Prognostic Variables Associated with Implant Failure: A Retrospective Effectiveness Study

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The purpose of this study was to determine implant survival rates by means of life table analyses for a cohort of patients not part of a prospective efficacy trial and treated by practitioners at varying experience levels. Prognostic variables associated with implant failure were identified by means of proportional hazards models and advanced statistical methods that account for patient effects. Ninety-nine consecutive patients treated from 1987 to 1991 with follow-up to 1994 were included in this retrospective study. A total of 384 dental implants (79.7% Brånemark, 19.3% IMZ plasma-sprayed, 1% IMZ hydroxyapatite-coated) were placed and subsequently supported 108 prostheses. Survival and proportional hazards modeling were used to generate Kaplan-Meier survival curves and to identify variables associated with implant failure. Survey data analysis was used to adjust for any patient effects for variables identified as significant through the proportional hazards models. Thirty-four implants failed over the follow-up period (median follow-up time 3.6 years), resulting in an overall failure rate of 8.9%. Seventeen of 99 patients experienced an implant failure. When prosthesis type was excluded from the modeling process, survey data analysis identified posterior location and an implant width of less than 4.0 mm as being associated with implant failure (all $P < .05$).
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Key words: dental implants, effectiveness, proportional hazards, retrospective, survey data analysis, survival analysis

Since their introduction, use of dental implants has rapidly expanded beyond the original protocols documented by Brånemark and colleagues.[1,2] Protocols with different implant designs, materials, and techniques for patients with varying numbers of missing teeth are being used by a larger number of practitioners than ever before. While research reports of these alternate therapies often document high success rates, these mostly prospective studies are usually of short duration, apply strict patient inclusion criteria, and involve therapy usually provided by experienced clinicians.[3–8] Information from such efficacy trials may not be generalizable, either to the average dental implant patient or to a less experienced practitioner. Further, with few failures identified, those factors associated with dental implant failure have been poorly characterized to date.[9]

Retrospective evaluation of dental implant patient cohorts not part of prospective trials may provide more generalizable information, especially if the therapy is provided by clinicians of varied experience levels. Further, by using implant removal as the only measure of failure, larger patient cohorts with longer follow-up periods can be identified and analyzed for those factors most commonly associated with failure.

The purposes of this study were *(1)* to determine implant survival rates by means of life table analyses for an implant patient cohort not part of a prospective efficacy trial and treated by practitioners of var-

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Table 1 Description of Indications/Prostheses Provided (n = 108 Prostheses)

Description	No. (%)
Completely edentulous/fixed-detachable hybrid prosthesis	41 (37.9)
Partially edentulous/fixed partial denture	33 (30.6)
Completely edentulous/removable overdenture	20 (18.5)
Single tooth replacement	13 (12.0)
Partially edentulous/removable partial denture	1 (0.9)

ied experience levels; and *(2)* to identify those variables associated with implant failure by means of proportional hazards modeling and advanced statistical methods that account for patient-level effects.

Materials and Methods

Ninety-nine consecutive patients treated in the University of North Carolina Clinical Implant Program were included in this retrospective study. These patients were treated between 1987 to 1991 with potential follow-up through 1994. The original date coincided with the inception of the dental implant program at the institution.

After initial screening by faculty from the departments of oral surgery, periodontics, and prosthodontics, requisite radiographs and diagnostic templates were obtained. Patients were assigned to one of six periodontist or oral surgeon faculty members for implant placement, and to 1 of 12 prosthodontists for rehabilitation (8 faculty, 4 graduate prosthodontic residents).

Patients ranged in age from 23 to 84 years (mean = 60.5 years) and 67% were female. In all, 384 endosseous implants were surgically placed according to standard protocols; of these, 306 were Brånemark (Nobel Biocare, Westmont, IL), 74 were IMZ plasma-sprayed (Interpore International, Irvine, CA), and 4 were IMZ hydroxyapatite-coated. The implants were allowed to integrate for a minimum of 3 or 6 months for the mandible and maxilla, respectively. Rehabilitation was accomplished with the placement of 108 prostheses, as listed in Table 1.

All data were obtained through chart reviews for each of the 99 patients. Data included from each record review are as follows:

Patient ID number
Patient gender
Patient date of birth
Implant manufacturer
Implant width
Implant length
Implant location
Surgeon
Stage-one surgery date
Stage-two surgery date
Prosthodontist
Type of prosthetic rehabilitation
Prosthesis placement date
Implant removal
Implant failure date
Last recall date

Failure was noted by removal of the implant. The data were converted into an SAS (SAS Worldwide Institute, Cary, NC) data set by means of an infile statement. Frequency tables for sites by each explanatory variable, as well as explanatory variables by implant failure status, were generated as an exploratory analysis to verify that the number of sites in each cell was large enough to implement survival modeling. Life table methods (SAS LIFETEST) were used to generate Kaplan-Meier survival curves and to make comparisons among groups. Any associations between implant failure and individual explanatory variables were noted. Under the assumption of independence among multiple implants in the same patient, log-rank and Wilcoxon's rank sum tests were used in a preliminary fashion to evaluate the homogeneity for these explanatory variables, and proportional hazards modeling (SAS PHREG) was used to simultaneously assess the explanatory variables and to identify important variables associated with implant failure. For more rigorous analysis with adjustment for intrapatient correlation because of many patients having multiple implants, survey data analysis (SUDAAN) was used to adjust for any patient effects for the important covariates identified through the proportional hazards modeling.[10–13]

Results

Three hundred eighty-four implants were followed for an average of 3.9 years after surgical placement (range 2.4 months to 7.6 years; median 3.6 years). Thirty-four implants failed during this period, yielding an overall failure rate of 8.9%. Seventeen of 99

Table 2 Follow-Up Time (in Years) From Surgical Placement for Failed Implants

	Range	Median	Mean
All implant failures (n = 34)	0.2–4.1	0.9	1.4
Preprosthetic failures (n = 20)	0.2–1.0	0.5	0.5
Postprosthetic failures (n = 14)	1.0–4.1	2.6	2.6

Table 3 Implant Failure and Total Implant Distributions by Gender, Implant Width, Length, Type, Location, and Prosthesis Type

	Implants failed (% of total placed in subclassification)	Total implants placed (% of total placed in classification)
Gender		
Female	23 (8.5)	272 (70.8)
Male	11 (9.8)	112 (29.2)
Implant width (mm)		
3.3	2 (15.4)	13 (3.4)
3.75	26 (9.8)	266 (69.3)
4.0	6 (5.7)	105 (27.3)
Implant length (mm)		
7	4 (16.0)	25 (6.5)
8	0	4 (1.0)
10	13 (13.0)	100 (26.0)
11	5 (14.3)	35 (9.1)
13	5 (5.3)	94 (24.5)
15	6 (7.5)	80 (20.8)
18	1 (2.2)	45 (11.7)
20	0	1 (0.3)
Implant type		
Brånemark	26 (8.5)	306 (79.7)
IMZ plasma-sprayed	8 (10.8)	74 (19.3)
IMZ hydroxyapatite-coated	0	4 (1.0)
Implant location		
Anterior mandible	16 (6.4)	249 (64.8)
Anterior maxilla	3 (9.1)	33 (8.6)
Posterior mandible	7 (13.2)	53 (13.8)
Posterior maxilla	8 (16.3)	49 (12.8)
Prosthesis type		
Completely edentulous/fixed	8 (3.9)	206 (53.6)
Completely edentulous/removable	15 (22.7)	66 (17.2)
Partially edentulous/fixed	8 (8.8)	91 (23.7)
Partially edentulous/removable	0	3 (0.8)
Single tooth replacement	1 (7.7)	13 (3.4)
Unrestored	2 (40.0)	5 (1.3)
Total	34 (8.9)	384

patients experienced an implant failure, nine of whom had multiple failures. Twenty of the failures occurred prior to prosthetic rehabilitation. Table 2 presents the range, median, and mean follow-up times from surgical placement for the failed implants. Table 3 reports the failed implant and total implant distributions by gender, implant width, length, location, manufacturer, and prosthesis type. Kaplan-Meier survival curves for implant width, length, location, and prosthesis type are presented in Figs 1 to 4. Log-rank and Wilcoxon's rank tests identified removable prosthesis type as a significant factor associated with implant failure ($P < .0001$). The survival curves demonstrate trends toward decreasing survival probability with implants: *(1)* less than 13 mm long, *(2)* less than 4.0 mm wide, and *(3)* placed in posterior versus anterior locations. Log-rank and Wilcoxon's tests of homogeneity, however, were not statistically significant for these variables ($P > .10$).

Proportional hazards models were used to assess explanatory variables simultaneously. Every variable was first assessed individually: removable treatment was strongly associated with implant failure ($P <$ .0001), while completely edentulous fixed treatment

Fig 1 Kaplan-Meier survival curve by implant width. The category "< 4.0 mm" includes all 3.75-mm and 3.3-mm implants. The trend toward decreasing survival probability for widths of less than 4.0 mm, as determined by log-rank and Wilcoxon's rank sum tests of homogeneity, was not statistically significant ($P > .10$).

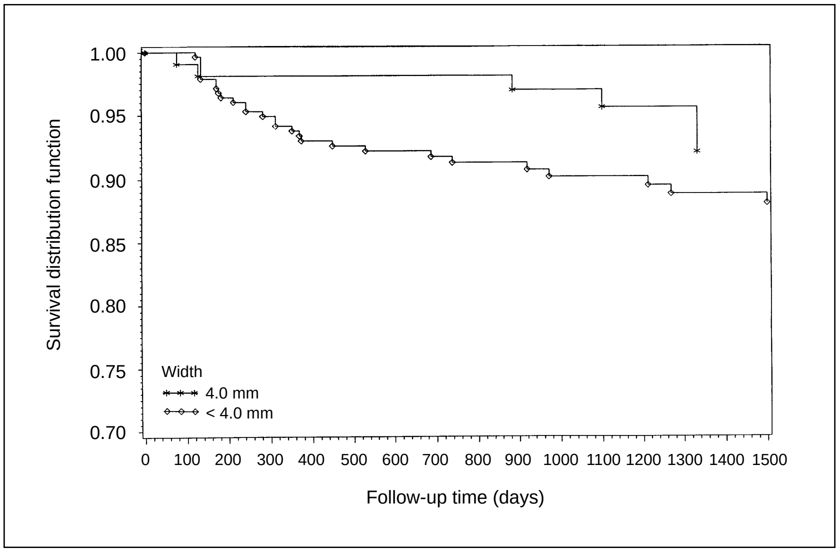


Fig 2 Kaplan-Meier survival curve by implant length. The trend toward decreasing survival probability for implant lengths of less than 13.0 mm, as determined by log-rank and Wilcoxon's rank sum tests of homogeneity, was not statistically significant ($P > .10$).

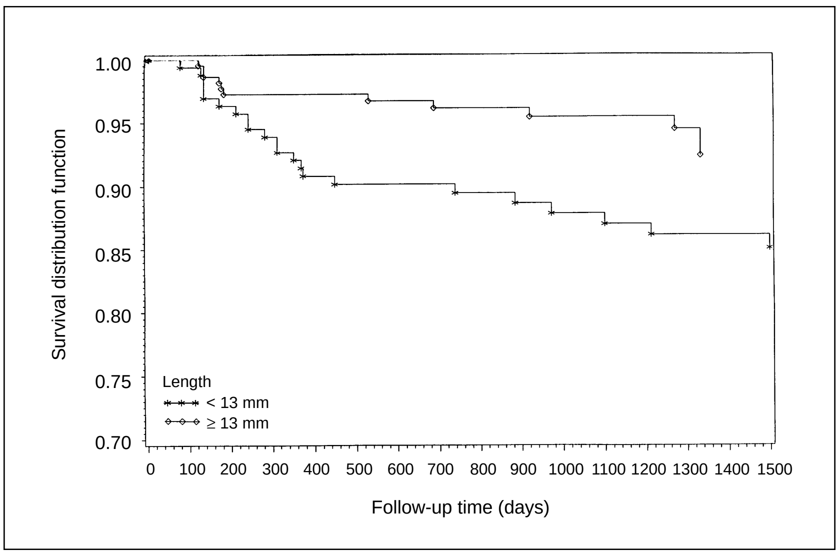
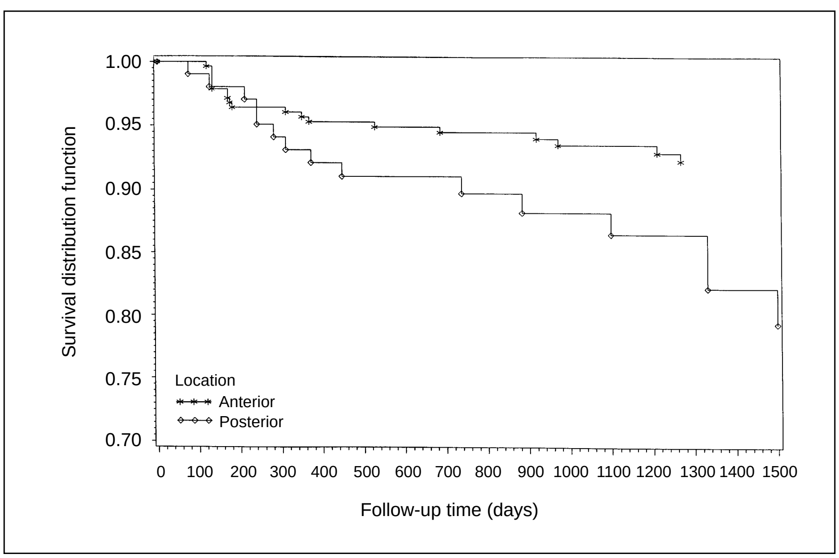


Fig 3 Kaplan-Meier survival curve by implant location. The trend toward decreasing survival probability for posterior versus anterior locations, as determined by log-rank and Wilcoxon's rank sum tests of homogeneity, was not statistically significant ($P > .10$).



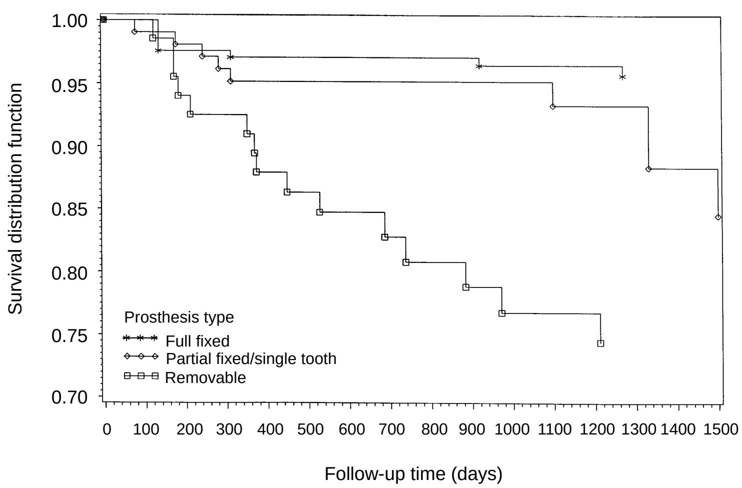


Fig 4 Kaplan-Meier survival curve by final prosthesis type. Although log-rank and Wilcoxon's tests of homogeneity were highly significant (P < .0001), indicating that removable prosthesis treatment was associated with implant failure, the majority of failures occurred prior to prosthetic rehabilitation. Typically, an implant failure prior to a planned rehabilitation with a fixed detachable prosthesis for the edentulous patient would result in final rehabilitation with an overdenture. Partial fixed and single tooth restorations are grouped together.

and anterior mandible location were negatively associated with failure (P = .0004, P = .03, respectively). Stepwise models were generated for all failures with and without the effect of prosthesis type. Additionally, stepwise modeling was performed for prerehabilitation failures without the effect of prosthesis type, and for postrehabilitation failures with the effect of prosthesis type included. When the effect of prosthesis type was not included in the models, posterior location, implant length less than 13 mm, and implant width less than 4.0 mm were associated with implant failure (all P < .05). When prosthesis type was included in the models, removable treatment (overdenture) was strongly associated with implant failure (P < .001).

SUDAAN was used to adjust for any patient effects related to multiple implants having been placed in individual patients. Models similar to the proportional hazards models were assessed. Again, when prosthesis type was included in the models, removable treatment was strongly associated with implant failure (P < .01). When prosthesis type was not included in the models, only posterior location and implant width less than 4.0 mm were associated with implant failure (P < .05).

Discussion

As Weyant and Burt[14] noted in 1993, many clinicians, guided primarily by clinical judgment, select a variety of implant types to address the various clinical problems found in their patients. As such, it is important to characterize the outcomes that can be expected from the routine use of implants in a variety of clinical settings. This study provides further information on the outcomes of dental implant therapy for those patients who were not part of a prospective efficacy trial and were treated by practitioners of varying experience. Because the study coincides with the inception of the Clinical Implant Program at the University of North Carolina, all practitioners were in the early phases of the learning curve for implant therapy. Future studies should more finely focus on practitioner experience level as a potential explanatory variable. The survival rate of 91.1% of implants during a median follow-up time of 3.6 years and a patient-specific failure rate of 17% are remarkably similar to the findings of an earlier analysis of VA implant patients.[14]

When prosthesis type was included in the analyses, removable prostheses were most significantly associated with implant failure. The failure rate of 22.7% is much higher than rates from most other reports.[15–19] In this study, however, 40% of the failed implants associated with a removable prosthesis were originally intended to support a fixed-detachable prosthesis. Since more of the implant failures occurred prior to prosthesis placement, the authors place more weight on those models that do not include the effect of prosthesis type.

This study's findings of decreased survival probability with shorter implants, though not statistically significant with the SUDAAN analysis, concurs with previously published reports.[20–24] While no attempt was made to categorize bone type, decreased survival probability was evident with posterior anatomic locations. In contrast to some studies,[24,25] but in agreement with another retrospective effectiveness study,[22] no effect was noted with maxillary versus mandibular arch when other variables were controlled. The finding of decreased survival probability with implants of less than 4.0 mm in width is interesting and should be evaluated in other studies, especially as a wider range of implant diameters comes into clinical use. Since the number of implant failures is small, the results reported for their association with the various explanatory variables should be interpreted cautiously.

Using implant removal as the key criteria of failure may tend to inflate the overall success rates, since the patient chart reviews clearly indicated the presence of ailing or failing implants. Longer follow-up periods and larger cohorts would tend to minimize the effect of these implants that are surviving but would not be judged successful according to more strictly defined criteria.[26] More complete follow-up would also reduce potential ambiguity (or potential bias) from the uncertain status of implants in patients lost to follow-up. Using implant removal as the only outcome variable does account for surviving and clinically viable prostheses, and more importantly, simplifies the chart review process, thereby facilitating the evaluation of larger community-based cohorts who are not part of prospective efficacy trials.

Conclusion

The present study characterizes the outcomes of dental implant therapy for a range of patients requiring various degrees of tooth replacement, who were treated by many practitioners at the early phase of the implant learning curve. An overall survival rate of 91.1% was documented for implants with a mean follow-up time of 3.9 years. Nearly one in five patients experienced an implant failure. Life table analyses generated Kaplan-Meier survival curves for different implant lengths, widths, and locations, and for different prosthesis types. Proportional hazards modeling, combined with SUDAAN modeling, identified removable prosthesis type, posterior location, and implant widths of less than 4.0 mm to be significantly associated with implant removal.

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