Treatment Outcomes of Patients With Implant-Supported Fixed Partial Prostheses

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Implant and prosthesis success for 77 partially edentulous patients, provided with 97 fixed prostheses, supported by 230 Brånemark implants, in place for up to 12 years (mean 5.41 years), were documented in this study. Implant losses per location mirrored their placement, with no difference between zones I and II or between the maxilla and mandible. The implant success rate was 94%, and continuous prosthesis stability was 97%. These results indicate that the Brånemark implant-supported fixed partial prosthesis is a highly efficacious treatment. (INT J ORAL MAXILLOFAC IMPLANTS 1998;13:204–211)

Key words: Brånemark implants, osseointegration, partial edentulism, success/failure

The use of osseointegrated implants to support prostheses in partially edentulous patients is a relatively new treatment modality based on documented long-term success in restoring completely edentulous jaws.[1] However, partial edentulism (Figs 1a and 1b) is quite different from complete edentulism (Figs 2a and 2b), since the presence of teeth may complicate the oral environment in which the implant prosthesis must function. Occlusal forces, tooth wear, abrasion resistance, differences in resiliency between teeth and implants, and microbiologic flora differ between partially and completely edentulous patients. Furthermore, the presence of adjacent teeth can help preserve the edentulous ridge width and height, which has a major determining factor in the placement of the implants and esthetics of the prosthesis.[2] Load distribution on the implants is altered as well, especially in the horizontal plane, because of the lack of cross-arch stabilization in partially edentulous patients. Theoretically, remote loading of fixed partial prostheses also produces higher bending moments on the supporting implants,[3] with a consequent increase in the implant-bone interfacial stress concentration. The process of osseointegration and the resulting long-term treatment outcome may therefore be adversely affected.

In spite of these reservations, clinical researchers have documented successful implant-supported fixed partial prostheses over the short-to-medium term in both anterior and posterior jaw locations.[4,5] A high rate of implant and prosthesis success over a 3-year period has also been documented in the posterior partially edentulous mandible using completely implant-supported prostheses and combined implant- and tooth-supported prostheses.[6] The objective of this paper was to document the treatment of partially edentulous patients with implant-supported fixed prostheses at a multidisciplinary implant prosthodontic clinic.

Materials and Methods

The initial 88 patients of the Implant Prosthodontic Unit (Faculty of Dentistry, University of Toronto, Toronto, Canada) treated with implant-supported fixed partial prostheses were documented in this study. All patients were assessed clinically by a prosthodontist and an implant surgeon (oral surgeon

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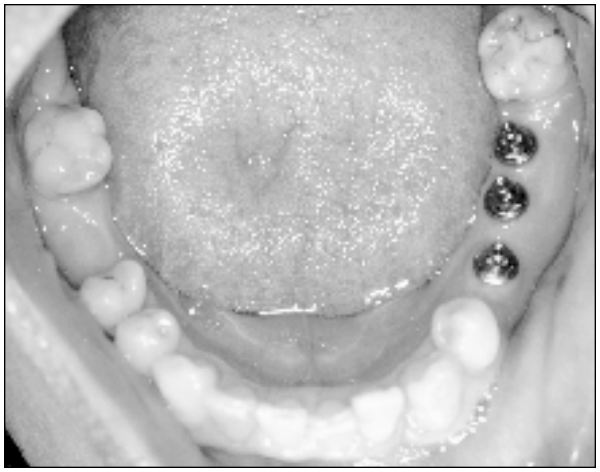
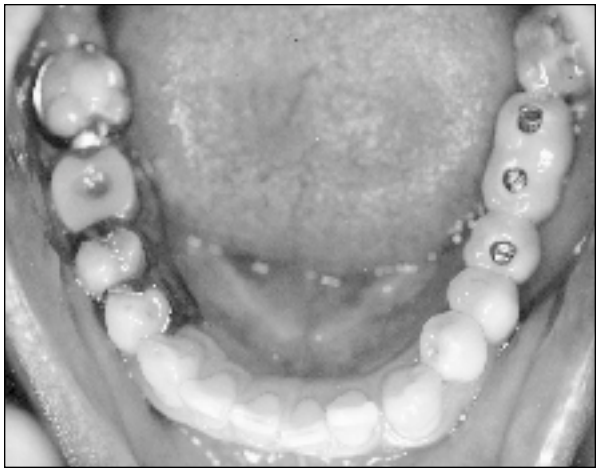
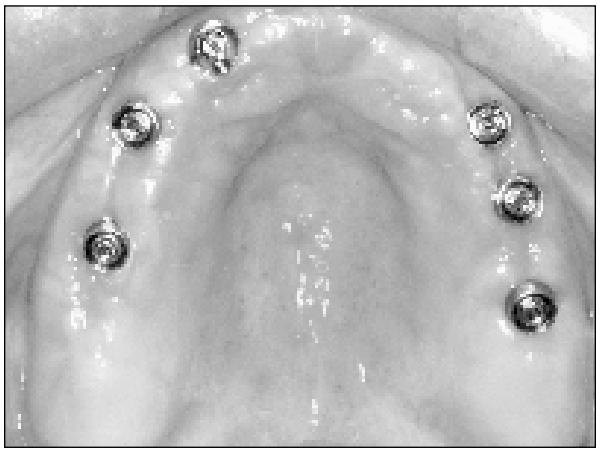
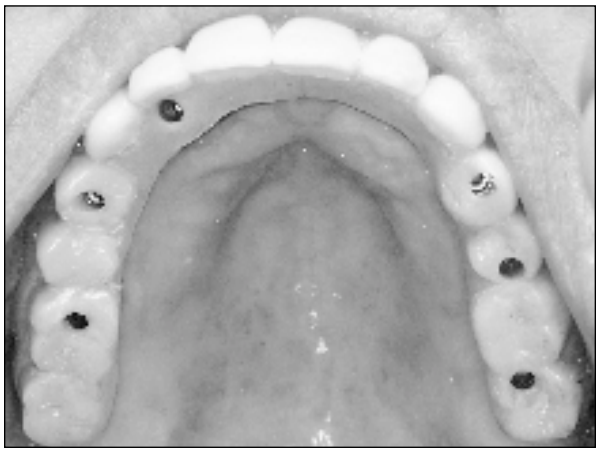




Figs 1a and 1b Three Estheticone abutments were used to support a fixed partial prosthesis.





Figs 2a and 2b Five standard abutments and one angulated abutment were used to support a fixed complete arch prosthesis.

or periodontist) who selected patients to be treated based on the following criteria:

Inclusion criteria
- Missing teeth (more than one tooth per edentulous space but less than all the teeth per arch)
- Adjacent teeth structurally sound and esthetically acceptable to the patient (natural and/or restored)
- Restored adjacent teeth preclude placement of a fixed partial prosthesis
- Patient and/or clinician's preference to avoid involving adjacent teeth in a fixed partial prosthesis
- Maladaptive experience or refusal to wear a removable partial prosthesis
- Adequate or modifiable bone dimensions for Brånemark implant placement
- Absence of vital anatomic structures in close proximity to the proposed implant sites
- Adequate interarch space for implant surgical instrumentation
- Adequate interarch space for abutments, prosthetic components, and prosthesis
- Adequate control of occlusal load distribution to implants and teeth
- Ability to provide written consent to treatment

Exclusion criteria
- Inability to undergo a minor oral surgical procedure
- History of substance abuse
- Psychoses
- Unrealistic patient expectations of the treatment with respect to esthetics, comfort, and function

Table 1 Implant Distribution by Jaw and by Zone*

	Zone I	Zone II	Total
Maxilla	70 (30%)	31 (13%)	101 (44%)
Mandible	49 (21%)	80 (36%)	129 (56%)
Total	119 (52%)	111 (48%)	230

*The premolars in both arches serve as the division between the anterior (zone I) and the posterior (zone II) areas.

Table 2 Implant Distribution by Length

Length (mm)	No. (%)
7	12 (5%)
8.5	1 (0.004%)
10	93 (40%)
13	58 (26%)
15	53 (23%)
18	12 (5%)
20	1 (0.004%)
Total	230

- Insufficient bone quality or compromised health of the edentulous site
- Insufficient bone dimensions for Brånemark implant placement
- Incomplete facial growth and eruption of adjacent teeth
- Inability to provide written consent to treatment

Patients were seeking treatment to restore 97 edentulous spans created by tooth loss resulting from caries, periodontitis, endodontic complications, trauma, and/or congenital deficiency. Fifty-four edentulous areas were restored with removable partial prostheses, one with a failing provisional fixed partial prosthesis (abutment teeth were planned for extraction); 35 were without any prostheses; and 7 were undocumented. During the initial examination, the majority of patients described their chief complaint as a difficulty in wearing or an unwillingness to wear removable prostheses.

Eleven (12.5%) patients with 13 edentulous areas scheduled for treatment with fixed partial prostheses supported by implants did not receive the proposed treatment. At the time of this chart review, three patients had not yet completed treatment, one patient's implants were being used for orthodontic tooth movement, and two patients received no further treatment following loss of implants prior to stage-two surgery. The remaining patients received implant-supported partial overdentures (five) and fixed partial prostheses supported by single implants (three). Changes to the proposed treatment for these patients were mainly the result of implant loss; the majority of losses occurred between stage-one and stage-two surgeries (five), with the remaining (two) occurring prior to final implant prosthesis placement. Eight patients were restored using implant-supported prostheses, one was awaiting treatment, and two decided not to pursue any further treatment after stage-two surgery.

The remaining 77 patients—47 females and 30 males with a mean age of 45.14 years (range 15 to 72 years)—received implant-supported fixed partial prostheses. Sixty percent of the study population was made up of females with a mean age of 43.02 years. Nearly one fourth of the patients were under 40 years of age, and 10% were over 59 years.

The patients underwent two-stage implant surgery according to accepted dental implant techniques.[7] The edentulous ridges that were to receive the implants, as well as the adjacent structures, were evaluated using an appropriately prescribed combination of periapical, occlusal, panoramic, and tomographic radiographs. A total of 230 Brånemark implants (Nobel Biocare AB, Gothenburg, Sweden) were initially placed by six surgeons over an 11-year period between 1983 and 1994. Treatment details and complications were documented chronologically in the patients' charts.

The distribution, numbers, and dimensions of implants placed were a function of the length of the edentulous span, the dimensions of the proposed host bone, and the proximity of adjacent anatomic structures at each surgical site. The premolars in both arches represented the division between the anterior (zone I) and posterior (zone II) areas. In general, zone I of the maxilla and mandible are reported as more favorable for osseointegration than zone II, with the anterior mandible being the preferred site with respect to bone quality and quantity.[7] The mandibular posterior region received the most implants followed by the maxillary anterior, the mandibular anterior, and lastly, the maxillary posterior region (Table 1).

The dimensions of each of the implants were documented. All but one implant (4.0 mm diameter, 10 mm length at the maxillary left second premolar) were a standard 3.75 mm diameter. Fourteen of the implants were self-tapping, and the remainder were of the standard variety. The self-tapping and 4.0-mm-diameter implants are intended for use in low-density bone. These implants increase the surface area in contact with bone, which improves the possibility of achieving the necessary initial stability of the implant in the bone compared to standard implants. The majority of implants were 10 mm in length, followed by 13 mm and 15 mm (Table 2).

The average length of time between stage-one and stage-two surgeries was 6.88 months (SD 3.48

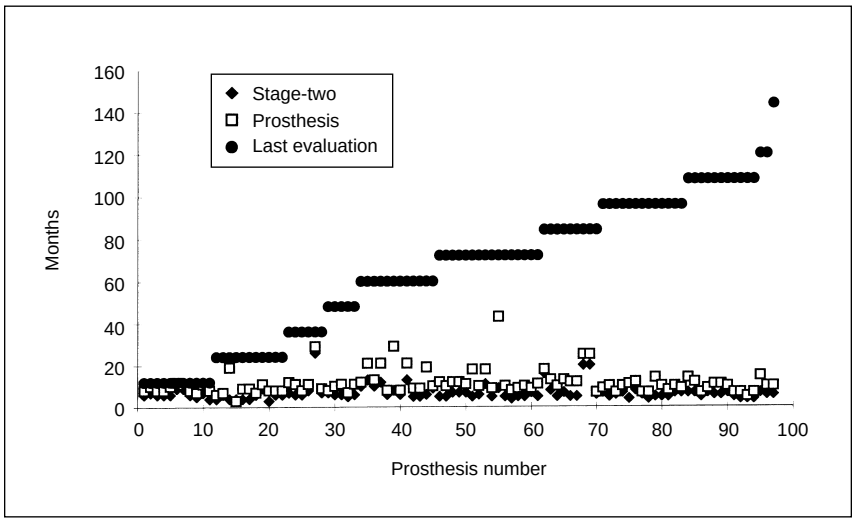


Fig 3 Follow-up of 97 fixed partial prostheses supported by implants.

months), with a range of 3 to 26 months. The recommended 3 months in the mandible and 6 months in the maxilla for osseointegration was exceeded in most patients. Only two patients had delayed second-stage surgeries related to loss of implants and replacement. Forty-nine patients wore removable prostheses between stage one and stage two, 40 patients went without a prosthesis, and 8 were undocumented.

Between 2 and 4 weeks were allowed for healing after stage-two surgery, prior to final abutment selection and commencement of prosthetic treatment. Two hundred twenty-eight abutments were placed involving three types and various lengths. Standard abutments were generally selected, but Estheticone and Angulated abutments of varying sizes (Nobel Biocare) were also used, depending on mucosal depth, angulation of the implant to the occlusal plane, interocclusal distance, and esthetics.

The prostheses were fabricated either by staff (n = 39) or by supervised residents (n = 58). The average time between stage-two surgery and placement of the final prosthesis was 4.61 months (SD 4.31 months), with a range of 1 to 34 months (Fig 3). Oral and prosthetic hygiene instruction and samples of recommended oral hygiene aids (specific toothbrushes, dental floss, and so forth) were provided upon placement of each prosthesis.

All prostheses were fabricated to be easily removable at recall appointments by using gold screw retention rather than cementation. The Brånemark implant system initially had a tapered slot screw, which was replaced with a flat head in the 1980s because of a concern about fractured screw heads. In addition, a hexagonal-patterned head gold screw that can be carried by a corresponding driver was introduced to make maxillary placement easier. Forty-seven of the prostheses were retained by the now obsolete tapered-head screws, 45 by the flat-head screws, and 5 were undocumented.

All 97 implant-supported fixed partial dentures were fabricated on metal alloy frameworks; 82 were covered by veneers of acrylic resin or composite and 15 by dental porcelain. The number of implants supporting each prosthesis was determined by the length of the edentulous span. The mean number of implants per prosthesis was 2.37 (SD 0.66, range 2 to 6), which corresponds to a mean pontic-to-implant ratio for all prostheses of 1.46.

Patients were recalled 1 week, 6 months, and 12 months after placement of the prostheses, and yearly thereafter. The condition of the prosthesis and gold retaining screws, implant abutments and abutment screws, and implant mobility, and of adjacent mucosa were all evaluated at each recall appointment. Patient symptoms were also recorded and used, along with the clinical and radiographic signs, to diagnose problems. Additional treatment was then provided as needed. The success criteria proposed by Smith and Zarb[8] for evaluation of osseointegrated dental implants were used to evaluate individual implants at each recall appointment.

The fixed partial prostheses supported by implants were placed over an 11-year period between 1983 and 1994. The number of years between stage-one surgery and the most recent recall appointment was defined as the follow-up period for the treatment. Ninety-seven prostheses were followed over a period of 1 to 12 years, with a mean follow-up per prosthesis of 5.41 years (SD 2.75 years) (Fig 3).

Results

No immediate stage-one surgical complications were noted; however, 15 patients experienced complications between stage-one and stage-two surgeries. These included 11 implant dehiscences, 1 persistent mucosal inflammation, 1 temporary altered nerve sensation of the lower lip, and 2 implant losses. After healing abutment connection and prior to prosthesis placement, 8 edentulous sites had complications (3 loose healing abutments; 4 sites had signs and symptoms of inflammation; and 1 implant was surgically covered by mucosa to alleviate an altered nerve sensation), 81 were complication-free, and 8 were undocumented. Following prosthesis placement, 13 prostheses had at least one soft tissue complication documented in the patient's history. Five separate infections were associated with mucosal tissue surrounding the abutments of 4 prostheses. Fifteen documented occurrences of inflammation of mucosal tissue adjacent to abutments were noted for 9 prostheses. Inflammation was associated with the presence of plaque and/or food debris in all instances, and was remedied by additional oral hygiene instruction by the clinician and performance by the patients. One patient experienced myofascial pain, without implant or prosthesis complications, which subsided after several weeks with counseling.

Nine prostheses had abutment screw complications: 10 fractured abutment screws in four prostheses and 10 loose screws in seven prostheses. Removal of the remaining portion of the abutment screw and replacement was achieved in all but one patient (this implant was covered surgically by mucosa). Abutment screw complications occurred in almost equal numbers of prostheses located in the maxilla and mandible, and those bounded by teeth and without teeth distally.

Fifteen of the 97 prostheses experienced gold screw complications; the majority of these prostheses were located in the mandibular posterior region. Nineteen separate occurrences of loose gold screws were associated with 13 prostheses. Two tapered screws fractured in 2 prostheses and were removed and replaced by flat-head screws. In 6 patients, loose abutment screws occurred concurrently with loose gold screws. Twenty-eight percent of prostheses supported by two implants had gold screw complications, compared to 10% for those prostheses supported by more than two implants.

Twenty-five prostheses had prosthetic complications: 23 had fractured acrylic resin that did not involve fracture of the metal framework, and 2 prostheses were remade because of poor fit of the gold cylinders to the abutments, which went undetected until after the prostheses were placed. Both of these patients experienced gold screw loosening, one had an abutment screw loosen, and both lost implants after the prostheses were placed. One patient had an additional implant placed and a second fixed partial prosthesis fabricated. The second patient fractured an abutment screw, which was irretrievable; the implant was surgically covered by mucosa, and the remaining implant served as an overdenture abutment for a removable partial prosthesis.

Twenty-one prostheses were replaced in 16 patients: 11 were replaced once, and 5 were replaced twice. Six of the replacements were a result of implant failure, including the two nonpassive prostheses mentioned in the preceding paragraph. The remaining prostheses, along with their standard abutments, were replaced at the clinician's discretion to take advantage of improved esthetics using the newer Estheticone and Procera abutment systems (Nobel Biocare). Two fixed prostheses were replaced by removable prostheses because of implant failure.

A total of 230 implants were initially placed to support 97 fixed partial prostheses. Fourteen implants were lost, 11 additional implants were placed in seven patients, 3 were converted to "sleepers," and 3 were used to support removable partial prostheses. At stage-two surgery, it was determined that two implants were unusable because of the proximity of adjacent teeth and adjacent implants, and therefore were left as "sleepers." The third implant was converted to a "sleeper" after prosthesis placement because of an irretrievable abutment screw fracture. At the most recent follow-up appointment, 97 fixed partial implant prostheses were supported by 221 implants.

Fourteen implants were lost in 12 patients over the 12 years of follow-up. Six implants in 5 patients were lost between stage-one and stage-two surgeries, 1 implant was lost between stage-two surgery and prosthesis placement, and seven were lost after prosthesis placement. Of the patients who lost implants, 7 were male and 5 were female, and their average age was 48.75 years (SD 13.48 years). Implants were lost equally in zones I and II, and two more were lost in the mandible than in the maxilla (Table 3).

All of the lost implants were of the standard variety (width 3.75 mm), but of varying lengths (Table 4). The majority had been placed in bone quality/quantity "3b," followed by "3c," and "2b."[9] Nine patients lost only one implant, two experienced multiple losses, and one lost three implants in two edentulous areas. Ten of the 14 (71%) implants lost were in patients who wore removable partial prostheses between stage-one and stage-two surgeries.

There was no difference between each surgeon's loss percentages and their placement percentages. Nine of the lost implants were placed to restore distal

Table 3 Implant Losses by Location Compared to Placement

	Zone I	Zone II	Total
Maxilla			
Lost	4 (29%)	2 (14%)	6 (43%)
Placed	70 (30%)	31 (13%)	
Mandible			
Lost	3 (21%)	5 (36%)	8 (57%)
Placed	49 (21%)	80 (36%)	
Total lost	7 (50%)	7 (50%)	14

Table 4 Success and Failure of Various Lengths of Implants

Length (mm)	Success	Failure	Total
7	9 (75%)	3 (25%)	12
8.5	1 (100%)	0 (0%)	1
10	86 (92%)	7 (8%)	93
13	55 (95%)	3 (5%)	58
15	52 (98%)	1 (2%)	53
18	12 (100%)	0 (0%)	12
20	1 (100%)	0 (0%)	1
Total	216 (94%)	14 (6%)	230

extension edentulous areas, while five were to be bounded by teeth. Two of the implants lost after prosthesis placement involved restorations supported by 3 implants, and 4 implants involved restorations supported by 2 implants.

Discussion

Several clinical researchers have previously reported treatment outcomes for implant-supported fixed partial prostheses over the short-to-medium term.[4,5,10–12] These studies involved a limited number of patients followed over relatively short periods of time, which suggested the need for further research on clinical outcome for this form of treatment. This study sought to address these problems by assessing the treatment outcomes for 230 Brånemark implants supporting 97 prostheses in 77 patients for up to 12 years.

The average number of implants used to support the final prostheses was 2.37 for 3.46 pontics; this translates into a pontic-to-implant ratio of 1.46, or approximately 3:2. The number of implants needed to support fixed partial prostheses of varying lengths is unknown at this time, but it is generally believed that greater numbers and longer lengths of implants are preferable to fewer and shorter.

The incidence of soft tissue complications was rare; no complications were noted at the time of stage-one surgery, while 15% of the prostheses were associated with complications between stage-one and stage-two surgeries, 8% after stage-two surgery, and 13% were associated with soft tissue complications after the prostheses were placed.

The low overall abutment screw complication rate of 7% was equally distributed throughout the mouth. Abutment screw complications appeared to be clustered within a limited number of prostheses; 8 of the 10 abutment screw fractures occurred in two prostheses. Interestingly, both prostheses involved multiple complications of abutment loosening and fracture. Of the nine prostheses with abutment screw complications, only two implants were lost. Only two of the documented cases of abutment screw complications were associated with a soft tissue complication; one of these patients eventually lost an implant.

Fifteen percent of the prostheses experienced gold screw complications; 19 were loosened and 2 were fractured. Multiple loosening of gold screws occurred in three patients, which accounted for 53% of the documented gold screw loosenings. Increased probability of gold screw loosening in fixed partial compared to complete prostheses has been reported.[13] This may be the result of unfavorable distribution of forces placed on fewer implants in a relatively straight line in the partially edentulous situation, compared to more implants placed on a curve in the completely edentulous situation.[14] The majority of gold screw complications occurred in the posterior region. The increased forces encountered in the posterior region of the mouth may have resulted in increased gold screw fracture, as reported in the studies of Lundgren et al.[15,16] A higher percentage of gold screw fractures and loosenings has been noted with fixed partial prostheses supported by less than three implants,[13] and this was confirmed by the present study.

Twenty-three prosthetic complications similar to those reported by Jemt et al[13] were noted during the follow-up period. The majority were acrylic resin fractures, with the others involving poor fit of the prosthesis gold cylinders to the abutments. Since fit of components should have been assessed prior to prosthesis placement, these were classified as clinical errors.

Six (43%) of the 14 implants that were lost occurred between stage-one and stage-two surgeries, 1 (7%) was lost between stage-two surgery and the prosthesis placement, and 7 (50%) were lost upon completion of the prosthetic treatment. Five of the 7 implant losses after prosthesis placement occurred

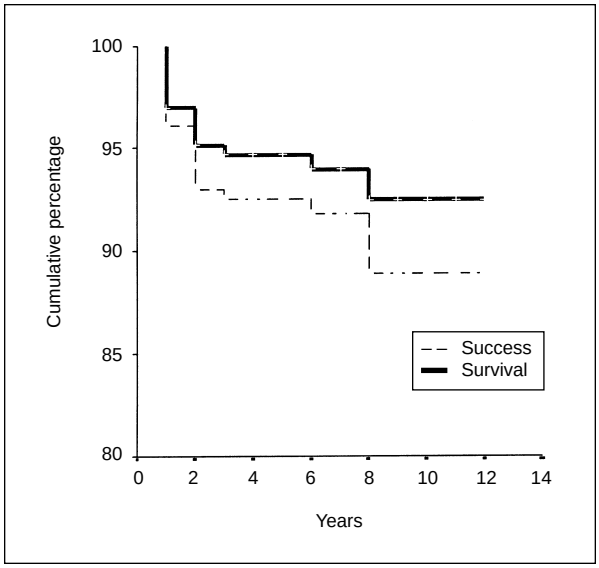


Fig 4 Cumulative survival and success for 230 implants using Kaplan-Meier curves.

within 1 year, one at 3 years, and one after 6 years. The near equal numbers of early and late losses is an unexpected result, since other implant studies for partially edentulous patients have documented greater numbers of early losses over late losses.[10,11,17,18]

It is difficult to draw any firm conclusions from such a small number of implant losses. Seven male (9%) and five female patients (6%) experienced implant losses. An increased rate of failure was also seen in males (13%) compared to females (7%) in the multicenter study of van Steenberghe et al.[10] The mean age of patients with implant losses (48.75 years, SD 13.48 years) was slightly higher than the mean for all patients (45.14 years, SD 13.36 years).

Implant loss seemed unrelated to bone quality and quantity readings and implant location. Jaffin and Berman[19] found that 35% of implants placed in type IV bone failed, compared to 3% of those placed in types I, II, and III bone. The multicenter studies published by van Steenberghe et al[10] and Higuchi et al[20] both found a correlation between implant loss and decreasing bone quality, but not bone quantity, for partially edentulous patients.

The percentage of implant losses per location mirrored the percentage of implants placed. The increased failure rate of implants supporting fixed partial prostheses placed in the maxilla compared to the mandible[18,21] was not seen in this study. Implant losses were not associated with any one surgeon.

The higher failure rate documented for shorter implants (25% failure of the 7-mm implants placed) compared to longer ones may be related to compromised placement in restricted anatomic sites. Alternately, the effect of the same amount of bone loss on a short and long implant may result in dramatic differences in their survival rates. Multiple studies have found that shorter implants have a greater chance of loss compared to their longer counterparts.[10,12,20,22]

It is interesting to note that 64% of the implants that failed were found in prostheses restoring distal extension edentulous areas. Using an in vitro model, Patterson et al[14] found a positive association between distal cantilever length and bending forces measured on implants and their components supporting fixed partial prostheses. They further postulated that the increased bending forces in these prostheses could result in implant failure. In the two patients in whom the final prostheses were replaced because of poor component fit, implants were lost.

Implant success rates of 94% were calculated for both the maxilla and the mandible over the 1- to 12-year follow-up period. This is comparable to the implant success rates reported by Lekholm et al[18] of 92% and 94%, respectively, for maxilla and mandible, 92.5% for the mandible and 94.8% for the maxilla by Higuchi et al,[20] and 93.9% overall by Gunne et al.[23] However, the present success rate is lower than that achieved in other 5-year follow-up studies: 97.2% reported by Jemt and Lekholm[17] and 96% by Naert et al.[11] The suggested criteria by Albrektsson and Zarb[24] for evaluation of implant systems specified more stringent success rates for zone I (90% at 5 years) than for zone II (85% at 5 years) based on increased success seen in multiple studies for implants placed in the anterior region of the jaw. In this study, the implant success rate (94%) was the same for zones I and II. The surgical placement of implants and fabrication of the fixed partial prostheses under the supervision of experienced clinicians may have resulted in the high success rate for this treatment overall. A Kaplan-Meier life table analysis showed a 92.5% cumulative survival rate, with a mean survival time of 11.34 years (Fig 4). If implants no longer in function are considered failures, then the cumulative success rate drops to 88.9%, with a mean of 11.06 years (Fig 4). Kaplan-Meier life table analyses are difficult to interpret with variable follow-up periods and the lack of independence between implants supporting single prostheses and within the same subjects. At the last recall appointment, seven implants in three patients were no longer supporting fixed partial prostheses. This translates into a continuous prosthetic stability of 97%, which is superior to the 92 to 94% at 5 years reported by Lekholm et al,[18] but is consistent with other studies reported in the literature.[11,17]

Conclusion

The use of Brånemark implants to support fixed partial prostheses appears to be a highly successful treatment alternative for restoration of the partially edentulous patient. Satisfactory treatment outcomes are possible for a broad range of patients using various implant, abutment, and prosthetic components, as was documented in this 1- to 12-year follow-up study.

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