and prosthesis treatment cumulative survival rates (98.6–100%), all in line with formerly published long-term follow-up studies on one and two-stage surgery with delayed loading.[14–18] Mean values of marginal bone level and marginal bone loss were close to identical, albeit the central (midline) oxidized implant (Group 3) differed from the correspondingly placed turned ones as well as from all other implants in terms of increased bone loss at the 1-year follow-up.

The aims of the present study were to follow up the four utilized procedures (Groups 1–4) for 5 years with regard to implant and prosthesis cumulative survivals rates and to relate the results over 5 years to the age of the patient at the time of implant surgery. With regard to bone loss, special focus was kept on the central (midline) implants placed in three of the four groups.

MATERIALS AND METHODS

The current patient groups comprising edentulous mandibles have been subjected to more detailed presentations in three previous reports,[11–13] and are thus only briefly described below. Altogether, 385 patients were distributed into four different study groups (Table 1, Figure 1), provided with a total of 1,838 Brånemark System implants from March 1996 to June 2007. Information on general health, smoking habits, and dentition in opposing jaw at implant surgery is presented in Tables 2 and 3.

The four different study groups were used in the three different publications; in the first previous publication, Group 1 served as control to Group 2,[11] in the second publication Group 2 served as control to Group 3,[12] and in the third publication Group 3 served as control to Group 4.[13]

Study Groups

Group 1; Turned Implants; Two-Stage Surgery. Sixty-eight patients (Table 1) were provided with a total of 338 Brånemark System® implants with turned surfaces placed according to a standard, two-stage surgical protocol. Three, 60, and 5 patients received 6, 5, and 4 implants each in this group, respectively. In the five implant cases, the central one was placed in the symphyseal region. The prosthetic procedure was commenced in general one week after abutment connection; that is, >3 months after implant placement.[11]

Group 2; Turned Implants; One-Stage Surgery. One-hundred and 52 patients (Table 1) were provided with a

TABLE 1 Distribution of Total Number of Included Patients in the Study Groups with Regard to Mean Age (SD), Gender (%), and Inclusion Period

Study Group	Mean Age	Total	Females	Inclusion Period
Two-stage, Machined*	67.3 (11.0)	68	34 (50%)	Mar.'96 to Sept.'97
One-stage, Machined	66.0 (10.4)	152	90 (59%)	Nov.'96 to Dec.'02
One-stage, 5 TiUnite	70.7 (11.1)	90	47 (52%)	Jan.'01 to Sept.'05
One-stage, 4 TiUnite	68.7 (10.1)	75	41 (55%)	Oct.'01 to June'07

*"Reference group"; Friberg et al.,[11] Örtorp, Jemt.[34]
SD = standard deviation.

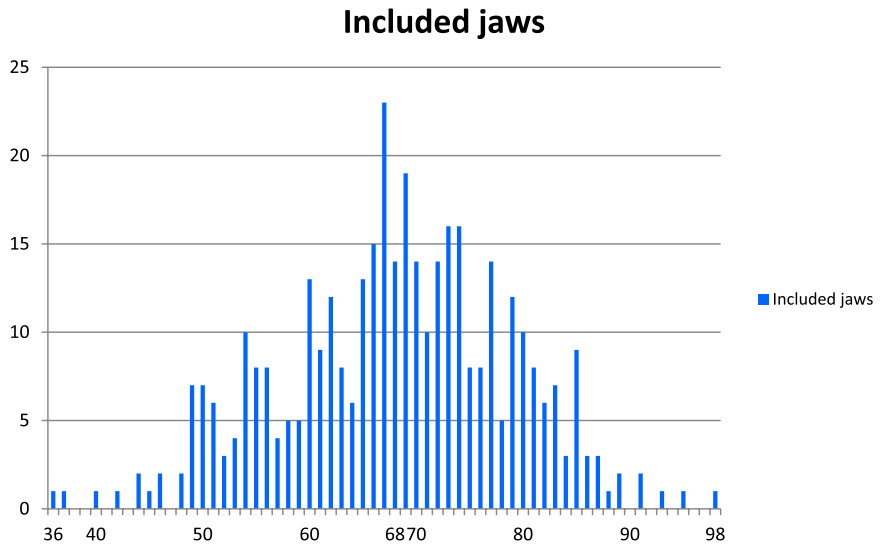

Figure 1 Distribution of included 385 patients with regard to age at implant surgery.

total of 750 Brånemark System® implants with turned surfaces using a one-stage surgical procedure. Apart from 12 patients, of whom 11 patients received 4 implants and 1 patient, 6 implants, all remaining 140 patients received 5 implants each. In the five implant cases, the central one was placed in the symphyseal region. The prosthetic procedure was commenced as a mean 13 days after implant placement.[11]

Group 3; TiUnite® Implants; One-Stage Surgery with Five Implants. Ninety patients (Table 1) were provided with a total of 450 Brånemark System® implants with a medium rough surface (TiUnite®, Nobel Biocare AB, Gothenburg, Sweden), using a one-stage surgical protocol. The central implant was placed in the symphyseal region. The prosthetic procedure was commenced as a mean 8 days after implant placement.[12]

TABLE 2 Distribution of Number of Patients Recorded with General Health Disorders

Diagnosis	2-Stage, Machined (*n* = 68)*	1-Stage, Machined (*n* = 152)	1-Stage, 5 TiUnite (*n* = 90)	1-Stage, 4 TiUnite (*n* = 75)
Cancer	1 (1%)	3 (2%)	2 (2%)	9 (12%)
Cardiac and vascular diseases	19 (28%)	53 (36%)	34 (38%)	42 (56%)
Deep depression	3 (4%)	1 (1%)	5 (6%)	4 (5%)
Diabetes	8 (12%)	5 (3%)	6 (7%)	10 (13%)
Rheumatoid arthritis	5 (7%)	4 (3%)	5 (6%)	3 (4%)
Tuberculosis/lung disease	0	1 (1%)	7 (8%)	8 (11%)
Warfarin medication	0	6 (4%)	3 (3%)	2 (3%)
Irradiation head & neck	0	1 (1%)	1 (1%)	0
Cytotoxic drugs	0	0	1 (1%)	0
Smokers	36%	39%	34%	40%
Healthy patients, no diagnoses	26%	46%	33%	17%
No drugs or medications	34%	49%	36%	24%

*"Reference group"; Friberg et al.,[11] Örtorp, Jemt.[34]

TABLE 3 Distribution of Dentition in the Opposing Maxilla

Dentition in Upper Jaw	2-Stage Machined ($n = 68$)*	1-Stage Machined ($n = 152$)	1-Stage 5 TiUnite ($n = 90$)	1-Stage 4 TiUnite ($n = 75$)
Natural teeth with/without removable partial denture	20 (29%)	38 (25%)	25 (28%)	17 (23%)
Natural teeth and implants	2 (3%)	4 (3%)	1 (1%)	1 (1%)
Fixed implant-supported prosthesis	12 (18%)	31 (20%)	24 (27%)	28 (37%)
Removable implant-supported denture	2 (3%)	1 (1%)	1 (1%)	1 (1%)
Complete removable denture	32 (47%)	78 (51%)	39 (43%)	28 (37%)

*Friberg et al.,[11] Örtorp, Jemt.[34]

Group 4; TiUnite® Implants; One-Stage Surgery with Four Implants. Seventy-five patients (Table 1) were provided with a total of 300 Brånemark System® implants with a medium rough surface (TiUnite®) using a one-stage surgical protocol. The prosthetic procedure was commenced as a mean 9 days after implant placement.[13]

Prosthetic Treatment and Follow-Up

All patients treated at the clinic received a fixed screw-retained prosthesis attached to standard abutments. The 10 to 12-unit prostheses were fabricated with a metal framework supporting artificial resin teeth. Eleven of the patients had their prostheses delivered by their referral dentists.

Patients were referred back to their dentist after treatment, but they were all invited to participate in a routine follow-up program at the clinic, accounted for elsewhere.[9] This program was based on routine clinical follow-up examinations after 1 and 5 years.

Radiographs were in general obtained at connection of prostheses for bone level registrations. These radiographs served as baseline images for the subsequent marginal bone loss calculations, which were presented as mean values of mesial and distal measurements at the 1 and 5-year checkups. Marginal bone loss around a subsample of implants placed in distal, mesial (intermediate), and central (midline) positions were as well compared.

Population Data

Population survival data were collected from Sweden Statistics, covering the period of inclusion from 1996 to 2007.[19,20] Regarding deceased patients during 5 years of follow-up, information was continuously collected from the official population database (Västfolket).

Statistical Analyses

In the present report, descriptive statistics and life table analysis expressing implant/treatment/patient cumulative survival rates (CSRs) were used. For comparison of impact of age at surgery, the population was divided into two subgroups: the 50% youngest patients (Youngest$^{50\%}$ group; $n = 193$) and the 50% oldest patients in the test group (Oldest$^{50\%}$ group; $n = 192$). Comparison of distribution of, for example, failures between the test and control groups was performed with the chi-square test. When comparing differences of mean values between the groups, the *t*-test was used. Statistical significant difference was set to 5% and was only conducted on patient level.

RESULTS

Patient Lost to Follow-Up

Altogether, 123 patients (32%) were lost to follow up during 5 years as accounted for in Table 4a and Table 5. Eleven of these patients (9%) were treated by referral dentists, and 49 patients were deceased (40%). The remaining 63 patients were not able to come due to general health conditions, had moved from the region (3 patients), or were not compliant.

Overall patient 5-year mortality rate was 13.5% as compared to normal population 5-year mortality rate of 14.7%. However, significant differences ($p < .05$) in patients mortality were observed between 5-year CSR when comparing the Youngest$^{50\%}$ and the Oldest$^{50\%}$ groups as well as comparing the subgroups (Youngest$^{50\%}$/Oldest$^{50\%}$) to normal populations, respectively (Figure 2, A and B).

TABLE 4A Life Table Regarding Number of Treated/Followed-Up Patients at Implant Placement Surgery (Placem.), Prosthesis Placement (Prosth.), and at 1 and 5 Years of Follow-Up (1-Year/5-Year). Patients Are Reported in Relation to Numbers of Treated/Followed-Up (F-u), Failed (F), or Lost to Follow-Up/Withdrawn Patients (W), Respectively. Cumulative Survival Rate (CSR) Is Presented in Percentage of Treated Patients (%)

	Distribution of Treated and Followed-Up Patients															
	2-Stage, Machined*				1-Stage, Machined				1-Stage, 5 TiUnite				1-Stage, 4 TiUnite			
	F-u	F	W	CSR	F-u	F	W	CSR	F-u	F	W	CSR	F-u	F	W	CSR
Placem.	68			100	152			100	90			100	75			100
Prosth.	68			100	152			100	89		1	100	75			100
1-year	66		2	100	141	1	10	99.3	82		7	100	67	1	7	98.6
5-year	55		11	100	105		36	99.3	49	1†	32	98.5	50		17	98.6
Total	55	0	13	100	105	1	46	99.3	49	1	40	98.5	50	1	24	98.6

*Friberg et al.,[11] Örtorp, Jemt.[34]
†One patient with five well-integrated implants removed due to adaptation problems.

TABLE 4B Life Table Regarding Number of Placed/Followed-Up Implants at Implant Placement (Placem.), Prosthesis Placement (Prosth.), and at 1 and 5 Years of Follow-Up (1-Year/5-Year). Implants Are Reported in Relation to Numbers of Treated/Followed-Up (F-u), Failed (F), or Lost to Follow-Up/Withdrawn Implants (W), Respectively. Cumulative Survival Rate (CSR) Is Presented in Percentage of Treated Implants (%)

	Distribution of Placed and Followed-Up Implants															
	2-Stage, Machined				1-Stage, Machined				1-Stage, 5 TiUnite				1-Stage, 4 TiUnite			
	F-u	F	W	CSR	F-u	F	W	CSR	F-u	F	W	CSR	F-u	F	W	CSR
Placem.	338			100	750			100	450			100	300			100
Prosth.	337	1		99.7	745	5		99.3	445		5	100	300			100
1-Year	327		10	99.7	687	13	45	97.5	410		35	100	268	4	28	98.6
5-year	273		54	99.7	512	3	172	97.0	245	5*	160	98.5	200		68	98.6
Total	273	1	64	99.7	512	21	217	97.0	245	5	200	98.5	200	4	96	98.6

*Five well-integrated implants removed due to adaptation problems in one patient.

Implants and Prostheses

Altogether, 31 implants failed in 17 different patients, where 2 patients lost all implants after 1 year in function (Table 4a and Table 6). Significantly, more patients in Group 2 lost implants than patients in the other three groups ($p < .05$). Implant cumulative survival rates (CSRs) at 5 years of follow-up were comparable to the figures obtained at the 1-year follow-up, and only small changes in CSR had taken place (Table 4b). Between the first and the fifth year of follow-up, one implant in each

TABLE 5 Patients Lost to Follow-Up

		1st Surgery to 1st Year		1st Year to 5th Year		
Test Group	Included Patients	Deceased	Non-Compl.	Deceased	Non-Compl.	Total
2-stage Machined	68	0	2	7	4	13
1-stage Machined	152	5	5	9	27	46
1-stage 5 TiUnite	90	1	7	17	15	40
1-stage 4 TiUnite	75	1	6	9	8	24
Total	385	7	20	42	54	123

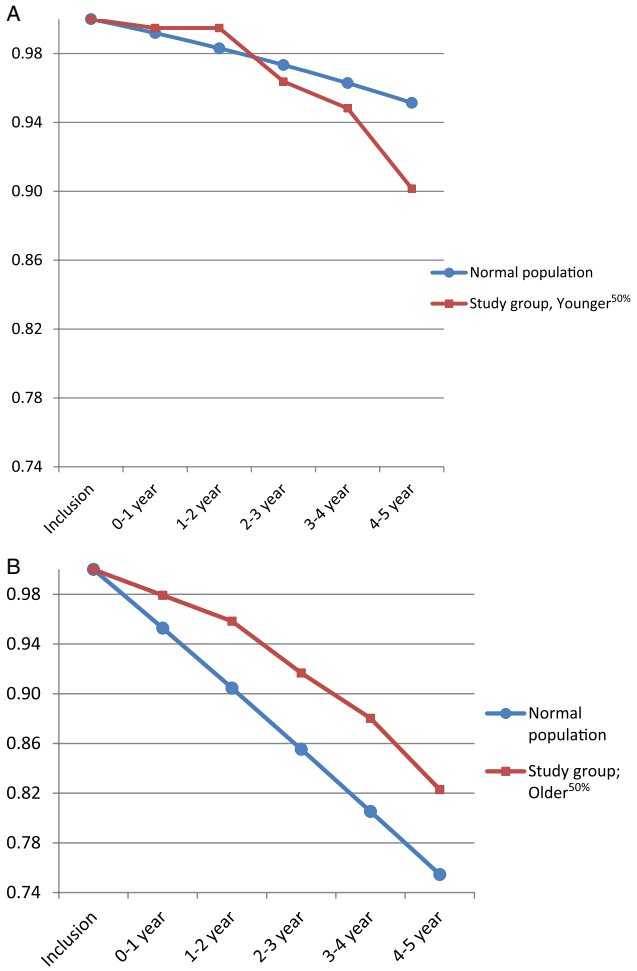

Figure 2 *A*, Five-year CSR life table for the Younger$^{50\%}$ patient group and a corresponding normal population. An increased mortality of 4.9% could be observed in the present study group. *B*, Five-year CSR life table for the Older$^{50\%}$ patient group and a corresponding normal population. A decreased mortality of 6.8% could be observed in the present study group (CSR = cumulative survival rate).

of three patients belonging to Group 2 was mobile and removed. One patient belonging to Group 3 had all five well-integrated implants out-trephined for psychological reasons. Thus, implant CSRs at 5 years for Groups 1–4 were 99.7, 97.0, 98.5, and 98.6%, respectively (Table 4b).

Patient follow-up with "no event" (no clinical complications or comments) ranged between 67% and 84% in the different groups of patients (Table 6). Three patients presented a complete failure of the implant treatment, and another two patients had new prostheses replaced due to design and fit problems (Tables 4a and 6). Another patient had the prosthesis shortened after a failure of a terminal implant (Table 6).

Hyperplasia/mucosal inflammation was the most common observed complication in the four different groups (31 patients), followed by implant failures (17 patients) and veneer fractures (15 patients; Table 6). Prosthesis treatment cumulative survival rates at 5 years were also close to identical with the ones obtained at the 1-year follow-up (Table 4a). Between the first and the fifth year of follow-up, one patient lost the prosthesis in Group 3 due to reasons stated above, why the prosthesis treatment CSRs at 5 years for Groups 1–4 were 100, 99.3, 98.5, and 98.6%, respectively (Table 4a).

Smoking habits were evenly distributed among the four groups (34–40%).

Patients in Group 4 were more heavily burdened with general health disorders (cancer, cardiac and vascular disease, diabetes, and lung disease) as compared to the others (Table 2), albeit without any influence on the implant survival during the 5-year follow-up period.

Radiographs

Levels of marginal bone were registered at three different occasions; that is, at connection of prostheses (375 patients/1,780 implants), at the 1-year checkup (348 patients/1,652 implants), and at the 5-year checkup (251 patients/1,191 implants). The bone levels were presented in relation to the fixture/abutment junction and the distributions are shown in Table 7. As can be seen, the mean values were more or less identical for all groups throughout the study period.

Altogether, 41 patients (16.3%) presented one or more implants with a bone level below the third implant thread after 5 years in function (Table 6; >2.5 mm). Frequency distributions in 5 years revealed that bone levels around 870 implants (73%) presented a bone level at or above the third implant thread after 5 years in function (Table 7). At 129 implants (10.8%), bone levels were situated below the second thread (2.5 mm). Of these, 63 implants (5.3%) showed a bone level that reached below the third thread (3.7 mm), and 40 implants of the latter (3.4%) reached a bone level below the fourth thread (Table 7).

Calculations of marginal bone loss were conducted at the 1-year checkup (343 patients/1,626 implants) and at the 5-year checkup (246 patients/1,166 implants), and mean values of mesial and distal measurements are presented in Table 8. Altogether, 810 implants (69.5%) showed no or not more than 0.6 mm (one thread) of

TABLE 6 Clinical Complications

Clinical Complications	Patient Related Complications during 5 Years (%)			
	2-Stage Machined ($n = 68$)*	1-Stage Machined ($n = 152$)	1-Stage 5 TiUnite ($n = 90$)	1-Stage 4 TiUnite ($n = 75$)
No event (total)	47 (69%)	110 (72%)	74 (82%)	63 (84%)
No event (followed up for 5 years)	37 (67%)	70 (67%)	36 (73%)	36 (72%)
Implant failure	1	13†	2	1
Complete treatment failure	0	1	1*	1
Re-entry surgery before placement	0	1	0	0
Fractures				
– Resin veneers	1	6	3	5
– Implants	0	0	0	0
– Abutment/gold screws	0	1	0	0
– Framework	0	0	0	0
Loose abutment/gold screw	0	1	0	0
Mucosa-related				
– Hyperplasia/inflammation	6	13	8	4
– Peri-implantitis surgery	1	1	1	2
Bone level > 2.5 mm (5 years)				
1 implant	5	13	7	5
>1 implant	2	4	3	2
Bone loss ≥ 2.0 mm (1–5 years)				
1 implant	4	6	4	4
>1 implant	0	0	3	0
Prosthesis-related				
– Adjustment/redesign	2	0	1	1
– Remake of prosthesis	0	1	0	1
TMD problems	2	0	0	0

*Five well-integrated implants removed due to adaptation problems.
†Significantly more patients in Group 2 ($p < .05$).
TMD = Temporomandibular disorder.

bone loss from the first to the fifth year of follow-up (Table 8). As can be seen, the mean values for the time period 1–5 years were similar (0.2 mm) for Groups 1, 2, and 4, whereas Group 3 showed an increased mean value (0.5 mm). A major reason for this difference was the more pronounced bone loss at the central (midline) TiUnite™ implant (Table 9). Altogether, 21 patients (8.5%) presented a marginal bone loss of ≥2.0 mm at one or more of the implants during 1 to 5 years of follow-up (Table 6). Significantly, more patients ($p < .05$) in Group 3 presented a central implant with bone loss >1.8 mm.

Frequency distributions for the time period 1–5 years revealed that >1.2 mm bone loss was seen around 75 implants (6.4%). Of these, 33 implants (2.8%) showed >1.8 mm bone loss, and 20 implants of the latter (1.7%) showed >2.4 mm of bone loss (Table 8). A clear trend toward more implants with increased bone loss was seen in Group 3, which is in accordance with the aforementioned situation around that central implant.

Age at Implant Surgery

The Younger$^{50\%}$ and the Older$^{50\%}$ patient groups presented a mean age at first implant surgery of 59.5 (SD 7.19) years and 76.6 (SD 5.93) years, respectively. Patient 5-year CSR was 90.2% and 82.3% for the Younger$^{50\%}$ and the Older$^{50\%}$ patient groups, while corresponding 5-year CSR for normal populations is 95.1% and 75.5%, respectively ($p < .05$). This indicates an *increased* 5-year patient mortality ($p < .05$) in the Younger$^{50\%}$ patient group of

TABLE 7 Mean Marginal Bone Level in Relation to FAJ (Fixture – Abutment – Junction) during the Follow-Up Period. The Thread of the Implant Is Placed on an Average 1.9 mm Below FAJ. The 2nd, 3rd and 4th Threads of the Implants Are Placed on an Average 2.5 mm, 3.1 mm, and 3.7 mm below FAJ, Respectively

	2-Stage, Machined*			1-Stage, Machined			1-Stage, 5 TiUnite®			1-Stage, 4 TiUnite®		
	Prosth.	1-yr.	5-yrs.	Prosth.	1-yr.	5-yrs.	Prosth.	1-yr.	5-yrs.	Prosth.	1-yr.	5-yrs.
Patients	68	65	**55**	151	141	**101**	82	76	**48**	74	66	**47**
Implants	337	322	**271**	738	687	**494**	410	379	**238**	295	264	**188**
Patient mean bone level in relation to FAJ												
Mean	1.2	1.6	**1.8**	1.2	1.6	**1.7**	1.1	1.6	**1.9**	1.3	1.6	**1.8**
SD	0.40	0.49	**0.59**	0.40	0.55	**0.64**	0.38	0.55	**1.01**	0.78	0.57	**0.72**
Distribution of implants in relation to FAJ												
0–0.8 mm	192	85	**55**	466	286	**192**	307	153	**85**	182	108	**65**
0.9–1.9 mm	121	177	**133**	226	267	**184**	83	153	**84**	101	114	**72**
2.0–2.5 mm	19	38	**53**	27	86	**65**	12	50	**41**	4	30	**33**
2.6–3.1 mm	3	19	**19**	8	33	**29**	7	19	**11**	1	6	**7**
3.2–3.7 mm	2	2	**6**	8	13	**10**	0	2	**4**	2	2	**3**
>3.8 mm	0	1	**5**	3	2	**14**	1	2	**13**	5	4	**8**

*"Reference group"; Friberg et al.,[11] Örtorp, Jemt.[34]
SD = standard deviation.

4.9%, and a *decreased* mortality of 6.8% ($p < .05$) in the Older$^{50\%}$ patient group (Figure 2, A and B).

Nine and eight patients lost 18 and 13 implants in the two groups, respectively. Furthermore, both patients presenting complete failures due to that all implants were found loose at the first annual examination belonged to the Younger$^{50\%}$ patient group, and three out of four patients with four implants presenting bone

TABLE 8 Intra-Individual Measurements of Mean Marginal Bone Loss and Distribution of Implants with Regard to Bone Resorption during Five Years in Function. Distance between Threads is 0.6 mm

	2-Stage, Machined*			1-Stage, Machined			1-Stage, 5 TiUnite®			1-Stage, 4 TiUnite®		
	0–1 Year	0–5 Years	1–5 Years	0–1 Year	0–5 Years	1–5 Years	0–1 Year	0–5 Years	1–5 Years	0–1 Year	0–5 Years	1–5 Years
Patients	65	54	**54**	141	101	**101**	71	48	**44**	66	47	**47**
Implants	322	266	**266**	686	492	**494**	354	238	**218**	264	188	**188**
Patient mean bone loss in relation to FAJ												
Mean	0.4	0.6	**0.2**	0.4	0.5	**0.2**	0.4	0.8	**0.5**	0.3	0.4	**0.2**
SD	0.35	0.55	**0.42**	0.43	0.59	**0.51**	0.50	1.01	**1.06**	0.74	0.93	**0.50**
Distribution of implants in relation to amount of bone loss (%)												
Increase	25	30	**64**	44	47	**80**	10	16	**25**	17	13	**12**
0 mm	119	65	**107**	358	203	**269**	203	102	**119**	158	93	**134**
0.1–0.6 mm	81	58	**53**	83	45	**57**	21	10	**14**	24	15	**12**
0.7–1.2 mm	79	72	**25**	151	138	**63**	86	60	**38**	46	36	**19**
1.3–1.8 mm	14	23	**13**	40	41	**16**	22	28	**6**	13	22	**7**
1.9–2.4 mm	3	12	**3**	8	10	**5**	10	8	**4**	2	2	**1**
>2.4 mm	1	6	**1**	2	8	**4**	2	14	**12**	4	7	**3**

*"Reference group"; Friberg et al.,[11] Örtorp, Jemt.[34]
SD = standard deviation.

TABLE 9 Mean Bone Loss and Distribution of Patients with Regard to Implant Position in the Edentulous Jaw

Bone Loss from 1st to 5th Year of Follow-Up at Different Sites						
	Distal R	Mesial R	Central	Mesial L	Distal L	Total
Group 1; 2-stage, Machined implants*						
Patients*/implants	51	51	46	51	49	51/248
Mean (SD)	0.1 (0.47)	0.1 (0.59)	0.3 (0.65)	0.3 (0.67)	0.1 (0.74)	0.2 (0.42)
# Impl.; ≤1.8 mm	51	51	45	49	48	244
# Impl.; >1.8 mm	0	0	1	2	1	4
Group 2; 1-stage, Machined implants						
Patients/implants	99	101	93	100	100	101/494
Mean (SD)	0.0 (0.61)	0.1 (0.69)	0.4 (1.02)	0.2 (0.68)	0.1 (0.77)	0.2 (0.51)
# Impl.; ≤1.8 mm	98	101	87	99	99	486
# Impl.; >1.8 mm	1	0	6	1	1	9
Group 3; 1-stage, 5 TiUnite implants						
Patients/implants	44	44	42	44	44	44/218
Mean (SD)	0.5 (1.71)	0.3 (0.55)	0.8 (1.92)	0.4 (1.07)	0.3 (1.12)	0.5 (1.06)
# Impl.; ≤1.8 mm	41	43	35	41	42	202
# Impl.; >1.8 mm	3	0	8†	2	3	16
Group 4; 1-stage, 4 TiUnite implants						
Patients/implants	47	47		47	47	47/188
Mean (SD)	0.2 (0.82)	0.3 (0.74)		0.3 (0.75)	0.1 (0.40)	0.2 (0.50)
# Impl.; ≤1.8 mm	46	46		45	48	184
# Impl.; >1.8 mm	1	1		2	0	4

*Three patients excluded with six implants each in the reference group (2-stage, Machined).[34]
†Significantly, more patients ($p < .05$) in Group 3 presented a central implant with bone loss >1.8 mm.
SD = standard deviation.

levels ≥2.5 mm after 5 years in function (Table 6) belonged to the Younger$^{50\%}$ patient group as well.

Mean bone level after 5 years was 1.8 mm (SD 0.72) and 1.7 mm (SD 0.72) in the Younger$^{50\%}$ and the Older$^{50\%}$ patient groups, respectively. Corresponding mean marginal bone loss during 1 to 5 years of follow-up was 0.2 mm (SD 0.68) and 0.2 mm (SD 0.56), respectively.

DISCUSSION

The present investigation reports on the outcome of four different treatment procedures handling the edentulous mandible; that is, two-stage and one-stage surgery with turned Brånemark System® implants and one-stage surgery using either 5 or 4 TiUnite™ Brånemark System® implants. With 5-year implant CSRs and prosthesis treatment CSRs ranging between 97.0–99.7% and 98.5–100%, respectively, one may consider implant treatment of the edentulous mandible to be one of the most predictable and safe comprehensive rehabilitations in dentistry. All procedures served well their purpose, but the results of Group 2 indicated a higher patient implant failure rate ($p < .05$), however not significantly affecting the prosthesis survival (Tables 4, a and b). During the follow-up period of 1 to 5 years, only three implants lost integration (Group 2). The patient in Group 3 who demanded the removal of five well-integrated and functioning implants suffered from psychological problems (antidepressant medication, dry mouth, taste and smell sensations, etc.). Despite efforts to persuade her not to go through with the procedure, she insisted and, as expected, she was not helped by the intervention.

The number of patients lost to follow-up was high and only ~68% of the subjects, which is below the critical level of 75%,[21,22] showed up on the 5-year follow-up visit. With a patient mean age of close to 70 years at implant placement, ranging from 36 to 98 years for the entire group, failure to attend was often related to natural courses (49 patients deceased). However, apart

from those patients who had moved out, were kept in institutions, had medical illness etc., an obvious number that were called in over telephone did not see a need to come, claiming a situation free from problems. It is a clear trend among patients of today that implant treatment is regarded a standard and obvious part of the current oral rehabilitation, and they do not feel obliged to keep up continuous examinations. This is in contrast to the early-treated patients who felt special to undergo a new, exciting procedure and were thus "always" compliant and turned up on scheduled follow-up visits. Such behavior of early-treated implant patients has been reported on before.[14–16]

Over the years, rehabilitation of edentulous mandibles with fixed implant-supported prostheses has shown a gradual reduction of the implant number used per patient. The initial recommendation of six implants[5] was reduced to five implants during the late 1980s[23] and then further reduced to four[6,24] and even three implants[25,26] some 10 years later. A reduced number of implants, being more cost-effective but also implying a reduced support for the prosthetic construction, had no impact on the implant/prosthesis survival rates over a 5-year period in the present study, which is in accordance with the systematic review paper on implants in edentulous mandibles by Papaspyridakos and colleagues.[27]

Mean values of the marginal bone level were close to identical at delivery of prostheses (baseline radiographs) despite the various time periods elapsing from implant surgery to prosthesis placement for the Groups 1–4 (range: ~32–>100 days). This is probably an expression for the stable early marginal bone response seen in relation to threaded titanium implants. Similar outcomes were at hand also with regard to marginal bone loss during the 5 years of follow-up for Groups 1, 2, and 4. However, an increased mean value as well as increased numbers of more obvious bone loss ($p < .05$) was seen in Group 3, which could in its entirety be explained by extended bone loss seen in relation to the central (midline) implant. Furthermore, the one-stage placed TiUnite™ implant in the midline indicated more bone loss than observed for machined implants after one and two-stage surgery (Table 8). This outcome was observed already at the 1-year follow-up[12] and was one main reason to refrain from this central site and subsequently only place four implants.[13] One cannot exclude the possibility that the latter, more reactive, oxidized surface may have responded more "aggressively" to the anatomical "provocation" of the midline. Mandibular midline anatomy may reveal compromised conditions with more calculus formation, unfavorable pull from buccal/lingual frenulum, interference with prominent mental spine, which may explain differences between more distally placed implants and implants placed in the symphyseal region in edentulous mandibles. Such results have previously been reported.[28,29]

In general, it may be stated that apart from the observed implant failures, few clinical complications occurred during the study period in the four groups of patients. Hyperplastic/inflamed mucosa was noted in 31 patients (8.1%) and mainly involving the central (midline) implant in Group 2. Peri-implant surgical interventions were few and required in a total of five patients (1.3%).

It has been suggested that placement of implants induces a foreign body response, which is characterized by rejection or a chronic inflammation and encapsulation of the foreign body implant.[30,31] For the clinician, a clinically successful foreign body response would be when the implant is encapsulated by bone, referred to as *osseointegration* by Brånemark,[32] while a fibrous encapsulation is a clinical criterion for a failure. Accordingly, the biological response at the implants must be related to both local impact factors as well as systemic host response factors.[33] As a systemic observation, it can be noticed that the younger half of the total group of included patients (Younger$^{50\%}$ patient group) presented an increased mortality during the first 5 years of function as compared to normal population (Figure 2, A). On the other hand, the older part of the patients (Older$^{50\%}$ group) showed a decreased mortality as compared to normal population (Figure 2, B). It has earlier been reported that tooth loss is an independent predictor for mortality in the population.[3,4] Accordingly, it can be suggested that younger patients losing all their teeth in one jaw are associated with a general higher risk of systemic problems, here reflected in an increased mortality. Edentulism is a more common problem in older age groups, and patients in these older age groups that are asking for implant treatment can be assumed to be healthier than older edentulous patients who are maintaining their removable dentures. Despite an overall similar bone response in the two subgroups, this small difference in general health, here reflected by difference in mortality in relation to normal populations, may explain the present small overrepresentation of younger

patients who lose all their implants or experience most implants with the most obvious bone loss.

In the current study, the additional treatment option of using one-stage surgery and immediate loading with connection of temporary prostheses on the day of implant placement has not been utilized as a standard procedure. This has mainly been due to logistic issues, being problematic to coordinate such interventions between the 14 practicing dentists at the clinic. Further, the Swedish dental insurance system has not included this extra temporary prosthesis, why the cost would have amounted some additional 25% of the total, and therefore, the majority of patients have refrained from this procedure. Nonetheless, similar good 5-year data, as the ones reported on here, have been presented with this technique as well.[24,27]

CONCLUSION

Four different treatment procedures, using two-stage and one-stage surgery with turned Brånemark System® implants (Groups 1 and 2) and one-stage surgery using either five or four TiUnite™ Brånemark System® implants (Groups 3 and 4) in the rehabilitation of edentulous mandibles with fixed prostheses resulted all in good outcomes during a 5-year study period. Treatment with "no event" during follow-up ranged between 67% and 84%, and implant CSRs and prosthesis CRSs were comparable and ranged between 97.0–99.7% and 98.5–100%, respectively. Significantly, more patients ($p < .05$) in Group 2 lost implants as compared to other groups. Marginal bone levels measured at prostheses placement and used as baseline radiographs were close to identical for the four Groups. However, the marginal bone loss in Groups 1, 2, and 4 were as well close to identical, whereas patients in Group 3 presented higher mean values. Significantly, more patients with obvious amount of bone loss (>1.8 mm) at the central (midline) implant were found in Group 3 as compared to Groups 1 and 2.

Altogether, eight patients (2.1%) presented complete failure or several implants (>2 implants) with obvious bone loss (>1.8 mm). The present study indicates associations between implant loss/severe bone loss in relation to both local and systemic factors:

- More implant failures ($p < .05$) were observed in patients provided with implants with turned surfaces in one-stage surgery (*local*; surface, surgical technique).
- More patients ($p < .05$) showed obvious bone loss (>1.8 mm) at the midline implant (central) when using a moderately rough surface (*local*; surface, site).
- A trend of more patients showed obvious bone loss (>1.8 mm) at the midline implant (central) when using turned surface in one-stage as compared to two-stage surgery (*local*; surgical technique).
- Younger patients treated with implants in the present study (Younger$^{50\%}$ group) showed increase mortality as compared to older patients and to normal populations ($p < .05$). These younger patients showed also an association to patients with total implant failure and patients with most implants with obvious bone loss (>1.8 mm) after 5 years (*systemic*).

ACKNOWLEDGMENT

The authors acknowledge research assistant Marianne Spångberg, Brånemark Clinic, Göteborg, Sweden, for assistance in data compilation.

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