Long-Term Treatment Outcomes in Edentulous Patients with Implant-Fixed Prostheses: The Toronto Study

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Purpose: The aim of this prospective study was to report long-term treatment outcomes (prosthetic and implant related) of edentulous patients treated with implant-supported fixed prostheses who participated in the first clinical implant study in North America. ***Materials and Methods:*** Forty-five patients were treated with Brånemark implants supporting a total of 47 fixed prostheses (42 mandibular and 5 maxillary) between 1979 and 1984. All patients were recalled regularly for comprehensive prospective clinical and radiographic assessments. ***Results:*** Thirty-one patients (33 prostheses) attended a final recall visit in 2002; 71% of patients had been followed for 20 years (range 18 to 23 years), with overall prosthetic plan and implant outcome success rates of 84% and 87%, respectively. Mean marginal bone loss around the implants after the first year of loading was small (0.05 mm/year), with high individual variations. Poor oral hygiene, smoking history, and implant position appeared to be predictors of marginal bone loss. Prosthetic maintenance was ongoing and included fractured components and replacement of prostheses; the longevity of a fixed prosthesis for this group of patients was 8.39 ± 5.30 years. ***Conclusion:*** This study confirmed the overall long-term treatment outcome success of patients treated with fixed prostheses supported by Brånemark implants. Successful osseointegration with a small mean bone loss was maintained as study patients aged, although prosthetic maintenance was required. The latter consideration should be discussed with all patients seeking such treatment. *Int J Prosthodont 2004;17:417–424.*

Osseointegration has successfully addressed the inherent shortcomings of the complete denture service. The resultant predictable retention and stability of implant-supported complete-arch prostheses eclipsed previous traditional attempts at improving the prosthetic experience of maladaptive patients via technical innovations and preprosthetic surgery.[1,2] Brånemark et al's first publication[3] has now been endorsed by numerous international studies,[4–14] and the present study was first presented in 1990[15–17] and subsequently updated.[18,19]

Most treatment outcome reports on this topic have been implant-system specific and largely restricted to implant survival data. Their occasional inclusion of details on marginal bone height levels as a surrogate for long-term prognosis of osseointegration has been an infrequent reminder of the larger context in which clinically relevant implant treatment outcomes should be examined. Most of the published long-term studies support the notion that osseointegration is best achieved and maintained with Brånemark implants (Nobel Biocare), given the reported long-term stable marginal bone level measurements.[4,14,20,21]

While implant-related outcomes per se are obviously important, other essential determinants, such as prosthetic maintenance and longevity requirements, as well

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Table 1 Long-Term Studies of Implant-Supported Fixed Prostheses in Edentulous Patients*

Study	No. of patients/ implants	Implant system	Follow-up period	Implant outcomes: Implant success	Implant outcomes: Bone level	Prosthodontic outcomes
Adell et al[5]	2,847/482 Mn 1,786/277 Mx	Brånemark	1–15 y	86%–96% 78%–92%	–	–
Henry et al[8]	15/83 Mn	Brånemark	10 y	97.6%	0.02 mm > 1 y	Reported
Carlsson et al[10]	13/75 Mx	Brånemark	10 y	93%	0.05 mm > 1 y	–
Snauwert et al[11]	154/785 Mx 154/825 Mn (prostheses, not patients)	Brånemark	5.1 y (1–15 y) 71 prostheses > 10 y	95.2% Mx 97.6% Mn	< 0.5 mm > 1 y	Reported complications
Ferrigno et al[13]	55/440 Mx 40/320 Mn	ITI (Straumann)	10 y; minority in 10-y interval	> 90%	0.14 mm > 1 y	–
Lindquist and coworkers[14,21]	47/273 Mn	Brånemark	20 y	98.9%	0.5 mm > 1 y	Reported
Zarb and Schmitt[18]	45/263; majority in Mn	Brånemark	11–15 y	87.6%	0.1 mm > 1 y	Reported

*These studies were selected because they report specific patient selection criteria and success outcomes, although not necessarily common to all.
Mn = mandible; Mx = maxilla.

as the psychosocial impact of treatment and economic domains, have also emerged as compelling concerns.[22–25] Few authors have reported diverse overall maintenance documentation (Table 1), and actual prosthodontic treatment outcomes are only sparsely documented. These reports, combined with clinical experience, suggest that irrespective of any specific study's design and duration, all patients will require regular maintenance of their implant-supported prostheses, with inevitable clinical and patient time costs.[6,17,26–30] This suggests the need for comprehensive discussion with patients during treatment planning so that all aspects of long-term maintenance are presented and understood. The objective of the present prospective study was to report long-term treatment outcomes in edentulous patients treated with fixed implant-supported prostheses, with special emphasis on the overall maintenance requirements of their prosthodontic management.

Materials and Methods

This ongoing study formerly comprised 46 of 90 patients who were treated with Brånemark implants to manage their maladaptive prosthodontic experience. The study started in the late 1970s and continued up to 1984 at the Implant Prosthodontic Unit, University of Toronto, and details of the study group and inclusion criteria were presented previously.[15] All patients had their prostheses optimized the year prior to commencement of the study. One patient was transferred to the overdenture treatment study, leaving in total 45 consecutively treated patients (36 women and 9 men) with fixed prostheses in 47 arches (42 mandibular and 5 maxillary).

Clinical Procedures

Patients were treated with a two-stage surgical procedure, with the interstage surgical healing phase varying with the jaw location of the implant. On average, five to six Brånemark implants were placed in either the mandible or maxilla, although the actual number varied in certain patients (four to eight implants). Surgery was mainly performed under local anesthesia and oral sedation, and the surgeon graded the host site bone quantity and quality at the time of surgery. This was matched to the proposed radiographically based classification of Lekholm and Zarb.[31]

At second-stage surgery, the implants were exposed to the oral environment and standard abutments were attached. A 12-unit fixed prosthesis with posterior cantilever segments was fabricated in metal alloy and stock denture teeth. The bridge design was revised to allow adequate beam dimensions in the cantilevered portion. Prosthodontic staff carried out the prosthodontic treatment initially; in latter years, graduate residents provided maintenance and replacement treatment under supervision.

The evaluation criteria—those proposed in 1986 and subsequently reiterated at the Toronto Consensus Conference[25]—were rigorously applied. While follow-up visits were scheduled on an annual basis for all patients, infrequent attendance lapses were recorded. Each recall visit included an updating of the medical history plus a comprehensive clinical examination. Osseointegration status of all individual implants was initially evaluated at second-stage surgery and then monitored clinically and radiographically during the recall visits when the prosthesis was removed. Implants were clinically evaluated for mobility by torquing the abutment screws to 20 Ncm with a calibrated torque wrench. Any mobility or painful response to the torquing was designated as a failed implant. Standardized periapical radiographs using a locating jig that controlled for angulation were taken[32,33] to establish bone heights. All calculations with respect to bone loss were conducted in a blind fashion. The main investigator was calibrated with an experienced investigator. Cumulative implant survival outcomes were based on clinical testing only; therefore, only implant losses were considered failures.

Maintenance considerations for every prosthesis were recorded as per traditional protocols and included the nature and number of events per patient, such as fractured hardware and acrylic resin superstructure, prosthesis remakes, and laboratory relines of opposing prostheses.[34] Prosthetic success was defined as an unmodified original prosthetic treatment plan. Prosthesis longevity was defined as the period from insertion to replacement of the prosthesis. Complications were viewed as events that led to loss of the original prosthetic plan. The prosthesis was then removed, and the condition of the soft tissue around the implants was assessed for signs of inflammation. Detailed periodontal-related indices were initially used but discontinued in later years because of reported lack of correlation with loss of osseointegration.[19] However, for this study, an oral hygiene score of the implant framework and abutments was recorded at each appointment and obtained by inspection of the dental records and observation of oral hygiene at the last recall visit: Frameworks and/or abutments with no to minor plaque accumulation were labeled as good to fair hygiene, and frameworks/implants with heavy plaque and/or calculus buildup on the abutments were labeled as poor oral hygiene.

Statistical Methods

Clinical data were collected and input in an SPSS statistical package for analysis (SPSS). Bivariate analyses to explain the association between the independent variables and measured outcomes were carried out. The tests carried out were the Mann-Whitney *U* test for continuous variables and the chi-square test for categoric data to test for statistical significance. Survival analyses of the implants were carried out with the Kaplan-Meier test[35] and Cutler and Ederer test.[36] An intraclass correlation study was done prior to bone measurements to calibrate the main investigator and assess the degree of agreement between the investigator and an experienced investigator in the Department of Prosthodontics. Multivariate analyses were performed to identify factors that explained the bone loss measured around Brånemark endosseous dental implants. Specifically, multiple linear regression was used to test the joint effect of independent variables on continuous dependent variables such as bone loss outcomes. Statistical significance was set at $P < .050$.

Results

Patient Demographics

The 45 patients had worn complete dentures for at least 15.13 ± 7.20 years before participating in this study. Thirty-one patients (26 women and 5 men) from the original group of 45 patients treated with fixed prostheses attended the recall visit in 2002 and were followed for a mean of 20 years (Tables 2 and 3). A total of 14 patients were lost to follow-up, 6 because of death and 7 because of migration or lack of interest in participation; 1 patient dropped out at year 7 because of loss of all the implants. Seventy-four percent of the patients reported a chronic medical condition (including cardiac conditions, endocrine disorders, arthritides, and osteoporosis) managed with medications. Seventy percent of the patients were nonsmokers, whereas 30% were active smokers at the time of surgery. There was no attempt to quantify actual smoking consumption, since these data were judged to be unreliable.

Prosthesis Outcomes

All 33 prostheses (29 mandibular and 4 maxillary) in the attending 31 patients were clinically stable at the last recall visit (Table 4). Six of the 14 prostheses were not followed because of patient death. However, reliable information from the latter group's relatives indicated that they all successfully wore their implant-supported prostheses until the time of death. Another 7 prostheses were lost to follow-up because of patient migration, and progressive implant loss in one man led to conversion of the prosthesis to an overdenture and subsequently to a complete mandibular denture following failure of all the implants at year 7. Overall, the cumulative success rate of the implant-supported prostheses in function reached a steady state at 97.85% after 7 years. However, during the observation period, 6 prostheses were converted to overdentures because of implant losses in three patients and because of a clinical diagnosis of unfavorable biomechanical loading in the other three. If the clinical judgment call of the original fixed prosthesis plan is considered the unit of success (ie, conversion of the prosthesis to either an overdenture or conventional denture is denoted as a failure), the cumulative success rate at 20 years was 84.34%.

Prosthesis maintenance for this group of patients included a variety of requirements (Table 5). Ten patients also sustained breakage of the metal framework. In 13 frameworks, the fracture occurred at the junction of the

Table 2 Patient Demographics (n = 31)

Parameter (y)	Mean	Standard deviation	Minimum–maximum
Age at initiation of study	49.45	10.13	30–66
Age at last recall	70.16	10.17	52–89
Length of edentulism prior to placement of implants	15.13	7.20	1–30
Follow-up time	20.67	1.34	18–23

Table 3 Life Table Analysis of Patient and Implant Follow-up

Interval	No. of patients entering interval	No. of patients withdrawn during interval	No. of patients lost	Cumulative proportion of patients followed (%)	No. of implants entering interval	No. of implants withdrawn during interval	No. of implant failures during interval	Cumulative proportion of implants surviving (%)
Baseline	45	0	0	100.00	265	0	0	100.00
Stage two	45	0	0	100.00	265	6[a]	21	91.98
1–5 y	45	0	0	100.00	238	0	9, 1[b]	88.12
6–10 y	45	0	2[c], 1[d]	93.30	228	8[e]	2	87.34
11–15 y	42	0	3[c], 2[d]	82.20	218	26[e]	0	87.34
16–20 y	37	0	2[c], 3[d]	71.00	192	24[e]	1[f]	87.34
21–23 y	32	0	1[c]	65.70	87	0	0	86.76

a = implants put to sleep; b = one implant removed at patient's request; c = patient lost to follow-up; d = patient died; e = implant not followed because of patient migration and death; f = implant lost because of fracture.

Table 4 Cumulative Success Rate of Implant-Supported Prostheses

Interval	No. of prostheses entering interval	No. of prostheses lost to follow-up	No. of prostheses lost	Cumulative proportion of implant prosthesis designs maintained (%)*	No. of prostheses entering interval	No. of prosthesis plans converted	Cumulative proportion of fixed prosthesis designs surviving (%)†
Loading	47	0	0	100.00	47	1[a]	97.87
1–5 y	47	0	0	100.00	47	1[b]	95.74
6–10 y	47	2[c]	1	97.85	46	3[a]	89.42
11–15 y	44	2[c], 3[d]	0	97.85	41	1[a]	86.89
16–20 y	39	3[c], 2[d]	0	97.85	35	1[a]	84.34
21–23 y	17	1[d]	0	97.85	15	0	84.34

*Cumulative survival rate if conversion of fixed to overdenture prosthesis is not considered failure.
†Conversion of fixed to overdenture prosthesis considered failure.
a = prosthesis converted to overdenture; b = prosthesis converted first to overdenture and then to conventional denture; c = prosthesis lost because of patient migration; d = prosthesis lost because of patient death.

cantilever portion to the last gold cylinder. One patient experienced a midline fracture of the framework 6 years after functional loading. Most of these prosthesis fracture complications were encountered earlier in the study and resulted in redesign of the framework, with increased cross-sectional dimensions of metal contact to the prosthetic copings. Three other fractures occurred later in the study, after 10 years of implant placement.

Reasons for prosthesis replacement, other than framework fracture, were the results of acrylic resin wear that required esthetic and function-related improvements. On average, a patient received 2.27 implant-supported prostheses (range 1 to 4) throughout the study period. The mean period prior to prosthodontic retreatment following insertion of the first prosthesis (or longevity of the first prosthesis) was 6.57 ± 3.87 years. The longevity of the prostheses inserted after the first ones was 8.39 ± 5.30 years.

Maintenance of the opposing dentition consisted of laboratory relines of complete dentures as well as fabrication of new prostheses. Patients received an average of 2 opposing complete dentures (range 1 to 3). The mean period prior to retreatment (longevity of the first complete denture) was 12.22 ± 6.12 years. The longevity of opposing prostheses was 13.00 ± 4.15 years. Laboratory relines were performed on average every 7.04 ± 3.54 years.

Table 5 Prosthodontic Maintenance*

Type of maintenance	Study group: Active	Dead	Lost to follow-up	Total
Fixed prosthesis converted to				
Overdenture	5 (5)	1 (1)	NA	6 (6)
Conventional denture	NA	NA	1 (1)	1 (1)
Tissue hyperplasia/inflammation	34 (16)	6 (2)	7 (2)	47 (20)
Broken gold screw	56 (10)	8 (1)	14 (2)	78 (13)
Broken abutment screw	20 (8)	3 (1)	2 (1)	25 (10)
Fractured denture teeth	19 (9)	2 (1)	1 (1)	22 (11)
Fractured opposing denture	3 (2)	NA	2 (1)	5 (3)
Laboratory reline of opposing denture	45 (12)	4 (2)	2 (1)	51 (15)
Fractured framework	13 (7)	1 (1)	2 (2)	16 (10)
Remake of fixed prosthesis	46 (31)	5 (4)	6 (5)	57 (40)
Fabrication of new opposing denture	22 (16)	4 (2)	1 (1)	27 (19)

*No. of instances (No. of patients).
NA = not applicable.

Implant Outcomes

The first report on this prospective study in 1990[15] reported the placement of 274 implants in 46 patients. One patient, who had 11 implants, was treated with overdentures in two arches and was excluded from this report, leaving 263 implants that were restored with fixed prostheses. A further 2 implants were placed to replace implants that had fractured in a patient later in the study. A total of 265 Brånemark implants (30 maxillary and 235 mandibular) were placed in this group of patients.

All implants were tested and judged to be clinically osseointegrated. The cumulative survival rate of the implants is presented in Table 3. Six implants were not included in the final prosthodontic design because of an unfavorable position and were put to sleep. Twenty-one implants failed to integrate by second-stage surgery. Another 13 implants failed following loading. One implant, although osseointegrated, was removed at the patient's insistence. One late implant failure occurred after 17 years of loading because of fracture of the implant. The cumulative survival rate of the implants at 20 years of functional loading was 86.76%. Analyses of factors that could explain the early implant failures (ie, implants that failed to integrate) were investigated: gender, jawbone in which implants were placed, oral hygiene, dichotomized implant length (10 mm and shorter, and more than 10 mm), and smoking history at the time of first-stage surgery; all were statistically insignificant (Fisher's exact test, $P > .050$). Further variables investigated—history of a chronic medical condition, bicortical stabilization of the implant, and jawbone quantity and quality—were also insignificant (chi-square test, $P > .050$). Continuous variables investigated were years of edentulism prior to first-stage surgery and months of healing prior to stage two, and both were also statistically insignificant (Mann-Whitney *U* test, $P > .050$). Kaplan-Meier analyses of the cumulative survival rate were carried out, but no factor was statistically significant in explaining the outcomes observed. This was probably due to the small number of failures observed over the study period.

Bone Loss Around Brånemark Implants

Long-term bone measurements around dental implants were assessed initially to determine any measurement differences in the observed sites. The bone measurements for mesial and distal sites showed no statistical differences between the sites for any of the years calculated and were pooled for final analyses (Mann-Whitney *U* test, $P > .050$). The crestal bone loss measured in this group of patients is shown in Table 6. The mean bone loss during the first year of loading was 0.98 mm. The mean bone loss after year 1 was calculated as the slope of a linear regression equation based on all the bone measurements for the particular follow-up period. During this period, a modest progressive mean annual crestal bone loss (0.05 mm) was observed. Of interest, the mean annual crestal bone loss after the first year of loading was less than half that reported earlier, suggesting that the mean bone loss might continue to decrease. The data indicated that gradual bone loss over the follow-up period resulted in a mean of 2 mm lost over more than 20 years. However, the range of bone loss was high, with some implant sites experiencing about 6 mm of bone loss. Although this amount may be regarded as alarming, all the implants are still osseointegrated and in function.

The bone level changes observed in the first year of loading indicated that women had more bone loss than men (Mann-Whitney *U* test, $P < .050$). Implants placed in the maxilla ($P < .050$) and mandibular implants

Table 6 Crestal Bone Loss (mm/y) in Implant Sites

Interval	Mean	Standard error	Minimum mean	Maximum mean	No. of sites
0–1 y	0.9800	0.045	0.580	2.140	40
1–5 y	0.0700	0.015	–0.780	1.620	302
6–10 y	0.0550	0.018	–0.530	0.843	335
11–15 y	0.0500	0.019	–0.970	0.710	195
16–23 y	0.0505	0.018	–0.465	1.310	158
Overall	0.0466	0.006	–0.380	0.780	366

Table 7 Linear Regression Model for Overall Mean Bone Loss (mm/y)*

Factor	Beta	Standard error	Significance
(Constant)	–	0.036	.004
Smoking status	–0.094	0.015	.086
Opposing dentition	–0.047	0.015	.409
Implant position in prosthesis	–0.147	0.010	.005
Bone quality[31]	–0.004	0.014	.944
Bone quantity[31]	–0.027	0.012	.639
Plaque	0.361	0.011	$<$ .001
Abutment length	–0.093	0.005	.107

*$F = 5.23$, $P < .001$, $R^2 = .091$.

opposed by an implant-supported prosthesis had more bone loss in the first year of loading (Mann-Whitney *U* test, $P < .050$), although this trend was not significant in the following years. Bivariate analysis of the overall bone loss displayed the same trend for gender, with women experiencing more bone loss (Mann-Whitney *U* test, $P = .032$). Implants at the most distal position in the mandibular prosthesis design showed less bone loss than implants in a central position (Mann-Whitney *U* test, $P = .013$). There was also a tendency for implants positioned in jawbones with severe bone resorption (quantity E) to experience more bone loss following loading (Kruskall-Wallis and Mann-Whitney *U* tests, $P < .050$).

A statistically significant trend for more peri-implant bone loss in smokers was observed throughout the study after the first year of functional loading, with smokers experiencing approximately twice as much bone loss as nonsmokers (Mann-Whitney *U* test, $P = .036$). Patients with recorded measurements of poor oral hygiene (48% of implants investigated) experienced more bone loss compared to patients with good to fair oral hygiene, with roughly twice as much bone loss recorded overall (Mann-Whitney *U* test, $P = .003$).

The linear regression model (Table 7) indicated that oral hygiene and implant position were independent factors that explained the bone loss observed in this group of patients. More bone loss was observed around implants with poor oral hygiene and in implants placed in a central position. Behavioral and local bone factors were not statistically significant in the model.

Discussion

The initial aim of this study was to replicate the findings of Brånemark et al's study,[3] and the recorded treatment outcomes confirm the excellent results possible with fixed prostheses. The recall rates for this aging group of patients are encouraging, since 71% of the patients were followed for 20 years, allowing us to closely examine both implant and prosthodontic outcomes. Only eight patients were lost because of migration, while the other six patients were excluded from the study because of death. More attrition of our database is expected in the future as our patients age; this is bound to negatively affect our survival rates, even if we predict that both implants and prostheses will remain stable.

It is recognized that individual implant success should not be assessed separately from a successful prosthodontic result.[24] If maintenance of an implant-supported prosthesis is viewed as the objective of treatment, the cumulative survival rate in our study was 97.85%. With a more conservative approach in which the maintenance of a fixed tissue-integrated prosthesis as originally desired for these patients is considered the unit of success, the cumulative success rate was 84.34%. This result is more important from the patient's perspective, since it underscores the effect of individual implant losses or unfavorable implant position on the longevity of the specific prosthetic prescription.

Prosthetic revisions regarded as complications were due to biologic failures (implant loss) in four patients, resulting in conversion of the fixed prosthodontic plan into overdentures, and in one patient to a conventional denture. In three other patients, unfavorable biomechanical loading led to repeated gold screw fractures and required fixed prosthesis conversion to an overdenture. The long-term maintenance required by all patients included component and acrylic resin fractures that were easily rectified. It should be noted that all patients required new prostheses during the study. The mean time to retreatment of the first prosthesis was 6.57 ± 3.87 years, and the longevity of a fixed prosthesis was 8.39 ± 5.30 years. This important information should be discussed with patients seeking treatment with fixed implant prostheses, since further costs can be incurred over time. In a previous study,[37] we reported that fixed implant prostheses are more expensive to maintain compared to the overdenture approach. The prosthetic design context of this study must also be recognized, since an all–acrylic resin analogue for the replaced dentition and gingival tissues (albeit supported by an all–metal alloy framework) is vulnerable to time-dependent wear and tear that necessitate a relatively high degree of maintenance.

The 20-year implant survival rate, as calculated with the life table analysis technique, was 87.34%; a total of 34 implants failed throughout the study. Twenty-one of these implants failed to osseointegrate at second-stage surgery. The rest lost osseointegration after loading, within a 7-year follow-up period. A late failure of a distally positioned implant occurred after 17 years of loading because of fracture. These success rates are slightly lower than those reported by others,[8,10,21,38] although they clearly reflect a surgical learning phase.[5] These results strongly suggest that once osseointegration is established, it is maintained with an excellent prognosis for long-term function.

The mean bone loss around the implants was greatest for year 1 of loading, after which the mean magnitude of bone loss was extremely small. Bone loss was stable and within the limits suggested in the literature, suggesting that the prognosis for long-term function was not compromised. Bivariate analysis of long-term bone loss indicated that history of smoking and poor oral hygiene and mandibular implants positioned in the anterior part of the prosthesis resulted in slightly more bone loss. On the other hand, the multivariate analysis of the bone loss maintained this trend. Both implant position in the prosthesis and poor oral hygiene were significant factors. Smoking habits registered as not significant. Our study corroborated the report of Carlsson et al[10] that more bone loss is observed around the central implants, suggesting that this trend may be factual rather than an observational error.

Poor oral hygiene appeared to correlate with increased marginal bone loss. This suggests that while poor oral hygiene did not affect the osseointegration process itself, it was related to long-term peri-implant bone physiology. In earlier studies, we reported that periodontal indices are not related to implant success outcomes[39] and that probing depths and Gingival Index are only weakly correlated with mean bone loss.[33] We concluded that these time-consuming indices provide no diagnostic or prognostic insights; therefore, their use was discontinued. The current results corroborate our previous reports and suggest that a simple index of plaque buildup served us well to indicate that patients with heavy plaque and calculus showed a correlation with observed bone loss. These results only apply to the machined implant surfaces employed in this study. This raises the issue of what effect poor oral hygiene may have on the long-term prognosis of implants with modified surface topography. The latter observation may therefore suggest a greater vulnerability for implants with roughened as opposed to machined surfaces extending to their cervical regions. Thus, the observed statistically significant effect of oral hygiene on machined implants may become a statistically and clinically significant issue in implants with modified surface topography.

Conclusions

This study confirms favorable long-term outcome results for a group of prosthodontic maladaptive patients treated with osseointegrated implants and restored with fixed tissue-integrated prostheses. The results showed that:

1. The cumulative fixed prosthesis survival rate of the study sample was 84.34%. The remaining patients, in whom implant failure resulted in a modified prosthesis (overdenture), also enjoyed successful prosthesis outcomes, with a continuation of satisfactory function.
2. Cumulative individual implant success was 87.34% at 20 years of follow-up. The majority of the recorded failures were early ones that occurred at the second surgical stage. The late failures were clustered within the first 10 years of this longitudinal study. Successful osseointegration was maintained as patients got older, although their health frequently became compromised.
3. Mean marginal bone levels were stable: The observed bone loss was 0.98 mm for the first year of loading and within the suggested 0.2 mm/year after the first year of loading. However, the amount of bone loss varied considerably among patients.
4. Implant position and poor oral hygiene were associated with mandibular implant bone loss, but not implant failure. Patients with a smoking history had more marginal bone loss than did nonsmokers.
5. Analysis of prosthodontic maintenance requirements showed that time to retreatment was 8.39 ± 5.30 years. This underscores the need to discuss specific prosthesis design maintenance requirements with patients during the treatment-planning

phase. Success outcomes should not revolve solely around implant success per se, but the possibility of modified prosthodontic treatment and the incurred costs over time should be emphasized.

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