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Nine- to fourteen-year follow-up of implant treatment. Part I: implant loss and associations to various factors

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Abstract

Objectives: The aim of the present study was to evaluate the long-term result of implant therapy, using implant loss as outcome variable.

Material and Method: Two hundred and ninty-four patients had received implant therapy (Brånemark System®) during the years of 1988–1992 in Kristianstad County, Sweden. The patients were recalled to the speciality clinic 1 and 5 years after placement of the suprastructure. Between 2000 and 2002, 9–14 years after implant placements, the patients were again called in for a complete clinical and radiographic examination.

Results: Two hundred and eighteen patients treated with 1057 implants were examined. Twenty-two patients had lost 46 implants and 12 implants were considered ''sleeping implants''. The overall survival rate was 95.7%. Implant loss appeared in a cluster in a few patients and early failures were most common. Eight patients lost more than one fixture. A significant relationship was observed between implant loss and periodontal bone loss of the remaining teeth at implant placement. Maxillary, as opposed to mandibulary implants, showed more implant loss if many implants were placed in the jaw. A significant relationship between smoking habits and implant loss was not found.

Conclusion: A history of periodontitis seems to be related to implant loss.

Key words: dental implants; implant loss; long-term follow-up; periodontitis; smoking; survival rate

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Over the last decades, dental implants have become a commonly used treatment alternative to removable dentures. Several longitudinal studies have reported survival rates of around 90–95% over periods of 5–10 years (for a review, see Esposito et al. 1998a, Berglundh et al. 2002). However, complications do occur because of biological or mechanical causes. Implant loss can be classified into ''early implant loss'' (before functional loading) or ''late implant loss'' (following functional loading) (Berglundh et al. 2002). The cause of these losses has been proposed to be surgical trauma, infection, overload and certain local and systemic conditions (Esposito et al. 1998b).

In previous studies, early implant loss has been reported in the range of 0.76–7.47% and late implant loss (5–10 years) in the range of 2.1–11.3% (Berglundh et al. 2002). In the present study, the outcome of titanium implant therapy was evaluated over a period of 9–14 years. In addition, possible associations between implant loss and various factors were analysed.

Material and Methods

This study was approved by the Institutional Review Board, University of Lund, Sweden. All participating individuals signed an informed consent. The study reports on patients treated with titanium implants (Brånemark System®, Nobelpharma, Göteborg, Sweden) at the Public Dental Health Service in Kristianstad, Sweden, during a period from January 1988 to December 1992. During this interval, a total of 294 patients were provided with implant-supported fixed or removable restorations at the Department of Prosthodontics by two prosthodontists. Before implant installation, dentate patients were, if needed, periodontally treated to obtain periodontal health. The two-step implant surgery procedures were performed either at the Department of Oral Surgery (three oral

surgeons) or at the Department of Periodontology (three periodontists).

Systemic antibiotics were prescribed to all patients for 10 days, starting the day before implant installation. Twice daily chlorhexidine rinses were recommended until the sutures were removed after 7 days. Submerged implant healing was allowed for a minimum of 3 months, after which the surgical abutments were fitted. Shortly thereafter, the suprastructure was placed. All patients were instructed how to maintain proper oral hygiene around the implants and remaining teeth. The patients were then referred back to their general dentist for follow-up.

One and 5 years after placement of the suprastructure, the patients were examined at the Department of Prosthodontics and new sets of intra-oral radiographs were obtained. Between January 2000 and December 2002 the patients were again called in for a clinical and long-cone radiographic examination. This final examination, on which the main outcome data of this paper are based, was performed 9–14 years after suprastructure placement at the dental clinic of the University of Kristianstad by one and the same examiner (author C. L.). An update of the medical and dental history was made on all patients attending this examination, which included the following items used for data analyses of the present reports:

- *age at final examination*,
- *gender*,
- *dental status (dentate/edentulous)* at time of implant placement,
- *years of education* (<12 *versus* $\geqslant 12$ years),
- *number of dental visits* (dentist and dental hygienist) since placement of the suprastructure,
- *smoking habits* (current smoker, former smoker, never smoking; if current or former smoker, numbers of cigarettes/day were used to calculate pack-years),
- *medical history* (focus on diabetes, osteoporosis and coronary heart disease),
- *medication* (number of different drugs used daily at the time of examination),
- *number of implants placed* (1–4 *versus* $\geqslant 5$),
- *implant position* (maxillary; mandibulary; anterior = incisor/cuspid region; posterior = premolar–molar region),
- *implant loss*: The time in months for any implant lost was determined from radiographs and patient records and categorized as ''early'' (before placement of suprastructure), ''1 year'' (implant lost within the first year after loading) and ''late'' (implant lost after the first year of loading),
- *plaque score* [presence/absence of plaque after using a disclosing dye; total score for both teeth and implants (full mouth) and for implants alone, measured at four sites per tooth and implant and expressed as a percentage of examined sites],
- *bleeding on probing score* [total score for both teeth and implants (full mouth) and for implants alone, measured at four sites per tooth and implant and expressed as a percentage. The bleeding scores were also categorized into three categories: 0–20%, 21–50% and 51–100%], and
- *Percentage of remaining teeth before extraction initiated by implant therapy or at implant placement with bone loss* $\geqslant 4$ *mm* (measured by author A.-M. R.-J. from the cemento-enamel junction on radiographs). The extent of bone loss within the mouth was divided into three categories: 0–30%, 31–50% and 51–100% of teeth with bone loss $\geqslant 4$ mm at mesial and/or distal aspect.

Statistical analyses

Descriptive statistics and frequency distributions were performed. The statistical computations were carried out using SPSS for Windows (release 11.5.1; SPSS Inc., Chicago, IL, USA). Outcome data on time-to-event for implant loss were described by Kaplan–Meier curves. First event (in maxilla or mandible) was considered as the end-point event when exploring the effect of each of the following potentially influential variables: age, gender, dentate *versus* edentulous, years of education (<12 *versus* $\geqslant 12$), number of visits with dentist/hygienist since placement of the suprastructure, number of visits with dentist per year, and number of visits with hygienist per year, smoking status (never smoker, ex-smoker and smoker), smoking duration, pack-years, medical history (any of diabetes, osteoporosis and coronary heart disease *versus* no such diseases), medication (number of different drugs used daily), total plaque score, plaque score at implants, total bleeding on probing score, bleeding score at implants, bleeding category (0–20%, 21–50%, 51–100%) and bone loss $\geqslant 4$ mm at teeth by category (0–30%, 31–50%, 51–100%). The prognostic effect of each variable was examined by Kaplan–Meier curves and the log-rank test (Altman 1991). As a supplementary approach to exploring prognostic effects, Cox's regression modelling was employed (Altman 1991).

Two other potentially influential variables were considered: numbers of implants placed in maxilla and mandible. For these two variables, the first event in maxilla (first loss of maxillary implant) and first event in the mandible (first loss in the mandible) were the end point.

The amount of time between the first and second events was also calculated (second event: loss of additional implant at a later occasion). The amount of time for the first event was compared with amount of time from the first to second event by the log-rank test. Moreover, among the patients with time-to-first-event $\leqslant 12$ and >12 months, the numbers of patients with a second event were compared using Fisher's exact test (Altman 1991).

Results

Out of the 294 patients that received implants during the period of 1988–1992, 76 patients did not attend final examination. Twenty-two patients had died and 54 patients did not want to participate or were unable to attend because of health reasons. This paper is the first in a series of three papers on this patient material. Thus, this report includes a study group of 218 individuals with 1057 implants from whom final 9–14 year data were gathered and 54 drop-outs out of which 40 had radiographs taken 5 years after placement of the suprastructure. The characteristics of these three patient groups are presented in Table 1. For those characteristics that were available for all three groups, similar data were observed, except for percentage females, which was higher among the drop-outs.

The mean age of the 218 patients from which 9–14 year data were gathered was 65.6 years (range 29–92). One hundred and ten patients were female (50.5%). Sixty-four (29.4%) were totally edentulous. Totally, 1057 implants were inserted, 524 maxillary and 533 mandibulary. Thirty-two patients received implants in both jaws (14.6%).

Table 1. Characteristics of patients with 9–14 years of follow-up ($N = 218$); drop-out patients ($N = 54$); and drop-out patients evaluated radiographically 5 years after placement of suprastructure ($N = 40$)

Characteristics	9–14 year follow-up ($N = 218$)	Drop-outs ($N = 54$)	Drop-outs with 5-year follow-up ($N = 40$)
Age	65.6 ± 13.9 (29–92)	69.1 ± 16.8 (32–91)	70.4 ± 17.6 (32–91)
Females (%)	50.5	72.2	67.5
Edentulous (%)	29.4	24.0	27.5
Patients with maxillary implants (%)	46.3	46.3	50.0
Patients with mandibulary implants (%)	38.9	44.4	37.5
Patients with implants in both jaws (%)	14.6	9.3	12.5
No. of maxillary anterior implants	331	83	72
No. of maxillary posterior implant	193	39	35
No. of mandibulary anterior implants	330	92	52
No. of mandibulary posterior implants	203	48	34
Plaqueindex – full mouth (%) ($N = 195$)	52.3 ± 27.9 (0–100)	NA	NA
Plaqueindex – implants (%) ($N = 217$)	41.7 ± 32.5 (0–100)	NA	NA
BOP – full mouth (%) ($N = 193$)	48.0 ± 22.7 (0-100)		
BOP – implants (%) ($N = 217$)	46.6 ± 27.0 (0-100)		
Years of education	9.2 ± 3.4 (2-20)	NA	NA
Current smokers (%)	26.1	NA	NA
Former smokers (%)	37.2	NA	NA
Never smoking (%)	36.7	NA	NA
Packyears	17.5 ± 22.1 (0–180)	NA	NA
Smoking duration (years)	18.9 ± 20.7 (0–60)	NA NA	NA NA
Patients with diabetes (%)	4.6	NA	NA
Patients with osteoporosis (%)	0.9	NA	NA
Patients with coronary heart disease (%)	17.0	NA	NA
1–3 drugs daily	43.6	NA	NA
4–6 drugs daily	6.0	NA	NA
⩾7 drugs daily	5.5	NA	NA
No. dental visits	15.4 ± 10.2 (0-60)	NA	NA

Means+SD (range); proportions (%)
NA, not applicable/unknown; BOP, bleeding on probing.

Maxillary implants were inserted in 101 patients (46.3%) and mandibulary implants in 85 patients (38.9%). Mean years of education were 9.2 years with a wide range from 2 to 20 years. A total of 57 patients (26.1%) reported to be current smokers, 81 individuals (37.2%) were former smokers and 80 subjects (36.7%) had never smoked. Ten individuals had diabetes (4.6%). Twelve patients (5.5%) used more than seven drugs, 13 patients (6%) used four to six drugs and 95 patients (43.6%) used one to three drugs daily. During the years from placement of the suprastructure until the final examination the mean number of visits at the dental clinic as 15.4 (range 0–60).

Mean age among the 54 drop-outs was 69.1 years (range 32–91). Thirty-nine of the patients were women (72.2%) and 15 were men (27.8%). Forty-one of the individuals (24.0%), in the drop-out group, were partially dentate. A total of 262 implants were inserted, 122 maxillary and 140 mandibulary. The implants were placed in the maxilla in 25 individuals (46.3%), in the mandible in 24 individuals (44.4%), and five patients (9.3%) received implants in both jaws.

Table 2 presents the length of observation for the group that received final examination. The majority of the patients (65%) and implants (60%) had a follow-up of 11 years or more: 85% of the patients and 80% of the implants had a follow-up of 10 years or more. Twelve implants (1.1%) in 10 patients (4.6%) were not used in restorations because of different reasons, including improper angulations of the implant. These implants were termed ''sleeping implants''.

Table 2. Years of follow-up by patient and implant

Years of follow-up	No. patients (%) ($N = 218$)	No. implants (%) ($N = 999$)*
9	34 (16%)	196 (20%)
10	44 (20%)	204 (20%)
11	64 (29%)	272 (27%)
12	45 (21%)	197 (20%)
13	21 (10%)	87 (9%)
14	10 (5%)	43 (4%)

*Number of initially placed implants ($N = 1057$) minus ''sleeping implants'' ($N = 12$) and lost implants ($N = 46$).

Implant loss

Implant loss in the study population is described in Table 3. Totally, 46 implants (4.4%) in 22 patients were lost during the observation period. Twenty-nine implants (2.7%) in 15 patients were lost before placement of the suprastructure (''early''). Seven implants (0.7%) in five patients were lost within the first year of loading (''1 year''). Following the first year of loading, an additional 10 implants (1%) in five patients were lost (''late''). This group of late implant losses as subdivided into two groups: (i) implant loss between >1 and 5 years (in order to compare with the drop-out group with radiographs available at 5-year follow-up, Table 4), and (ii) after 5 years. Three implants (0.3%) in two patients were lost between >1 and 5 years (mean time 2.8 years) and seven implants (0.7%) in three patients were lost after 5 years (mean time 8.9 years). More implants were lost in the maxilla compared with implants placed in the mandible. This was most apparent for late implant losses: 1.4% *versus* 0.6%.

A comparison of implant loss for the 40 drop-outs with 5-year data (Table 4) to those of the study group (Table 3) shows similar numbers for ''early'' and ''1 year'' loss, but higher numbers for the >1–5 year period (11.1% *versus* 0.9% for patients and 4.5% *versus* 0.3% for implants).

Kaplan–Meier estimate of survival rates are presented in Figs 1–4.

Time to first event

For 22 out of the 218 patients, at least one event occurred. Figure 1 shows the Kaplan–Meier curve based on the total patient group. With the first event as the end-point, only one of the investigated variables was statistically significant,

Table 3. Implant loss for study group ($N = 218$)

	Early*	1 year†	Late‡ (years)	
			>1–5	>5
% of patients ($N = 218$)	6.9	2.3	0.9	1.4
% of implants ($N = 1057$)	2.7	0.7	0.3	0.7
% of maxillary implants ($N = 524$)	3.2	0.8	0.6	0.8
% anterior implants ($N = 331$)	3.3	0.9	0.3	0.6
% posterior implants ($N = 193$)	3.1	0.5	1.0	1.0
% of mandibulary implants ($N = 533$)	2.2	0.6	0	0.6
% anterior implants ($N = 330$)	1.2	0.3	0	0
% posterior implants ($N = 203$)	3.9	1.0	0	1.5
Time of implant loss (mean)	7.0 months	7.4 months	2.8 years	8.9 years

*Implant loss before placement of supra structure.
†Implant loss within the first year of loading.
‡Implant loss during two time periods; 1–5 years and more than 5 years after application of the suprastructure.

Table 4. Implant loss for drop-outs with 5 year follow up ($N = 40$)

	Early*	1 year†	Late‡
			>1–5 years
% of patients ($N = 40$)	7.5	2.7	11.1
% of implants ($N = 198$)	1.5	1.5	4.5
% of maxillary implants ($N = 107$)	2.7	2.8	6.7
% anterior implants ($N = 72$)	2.7	4.1	5.8
% posterior implants ($N = 35$)	2.8	0	8.6
% of mandibulary implants ($N = 86$)	0	0	2.2
% anterior implants ($N = 52$)	0	0	0
% posterior implants ($N = 34$)	0	0	4.6
Time of implant loss (mean)	9.6 months	9.0 months	2.0 years

*Implant loss before placement of supra structure.
†Implant loss within thefirst year of loading.
‡Implant loss after the first year of the supra structure in function until 5 years of follow-up.

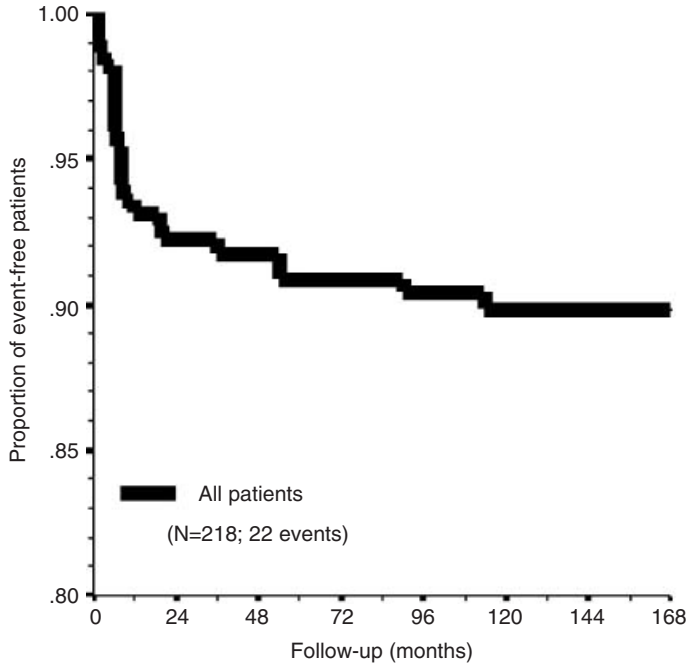

Fig. 1. Kaplan–Meier estimates of survival rates for all patients.

namely teeth with bone loss $\geqslant 4$ mm (Fig. 2). In the graph of Fig. 2, categories 31–50% and 51–100% are combined, as the curves for these groups were similar. The log-rank test showed a significant effect ($p = 0.01$). Cox's regression analyses revealed similar results. Two other variables showed a tendency ($p < 0.20$) for prognostic effect: (i) years of education [$p = 0.11$; <12 years: 21 patients with events out of 176 (12%); $\geqslant 12$ years: one patient with an event out of 41 (2%)]; (ii) smoking status [$p = 0.16$; never smoker: five patients with events out of 80 (6%); smoker/ex-smoker: 17 patients with events out of 138 (12%)].

Evaluating the first event for maxillary implants (14 out of 133 patients), the event rate differed between patient groups categorized by number of implants placed (1–4 *versus* $\geqslant 5$ implants) ($p = 0.01$) (Fig. 3). However, when adjusting for teeth with bone loss $\geqslant 4$ mm, $p = 0.13$ was obtained.

Evaluating the first event for mandibulary implants (eight out of 119 patients), the event rate did not reach statistically significant difference between patients with 1–4 *versus* $\geqslant 5$ implants ($p = 0.07$) (Fig. 4).

Time between the first and second event

Among the 22 patients with a first event, eight (36%) had a further event at another occasion. Moreover, the times between the first and second events were short: two events after 1 month, two after 2 months, two after 4 months and two after 6 months. There was a significant difference ($p < 0.001$) between the time to first-event ($N = 218$; 22 events) and the time between the first and second event ($N = 22$; eight events).

Discussion

The patients included in the study were treated with Brånemark® implants by specialists in either periodontology or oral surgery. The surgical procedure as well as the initial follow-up was similar for all individuals. Thereafter, supportive therapy was provided at the discretion of the referring dentist. Although the mean number of dental visits (dentists + dental hygienists) was more than one per year, the range was wide (0–60 visits). In spite of this, no relationship was found between the number of dental visits and implant loss. However, it is possible that those patients that attended the dental office more frequently did so because of problems arising from the implant therapy, rather than for supportive treatment. Available records did not

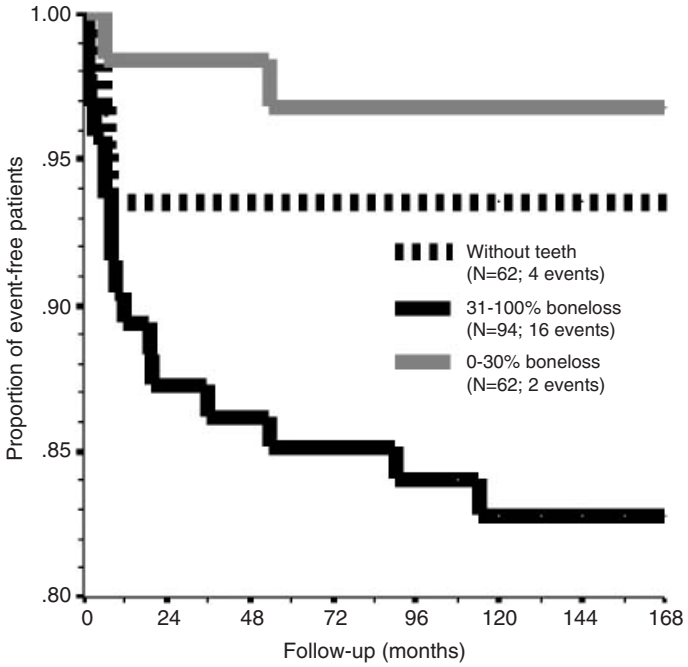

Fig. 2. Kaplan–Meier estimates of survival rates for patients without teeth and for patients with different levels of bone loss before implant placement.

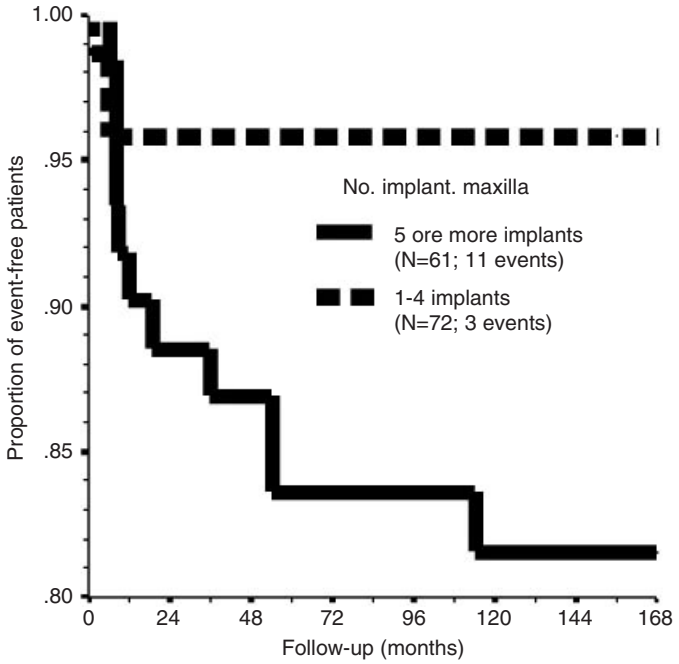

Fig. 3. Kaplan–Meier estimates of survival rates by numbers of implants placed in the maxilla.

allow any meaningful analyses of the nature and quality of supportive therapy.

Although efforts were made to clinically examine all living patients 9–14 years after placement of the implants, a number of individuals were unable or unwilling to attend. Data, when available from a radiographic examination 5 years after placement of the suprastructure, were used for this group. Late (1–5 years) implant losses were higher for this group (4.5%) compared with the study group (0.3%). Previous long-term studies have not reported data allowing for the analysis of the impact of dropouts. This should be kept in mind when interpreting the results.

The present study of the available subjects was limited to analyses of implant loss over 9–14 years. Future studies will focus on the degree of peri-implant lesions developing over the years in these subjects. The extent of implant loss before placement of the suprastructure observed in this study (2.7%) is similar to that previously reported. In the review by Berglundh et al. (2002), weighted means were reported for implant loss before loading. Evaluating data from 28 studies with different implant systems, they reported values between 2.16% and 2.53% for patients about to receive implant supported fixed complete dentures or fixed partial dentures.

All patients in this study were treated with the Brånemark® implant system having a machined surface. This is an advantage as possible differences between implant systems can be disregarded. Most of the implant losses were early (63%), and in this study, as in previous studies on long-term results of implant therapy, the majority of implant losses were concentrated in a relatively small number of individuals (Weyant & Burt 1993, Jemt 1994, Hutton et al. 1995, Friberg et al. 1997, Wyatt & Zarb 1998). Only a few of the patients that lost implants during the healing phase continued to demonstrate implant loss later during the follow-up period. This indicates that the loss of implants during the initial healing phase may be caused by factors not related to susceptibility to peri-implantitis, but rather other factors such as variation in surgical technique, postoperative infection, and inadequate adjustment of prostodontic appliances with overload as a consequence (Esposito et al. 1998a, b). However, the sample size in this study did not allow for an analysis of subsamples.

Implant loss after placement of the suprastructure was low: 1.7% of implants in the group examined after 9–14 years. This is slightly lower than the data presented for similar follow-up periods in the review by Berglundh et al. (2002).

A significant relationship between smoking habits and implant loss (first event) was not found in this study. However, a tendency for smoking to have a deleterious effect was recognized. In the present study, 6% of

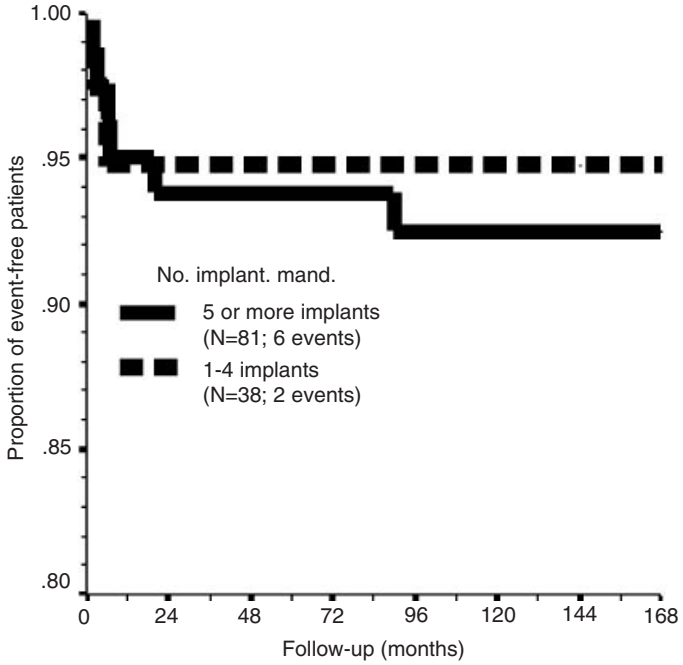

Fig. 4. Kaplan–Meier estimates of survival rates by numbers of implants placed in the mandibula.

non-smoking individuals and 12% of smokers or former smokers lost implants. Other studies have demonstrated a deleterious effect of smoking on implant loss (Bain & Moy 1993, Bain 1996, Wilson & Nunn 1999, Lambert et al. 2000, Wallace 2000). Wilson and Nunn (1999) reported an increased risk for implant loss among smokers by a factor of almost 2.5 compared with non-smokers and Wallace (2000) described failure rates of 16.6% in smokers as compared with 6.9% in non-smokers. The reason for the lack of statistical significance for smoking as a risk factor for implant loss in the present study may be related to the few number of individuals with implant loss, thus reducing the power of statistical analyses.

The only factor that showed a significant association to the first event implant loss in the present study was the degree of periodontal bone loss in the remaining teeth before implant placement i.e. previous history of periodontal disease. This confirms the observations by Karoussis et al. (2003), who found that patients who had lost teeth because of periodontitis demonstrated lower survival rates for implants (90.5%) compared with patients without a history of periodontitis (96.5%).

Patients with many implants had a higher failure rate. It is possible that these patients had lost their teeth because of periodontitis and may be more prone to peri-implantitis, leading to implant loss. Peri-implantitis may, at least in part, explain some of the implant losses in this study. Periodontitis and peri-implantitis seem to have similar etiologies (Mombelli & Lang 1998). The microbiota adjacent to implants and teeth in partially edentulous patients is similar, and putative pathogens are commonly found around implants with adjacent inflammation (George et al. 1994). The crevices around the teeth may act as reservoirs of bacteria, which can colonize the implant site (Koka et al. 1993, Gouvoussis et al. 1997). As a result, periodontitis patients may be exposed to a higher risk for peri-implantitis that may lead to implant loss. However, it is not possible from the data presented herein to definitively ascribe the implant loss to any particular process.

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Clinical Relevance

Scientific rationale for study: Limited data exist regarding associations between implant loss and patient-related factors.

Principal findings: Patients supplied with implants with a machined surface demonstrated a survival rate of 95.7% after 9–14 years. Implant loss appeared in a cluster in a few patients and was more common in the maxilla than in the mandible. The degree of bone loss around the remaining teeth before implant placement showed a significant association to implant loss. Smoking showed a tendency to have a deleterious effect.

Practical implications: Patients with a history of periodontitis and smokers may have lower implant survival rates.