Implants (3.3 mm Diameter) for the Rehabilitation of Edentulous Posterior Regions: A Retrospective Clinical Study with Up to 11 Years of Follow-Up

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ABSTRACT

Background: There is limited evidence for the use of narrow-diameter implants for rehabilitation of the posterior regions of the jaws using different surgical techniques.

Purpose: The purpose of this study was to report the clinical results of implant-supported prosthetic rehabilitations in the posterior regions of both jaws, using narrow-diameter implants.

Materials and Methods: The study included 147 patients (115 males and 32 females), with an age range of 26 to 77 years (mean = 47.5 years), with a total of 247 implants inserted and followed between 1 and 11 years, with a median follow-up time of 5 years. The patients were in need of fixed prosthetic implant-supported rehabilitations in the posterior region of the jaw, presenting a reduced interradicular bone or a thin alveolar crest. The implant survival estimate was computed using the Kaplan–Meier product limit estimator.

Results: The survival rate for narrow diameter implants was 95.1% at 11 years (Kaplan–Meier), with a distribution of 91.4% at 11 years, 95.9% at 10 years, and 95.5% at 9 years for the two-stage, one-stage, and immediate function techniques, respectively. The mean marginal bone resorption recorded at 1, 5, and 10 years were 1.16, 1.53, and 1.74 mm, respectively. Backward conditional logistic regression identified "type of implant" as a strong protective factor against implant failure (MkIII and NobelSpeedy implants compared to the MkII implant; OR = 0.14), and "type of rehabilitation" as a strong risk factor for implant failure (partial rehabilitations compared to single teeth rehabilitations; OR = 4.75).

Conclusions: The results indicate that within the limitations of this study, the use of narrow-diameter implants for the prosthetic rehabilitation of posterior regions of the jaws is viable, with good outcomes in the long-term, irrespective of the surgical technique implemented.

KEY WORDS: Brånemark system, immediate function, narrow-diameter implants, NobelSpeedy, posterior regions

The rehabilitation with oral implants is sustained in the osseointegration concept. This concept is based on the anchorage achieved by endosseous implants to the bone.[1–5]

Narrow-diameter implants are used in specific conditions of rehabilitation such as a reduced interradicular bone, thin alveolar crest, or replacing teeth with a small cervical diameter.[6]

The results from clinical studies on narrow-diameter implants have shown high survival rates irrespective from the surgical approach that was used, ranging between 96 and 98.7% at 5 years using a two-stage surgical approach,[7,8] 96.4% at 1 year using a one-stage surgical approach,[9] and 99.4% using the immediate function approach.[6]

Caution in the use of narrow-diameter implants has been advocated because of the concern regarding the negative impact of loading in these implants, with lower

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stability when compared to regular platform implants,[10] and increased probability of fracture in clinical practice.[11] Moreover, a nonlinear finite element analysis has shown that the neck of the implant represents a potential zone of fracture when subjected to high bending forces,[12] making it mandatory to increase the implant support to improve the biomechanical outcome of the treatment with narrow-diameter implants.[13]

Posterior regions of the jaws with reduced bone quantity and quality make it challenging to rehabilitate without the use of complex reconstruction techniques.[14,15] The use of narrow-diameter implants in delayed loading has shown to be an alternative treatment solution for these conditions.[7,16,17]

The aims of this retrospective clinical study were to: (1) assess the clinical outcome of narrow-diameter implants placed in posterior regions of both jaws; and (2) compare the implant outcome using two-stage, one-stage, and immediate function approaches.

MATERIALS AND METHODS

This study was performed at a private practice (Malo Clinic, Lisbon).

One hundred forty-seven patients were consecutively included in this study (115 males and 32 females), with an age range of 26 to 77 years (mean: 47.5 years). The patients were included provided the need of rehabilitation with narrow platform implants in posterior regions of both jaws. Objectively, in areas that either presented a reduced interradicular bone or a thin alveolar crest (with enough bone volume at the implant site to receive a 3.3 mm implant in diameter), sufficient residual bone volume to receive at least 10 mm implants in length. The patients with the following conditions were excluded from the study: insufficient bone volume to place implants with at least 3.3 mm in diameter and 10 mm in length, need of bone grafting procedure, and immunodeficiency pathology. A total of 247 implants were placed. They were 35 Mk II implants (Brånemark System®, Nobel Biocare, Göteborg, Sweden); 137 Mk III implants (Brånemark System); and 75 NobelSpeedy™ Groovy implants (Nobel Biocare). The first implant was placed in May 1995 and the last in June 2007, and were followed between 1 and 11 years (with a median of 60 months). The implants were all 3.3 mm in diameter and ranged between 10 and 15 mm in length. The implant distribution by the different locations and type of surgical approach is given in Table 1, A and B.

A total of 144 implants were placed in the maxilla and 103 in the mandible. One hundred twenty-seven implants were machined surface, and 120 implants were TiUnite™ surface (Nobel Biocare). Regarding the surgical technique, a total of 35 implants were inserted through the two-stage technique, 146 implants by the one-stage technique, and 66 implants inserted through the immediate function technique.

A total of 229 prostheses were placed, 138 in the maxilla and 91 in the mandible. Of these, 183 were single tooth restorations (110 in the maxilla and 73 in the mandible), 36 short-span (replacing up to four teeth) fixed partial dentures (23 in the maxilla and 13 in the mandible), and 10 complete edentulous rehabilitations (five in the maxilla and five in the mandible). The same team performed both surgery and prosthodontic treatment.

The surgical procedures were performed under local anesthesia with mepivacaine chlorhydrate with epinephrine 1:100,000 (Scandinibsa 2%; Inibsa Laboratory, Barcelona, Spain). All patients were sedated with one diazepam tablet (Valium 10 mg, Roche, Amadora, Portugal) prior to surgery.

Antibiotics (amoxicillin 875 mg plus clavulanic acid 125 mg Labesfal, Campo de Besteiros, Portugal) were given 1 hour prior to surgery and daily for 4 days thereafter (every 8 hours). Corticosteroid medication for control of the inflammatory response (prednisone; Meticorten, 5 mg, Schering-Plough Farma, Lda, Agualva-Cacém, Portugal) was given daily in a regressive mode (15 mg at surgery, 10 mg on the first 2 days postoperatively, and 5 mg at days 3 and 4 postoperatively). Anti-inflammatory medication (ibuprofen, 600 mg, Ratiopharm, Lda, Carnaxide, Portugal) was administered at day 5 postoperatively every 12 hours. Analgesics (Clonix 300 mg, Janssen-Cilag Farmaceutica, Lda, Barcarena, Portugal) were given on the day of surgery and postoperatively for the first 3 days, as needed.

Teeth or roots were extracted at the time of surgery prior to implant placement. The area was made free from soft tissue remnants and in for tooth extraction sockets, cleaned by curettage, to keep infected tissue to a minimum. After this, the insertion of the implants followed the standard procedures.[2,18] A surgical guide was used for optimal implant positioning when applicable. The drilling sequence was modified to achieve maximal apical anchorage, and countersinking was eliminated to preserve marginal bone. The implant neck was

TABLE 1 Estimated Fractions for Survival Using the Kaplan–Meier Product Limit Estimator for Narrow-Diameter Implants

Time (months)	Status (0 = non-failure; 1 = failure)	Cumulative Proportion Surviving at the Time		*N* of Cumulative Events	*N* of Implants at Risk
		Estimate	SE		
0	0	.	.	0	247
1	1	.	.	1	246
1	1	0.992	0.006	2	245
2	1	.	.	3	243
2	1	0.984	0.008	4	242
3	1	0.980	0.009	5	241
4	1	0.976	0.010	6	240
5	1	.	.	7	239
5	1	0.968	0.011	8	238
7	1	0.963	0.012	9	236
13	1	0.959	0.013	10	231
24	0	.	.	10	169
35	1	0.953	0.014	11	151
48	0	.	.	11	134
60	0	.	.	11	123
65	1	0.945	0.016	12	112
72	0	.	.	12	100
84	0	.	.	12	72
98	0	.	.	12	28
110	0	.	.	12	16
121	0	.	.	12	9
137	0	.	.	12	1
157	0	.	.	12	0

positioned at the coronal marginal crest level, and bicortical anchorage was established whenever possible. The decision between one-stage and immediate function was taken preoperatively, with the implants placed in aesthetic areas and with a minimum insertion torque of 30 Ncm for accepting the implant for immediate function.

The patients rehabilitated through the immediate function technique received an acrylic immediate provisional implant-supported restoration. After 4 to 6 months, the definitive abutments (Nobel Biocare AB) were placed when a change in abutments was indicated, an impression was made, (using silicone [Elite HD+, Zhermack, Rovigo, Italy]), and the patients received their definitive prostheses. In some completely edentulous situations, milled precision titanium prosthodontic frameworks (Procera® Implant Bridge, Nobel Biocare AB) were placed.

After surgery, the patients were enrolled in an implant maintenance program. The patients were placed on a soft food diet for 2 months.

Ten days after surgery, the sutures were removed, and evaluations were performed regarding hygiene and implant stability. The procedure was repeated 2 and 4 months after surgery until a stable situation was secured.

Periapical radiographs (Kodak, Rochester, NY, USA) were made at implant insertion 6 months, 1 year, and each year thereafter. A conventional radiograph holder (Super-bite®, Hawe-Neos, Bioggio, Switzerland) was used, and its position was manually adjusted for an estimated orthognatic position of the film, so that the position of the film was as parallel as possible to the implant. The reference point for the reading was the implant platform, that is, the horizontal interface between the implant and the abutment. Marginal bone remodeling was defined as the difference in marginal bone level

TABLE 2 Information on the Implant Loss

Patient	Gender	Age	Type of Implant	Implant Position	Surgery Staging	Time of Loss in Months	Observations
1	F	47	Mk III 3.3 × 11.5 machined	25	Two-stage	65	
2	F	32	Mk II 3.3 × 15 machined	14	Two-stage	5	
3	F	27	Mk II 3.3 × 10 machined	44	One-stage	2	
4	M	56	Mk II 3.3 × 10 machined	45	One-stage	13	
5	F	45	Mk II 3.3 × 10 machined	34	One-stage	4	Smoker, hepatitis B
6	M	62	Mk II 3.3 × 15 machined	45	One-stage	1	Smoker
7	F	56	Mk II 3.3 × 15 machined	24	Two-stage	7	
8	F	44	NobelSpeedy Groovy 3.3 × 13 oxidized	14	Immediate function	2	
9	F	51	Mk III 3.3 × 11.5 machined	47	One-stage	3	Smoker
10	F	64	Mk III 3.3 × 15 oxidized	24	One-stage	5	
11	F	29	Mk III 3.3 × 15 machined	14	Immediate function	35	Smoker
12	F	39	NobelSpeedy Groovy 3.3 × 10 oxidized	14	Immediate function	1	Hyperthyroidism

relative to the bone level at the time of surgery. The radiographs were grouped as follows: implant placement 1, 5, and 10 years of follow-up.

An implant was classified as a survival according to a criteria adopted by the authors: (1) it fulfilled its purported function as support for reconstruction; (2) it was stable when individually and manually tested; (3) no signs of infection observed; (4) no radiolucent areas around the implants; (5) demonstrated a good esthetic outcome of the rehabilitation; and (6) allowed a construction of the implant-supported fixed prosthesis which provided patient comfort and good hygiene maintenance. The following complication parameters were assessed: (1) mechanical complications (fracture or loosening of mechanical and prosthodontic components); (2) biological complications (peri-implant pathology, soft tissue inflammation, fistula formation, pain); (3) esthetic complications (esthetic complaints of the patient or dentist); and (4) functional complications (phonetic complaints, masticatory complains, comfort complains, or hygienic complains).

Descriptive statistics were used to classify the variables of interest. Survival estimates were computed using the Kaplan–Meier product limit estimation with comparison of survival through complementary statistical tests (Tarone–Ware).

The association between patient age (≤35, >35 years); patient gender (female, male); smoking status (nonsmoker, smoker); implant position (maxilla, mandible); type of implant (Mk II, Mk III, NobelSpeedy); implant length (≤11.5, ≥13 mm); implant surface (machined, TiUnite); staging of surgery (two-stage surgery, one-stage surgery, immediate function); type of rehabilitation (single, partial, complete edentulous); surgeon experience (limited experience, experienced, very experienced); and the outcome variable implant failures was evaluated by backward conditional logistic regression to estimate odds ratios (ORs) and corresponding 95% confidence intervals (CIs). The effect of each factor was assessed in univariate (crude) analysis and after adjusting for the other variables of interest. The level of significance considered was 5%.

RESULTS

A total of 12 implants were lost in 12 patients (one implant per patient) rendering a survival rate of 95.1% at 11 years (Kaplan–Meier) (see Table 1). The mean survival estimate was 149.2 months (95% CI: 144.9–153.5 months [the maximum registered follow-up for an implant was 157 months]). A total of 23 unaccounted implants were registered belonging to the group of dropout patients.

The distribution of the 12 implant losses is illustrated in Table 2.

Regarding the type of implants and respective follow-up, a total of 35 Mk II implants were inserted (23

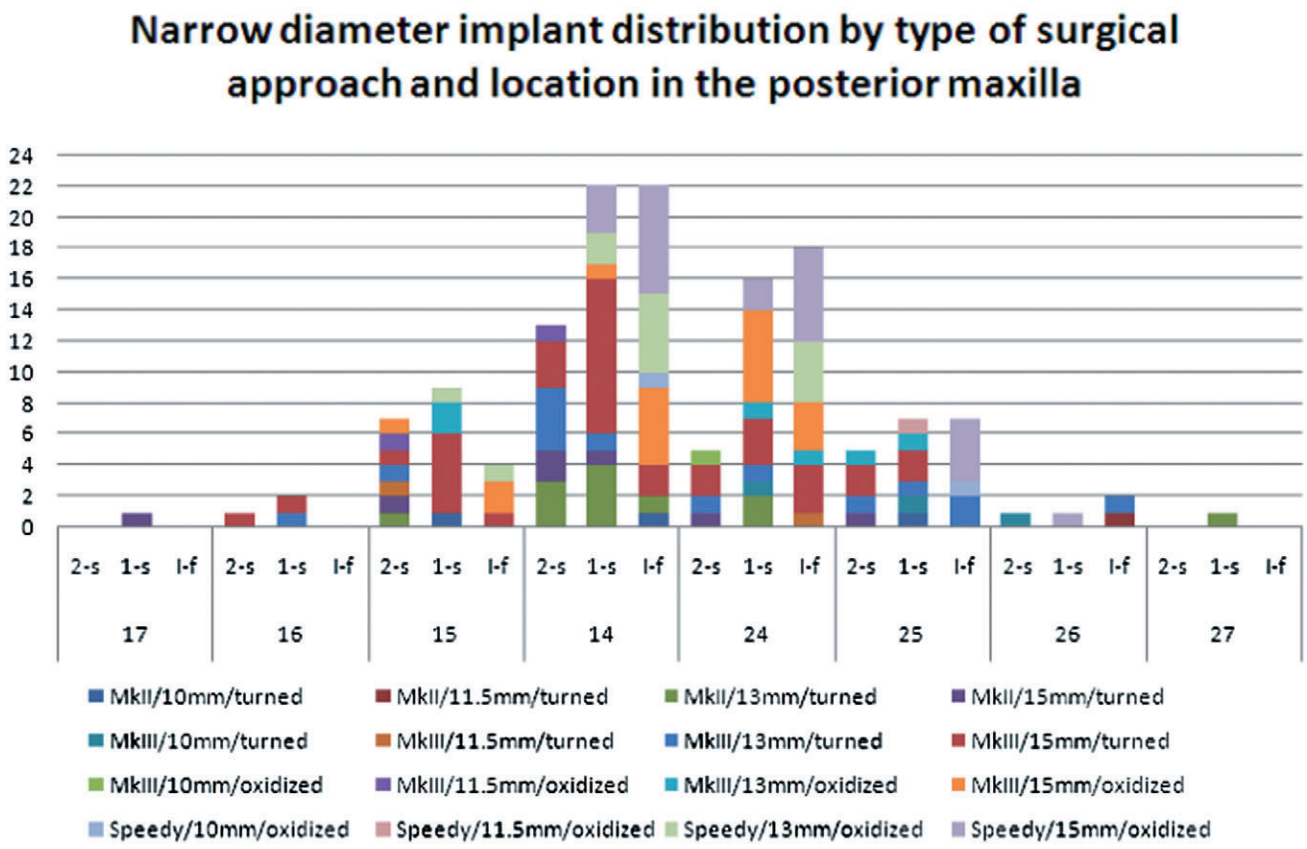

Figure 1 Implant distribution in the maxilla, according to type of implant, location in the maxilla (tooth positions #17 to #27), and type of surgical technique (2-s = two-stage surgical technique; 1-s = one-stage surgical technique; i-f = immediate function technique).

in the maxilla and 12 in the mandible) and followed between 26 and 157 months, 137 Mk III implants were inserted (82 in the maxilla and 55 in the mandible) and were followed between 8 and 128 months, and 75 Nobel-Speedy implants were inserted (39 in the maxilla and 36 in the mandible) and followed between 1 and 34 months (Figures 1 and 2). Taking into consideration the surgical technique, the distribution of survival was: for the two-stage technique, 91.4% at 11 years with a mean survival estimate of 145.6 months (95% CI: 133.1–158.2 months [for a maximum registered implant follow-up of 157 months]); for the one-stage technique, 95.9% at 10 years with a mean survival estimate of 117.2 months (95% CI: 113.4–121 months [for a maximum registered implant follow-up of 122 months]); for the immediate function technique, 95.5% at 9 years with a mean survival estimate of 104.6 months (95% CI: 97.2–112 months [for a maximum registered implant follow-up of 111 months]) (Figure 3).

The differences in survival between the three different surgical techniques were not significant ($p = .760$).

A total of 7, 31, and 100% periapical x-rays were available for reading the bone level. The overall mean (standard deviation) bone resorption was 1.16 (0.8), 1.53 (0.8), and 1.74 (0.9 mm) after the first, fifth, and tenth years of function, respectively. Representative periapical radiographs of implants with 1, 5, and 10 years of follow-up are displayed in Figures 4–6.

Table 3 shows the variables "type of implant" and "type of rehabilitation" that were significantly associated with the outcome variable implant failure. In multivariate analysis, the type of implants Mk III and Nobel-Speedy (OR = 0.14) remained as a protective factor against implant failure when compared with the Mk II implant (indicator variable). The partial rehabilitation (OR = 4.56) remained as a risk factor for implant failure when compared with the single tooth (indicator variable).

DISCUSSION

The 95% survival rate at 11 years for narrow-diameter implants placed in posterior regions is comparable to

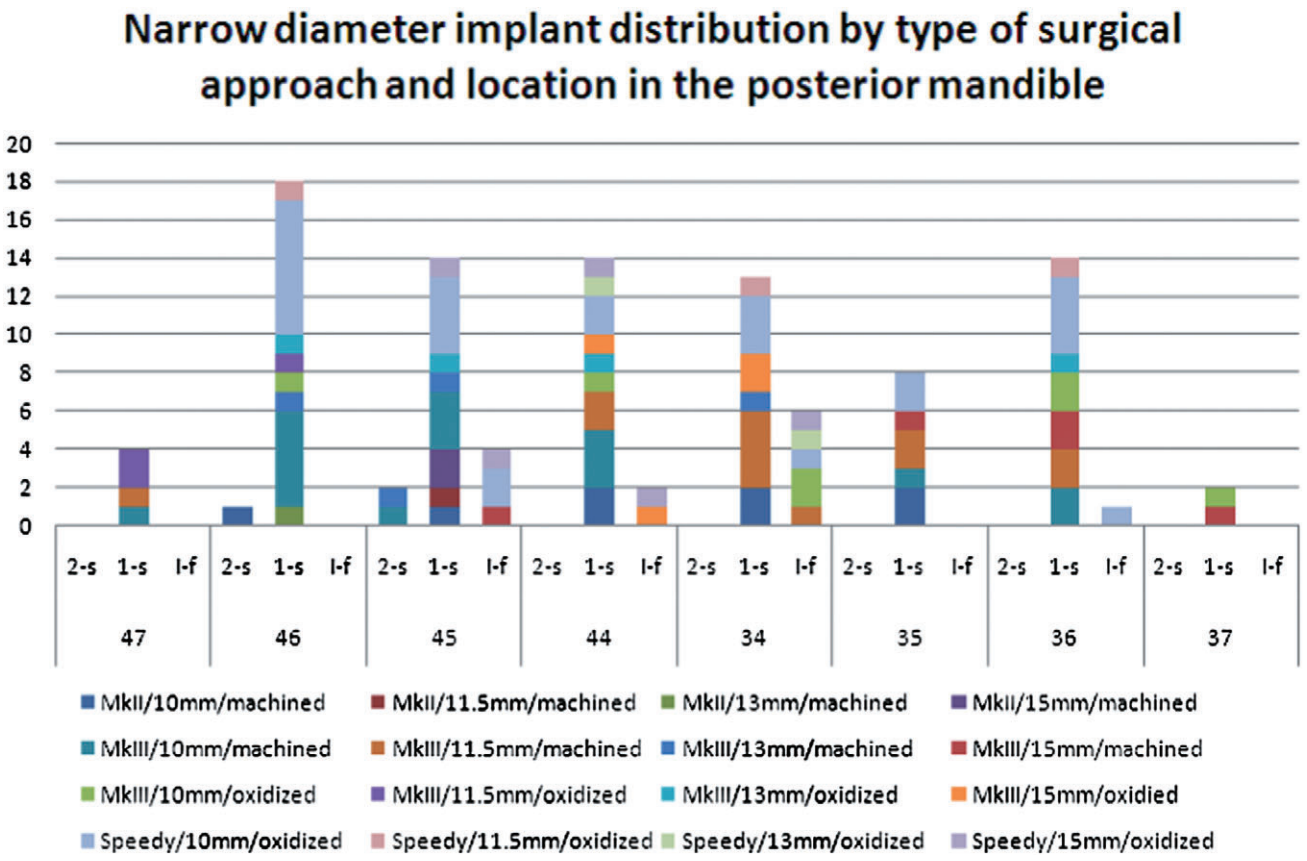

Figure 2 Implant distribution in the mandible, according to type of implant, location in the mandible (tooth positions #37 to #47), and type of surgical technique (2-s = two-stage surgical technique; 1-s = one-stage surgical technique; i-f = immediate function technique).

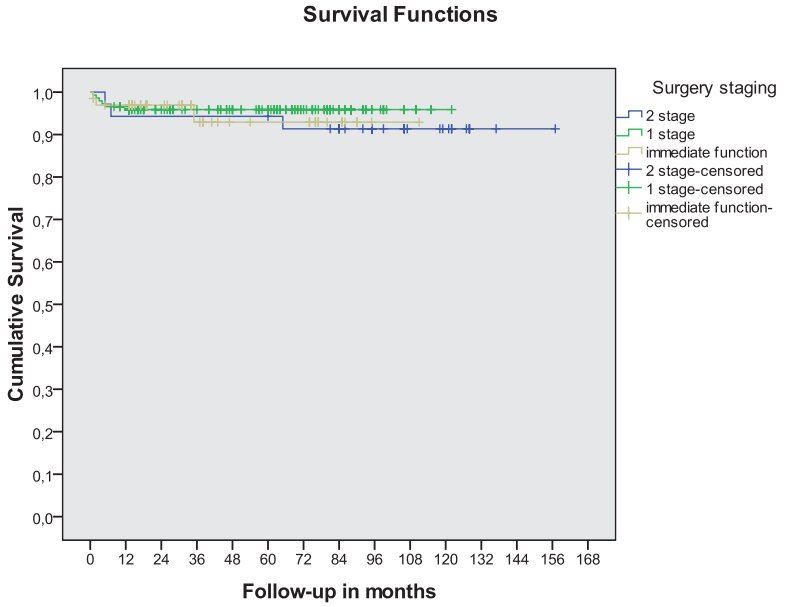

Figure 3 Kaplan–Meier product limit estimation for the survival of narrow-diameter implants according to the surgical technique. X-axis represents the follow-up time in months; Y-axis represents cumulative survival rate. A survival rate above 90% was registered for the implants irrespective of the surgical technique used. Implants inserted through one-stage technique had a higher survival rate, followed by implants inserted through the immediate function and two-stage surgical techniques.

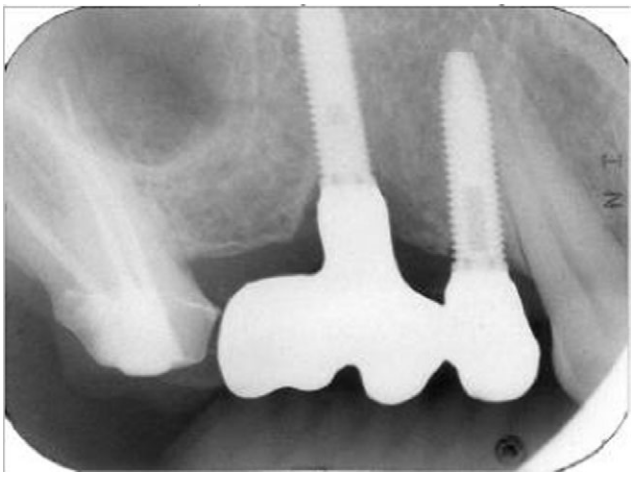

Figure 4 Representative radiograph of narrow-diameter implants (NobelSpeedy Groovy 3.3 × 13 mm) with 1 year of follow-up.

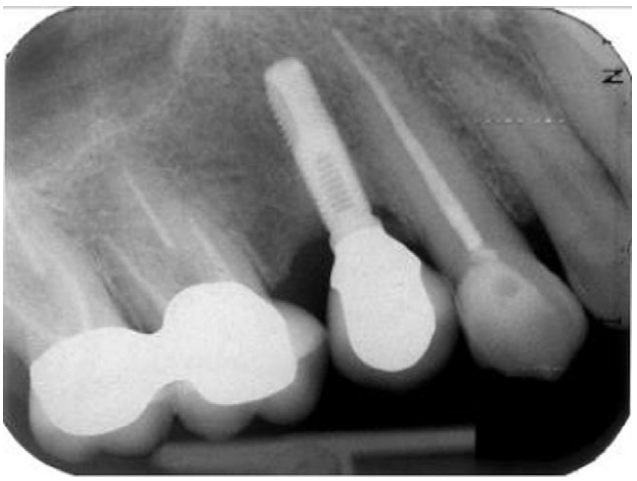

Figure 6 Representative radiograph of a narrow-diameter implant (Mk II 3.3 × 13 mm) with 10 years of follow-up.

results with larger-diameter implants.[19,20] It supports the hypothesis that narrow-diameter implants can be used in prosthetic rehabilitations in the posterior regions of both jaws with a predictable positive outcome.

The surgical technique did not influence the outcome of survival for narrow-diameter implants, with no significant differences between the two-stage technique, the one-stage technique, and the immediate function technique. This result is supported by the literature, where the survival results between two-stage and immediate function techniques are not significantly different,[21,22] provided that the minimum criteria for accepting the implant for immediate function are followed.

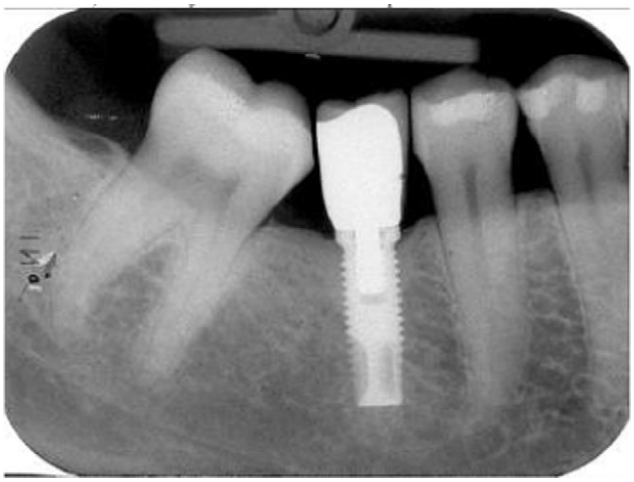

Figure 5 Representative radiograph of a narrow-diameter implant (Mk III 3.3 × 10 mm) with 5 years of follow-up.

The values for marginal bone resorption recorded in this study at 1, 5, and 10 years (not exceeding 0.2 mm/year of bone loss after the first year) are within the accepted standard success criteria for implants.[23] However, the low percentage of available periapical radiographs at 1 year did not allow to compute the success rate according to international standard criteria, and so only the survival estimates were computed.

Regarding the implant failures, the majority occurred in the first 6 months of function, following the pattern for Brånemark system implants,[24] with no significant differences in the location of the failures (maxilla or mandible). The variables associated with the outcome of implant failure in the regression analysis were "type of implant" and "type of rehabilitation." The results recorded for the type of implant variable revealed a strong protective effect for the Mk III and NobelSpeedy implants when compared with the Mk II implant. This protective effect observed in this study is maybe related to a more primary anchorage capacity of these implants compared to the Mk II implant, with increased advantages of its use for rehabilitating areas with less dense bone.[18,25,26]

Regarding the variable type of rehabilitation, the partial rehabilitations were identified as a strong risk factor for implant failure when compared with single teeth and complete edentulous rehabilitations. This result follows a similar pattern reported before, with single teeth implant-supported rehabilitations performing better in the long-term follow-up when compared to partial implant-supported rehabilitations.[27] Empirically, this result may be explained by the biomechanical effect:

TABLE 3 Odds Ratio (OR) with 95% Confidence Intervals (CIs) for Patient Age, Patient Gender, Smoking Status, Type of Rehabilitation, Surgery Staging, Type of Implant, Implant Surface, Implant Length, and Surgeon Experience Related to the Outcome Variable Implant Failure

Factor	OR	95% CI	OR*	95% CI
Type of rehabilitation				
Single teeth	1.0			
Partial bridge	4.56	1.32–15.78	4.75	1.29–17.53
Total bridge				
Surgeon experience				
Limited experienced	1.0			
Experienced	1.55	0.18–13.49		
Very experienced	0.25	0.02–2.59		
Type of implant				
Mk II	1.0			
Mk III	0.15	0.04–0.55	0.14	0.03–0.54
NobelSpeedy	0.13	0.03–0.69	0.14	0.03–0.75

*OR from backward conditional logistic regression analysis with patient age, patient gender, smoking status, type of rehabilitation, surgery staging, type of implant, implant surface, implant length, and surgeon experience as explanatory variables. The univariate and analysis disclosed significant differences for type of rehabilitation, surgeon experience, and type of implant. Type of rehabilitation and type of implant remained significant after adjusting for the other variables of interest.

adjacent teeth can have a protective effect on a single teeth implant, fact that does not occur in partial rehabilitations. The fact that no difference was found for the complete edentulous rehabilitations can, maybe, be explained by the load distribution (load distributed for all the implants reducing the load on posterior implants), while in partial rehabilitations the effect does not occur with such efficacy (only two implants in the posterior region supporting the load), adding to the known increase of stress and strain magnitudes around supporting implants when using narrow-diameter implants.[13] This study did not answer these questions and so they remain open to future research. The limitations of this study are the retrospective design of the study and only one clinic involved. Another limitation lies on the number of unaccounted implants belonging to the groups of dropout patients ($n = 23$), which could affect the failure rate as these patients could be expected to have more than double the failure rate compared to the patients complying with the follow-up in the study. Clinical trials with long-term follow-up should be performed to investigate the long-term outcome of using narrow-diameter implants when compared to regular platform implants in fixed prosthetic rehabilitations.

CONCLUSION

Within the limitations of this study, the use of narrow-diameter implants for the prosthetic rehabilitation of posterior regions of the jaws seems viable, with good outcomes in the long-term follow-up, irrespective of the surgical technique implemented (two-stage, one-stage, or immediate function). When rehabilitating the posterior regions of the jaws with narrow-diameter implants, the use of more recent implants seemed to favor a protective effect against implant loss, whereas the type of rehabilitation to be performed, namely partial rehabilitations, yielded a risk factor for implant failure in this study, when compared with the single tooth and complete edentulous rehabilitations.

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