Outcome of Oral Implant Treatment in Partially Edentulous Jaws Followed 20 Years in Clinical Function

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ABSTRACT

Background: Most long-term follow-up studies of implants in partially edentulous jaws present their outcomes as mean values of implant survival and follow-up time, and few address the fate of the remaining teeth.

Purpose: The aim of this study was to investigate the results of oral implant treatment in partially edentulous jaws after 20 years, and simultaneously to assess what happens to teeth present at the time of implant placement.

Materials and Methods: Seventeen partially edentulous patients, of 27 originally treated individuals, were retrospectively reviewed after receiving implants from 1983 to 1985. The parameters studied were implant survival, prosthesis stability, marginal bone loss at teeth and implants, treatment complications, need for dental treatment, and patient's satisfaction with the outcome.

Results: The cumulative survival rate was 91%, when all 27 patients were assessed, that is, including the 10 dropouts. Of the 69 inserted and followed implants (Brånemark system®; Nobel Biocare AB, Göteborg, Sweden), six failed (8.7%) during the 20-year period, four during the first decade, and the remaining two during the second. A majority ($n = 4$) of the losses were due to implant fractures, two after 8 years, and two after 17 years. In all, 10 of the original fixed bridges being followed ($n = 24$) remained in function during the entire investigation period, whereas 12 were exchanged for new constructions after an average of 7 years. The mean marginal bone loss at teeth was 0.7 mm, and at implants it was 1.0 mm. The major complication observed during the second decade was veneer material fractures, which occurred 14 times in six patients. Component loosening and abutment- and bridge-locking screw fractures were the second most common problems seen, indicating material/component fatigue. Most patients were satisfied with their treatment and many mentioned that they did not think of the constructions as anything but a part of their own body.

Conclusion: Over the decades, treatment of partially edentulous jaws with turned titanium implants seems to function well and to provide patients with good support for fixed short-span bridge constructions.

KEY WORDS: follow up, implant treatment, long term, oral implant, partial edentulism, retrospective study

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The use of titanium implants in restoring partially dentate jaws to normal oral function has increased since such protocols started to be utilized in the early 1980s. Partially edentulous individuals have today become the main group of patients being considered for oral implant treatment, and several reports have been published showing favorable long-term outcomes with different oral implant systems.[1–3]

However, many reports claiming to show long-term results in reality present mean follow-up times much shorter than as stated in the title/abstract of the article.[3–6] Furthermore, most studies only focus on the

outcome of placed implants, whereas few deal with what simultaneously happens to the teeth present at the time of implant placement.[7]

As most treated partially edentulous patients seem to be middle-aged people, that is, between 40 and 50 years of age when provided with oral implants,[1,2,8] it has to be expected that the patients should function with their implant-supported constructions for many years. *Long term*, defined as at least 5 years of follow up,[9] then does not seem a sufficient length of time for evaluation; "over the years" should rather indicate a decade or even longer time periods.

Extended exposure of teeth to plaque is generally known to result in periodontitis.[10] As the microflora at implants in partially edentulous patients has been found similar to that at teeth,[11] it is not surprising that the soft tissues surrounding the implants are reported to respond to the presence of bacteria in a similar way as the gingiva.[12] Furthermore, patients who have experienced loss of teeth due to periodontitis prior to implant placement also show a higher degree of marginal bone loss, and even implant loss, during follow up.[13,14]

Consequently, similarities seem to exist between the response of teeth and implants to the oral microbiological environment, provided the exposure is to the same agents for the same length of time. No reports are available, however, where both implants and teeth have been followed for equal time periods, as the remaining teeth have mostly been in function for many more years before any implants may be placed. However, by increasing the follow-up time for the implants, at least a fairer comparison seems possible between the potentials of oral implants and those of teeth, when treating partially dentate jaws.

The aim of the present investigation was to study the outcome of oral implant treatment in partially edentulous jaws after 20 years of clinical function and to examine the simultaneous effects on the teeth present at the time of implant placement.

MATERIALS AND METHODS

Partially edentulous patients provided with implants from 1983 to 1985 at the Department of Special Jaw-Reconstructive Surgery, Public Dental Health Service, Göteborg, Sweden, and fulfilling the following selection criteria were included in the current report.

The inclusion criteria were:

1. All patients treated/followed by one and the same surgeon
2. Patients partially edentulous at the time of implant placement
3. A panoramic radiograph or a full-mouth survey of the remaining teeth at commencement of treatment should be available.

Altogether, 27 patients fulfilled these criteria. From 1983 to 1985, they received 112 standard Brånemark implants® (Nobelpharma AB, Göteborg, Sweden), according to the Brånemark system protocol.[15] Of the 27 patients treated, six individuals (27 implants) had died and three patients (13 implants) had moved beyond follow up. This meant they had either migrated abroad or had moved so far from Göteborg that it was not realistic to ask them to come back for a 20-year checkup. One patient, according to chart notes with three original implants still in function supporting a fixed construction, was living in Göteborg but was unwilling to attend an extra clinical and radiographic assessment. Thus, in all 10 patients (37%), corresponding to 43 implants in six partially edentulous upper and five lower jaws, dropped out of the study. To calculate the current cumulative survival rates, these patients were, however, included in the reporting of implant outcome as long as the patients were followed.

The remaining 17 patients (research group/patients; eight females and nine males) did present for examination and constitute the basis for the current report (Table 1). At the time of follow up, these patients were on average 68 years of age (range: 43–87 years).

In the research group, nine upper and 10 lower jaws had been provided with implants, that is, in two patients both jaws were treated. The implants had been placed in six anterior (incisor + canine) and 18 posterior (premolar + molar) regions, and hence five patients were treated bilaterally, one with two single implants (see Table 1).

The 17 research patients were provided with 69 original Brånemark implants of the standard diameter. The majority were either 7-mm (38%) or 10-mm (33%) long; other lengths used (13 or 15 mm) only accounted for 29%. Twenty-two fixed partial constructions and two single crowns (SCs) had been attached, 75% of which were located in posterior regions. The prosthetic treatment was performed according to the conventional Brånemark system protocol,[16] using original components available at the time. The patients were followed

TABLE 1 Distribution of Research Patients Regarding Gender, Jaw, and Jaw Classification and According to Originally Obtained Number of Implants

		Upper Jaws			
		KC I Jaws/Implant	KC II Jaws/Implant	KC IV Jaws/Implant	SC Jaws/Implant
Males	4		2/5	1/4	1/2†
Females	4*		3/10	2/9	
		Lower Jaws			
		KC I Jaws/Implant	KC II Jaws/Implant	KC IV Jaws/Implant	SC Jaws/Implant
Males	5	1/6	3/8	1/5	
Females	4*	3/14	2/6		
Total	17	4/20	10/29	4/18	1/2

*One patient treated in both jaws.
†Two single crowns placed bilaterally in one patient (13, 23).
KC I = Kennedy class I; KC II = Kennedy class II; KC IV = Kennedy class IV; SC = single crown.

up on a regular basis according to standard principles[17] and protocols for radiographic examinations (Gröndahl and colleagues[18]). On average, enrolled patients were followed up for 20 years (range: 19–21 years).

All research patients were evaluated retrospectively, using information from patient notes and from the 20-year examination. Clinical and radiographic parameters examined were:

1. Fixture survival – as studied from records and available 20-year panoramic radiographs
2. Prosthesis stability – as studied from records and clinical examinations
3. Marginal bone loss at implants – as studied from intraoral periapicals taken at abutment connection and from panoramic radiographs obtained at the 20-year examination
4. Severe implant treatment complications – as studied from records regarding the last 10 years in function only
5. Number of teeth from start – as studied from original intraoral or panoramic radiographs
6. Number of teeth persisting – as studied from the 20-year panoramic radiographs
7. Marginal bone loss at teeth – as studied from original intraoral or panoramic radiographs and 20-year panoramic radiographs, respectively, regarding contralateral teeth or close-standing teeth, if the patient was bilaterally treated
8. Amount of new dental treatment – as studied from the 20-year panoramic radiographs compared with the original radiographs, regarding number of teeth with new fillings, endodontic treatments, crowns, fixed bridge constructions, etc.
9. A questionnaire was used to rate the patient's level of satisfaction regarding construction outlook and function, and the patients were offered three alternatives: good, acceptable, or nonacceptable. They were also asked to rate their overall level of satisfaction with the treatment on a rating scale from 0 to 100, where 100 indicated the highest level of satisfaction.
10. Clinical photographs were taken of the constructions to be used for illustration.

RESULTS

The cumulative survival rate based on the entire group of 27 patients was 91% after 20 years of follow up (Table 2). Of the 69 implants within the research group, six failed (8.7%) during the 20-year follow-up period, resulting in an overall survival rate of 91.3% (90.0% for upper and 92.3% for lower jaw implants, respectively). Four of these losses took place during the first decade and two during the second, and the reasons for their failure were: one implant was lost after 3 years due to mucosal disorder and progressive marginal bone loss; in another patient, one implant fractured after 2 years and a second implant after 7 years; they were duly repaired but finally had to be removed after 8 years in situ, at which time one more implant was removed due to loss of osseointegration. In the same patient, two implants and one abutment screw fractured after 17 years (Figure 1, A–C), necessitating removal.

TABLE 2 Life Table Analysis of Brånemark System Implants Placed from 1983 to 1985

Years After Implant Placement	Total Number of Implants at Start of the Period	Number of Failures Within a Period	Number of Implants Lost to Follow Up Due to Death	Number of Implants Lost to Follow Up Within the Period*	Cumulative Success Rates (%)
Placement loading	112	1	0	0	99
Loading* – 1 year	111	0	0	0	99
1–5 years	111	3	8	7	96
5–10 years	93	3	3	7	93
10–15 years	80	0	9	0	93
15–20 years	71	2	6	0	91
20 years	63				

*Of the 40 implants lost to follow up, 26 were lost in deceased patients.

As a result of these implant losses, two patients required reoperation (after 8 and 18 years, respectively), after which they were provided with new fixed implant-supported constructions. These two patients, with one lost construction each, were considered as complete treatment failures. Of the remaining original constructions, 10 were still in function after 20 years of follow up (Figure 2, A–D), while in 12 instances the primary fixed prostheses had been exchanged for new structures after on an average 7 years of function (Figure 3, A–D). However, these patients had all continuously enjoyed the use of a fixed construction supported by the originally inserted implants throughout the entire 20-year period.

From the beginning, the research patients had an average of 16.7 remaining teeth, 0.8 bridge constructions supported by 3.4 teeth on average, 9.7 teeth with fillings or SCs, and 4.1 teeth that were root filled (Table 3). During the follow-up period, on average, each of these patients lost 1.1 tooth, had 5.1 new teeth restored, received 0.7 new bridge constructions supported by 2.7 teeth as a mean, and had 0.9 new root fillings (see Table 3).

The marginal bone loss that took place around the implants of the research group during the 20-year follow-up period, from abutment connection to final control, was on an average 1.0 mm (number of sites measured: $n = 118$), and the corresponding loss at teeth was 0.7 mm (number of sites measured: $n = 59$). Loss of 2 mm or more was observed at 8.5% of the implant sites measured (number of sites affected: $n = 10$) and at 13.6% of teeth sites (number of sites affected: $n = 8$).

The most common complication recorded from the chart notes within the research group during the 10th to 20th follow-up years (Table 4) was resin fractures of the veneer material, which was observed 14 times in a total of six patients during the time period studied. Component problems such as gold and/or abutment screw loosening and/or fractures were also noted on a relatively high level (eight and six times in three and two patients, respectively), whereas mucosa-related problems and tooth abrasion were reported three and four times, respectively, once in each of the affected patients.

From the follow-up questionnaire on the research patient's own opinion of the treatment outcome (Table 5), all patients were satisfied with the function of their fixed constructions. Many even said that they never thought of the implant-supported prostheses as anything but their own teeth. No patient was dissatisfied with the appearance of her or his construction(s), but 40% considered the aesthetics of their fixed bridges as just acceptable. When asked to rate their overall level of satisfaction with implant treatment on a scale from 0 to 100, where 100 corresponded to being highly satisfied, the patients rated their content level to 96, as a mean.

DISCUSSION

The present study showed that turned titanium implants functioned well as supports for short-span fixed bridges in partially edentulous jaws throughout a 2-decade period. The cumulative survival rate based on the 112 originally inserted implants was 91% after 20 years of function, and the overall failure rate for the 69 implants of the research group was 8.7%. No similar long-term results have previously been published for partially edentulous jaws, but for persons being edentulous.[19] In all, 10 patients (37%) dropped out from the follow-up;

six died for reasons not related to the implant treatment. However, this dropout rate must be considered acceptable for a group followed for 20 years. Besides, if all dropped-out patients/implants, except those due to death, were considered as failures, the worst-case analysis would only give a failure rate of 20.5% after 20 years.

A majority of the placed and followed implants of the research group was 7- or 10-mm long (70%) and had been placed in posterior regions (75%), that is, were

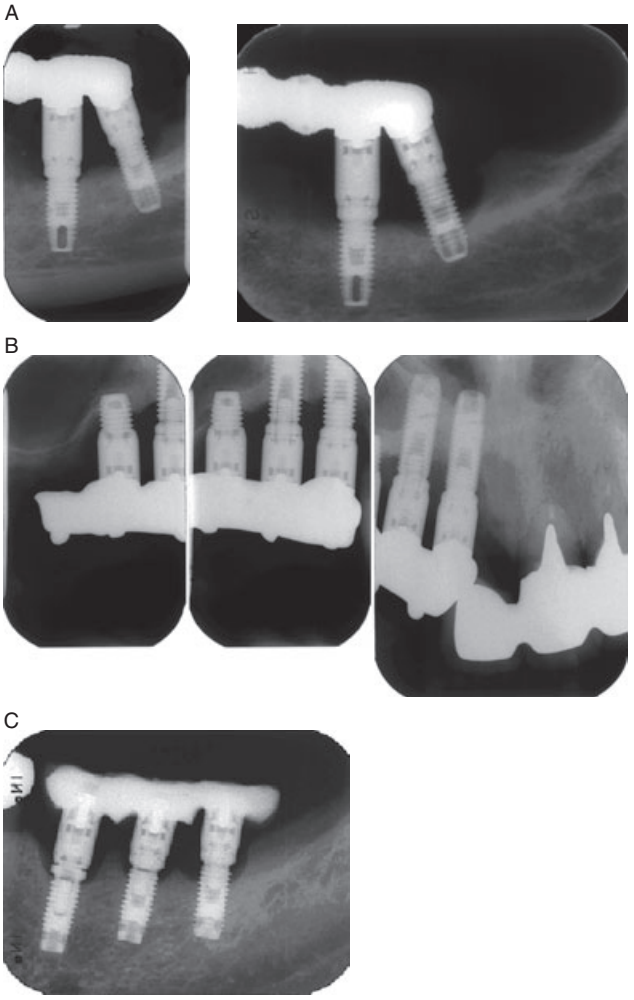

Figure 1 (A) Radiographs showing two fixtures (V2 and V3) 1 and 2.5 years, respectively, after bridge attachment and indicating progressive marginal bone loss around V3 causing mucosal disorder and resulting in the removal of fixture V3 6 months later. (B) Radiographs 7 years after bridge attachment showing a fractured (after 2 years) and repaired implant (H3) and a newly fractured implant (H2). After repairing H2, all fixtures functioned another year until H3 and H2 had to be removed with implant H1, which had then lost its osseointegration. (C) Radiograph 17 years after bridge attachment showing fractures of two implants (V2 and V3) and of one abutment screw (V1). V2 and V3 could not be repaired and had to be removed.

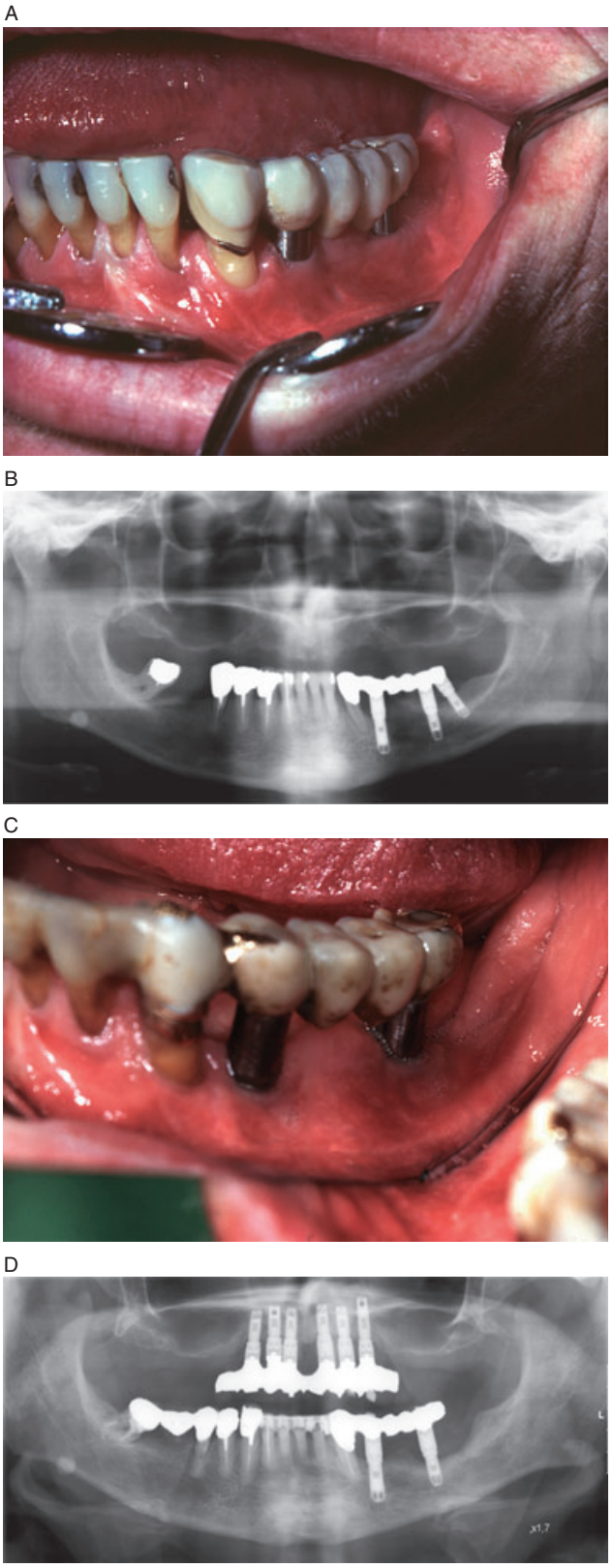

Figure 2 The same patient as in Figure 1A showing (A) the clinical situation after bridge attachment in 1984, (B) panoramic radiograph obtained after bridge attachment in 1984, (C) the clinical situation in May 2004 presenting the original bridge construction being supported by two implants (V1 and V2), and (D) panoramic radiograph taken at the 20-year follow-up control.

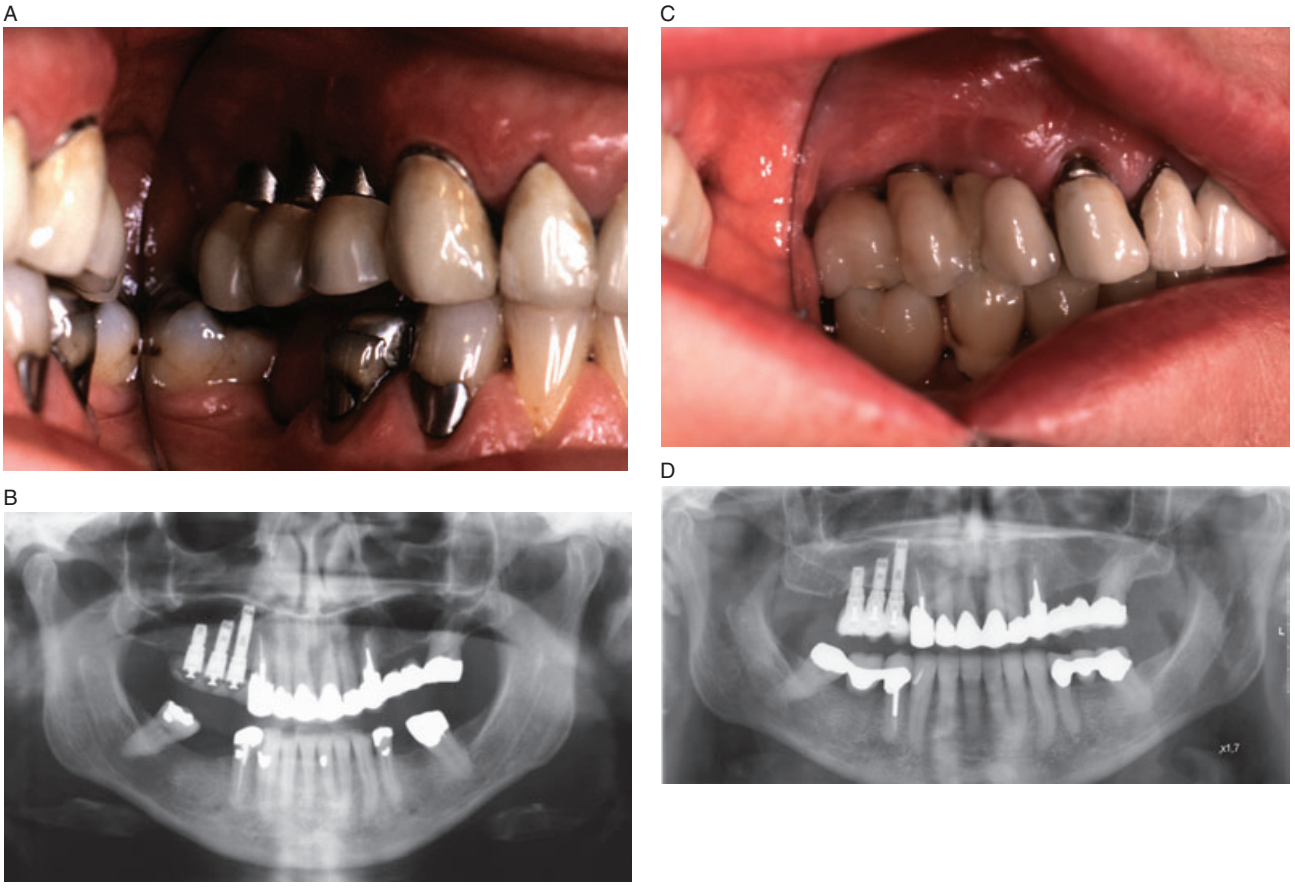

Figure 3 A patient provided with an implant-supported construction in the upper right quadrant: (A) clinical situation after bridge attachment in 1985, (B) panoramic radiograph taken after abutment connection, (C) clinical situation at the 20-year follow up showing a new bridge construction attached in 1994 and which has consequently been in function for 10 years, and (D) panoramic radiograph showing the marginal bone levels at the 20-year follow-up control.

short implants placed in regions of high loading. Nevertheless, favorable results were seen which corroborate well with outcomes of corresponding studies of partially edentulous jaws followed up for 10 years.[1–3,20] However, in contrast to earlier follow-up reports,[21,22] few ($n = 1$) implants were lost prior to loading, as the losses at least within the research group took place only after several years of function, mainly due to component fractures. This would seem to suggest the cause was minor mechanical maladjustments such as framework misfit or incorrect occlusion leading to abnormal loads and progressive loss of bone support, rather than poor oral hygiene.

Of the original constructions inserted within the research group ($n = 24$), 10 were still in function after 20 years, while two patients had lost their original fixed prosthesis due to implant fractures, one after 8 years and another after 17 years. In the remaining patients ($n = 12$), constructions had been in function the entire follow-up time, although having been exchanged after an average of 7 years in use. The reason for changing the bridges was either that the patient did not accept the aesthetics of the constructions, or mostly that the clinicians themselves suggested a change because new components had been developed, specifically for partially edentulous situations. The outcome corroborates well with previous reports of partially edentulous jaws, followed up for 10 years.[1,20]

The low loss of marginal bone observed, both at implants (1.0 mm) and at teeth (0.7 mm) within the research group after 20 years, indicated well-functioning anchorage units. The outcome also indicated that the two-component implant anchorage unit did not cause progressive marginal bone loss. Furthermore, very few implant sites showed bone loss of 2 mm or more after 20 years (8.5%), which indicates that few patients experienced major marginal bone loss during the follow-up period. The same was also true for the teeth sites (13.6%). These results confirm the findings previously shown for shorter follow-up periods.[1,7]

TABLE 3 Distribution of Dental State of Research Patients at Inclusion and Regarding Dental Treatment Achieved During the 20-Year Follow-Up Period

	State at Inclusion			Changes in State*		
	Total	Mean	Range	Total	Mean	Range
Number of teeth	283	16.7	3–26	−17	1.1	0–5
Number of fixed prostheses,	14[†]	0.8	0–3	+11[‡]	0.7	0–3
on no. of supporting posts	48	3.4	2–11	+30	2.7	2–8
Number of restored teeth	165	9.7	0–2	+82	5.1	0–17
Number of root-filled teeth	69	4.1	1–11	+15	0.9	0–4

*One patient was not included due to missing radiographic examination.
[†]In 11 patients.
[‡]In seven patients.

The need for conventional dental treatment did not seem to be pronounced in the present research group, as on average each patient only required five new restored teeth, one new root filling, and/or half a new bridge, during the 20 years the patients were followed up (see Table 3). The patients were obviously able to keep good oral hygiene during these years as well as the implant treatment seemed to have given effective support for the occlusion to function sufficiently during chewing. Besides, each patient as a mean lost one tooth during the 20-year period, which is less severe tooth loss than has been reported, for example, by Leonhardt and colleagues.[7] The latter study, though, was based on patients who had all undergone conventional periodontal therapy for severe periodontitis prior to implant treatment.

TABLE 4 Distribution of Complications (Times per Research Patient) Being Reported During the Last 10-Year Follow-Up Period (1994–2004)

Patient	Mucosal Disorder	Component Loosening	Component Fracture*	Resin Fracture[†]	Tooth Abrasion
1				3×	
2				×	×
3				3×	
4	×	×			×
5		×		×	×
6					×
7		6×	4×	4×	
8[‡]					
9[§]	×		2×		
10	×				
11					
12				2×	
13					
14					
15					
16[¶]					
17					
Total	3	8	6	14	4

*Excluding implant fractures.
[†]Including two bridge frame fractures.
[‡]One implant fractured after 2 years, and a second one after 7 years, both were repaired but finally removed after 8 years.
[§]Two implants fractured after 17 years and were thereafter removed.
[¶]Records missing for the period 1994–2004, that is, before the last checkup.

TABLE 5 Distribution of Questionnaire Results Regarding Research Patient's Own Opinion on Treatment Outcomes vis-á-vis Aesthetics, Function, and Satisfaction with the Treatment

Patient	Aesthetics Good/ Acceptable/Bad		Function Good/ Acceptable/Bad	Satisfaction 1–100*
1		×	×	100
2	×		×	100
3	×		×	95
4	×		×	95
5	×		×	100
6		×	×	80
7	×		×	100
8†				
9‡				
10	×		×	100
11	×		×	100
12		×	×	100
13		×	×	98
14	×		×	98
15	×		×	100
16		×	×	75
17		×	×	100

*100 = very satisfied.
†Implants lost after 8 years.
‡Implants lost after 18 years.

The present report considered only complications from the second decade. Complications which may occur during the first decade have been reported and discussed by others.[1,20] One interesting feature in the current report was the relatively high frequency of veneering and component fractures/loosening seen in the study group (see Table 4) during the second decade. This was most probably due to material fatigue as a result of repeated chewing. As 12 of the constructions were exchanged after an average of 7 years, fatigue-related problems might have been more frequent if all original constructions had remained in use for the same duration. It must be remembered too that these patients were the very first group of partially edentulous patients who had been treated with acrylic veneers from the start and components aimed for the edentulous situation. Where the bridges were subsequently replaced by porcelain fused to metallic frameworks on components designed for the partially dentate situation, the fatigue-related problems seemed to diminish. Similar behavior has been reported for partially dentate jaws followed for 5 years.[23] However, recent meta-analyses have also shown a relatively high mechanical failure rate for implant-supported constructions during the first decade, even 10% higher than for tooth-supported prostheses.[20]

Regarding mucosa-related complications, only three such instances were reported (in three separate patients) within the research group. This could, of course, be an underestimation, but if such conditions had really been of any significance, they ought to have influenced the marginal bone loss of the implant group patients also. However, as mentioned previously, the bone loss was only a mean of 1.0 mm after 20 years of function at implants and 0.7 mm at teeth. Consequently, mucosa-related problems do not seem to have been a major problem for the current research patients.

As many as 60% of the research patients were happy with the aesthetics of their constructions. The reason for this may be that a majority of the constructions were placed in posterior regions. It could also be because as many as 12 had been replaced with new constructions to improve the aesthetic appearance. All patients were also highly appreciative of the treatment provided 20 years earlier, as other studies have also reported.[24,25]

In conclusion, treatment of partially edentulous patients with turned titanium implants seems to function well over 2 decades and to provide patients with good support for fixed short-span constructions with no major complications.

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