Long-term follow-up of cross-arch fixed partial dentures in patients with advanced periodontal destruction

Evaluation of the supporting tissues

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The aim of the study was to evaluate the periodontal conditions in patients treated more than 10 years ago for advanced periodontal disease and rehabilitated with cross-arch fixed partial dentures (FPDs). Of 50 randomly selected patients, 34 subjects carrying 43 FPDs agreed to participate in a clinical and radiographic follow-up examination. The FPDs were divided into three groups on the basis of prosthesis design (end abutments, unilateral cantilever, and bilateral cantilevers) and amount of supporting tissues at the time of bridge installation. Seventy per cent of the FPDs were found to be unchanged, whereas the rest had been modified due to various complications leading to extraction of one or more of the abutment teeth. Six FPDs (14%) had been partially replaced by FPDs anchored to osseointegrated dental implants. A total of 21 (8%) of the original 274 abutment teeth had been extracted. Longitudinal changes in the amount of periodontal support were minimal over the average of 15 years of follow-up. FPD design or initial amount of supporting tissues was found not to have significant influence on longitudinal changes in periodontal conditions. It was concluded that combined periodontal and prosthodontic treatment of patients with advanced loss of periodontal support may provide a high rate of long-term successful outcome, provided proper adequate periodontal and prosthetic treatment and maintenance care are given.
☐ *Cantilever; implants, dental; outcome study; periodontitis; radiography*

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The biologic capacity of a reduced but healthy periodontium to successfully support a fixed bridge construction has been demonstrated in several studies (1–4). The results presented in these studies have shown that the limiting criteria for fixed bridge reconstructions to function successfully in patients with few abutment teeth and a reduced amount of periodontal support is primarily related to biophysical and technical factors and to the maintenance of healthy periodontal tissues rather than to the amount of periodontal support per se.

An evaluation of the literature with regard to the survival rate of fixed partial dentures (FPDs) shows that both the rate and the time of failures vary considerably (2, 4–9). One of several reasons accounting for this variability may be that the studies have involved patients with various degrees of periodontal destruction, and consequently, the conditions for an optimal crown retention and design of the metal framework and soldered joints for sufficient rigidity may vary among the patients. However, common observations are that failures i) will increase with time, ii) are more common in cantilever constructions, and iii) occur more frequently in patients treated by general practitioners than in patients treated at a specialist clinic.

Factors of particular importance for the long-term success of the prosthetic rehabilitation in periodontally compromised dentitions are i) proper treatment of the periodontal lesions and ii) maintenance of a healthy periodontium (2, 4). If proper attention is given to periodontal treatment, even patients with marked tooth hypermobility can be successfully restored with FPDs to provide an adequate functional capacity (10, 11). In addition, in situations with unfavorable distribution of the remaining periodontium and highly mobile abutment teeth, the dental arch often has to be lengthened unilaterally or bilaterally to balance the load, thereby preventing tilting movements (10). The response of the supporting tissues to loading in dentitions restored with FPDs with or without cantilever extensions has been discussed in several recent publications (8, 12, 13). The information contained in the papers referred to, together with that of some other recent publications (14–16), shows that the use of FPDs is a valuable alternative to removable partial dentures and implant-supported bridge constructions, with regard to both chewing ability and aesthetics.

Table 1. Distribution of the fixed partial dentures (FPDs) in the responding subjects with three groups of FPD design at the time of installation

FPD design	No. of FPDs	Years in service, mean (range)	Age of patients (1993), years, mean (range)
Group 1	12	14 (10–21)	65 (50–75)
Group 2	14	15 (12–25)	68 (50–81)
Group 3	17	15 (10–22)	67 (53–80)

Group 1: bilateral end abutments; group 2: unilateral cantilever units; and group 3: bilateral cantilever units.

The aim of the present retrospective study over a period of more than 10 years was to evaluate the periodontal conditions at abutment teeth supporting FPDs with a cross-arch design in patients with periodontally compromised dentitions.

Materials and methods

Fifty patients were randomly selected from a group of about 200 patients treated for advanced destructive periodontal disease and rehabilitated with FPDs of cross-arch design. The treatment was performed between 1967 and 1983 at a specialist clinic in Göteborg, Sweden.

A detailed description of the therapeutic procedures used has been reported previously (2, 17). After the active therapy all patients were enrolled in an individually designed maintenance care program including recalls to a dental hygienist at least once yearly. The recall protocol included evaluation of oral hygiene, periodontal conditions, and caries incidence, reinforcement with regard to self-performed oral hygiene, and scaling and root planing when indicated. When problems were encountered that could not be managed by the dental hygienist, the patients were referred to the dentist who had performed the periodontal/prosthetic therapy.

Thirty-four of the 50 randomly selected patients agreed to take part in a clinical follow-up examination in 1993. A total of 43 cross-arch FPDs had originally been placed in the participating patients—that is, 9 individuals had FPDs in both jaws. For the 16 other patients data were available from case records and radiographs made 1–3 years before the scheduled follow-up. The cross-arch FPDs were divided into three groups (Table 1) on the basis of design (18): group 1: abutment teeth present bilaterally at the distal termination of the FPDs; group 2: one side only with an end abutment (unilateral cantilever units); and group 3: no end abutments (bilateral cantilever units).

Examinations

The follow-up examination involved clinical and radiographic examinations of all abutment teeth. Radiographs were taken using the technique described by Eggen (19).

Clinical variables

The following variables were assessed at the mesial, buccal, distal, and lingual aspects of the abutment teeth:

Oral hygiene condition: presence/absence of plaque deposits after disclosure with erythrosin (Diaplac Rondell®, Astra, Sweden).

Gingival conditions (gingival bleeding score): gingival bleeding after probing of the orifice of the gingival crevice (20).

Probing pocket depth (PPD): measured with a calibrated periodontal probe (0.5 mm in diameter and 1-mm increments). Only pockets with a depth of $\geqslant 4$ mm were recorded. Bleeding after pocket probing was also determined.

In addition, increased *mobility of the FPD* was assessed in accordance with a modification of the tooth mobility index described by Nyman & Lindhe (21): degree 1: FPD mobility of 0.2–1 mm in any direction; degree 2: FPD mobility of 1–2 mm in any direction; and degree 3: FPD mobility exceeding 2 mm in any direction.

Radiographic variables

Radiographs taken at the time of installation of the FPDs and on the day of follow-up examination were analyzed. For the 16 non-responding patients, radiographs taken 1–3 years before the time of the follow-up examination were available for evaluation and included in the analysis.

Bone support (BS): the amount of alveolar bone support, expressed as percentage of the total root length, was registered. The radiographs were placed on an illuminated digitizer table (CalComp 91365, Digitizer Products Division, Scottsdale, Ariz., USA), and by means of a cursor, equipped with a magnifying lens ($\times 2.5$), the mesial and the distal marginal bone level and the apex of each root were identified. A measuring application program (Status XR, AEC, Göteborg, Sweden) based on AutoCAD (Autodesk Inc., USA) was used to assess the linear distance between the bone crest and the apex, at both the mesial and distal surface of the root. The measurements were repeated three times, and a mean value for each tooth was calculated. To calculate the amount of alveolar bone support in relation to the original root length, data for mean root length (22) were used.

Total and dental unit periodontal ligament area (PDL-T and PDL/DU): By using the calculated bone support (BS) values, the total periodontal ligament area of the abutment teeth was determined for each FPD, using the data of Jepsen (23). PDL-T was divided by the number of abutments to calculate PDL/DU.

Periodontal support index (PSI): According to Ante's rule (24) that 'the total periodontal membrane area of

Table 2. Description of the number of abutments and pontics in the three groups on the basis of fixed partial denture (FPD) design at the time of installation

FPD design	No. of bridge units, mean (range)	No. of abutments, mean (range)	No. of pontics, mean (range)	Ratio (abut./pont.), mean (range)	No. of cantilever pontics, mean (range)
Group 1 ($n = 12$)	12.4 (10–14)	6.3 (5–8)	5.6 (4–8)	1.3 (0.5–1.7)	–
Group 2 ($n = 14$)	11.7 (10–13)	5.9 (4–10)	4.9 (2–7)	1.5 (0.5–2.7)	2 (1–3)
Group 3 ($n = 17$)	10.7 (10–12)	5.3 (3–7)	5.2 (3–8)	1.2 (0.3–2.1)	3 (2–4)

Table 3. Periodontal status at the follow-up examination in the three groups on the basis of partial fixed denture (FPD) design. Percentage distribution of findings at four sites for each abutment tooth

FPD design	Oral hygiene condition, mean (SD)	Gingival bleeding score, mean (SD)	Pockets $\geq$ 4 mm, mean (SD)	Pockets with BoP*, mean (SD)
Group 1 ($n = 12$)	6 (7)	6 (8)	8 (9)	4 (6)
Group 2 ($n = 14$)	4 (4)	1 (2)	4 (8)	5 (7)
Group 3 ($n = 17$)	6 (9)	4 (6)	3 (5)	4 (6)

* Bleeding following pocket probing.

the abutment teeth should equal or exceed that of the teeth to be replaced', the ratio between the total remaining periodontal ligament area of the abutments and the total, maximal periodontal ligament area (23) of the replaced teeth was calculated (3).

Data analysis

The data on longitudinal change in the amount of supporting tissues were analyzed with regard to i) the design of FPDs and ii) the amount of periodontium at the time of bridge installation. A one-way analysis of variance (ANOVA; $p < 0.05$) was performed to test the statistical significance of the differences. The data were initially divided also on the basis of age (less or more than 70 years old at the follow-up examination) and gender, but since no statistically significant differences were found, the data were pooled in the analyses. When a significant difference was detected by the analysis of variance, a post hoc test (Sheffe F) was applied to identify significant differences between various subgroups.

Results

The FPDs had been in service for a mean of 14–15 years in all three subgroups of bridge design (Table 1). Of the 43 FPDs evaluated in the 34 patients participating in the follow-up examination, 23 (53%) were placed in the maxilla and 20 (47%) in the mandible. The FPDs had an extension at the time of installation which ranged from 10 to 14 units (Table 2). The mean number of abutment teeth in the 3 subgroups on the basis of bridge design was 5.3–6.3, whereas the average number of pontics was 4.9–5.6. On the average, the cantilever extensions (groups 2 and 3) included two to three pontics. The mean ratio between the number of abutments and pontics at the time of installation varied between 1.2 and 1.5 in the three subgroups.

At the follow-up examination all responding patients had well-functioning fixed prostheses. Only four of the FPDs showed mobility (degree 1).

The data describing the periodontal conditions at the follow-up examination are reported in Table 3. The variables describing the standard of self-performed oral hygiene (percentage plaque-harboring surfaces and bleeding gingival units) showed low mean values ($\leq$6%). Sites with probing pocket depth of $\geq$4 mm were observed at a frequency of 3–8% at the abutment teeth in the three groups of FPD design. No pocket exceeding 6 mm was recorded, and only a few sites showed bleeding after pocket probing (4–5%).

The calculated data for total periodontal ligament area (PDL-T) and per dental unit (PDL/DU), on the basis of the data from all the 50 randomly selected patients, are reported in Table 4. At time of bridge installations the remaining periodontal ligament area was on the average 1167 mm^2, which corresponded to 42.6% of the totally possible PDL area for the reconstruction. The PDL-T value decreased by 87–107 mm^2 over the observation period, resulting in a mean reduction of about 7 mm^2 per year. The PDL/DU value decreased by 6–8 mm^2, which corresponds to a decrease of 2–3% in BS during the 14–15 years of observation. Hence, the mean amount of reduction in PDL/DU area did not exceed 0.5 mm^2/year in any of the groups. The analysis (ANOVA) of change in supporting tissues with

Table 4. Periodontal ligament area (PDL, in mm^2) in the three groups on the basis of fixed partial denture (FPD) design. Means (SD) at installation (Install) and follow-up examination (Reexam) and changes over time (Δ) and per year (Δ/year)

		PDL total				PDL/dental unit			
FPD design	No. of FPDs	Install	Reexam	Δ	Δ/year	Install	Reexam	Δ	Δ/year
Group 1	22	1358 (344)	1261 (423)	−98 (156)	−7.4 (12.3)	175 (41)	169 (45)	−8 (13)	−0.5 (1.1)
Group 2	17	1203 (362)	1097 (353)	−107 (137)	−7.3 (8.6)	168 (31)	164 (40)	−6 (8)	−0.4 (0.6)
Group 3	20	926 (286)	840 (89)	−87 (129)	−6.1 (8.2)	166 (37)	159 (39)	−7 (18)	−0.4 (1.3)
Total	59	1167 (374)	1071 (411)	−96 (140)	−7.0 (9.9)	170 (36)	164 (41)	−7 (14)	−0.5 (1.1)

regard to FPD design failed to show any statistically significant differences between the groups ($p > 0.05$).

The calculated periodontal support index (PSI) varied from 0.3 to 2.5 at the time of the bridge installation in the present patient sample. The FPDs were therefore divided into 3 subgroups on the basis of the initial PSI value (Table 5): 'Unsafe' (PSI < 0.7; $n = 19$), 'Intermediate' ($0.7 \leqslant$ PSI < 1.0; $n = 11$), and 'Safe' (PSI $\geqslant$ 1.0; $n = 29$). The data showed a greater annual change in PDL-T for the Intermediate and Unsafe groups than for the Safe group ($p < 0.05$). However, analysis of longitudinal changes in supporting tissues did not show any statistically significant differences ($p > 0.05$) when excluding the abutment teeth that had been extracted (PDL/DU values; Table 5). The only statistically significant difference found with regard to annual change in PDL/DU values for the PSI grouping was for the FPDs with end abutments (group 1): Unsafe > Safe ($p < 0.05$).

Thirty (70%) of the 43 original FPDs were unchanged at the time of the follow-up examination, while 13 had been modified owing to various complications leading to extraction of one or several abutment teeth. A total of 21 (8%) of the original 274 abutments had been extracted during the 14–15 years of follow-up: 9 teeth in group 1 and 6 teeth each in groups 2 and 3. The reasons accounting for extractions of abutment teeth were root caries (2 teeth), endodontic complications (7 teeth), and root fracture (1 tooth) (Fig. 1), whereas 11 teeth of 6 FPDs (1 in group 1 (= 4 teeth), 2 in group 2 (= 2 teeth), and 3 in group 3 (= 5 teeth)) had been extracted as a consequence of fracture of the metal framework and the subsequent decision to replace the failing part of the original FPDs with implant-supported bridge segments (Fig. 2). Except for the cases in which fracture of the framework occurred, the extractions had been performed without altering the original extension of the FPDs (Fig. 1).

Discussion

Success and failure of oral rehabilitation are not clearly defined in the dental literature. In patients with periodontally compromised dentitions the treatment outcome is undoubtedly successful if, at follow-up examinations, the periodontal tissues are healthy and the originally inserted FPD is stable and functions well. This was true for 70% of this series of FPDs in the clinically examined patients.

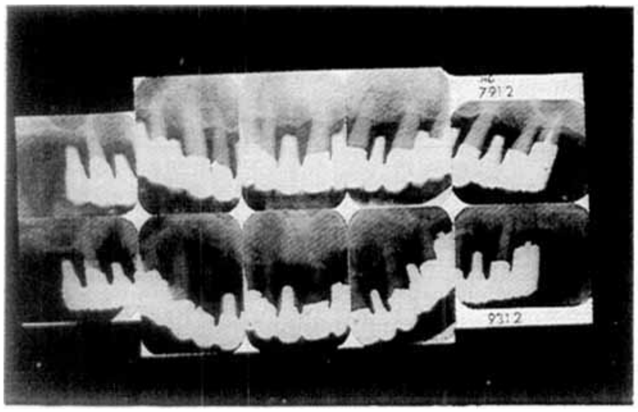
When some complications had occurred, necessitating extraction of one or two abutment(s) but not reduction of the extension of the FPD, the outcome can also be considered satisfactory if such a modified FPD remains stable and functions well. Seven (16%) of the clinically examined patients (= FPDs) belonged to this category in this series. Hence, 86% of the originally inserted FPDs were still in function at the follow-up

Table 5. Mean (SD) change in total periodontal ligament area (PDL-T, in mm^2) and per dental unit (PDL/DU, in mm^2) with regard to periodontal support index (PSI) in the three groups of fixed partial denture (FPD) design

	Group by PSI†: Unsafe ($n = 19$)				Intermediate ($n = 11$)				Safe ($n = 29$)			
	Change of PDL-T		Change of PDL/DU		Change of PDL-T		Change of PDL/DU		Change of PDL-T		Change of PDL/DU	
Group by design	Δ	Δ/year	Δ	Δ/year	Δ	Δ/year	Δ	Δ/year	Δ	Δ/year	Δ	Δ/year
Group 1	−256* (169)	−21.2* (14.0)	−18 (13)	−1.6* (1.2)	−48 (55)	−4.3 (5.1)	−6 (7)	−0.5 (0.6)	−37 (96)	−2.0 (6.9)	−3 (12)	−0.1 (0.7)
Group 2	−58 (98)	−3.5 (5.7)	−5 (5)	−0.3 (0.3)	−181 (127)	−13.0 (8.1)	−7 (5)	−0.6 (0.4)	−84 (154)	−5.6 (9.1)	−7 (10)	−0.4 (0.8)
Group 3	−73 (81)	−5.2 (5.3)	−4 (20)	−0.2 (1.6)	−241* (203)	−16.1* (11.8)	−20 (25)	−1.3 (1.6)	−16 (43)	−1.6 (3.8)	−2 (7)	−0.2 (0.6)
All	−128 (150)	−9.9* (11.6)	−8 (17)	−0.7 (1.4)	−179* (155)	−12.6* (9.5)	−12 (16)	−0.8 (1.0)	−45 (106)	−2.9 (7.0)	−4 (10)	−0.2 (0.7)

* Statistically significant difference ($p < 0.05$) compared with Safe.

† Unsafe group, PSI < 0.7; Intermediate, $0.7 \leqslant$ PSI < 1.0; Safe, PSI $\geqslant$ 1.0.



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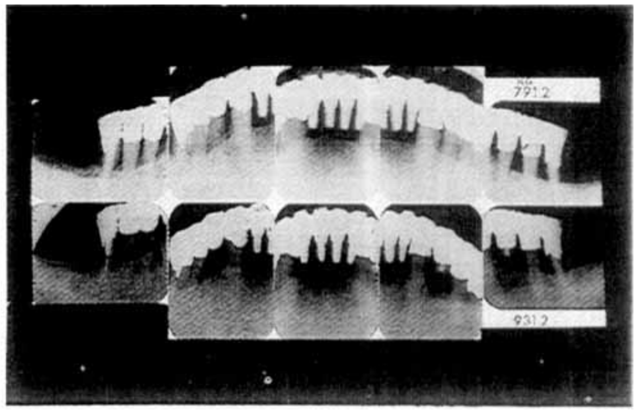

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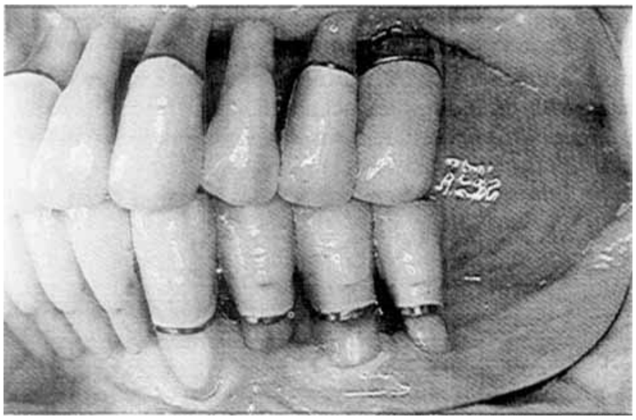

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Fig. 1. Radiographs of fixed partial dentures (FPDs) showing the situation in 1979 (5 years after installation) (A) and in 1993 (B). During this time the remaining root of tooth 26 had been removed (endodontic reason), as had the root of tooth 34 (endodontic reason). The remaining part of these dental units were redesigned to serve as pontics. 1C. Clinical view of left side at the follow-up (1993).

examination after an average time of 15 years. In fact, the six other patients also had stable fixed prostheses at the follow-up examination, but with some part of the original reconstruction replaced by a dental implant-supported FPD. In these patients the originally inserted FPDs had functioned 11–14 years without complications.

The 50 patients examined were randomly selected from a group of about 200 patients subjected to combined periodontal and prosthetic treatment owing to advanced tissue destruction in the dentition. A subsequent comparison between radiographs taken at the time of installation of the FPDs and in the beginning of the nineties—10–20 years later—it was obvious that the great majority of the subjects of the original group, who had not been selected for the follow-up examination, also belonged to the same category as those participating in this study.

When the long period of service is taken into consideration, these results are impressive and compare favorably with those reported in other long-term studies (4, 5, 7, 9, 25). However, in this comparison it is important to emphasize that in the present study the FPDs were inserted in patients with severely compromised dentitions from a periodontal point of view and that more than two-thirds (72%) of the FPDs had cantilever designs. It has been reported that the failure rate is much higher in FPDs with cantilevers than in those with end abutments (6, 7). In an evaluation of patients treated by general practitioners, Karlsson (7) found an overall failure rate of 26% for FPDs after 14 years in service, but the failure rate increased from 12% for restorations with end abutments to 36% for those with cantilever extensions. On the other hand, more favorable results have been presented for patients treated in specialist clinics, even when the fixed constructions included cantilever segments (2, 4). An extensive discussion on explanations of this difference was recently published by Lundgren & Laurell (26). They emphasize particularly the special requirements for the design of the FPDs with cantilever segments and the importance of proper handling of the periodontal tissues. The patients involved in the present study were treated in accordance with the concepts presented by Lundgren & Laurell (26), and the results give strong support to their suggestions. Furthermore, an important finding in our study, involving patients treated in a specialist clinic, is the lack of influence over time of FPD design (cantilever or not) or amount of periodontal support at the time of insertion of the FPD on changes in sup-

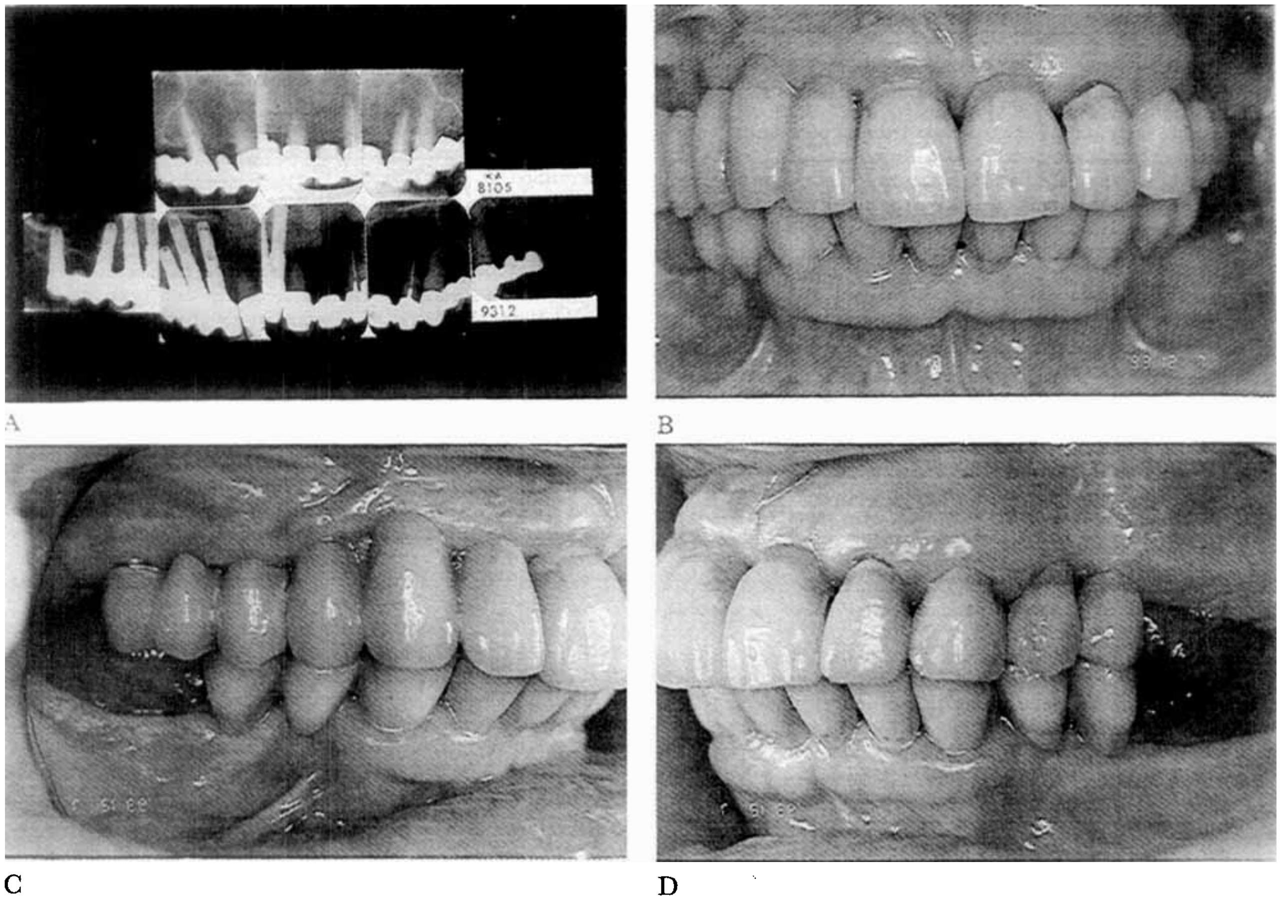

Fig. 2. Radiographs (2A) of a fixed partial denture showing the situation in 1981 and in 1993. Tooth 13 was extracted because of a root fracture, and the FPD was hemisectioned. After healing, four implants were placed in the first quadrant to serve as abutments for an implant-supported bridge reconstruction extending from 16 to 12. 2B–D. Clinical view at the follow-up (1993).

porting tissues. However, as discussed above, a strict recall program for maintaining a high standard of plaque control and an adequate design of the fixed prosthesis (2–4, 26) may be the factors that positively influenced the long-term outcome of the rehabilitation. Periodontal health was maintained in the present series of patients by a regular recall maintenance program offered to all patients and an excellent self-performed plaque control. In addition, the occlusion pattern of the FPD was regularly checked and, when indicated, adjusted by selective grinding to reduce the risk of unfavorable loading. The treatment regimen was thus as effective in the longer perspective of 14–15 years as in previously reported studies over shorter periods of time (5–8 years (2) or a mean of 8 years (4)).

Although periodontal problems were extremely rare during the follow-up period, some other complications occurred. These were partly of a biomechanical nature and partly of a biologic nature, with endodontic problems being most frequent. A detailed analysis and discussion of the significance of occlusal and restorative factors for the outcome of the treatment in our patient material will be presented in a separate communication.

In conclusion, the patients examined had a high rate of successful long-term outcome of the combined periodontal and restorative treatment, despite an initially advanced loss of periodontal support. The change in periodontal tissue support was minimal during an average of 15 years of follow-up and was not influenced by the design of the FPD (end abutments or cantilevers) or the amount of remaining supporting tissues.

Hence, provided proper maintenance care is given, the amount of periodontal support, within a reasonable limit, cannot be considered a decisive factor in the prediction of the capability of a tooth to serve as an abutment for fixed prosthodontics.

References

1. Lundgren D, Nyman S, Heijl L, Carlsson GE. Functional analysis

of fixed bridges on abutment teeth with reduced periodontal support. J Oral Rehabil 1975;2:105–12.
2. Nyman S, Lindhe J. A longitudinal study of combined periodontal and prosthetic treatment of patients with advanced periodontal disease. J Periodontol 1979;50:409–14.
3. Nyman S, Ericsson I. The capacity of reduced periodontal tissues to support fixed bridgework. J Clin Periodontol 1982;9:409–14.
4. Laurell L, Lundgren D, Falk H, Hugoson A. Long-term prognosis of extensive polyunit cantilevered fixed partial dentures. J Prosthet Dent 1991;66:545–52.
5. Öwall B, Cronström R, Rene N. Prosthodontic claims in the Swedish patient insurance scheme. Acta Odontol Scand 1992; 50:365–74.
6 Randow K, Glantz PO, Zöger B. Technical failures and some related clinical complications in extensive fixed prosthodontics. Acta Odontol Scand 1986;44:241–55.
7 Karlsson S. Failures and length of service in fixed prosthodontics after long-term function. Swed Dent J 1989;13:185–92.
8 Strub JR, Linter H, Marinellow CP. Rehabilitation of partially edentulous patients using cantilever bridge: a retrospective study. Int J Periodontol Res Dent 1989;9:365–75.
9 Glantz PO, Nilner K, Jendresen MD, Sundberg H. Quality of fixed prosthodontics after 15 years. Acta Odontol Scand 1993;51: 247–52.
10. Nyman S, Lindhe J, Lundgren D. The role of occlusion for the stability of fixed bridges in patients with advanced periodontal disease. J Clin Periodontol 1975;2:53–66.
11. Lundgren D, Laurell L. Occlusal force pattern during chewing and biting in dentition restored with fixed bridges of cross-arch extension. II. Unilateral posterior two-unit cantilevers. J Oral Rehabil 1986;13:191–203.
12. Landolt A, Lang NP. Erfolg und Misserfolg bei Extensionsbrücken. Schweiz Monatsschr Zahnmed 1988;98:239–44.
13. Isidor F, Budtz-Jørgensen E. Periodontal conditions following treatment with distally extending cantilever bridges or removable partial dentures in elderly patients. A 5-year study. J Periodontol 1990;6:21–6.
14. Budtz-Jørgensen E, Isidor F. A 5-year longitudinal study of cantilevered fixed partial dentures compared with removable partial dentures in a geriatric population. J Prosthet Dent 1990;64:42–7.
15. Carlson BR, Yontchev E, Carlsson GE. Extensive fixed partial dentures on mandibular canine teeth: a 5-year recall study. Int J Prosthodont 1989;2:265–71.
16. Carlson BR, Carlsson GE, Helkimo E, Yontchev E. Masticatory function in patients with extensive fixed cantilever prostheses. J Prosthet Dent 1992;68:18–23.
17. Lindhe J, Nyman S. The effect of plaque control and surgical pocket elimination on the establishment and maintenance of periodontal health. A longitudinal study of periodontal therapy in cases of advanced disease. J Clin Periodontol 1975;2:67–79.
18. Körber K. Zahnärztliche Prosthetik. Vol. II. Stuttgart: Georg Thieme Verlag, 1975:33–7.
19. Eggen S. Standardiserad intraoral röntgenteknik. Sveriges Tandlakareforb Tidn 1969;17:867–72.
20. Ainamo J, Bay I. Problems and proposals for recording gingivitis and plaque. Int Dent J 1975;25:229–35.
21. Nyman S, Lindhe J. Examination of patients with periodontal disease. In: Lindhe J, editor. Textbook of clinical periodontology. 2nd ed. Copenhagen: Munksgaard, 1989:10–22.
22. Wheeler RC. An atlas of tooth form. 4th ed. Philadelphia: Saunders, 1969.
23. Jepsen A. Root surface measurement and a method for X-ray determination of root surface area. Acta Odontol Scand 1963; 21:35–46.
24. Ante I. The fundamental principles of abutments. Mich State Dent Soc Bull 1926;8:14–23.
25. Erpenstein H, Kerschbaum Th, Fischbach H. Verweildauer und klinische Befunde bei Kronen und Brücken-eine Langzeitstudie. Dtsch Zahnaerztl Z 1992;47:315–19.
26. Lundgren D, Laurell L. Biomechanical aspects of fixed bridgework. Periodontol 2000 1994;4:23–40.

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