A 20-Year Retrospective Survival Study of Fixed Partial Dentures

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Purpose: This study of fixed partial dentures (FPDs) evaluated the long-term efficacy and determined frequencies and causes of failures. ***Materials and Methods:*** A total of 322 FPDs in 193 patients, fabricated at an undergraduate university clinic, were evaluated over a 20-year period. All patients were invited to participate in a supportive maintenance program. Failures of the FPDs were divided into irreversible complications (loss of FPD/abutment) and reversible complications (FPD intact after conservative treatment) and into biologic and technical/patient-related failures. ***Results:*** The Kaplan-Meier survival rate after 20 years was 66.2%. Statistically significant differences in survival rates were found between FPDs without post-and-core abutment teeth as compared to FPDs with at least one post-and-core abutment tooth ($P = .002$) and for vital abutments versus post-and-core abutments ($P = .001$), but significant differences were not found between restorations in the maxilla and mandible ($P = .27$). Caries and loss of retention were the main reasons for failure and accounted for 61% of the failures. ***Conclusion:*** The survival of FPDs by undergraduate students at a university clinic during a 20-year period was comparable to the results published by university departments or general practitioners. Occurrence of a previously reversible complication is a predictive factor for an irreversible complication later on. A reversible complication within the first 2 years will probably lead to an early irreversible complication. *Int J Prosthodont 2006;19:143–153.*

Restoring and replacing teeth with fixed partial dentures (FPDs) represents an important activity in dental practice, mainly because of the continuing high prevalence of caries and periodontal diseases in the adult and geriatric populations. Fixed prosthodontics is expensive because of the long chair time and the time-consuming laboratory procedures. Therefore it is important to ask whether this treatment option is accessible to all of our patients or if a conventional removable partial denture should remain a feasible alternative.[1,2]

Longitudinal studies that aim at measuring the lifespan of FPDs and at determining causes of failure are relatively uncommon in comparison to other topics in prosthodontics.[3] However, only with this kind of study is it possible to monitor the pattern and the rate of possible changes and to ascertain specific causes of failure. Conclusions drawn should provide clinicians and their patients with valuable prognostic information.[4] Analysis of failures and deterioration of dental restorations is important for the selection of materials and patients to improve clinical procedures.

The literature on the survival of fixed prosthetic restorations is based on 2 methodologic pathways. The longitudinal studies aim to measure the lifespan of

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the FPDs and determine the causes of failures in a certain timeframe. Studies that combine the 2 methodologic features, giving relevant information on biologic and technical failures and complications, are scarce.

Most publications[4–16] show a mean lifespan for FPDs of nearly 95% after 5 years, nearly 90% after 10 years, and approximately 65% survival after 15 years of function.

More difficult is the comparison of data on the survival of FPDs after 18 to 23 years.[17–22] Creugers et al,[23] Scurria et al,[24] and Tan et al[25] reported in their meta-analyses on conventional FPDs the need for standardization of the terminology and the consequent use of scientific rules in the design of the studies.

Only a few surveys have been carried out on dental school patients, examining the longevity and failures of FPDs.[26,27] There are hardly any studies in which data are collected for such restorations when placed by undergraduate dental students.[10,18,22,28]

Therefore, the aim of this retrospective study was to evaluate the long-term survival of prosthetic rehabilitation with FPDs and to determine frequencies and causes of failures of these restorations.

Materials and Methods

All FPDs made over a period of 20 years—between 1974 and 1992—in the undergraduate clinic of the former Department of Fixed Prosthodontics and Periodontology, University of Ghent, were included in this study. A total of 397 FPDs were made during that period. Cantilevered FPDs were not included in the present study. Complete treatment and follow-up records of 193 patients (62% women and 38% men) with 322 FPDs were available for analysis, representing 81% of the total number of FPDs made. Dropouts (19%) were caused by the following reasons: patients chose a private practitioner for maintenance, moved to another city, could not be traced, or died during the follow-up period. None of the patients in the dropout group were contacted by telephone, and no questionnaires were sent to them or to former or current clinicians of these patients to collect supplementary information.

The FPDs consisted of porcelain-fused-to-gold or gold retainers. Retainers in the visible (anterior) region were always covered with porcelain. Retainers on molars were gold or porcelain-fused-to-gold restorations, depending on the esthetic choice of the patient or the technical preference of the practitioner. In the posterior region, most retainers had a supragingivally located margin. For esthetic reasons, the retainer margin in the anterior region was located at the gingival margin. All impressions were made with a polyether material (Impregum, Espe). All posts and cores were casted in gold alloy and made separately from the retainer. No posts and cores made with a direct buildup technique were included in this study. Additional parapulpal pins to increase retention were not used. All FPDs were cemented with zinc phosphate (Harvard, Richmond Harvard). Approval was given for the protocol of this study, project EC UZG 2005/100, by the Ethics Committee, OG 017, University Hospital, Gent, Belgium.

After finishing prosthetic treatment, all patients were invited to participate in a regular supportive maintenance program every 6 months. During these maintenance sessions, a number of diagnostic and therapeutic steps were undertaken. The diagnostic interventions included: the whole-mouth plaque score with a dichotomous reading after staining (PI), bleeding on gentle probing of the gingival sulcus (BOP), periapical radiographs, recording of new caries lesions or secondary caries, control of the retention of the restoration, and mechanical failures. Probing depth at 6 or 8 sites per tooth was recorded using a Michigan periodontal probe. In each session, patients were reinstructed in plaque control. If the interdental morphology allowed, cleaning with interproximal brushes or superfloss was instructed. At each session, plaque, supragingival calculus, and subgingival calculus were removed. Patients were scheduled for scaling and root planing in a later session if periodontal problems occurred. By adding together the probing depth, BOP, and presence of calculus, the authors calculated a Community Periodontal Index of Treatment Needs (CPITN) score.[29]

Failures were divided into biologic or technical/patient related and into reversible or irreversible complications. Caries, periodontal problems, fracture of the abutment tooth, and endodontic problems were considered biologic failures. Loss of retention, fracture of the framework/impaired esthetics, and removal of FPD for extension of a new fixed partial restoration were considered technical/patient-related failures. Failures were also designated as *irreversible* if the FPD or an abutment tooth were lost or *reversible* if recementation after loss of retention, endodontic treatment, or filling in of an abutment tooth resulted in continued FPD presence and function. A FPD could have a reversible complication but nevertheless end up in the surviving group at the final evaluation, or it could have a reversible complication followed by an irreversible complication thus ending up in the failing group.

Statistical Analysis

The survival estimation method of Kaplan and Meier[30] was used. The log-rank test was used to calculate statistical differences in survival functions for different groups.[31] The Wilcoxon matched-pairs signed-rank test was used for the comparison between the PI and

Table 1 Frequency Distribution of FPDs Per Patient and No. of FPDs Failed (1) or Surviving (0) Within the Same Patient

FPD/patient	No. of failures	No. of patients
1 (60.1%)	0	94
	1	22
2 (22.3%)	0	32
	1	8
	2	3
3 (9.8%)	0	9
	1	4
	2	5
	3	1
4 (6.2%)	0	4
	1	5
	2	1
	4	2
5 (1.6%)	0	1
	1	1
	3	1

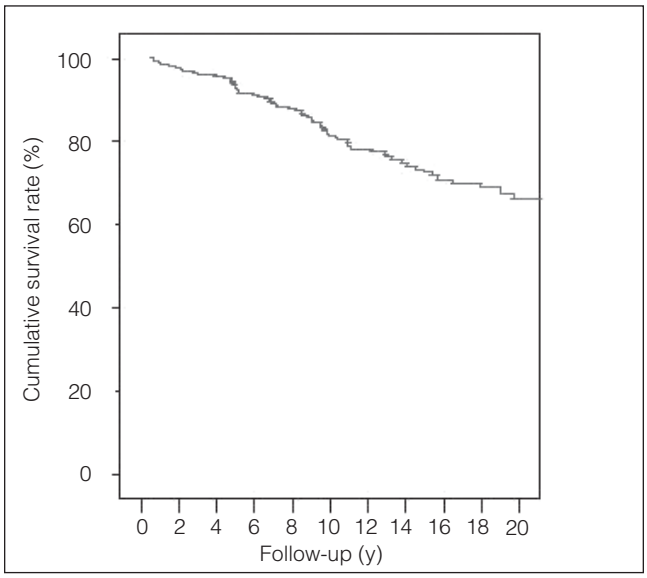

Fig 1 Kaplan-Meier survival curve (20 years) of all the restorations.

BOP versus failing or surviving restorations. The statistical significance of differences was calculated using a chi-square test. The significance level was set at $\alpha = .05$.

Results

Descriptive Data

The group of 322 investigated FPDs represents 81% of the total number of FPDs made in 193 patients with a mean age of 63 years (range, 33 to 94 years). The mean survival evaluation time was 11.4 years (range, 0.3 to 20 years). In this group, 39.1% (n = 126) of the FPDs were placed in the maxilla and 60.9% were placed in the mandible (n = 196). The frequency distribution of the number of FPDs per patient is shown in Table 1. In 60.1% (n = 116), the patients had 1 FPD, 22.3% (n = 43) of the patients received 2 FPDs, 9.8% (n = 19) of the patients had 3 FPDs made, 6.2% (n = 12) received 4 FPDs, and 1.6% (n = 3) had 5 FPDs made. This represented 1,308 fixed units, with a total of 704 retainers and 604 pontics. The mean number of units per FPD was 4.1 and the pontic/abutment ratio was 0.86. On average, 2.2 abutments and 1.9 pontics were made per FPD. Sixty-five percent of the abutment teeth were vital at time of preparation, whereas 35% had a casted post and core.

The group of FPDs with 2 abutment teeth represented 84.5% of FPDs; 12.4% of the FPDs consisted of 3 retainers, and 3.1% had 4 abutment teeth. Of the FPDs with 3 or 4 retainers, 10.5% had an intermediate abutment tooth and 5.0% included 2 retainers at the end.

The FPDs could be divided into 6 groups based on the number of pontics: 42.5% FPDs had 1 pontic, 37.3% had 2 pontics; the remaining 20.2% of FPDs had 3 pontics (11.5%), 4 pontics (7.8%), 5 pontics (0.6%), or even 6 pontics (0.3%). The distribution of the units per FPD was as follows: 41.6% were 3-unit FPDs, 31.7% were 4-unit FPDs, 12.1% were 5-unit FPDs, 10.9% were 6-unit FPDs, and 3.7% had 7 to 9 units.

The antagonists were the natural dentition in 57.1% of the patients, an FPD in 37.8%, and a complete denture or an edentulous space in 5.1%.

The patients' demand for treatment at the department was grouped in the following reasons: in 56% of the cases patients asked for a fixed prosthesis, after an extended period of partial edentulism, to restore their masticatory function. Twenty percent of the FPDs were made shortly after the extraction of a tooth (or teeth) because of periodontal problems, fracture, or an extensive caries lesion. Most patients preferred fixed restorations in the anterior and premolar area because of esthetic reasons. In 13% of patients, a malfunctioning FPD was replaced and in 11%, the reason for choosing a FPD was unknown.

Kaplan-Meier Survival Curves

The Kaplan-Meier survival curve of all the restorations is shown in Fig 1. After 20 years, 66.2% of the restorations were still surviving. The survival curves of all restorations by jaw location (maxilla versus mandible) are shown in Fig 2. After 20 years, 60.1% and 69.8%, respectively, of the restorations survived. There was no statistically significant difference between the survival

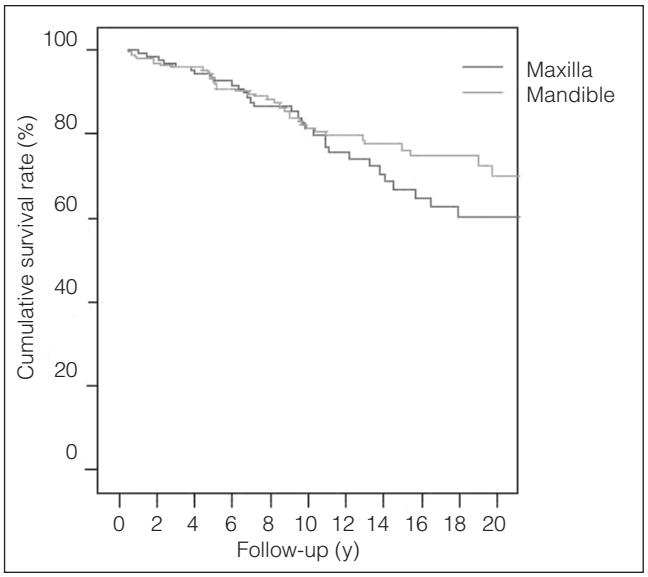

Fig 2 Kaplan-Meier survival curves of all restorations after 20 years, in the maxilla and the mandible ($P = .270$).

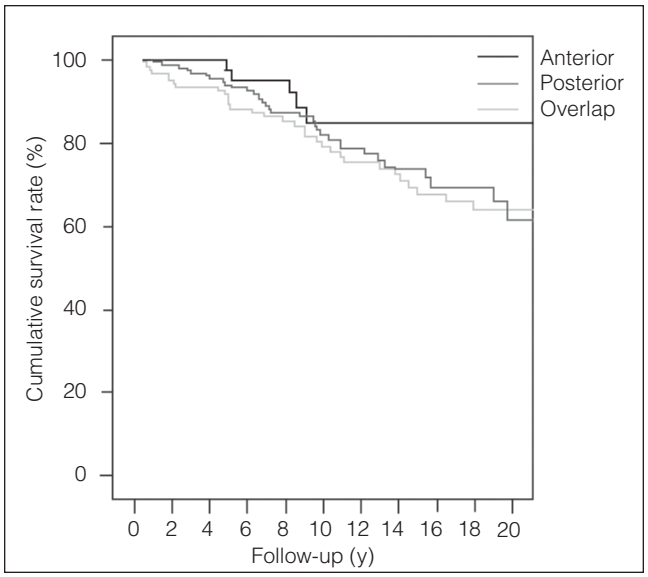

Fig 3 Kaplan-Meier survival curves of all restorations, in the anterior region, in the posterior region, and the overlap.

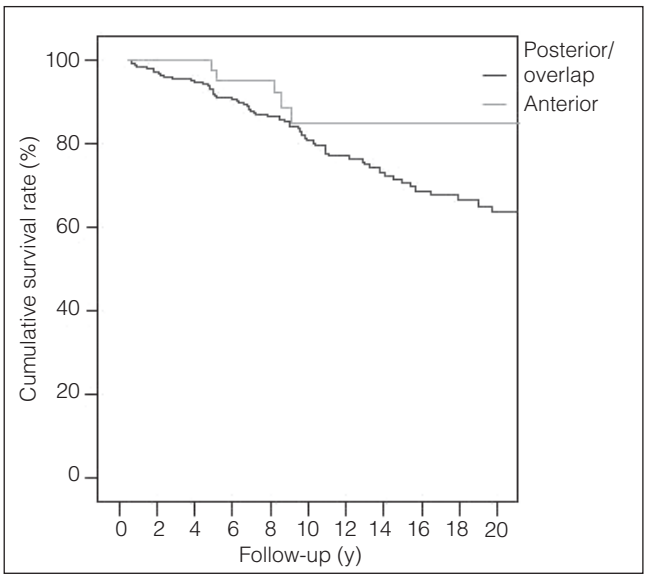

Fig 4 Kaplan-Meier survival curves of the restorations from the anterior group and of the restorations from the posterior/overlap group ($P = .075$).

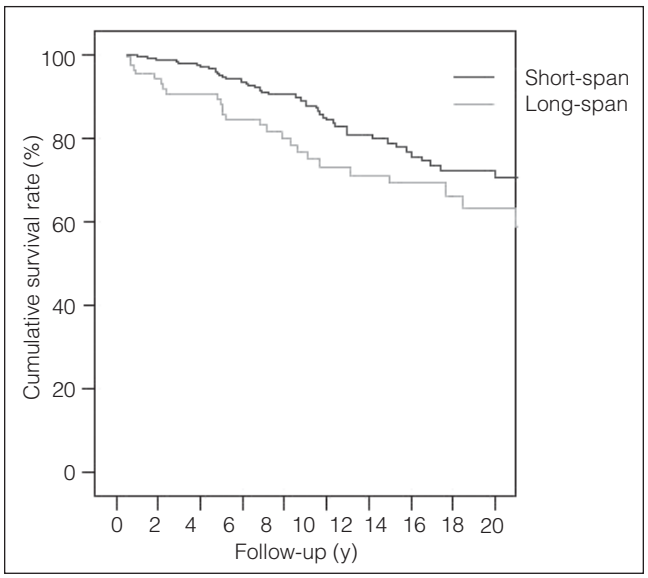

Fig 5 Kaplan-Meier survival curves for short-span FPDs (n = 3 or 4 units) versus long-span FPDs ($P = .030$).

of restorations in the maxilla or mandible (log-rank test; $P = .270$).

The survival curves of all restorations in the anterior region (incisors and canines) and the posterior region (premolars and molars) and FPDs with a canine as anterior abutment and a premolar or a molar as posterior abutment (overlap) are shown in Fig 3. In Fig 4, the latter 2 are grouped together into a posterior/overlap group. After 20 years, 85.0% of the restorations in the anterior region (n = 43) and 63.6% of the restorations in the posterior/overlap group (n = 279) were surviving. There was a nearly significant difference between groups ($P = .075$).

When the survival curves for short-span FPDs (n = 3 or 4 units) and long-span FPDs (n > 4 units) were compared, a statistically significant difference ($P = .030$) was found (Fig 5). The overall survival rate after 19 years for the short-span FPDs (n = 236) was 70.8%; for the long-span FPDs (n = 86) it was 58.7%.

In the mandible the survival rate for the short-span FPDs (n = 143) was 77.5% and for the long-span FPDs (n = 53) it was 60.3% (Fig 6). The difference was statistically

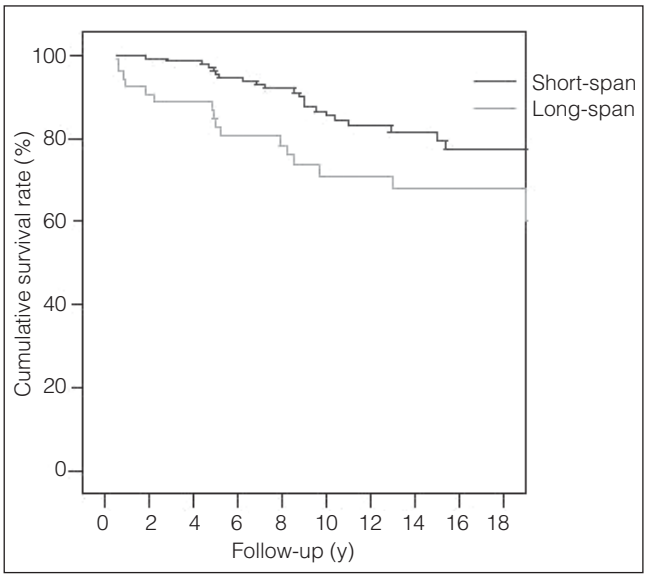

Fig 6 Kaplan-Meier survival curves in the mandible for short-span FPDs versus long-span FPDs ($P = .009$).

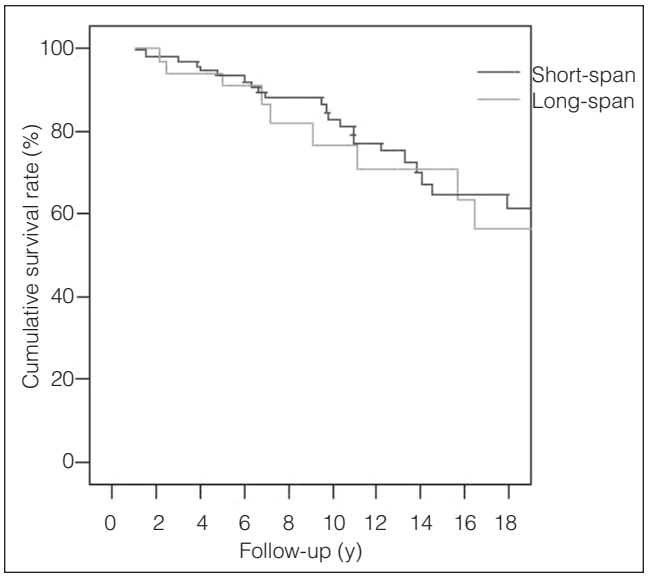

Fig 7 Kaplan-Meier survival curves in the maxilla for short-span FPDs versus long-span FPDs ($P = .671$).

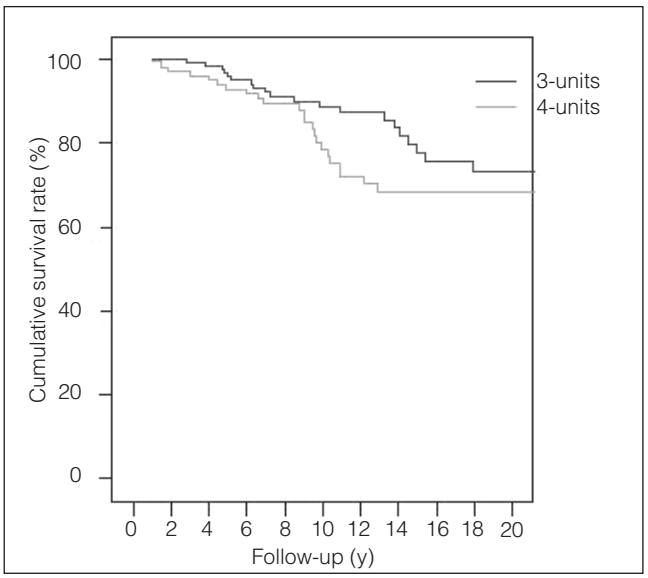

Fig 8 Kaplan-Meier survival curves for 3-unit versus 4-unit FPDs ($P = .140$).

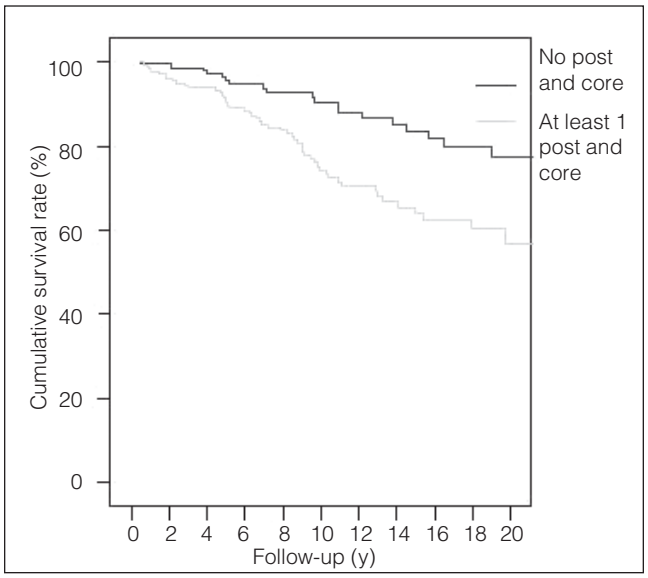

Fig 9 Kaplan-Meier survival curves for all restorations without post-and-core abutments (NPC) versus all the restorations with at least one post-and-core abutment (PC) ($P = .002$).

significant ($P = .009$). For survival in the maxilla, no statistically significant difference was found between short-span and long-span FPDs ($P = .671$). In the maxilla, the survival rate for the short-span FPDs (n = 93) was 61.2% and for the long-span FPDs (n = 33) was 56.5% (Fig 7).

There was no statistically significant difference ($P = .140$) in survival after 20 years between 3-unit and 4-unit FPDs. The survival rates were 73.1% (n = 134) and 68.3% (n = 102), respectively, as shown in Fig 8.

The effect of the presence of a post-and-core retainer on the survival of FPDs was studied at the abutment level and at the level of the FPD (Figs 9 to 13). At the abutment level, the effect of the use of a post-and-core abutment versus a vital abutment is shown in Table 2. There was a highly statistically significant difference in failure rates between the post-and-core abutment and the vital abutment ($P = .001$). Of the retainers cemented to a post-and-core–restored tooth, 30.6% failed, while only 18.9% of the retainers on a vital tooth failed. At the FPD level, the survival curves for all the restorations, after 20 years, without post-and-core abutments (NPC group, n = 142) versus all the restora-

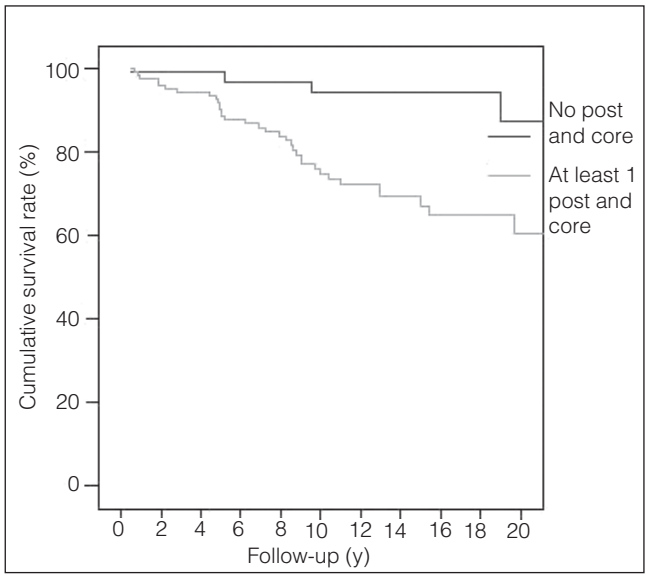

Fig 10 Kaplan-Meier survival curves for the "vital" FPDs (NPC) versus the FPDs with at least one post-and-core abutment (PC) in the mandible ($P = .001$).

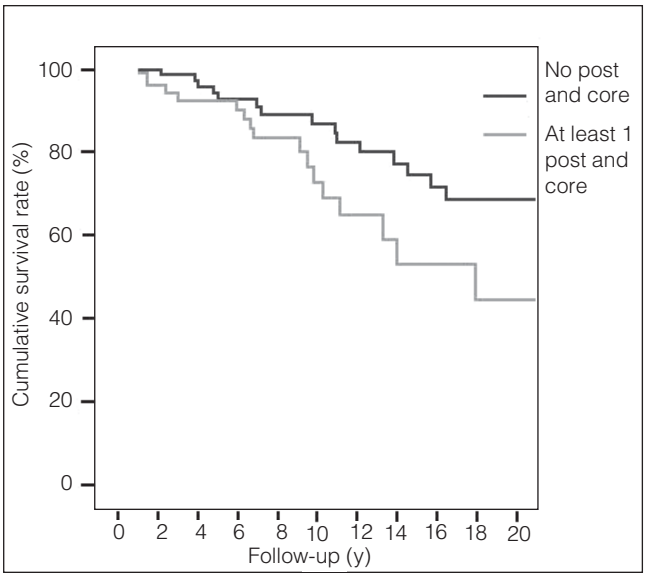

Fig 11 Kaplan-Meier survival curves for the "vital" FPDs (NPC) versus the FPDs with at least one post-and-core abutment (PC), in the maxilla ($P = .055$).

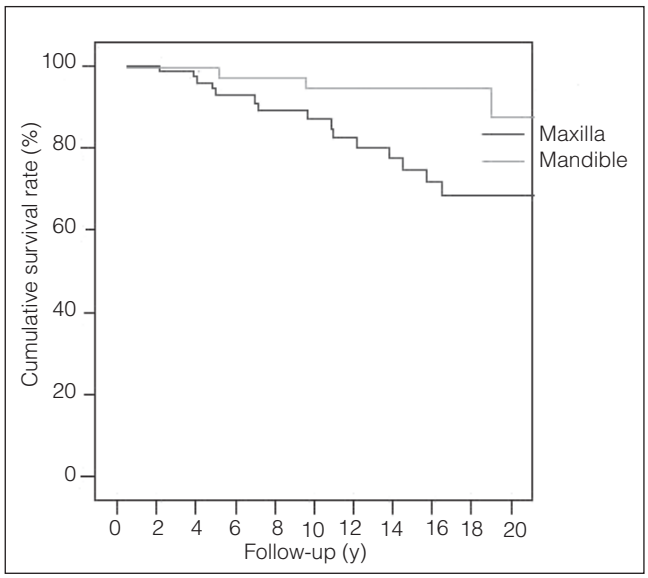

Fig 12 Kaplan-Meier survival curves for FPDs without post-and-core abutment: maxilla versus mandible ($P = .026$).

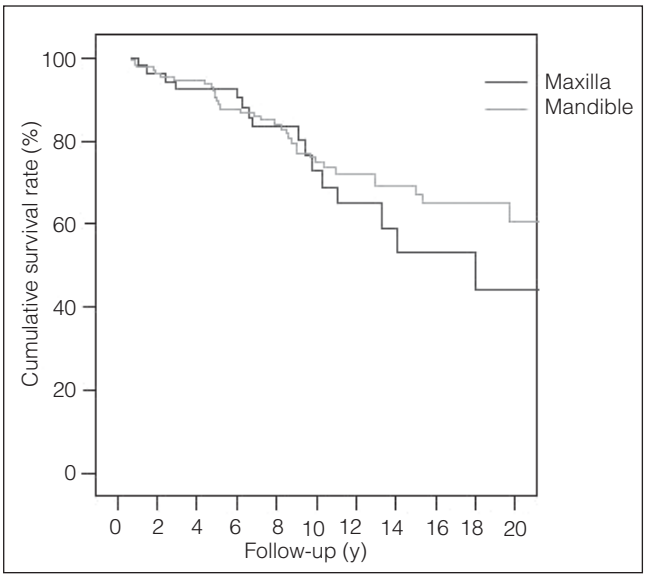

Fig 13 Kaplan-Meier survival curves for FPDs with at least one post-and-core abutment: maxilla versus mandible ($P = .382$).

tions with at least one post-and-core abutment (PC group, n = 180) is shown in Fig 9. For the NPC group, the survival rate was 77.4%, whereas for the PC group, the survival rate was 56.7%. The difference was statistically significant ($P = .002$).

In the mandible (Fig 10) the survival rate of the NPC group restorations (n = 69) was 87.6%, while for the PC group (n = 127) the survival rate was 60.1%; the difference was statistically significant ($P = .001$). For survival in the maxilla, there was a borderline missed significant difference between the NPC and PC groups ($P = .055$). The survival rate of the NPC group (n = 73) was 68.6%, while for the PC group (n = 53) the survival rate was 44.3% (Fig 11).

Considering only the NPC group (n = 142), the survival rate of the FPDs after 20 years in the mandible (n = 69) was 87.6% and in the maxilla (n = 73) was 68.6%, which is statistically significant different ($P =$

Table 2 Cross-Table: Post-and-Core Abutment or No Post-and-Core Abutment Versus Failure or Survival ($P < .001$)

Abutments	Surviving (%)	Failing (%)
Post and core	172 (69.4)	76 (30.6)
No post and core	370 (81.1)	86 (18.9)

Table 3 Cross-Table: Surviving Restorations Versus Failed Restorations, with Reversible Complication as Dependent Variable ($P < .001$)

	Reversible complication		
Irreversible complication	No (%)	Yes (%)	Total (%)
No	221 (88.4)	29 (11.6)	250 (100)
Yes	48 (66.7)	24 (33.3)	72 (100)

Table 4 Cross-Tabulation of CPITN at Time of Cementation Versus CPITN at Time of Re-evaluation for Surviving Restorations ($P = .237$)

	CPITN at time of re-evaluation		
CPITN at time of cementation	2 (%)	3 (%)	4 (%)
0–2	64 (56.6)	39 (34.5)	10 (8.9)
3	31 (38.8)	40 (50.0)	9 (11.2)
4	10 (47.7)	4 (19.0)	7 (33.3)

Table 5 Cross-Tabulation of CPITN at Time of Cementation and CPITN at Time of Failure ($P = .003$)

	CPITN at time of re-evaluation		
CPITN at time of cementation	2 (%)	3 (%)	4 (%)
0–2	16 (50.0)	14 (43.8)	2 (6.2)
3	2 (11.8)	12 (70.6)	3 (17.6)
4	0 (0)	2 (50.0)	2 (50.0)

.026) (Fig 12). The survival after 20 years of the PC group (n = 180) in the mandible (n = 127) is 60.1%, in the maxilla (n = 53) is 44.3% but is not statistically significant different ($P = .382$) (Fig 13).

Reasons for Failure

The most common reason for irreversible complication (failure) was caries (22.2%). Loss of retention was the cause of 15.3% of failures. For another 23.6%, both caries and loss of retention were observed at the same time. Fracture of the framework and impaired esthetics (including fracture of porcelain) accounted for 18.1%, and abutment fracture occurred in 8.3%. Progressive periodontal problems were, in 4.2% of the cases, the reason for failure. Abutment fracture, progressive periodontal disease, and caries were the most common reasons for removal of the abutment and the FPD. Three percent of the FPDs had to be removed for the extension of a new FPD. Only 2.9% of the total failures were caused by endodontic problems. In 2.4% of cases, the reason for failure was unknown.

The mean lifespan for the FPDs lost because of caries was 11.6 years, and it was 7.35 years when loss of retention was the reason for failure.

Table 1 shows the number of FPDs made in the present studied group and the number (irreversible complication) failing or surviving within the same patient, independent of the number of pontics per FPD. Remarkably, in 4 of the 193 patients (2%), 14 of the 72 FPDs failed, which is 19.4% of the total failure rate. Half the failures in this group of 4 patients were biologic and another 50% were of mechanical origin. Of the total population of 193 patients, only 53 patients (27.5%) had one or more failing FPD(s).

Table 3 presents a cross-tabulation of the surviving restorations versus the failing restorations, with reversible complication as dependent variable. Of the surviving restorations, only 11.6% had a reversible complication, which means that there was loss of retention and/or caries or pulpal problems, but the FPD could be recemented without failure of the abutment teeth, the preparation margin, or the FPDs. In the failing group, 33.3% had a reversible complication. Occurrence of a previous reversible complication is a predictive factor for irreversible complication later on. This is highly statistically significant (Table 2; $P < .001$). These reversible complications were divided into *early reversible complications* (failure within 2 years) and *late reversible complications* (failure later than 2 years). For the failing restorations, the mean survival time of

the early reversible complication group was 5.6 years, while the mean survival time of the late reversible complication group was 11.2 years. This difference was highly statistically significant ($P = .002$).

Periodontal Factors

The oral hygiene (PI) and gingival conditions (BOP) of the crowned (abutment) teeth were recorded. The mean PI and BOP at placement for the surviving restorations were 34.6% and 22.8%, respectively. For the failing restorations, the mean PI was 32.9% and the BOP 22.4%; these were comparable with the surviving restoration group. The Wilcoxon test revealed that, for the failing restoration group, the PI ($n = 38$; $P = .683$) and the BOP ($n = 39$; $P = .329$) at the time of cementation were not significantly different compared to PI and BOP obtained at the time of failure. For the surviving restorations, however, the PI was significantly different ($n = 176$; $P = .001$), but the BOP was not ($n = 179$; $P = .765$).

Finally, the CPITN of the FPDs at time of cementation were compared with those obtained at the time of evaluation (Table 4) or time of failure (Table 5). For the surviving restorations (Table 4), 56.6% of the patients with CPITN score from 0 to 2 at baseline had the same score at evaluation time, 34.5% got worse, and 8.9% deteriorated to CPITN group 4. Of the patients with a CPITN score of 4 at baseline, 47.7% improved to scores from 0 to 2, and 19% improved to a CPITN score of 3. This means that the majority of patients with low periodontal treatment needs (CPITN 0 to 2) at baseline did not have greater treatment need at the time of re-evaluation. About 48% of the CPITN 4 group improved remarkably during the follow-up period. The differences were not statistically significant ($P = .237$).

For the failed restorations (Table 5), the results for the 0-to-2 group were similar. In the CPITN 3 group, 70.6% had the same score at the time of failure and 11.8% improved, but 17.6% got worse. For the CPITN 4 group, 50% remained at CPITN 4 and 50% shifted to CPITN 3, but none improved to the first group (CPITN score of 0 to 2). The differences were statistically significant ($P = .003$).

Discussion

Comparison of clinical follow-up studies of FPDs is difficult because of variations in study designs, in the material being examined, and in the mean survival follow-up periods. In these studies, prosthetic treatments have been carried out by general practitioners or by senior undergraduate students, in a specialized clinic or a dental school, by numerous clinicians, or by one operator. Some researchers pooled FPDs and cantilevered FPDs,[5,17,20,22] whereas others did not specify whether cantilevered FPDs were included in their material. Results of a study of cantilevered FPDs were published by Decock et al[32] and are not included in the present study, because the inclusion of research groups of 2 different treatment modalities—conventional FPDs and cantilevered FPDs—would give a misrepresentation of the results. The results of the study of cantilevered FPDs (60% after 18 years) were less favorable, and the mean survival evaluation time (6 years) was not comparable to that of the present study (11.4 years).

Another reason that studies cannot be directly compared is that authors often vary in their definition of failure; even on the main reason for failure there is no agreement.[17,24,25,33] Whereas mechanical problems are, in general, more directly under influence of the clinician, biologic problems are less easily controlled and in some instances unrelated to the prosthetic treatment. Biologic problems may be a consequence of treatment procedures (pulpal problems), or they may be influenced by the form and gingival relation of the restorations (secondary caries, gingivitis, or periodontal destruction). In comparing the studies on FPDs published between 1980 and 1994[4,5,8,11,12,17] with more recent literature (published between 1995 and 2004[13,15,16,18–22,34]), few differences in the comments on the methodology of the compared studies, the composition of the studied groups, and the groups of practitioners performing the FPDs are mentioned. The majority of the reports comment on randomization or lack thereof, data collection methods, or unacceptably high dropout levels. Nevertheless, the results of this 20-year survival retrospective study are comparable to those of recently published studies[17–20] but differ from the studies of Glantz et al,[21] Walton,[15] and Holm et al.[22]

There is an important difference between the number of fixed units per FPD and the pontic/abutment ratio; it results in a lower or higher functional strain, which is believed to be related to technical failures.[11] Most of the (serial) studies based on the Swedish National Dental Insurance Program[5,7,8,11] report high mean numbers of units per FPD but low pontic/abutment ratios, meaning a high number of abutment teeth are used in the replacement of a small number of missing teeth. In the present study the mean number of units per FPD was low (4.1), but the pontic/abutment ratio was high (0.86). This accounts for a low number of abutment teeth replacing an equal number of missing teeth.

In the present study the main reasons for failure were caries and loss of retention (61.1%). The failure rate owing to caries was 22.2%; the failure rate owing to loss of retention was 15.3%. In addition a third group, in which caries and loss of retention were

grouped because the main reason could not be determined with certainty, the failure rate was 23.6%. This result is comparable to the results of other studies, which had caries as the main cause of failure.[3,5,10,18,19,22,35] In their earlier studies, Karlsson[8] and Glantz et al[11] found caries to be the most important reason for failure. Palmqvist and Swartz[17] and most of the studies based on the Swedish National Dental Insurance Program, except for the Randow et al study,[5] found loss of retention (50%) to be the main cause of failure.[4] If caries was detected, it was assumed to be a secondary problem caused by the loose retainer. It remains difficult to differentiate these complications from each other.

Combining the items on pontic/abutment ratio and main reason of failure, reveal the hypothesis that the lower this ratio (ie, the more abutment teeth for an equal replacement of missing teeth), the higher the percentage of loss of retention, sometimes in combination with a low percentage of caries (mean lifespan for caries in this study was 11.6 years, in contrast to 7.5 years for loss of retention). More retainers in function increase the risk of loss of retention and, sometimes, loss of the FPD. This type of FPD is more prone to failure because of the fact that the alignment of multiple tooth preparations is difficult and may result in excessive taper, which will jeopardize retention. These FPDs are technically more difficult to fabricate and to fit with accuracy.[33] Zidan and Ferguson[36] concluded that the difference in retention of crowns was significant between 6-degree or 12-degree tapers and a 24-degree taper. Foster[37] stressed the fact that when more retainers are used for a FPD, the lifespan is shorter.

Several authors have reported on the frequency and reasons for failure and estimated the mean lifespan of FPDs. Walton et al,[38] Foster,[39] and Valderhaug[10] concluded that the mean lifespan with caries as reason of failure was between 8.4 and 12 years, and for loss of retention the mean lifespan was between 4.5 and 9 years. These results are in agreement with the results of this study. The mean lifespan with caries as the reason for failure was 11.6 years, and for loss of retention the mean lifespan was 7.5 years. The hypothesis that loss of retention is the main cause of failure in prosthetic reconstructions with a low pontic/abutment ratio could elucidate the fact that in these studies, caries seems not to be the major problem owing to the longer mean lifespan when caries causes failure.

In the present study the influence of root canal–treated abutments was studied on 2 different bases: at the abutment level and at the FPD level. For both levels the outcome is similar: the use of an abutment with a cast post and core leads to statistically significantly more failures of the FPDs. These results are comparable to recently reported data[15,22,40] and are comparable but not always statistically confirmed in others[17,18] or even statistically significantly different.[13,19]

In the present study, failures were divided into 2 groups: irreversible complications (total failure) and reversible complications. A FPD could have a reversible complication but nevertheless end up in the surviving group, or it could have a reversible complication followed by an irreversible complication, thus ending up in the failing group. The occurrence of a reversible complication seems to have a predictive value for irreversible complication later on. The mean survival time of the early ($<$ 2 years) reversible complication group was 5.6 years, while the mean survival time of the late ($>$ 2 years) reversible complication group was 11.2 years. To our knowledge, this has not yet been published in another survival study, but it is confirmed by the same authors in a survival study on full crowns.[41]

The improvement of the PI between baseline and evaluation time was statistically significantly correlated to survival. This result is comparable to that in the above-mentioned paper on the survival of full crowns and is related to the results of the CPITN cross table for failing restorations. The importance of a well-maintained population[10] has to be stressed, but there was no statistical evidence in this study to support this conclusion. This result confirms the interrelationship between periodontal health and the survival of prosthetic reconstructions. Fixed restorations should not be performed without prior thorough periodontal examination and prophylactic or periodontal treatment.

Fracture of the framework and impaired esthetics (with fracture of porcelain) accounted for 18.1% of failures. According to the study of Coornaert et al,[42] it is clear that this type of technical failure becomes more frequent with time. The FPDs studied in the present group consisted only of porcelain-fused-to-gold or gold pontics and retainers. In a systematic review on FPDs in 2004,[25] 7 of the 19 studies reported on the FPD design; only 11.6% were metal-ceramic, whereas the others were of gold–acrylic resin design. This distribution in part reflects that there are few studies with long follow-ups of recent FPD design.[25]

Conclusions

This retrospective study of FPDs fabricated in a university clinic by undergraduate students showed a mean survival rate of 66.2% for a 20-year period. This is comparable to most of the data recently reported in other studies. There was no statistically significant difference between the maxilla and the mandible, but there was a statistically significant difference between FPDs without post-and-core abutments as compared with restorations with at least one post-and core-abutment and there was also a statistical significant dif-

ference for the vital abutments versus the post-and-core abutments. For the NPC group, a statistically significant difference was found for the mandible as compared to the maxilla. In the mandible there was a statistically significant difference between short-span FPDs and long-span FPDs and between the NPC group and the PC group. In the maxilla there was no statistically significant difference between short-span and long-span FPDs, but there was a borderline statistically significant difference between the NPC and PC groups. Caries and loss of retention were the main reasons for failure; in combination these causes were responsible for 61% of failures. The mean lifespan with caries as the reason for failure was 11.6 years, and with FPDS that lost retention the mean lifespan was 7.5 years. More retainers in function may increase the risk for loss of retention and, sometimes, loss of the FPD. Occurrence of a reversible complication seems to have a predictive value for an irreversible complication later on. A reversible complication within the first 2 years will probably lead to an early irreversible complication, with a mean survival rate of 5.6 years. PI and BOP were not directly related to failures; however, for the surviving restorations improvement in PI over time was statistically significant.

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References

1. Palmqvist S. Ideas about the future of prosthodontics. Int J Prosthodont 2000;13:80–81.
2. Klineberg I. Ideas about the future of prosthodontics. Int J Prosthodont 2000;13:81–82.
3. Goodacre C, Bernal G, Rungcharassaeng K, Kan J. Clinical complications in fixed prosthodontics. J Prosthet Dent 2003;90:31–41.
4. Karlsson S. Failures and length of service in fixed prosthodontics after long-term function. Swed Dent J 1989;13:185–192.
5. Randow K, Glantz P-O, Zöger B. Technical failures and some related clinical complications in extensive fixed prosthodontics. Acta Odontol Scand 1986;44:241–255.
6. Kerschbaum T, Gaa M. Longitudinale Analyse von festsitzendem Zahnersatz privatversicherter Patienten. Dtsch Zahnärztl Z 1987;42:345–351.
7. Ödman P, Karlsson S. Follow-up of patients with bridge constructions performed by private dental surgeons and at a university clinic, 8 years following insertion. J Oral Rehabil 1988;15:55–63.
8. Karlsson S. A clinical evaluation of fixed bridges, 10 years following insertion. J Oral Rehabil 1986;13:423–432.
9. Kerschbaum T, Paszyna C, Klapp S, Meyer G. Verweilzeit- und Risikofaktorenanalyse von festsitzendem Zahnersatz. Dtsch Zahnärztl Z 1991;46:20–24.
10. Valderhaug J. A 15-year clinical evaluation of fixed prosthodontics. Acta Odontol Scand 1991;49:35–40.
11. Glantz P-O, Ryge G, Jendresen M, Nilner K. Quality of extensive fixed prosthodontics after five years. J Prosthet Dent 1984;52:475–479.
12. Glantz P-O, Nilner K, Jendresen M, Sundberg H. Quality of fixed prosthodontics after 15 years. Acta Odontol Scand 1993;51:247–252.
13. Leempoel P, Käyser A, Van Rossum G, De Haan A. The survival rate of bridges. A study of 1674 bridges in 40 Dutch general practices. J Oral Rehabil 1995;22:327–330.
14. Walter M, Reppel P-D, Böning K, Freesmeyer W. Six-year follow-up of titanium and high-gold porcelain-fused-to-metal fixed partial dentures. J Oral Rehabil 1999;26:91–96.
15. Walton T. An up to 15-year longitudinal study of 515 metal-ceramic FPDs: Part 1. Outcome. Int J Prosthodont 2002;15:439–445.
16. Walton T. An up to 15-year longitudinal study of 515 metal-ceramic FPDs: Part 2. Modes of failure and influence of various clinical characteristics. Int J Prosthodont 2003;16:177–182.
17. Palmqvist S, Swartz B. Artificial crowns and fixed partial dentures 18 to 23 years after placement. Int J Prosthodont 1993;6:279–285.
18. Sundh B, Ödman P. A study of fixed prosthodontics performed at a university clinic 18 years after insertion. Int J Prosthodont 1997;10:513–519.
19. Valderhaug J, Jokstad A, Ambjornsen E, Norheim W. Assessment of the periapical and clinical status of crowned teeth over 25 years. J Dent 1997;25:97–105.
20. Lindquist E, Karlsson S. Success rate and failures for fixed partial dentures after 20 years of service: Part 1. Int J Prosthodont 1998;11:133–138.
21. Glantz P-O, Nilner K, Jendresen M, Sundberg H. Quality of fixed prosthodontics after twenty-two years. Acta Odontol Scand 2002;60:213–218.
22. Holm C, Tidehag P, Tillberg A, Molin M. Longevity and quality of FPDs: A retrospective study of restorations 30, 20, and 10 years after insertion. Int J Prosthodont 2003;16:283–289.
23. Creugers N, Käyser A, Van 't Hof M. A meta-analysis of durability data on conventional fixed bridges. Community Dent Oral Epidemiol 1994;22:448–452.
24. Scurria M, Bader J, Shugars D. Meta-analysis of fixed partial denture survival: Prostheses and abutments. J Prosthet Dent 1998;79:459–464.
25. Tan K, Pjetursson BE, Lang NP, Chan ES. A systematic review of the survival and complication rates of fixed partial dentures (FPDs) after an observation period of at least 5 years. III. Conventional FPDs. Clin Oral Implants Res 2004;15:654–666.
26. Schwartz NL, Whitsett LD, Berry TG, Steward JL. Unserviceable crowns and fixed partial dentures: Life-span and causes for loss of serviceability. J Am Dent Assoc 1970;81:1396–1401.
27. Nyman S, Lindhe J. A Longitudinal study of combined periodontal and prosthetic treatment of patients with advanced periodontal disease. J Periodontol 1979;50:163–169.
28. Näpänkangas R, Salonen M, Raustia A. A 10-year follow-up study of fixed ceramic prosthodontics. J Oral Rehabil 1997;24:713–717.
29. Ainamo J, Barmes D, Beagrie G, Cutress T, Martin J, Sardo-Infirri J. Development of the World Health Organization (WHO) community periodontal index of treatment needs (CPITN). Int Dent J 1982;32:281–291.
30. Kaplan EL, Meier P. Nonparametric estimation from incomplete observations. J Am Stat Assoc 1958;53:457–481.
31. Kalbfleish JD, Prentice RL. The Statistical Analysis of Failure Time Data. New York: John Wiley & Sons, 1980.
32. Decock V, De Naeyer K, De Boever JA, Dent M. 18-year longitudinal study of cantilevered fixed restorations. Int J Prosthodont 1996;9:331–340.
33. Selby A. Fixed prosthodontic failure. A review and discussion of important aspects. Aust Dent J 1994;39:150–156.

34. Söderfeldt B, Palmqvist S. A multilevel analysis of factors affecting the longevity of fixed partial dentures, retainers and abutments. J Oral Rehabil 1998;25:245–252.
35. Libby G, Arcuri M, LaVelle W, Hebl L. Longevity of fixed partial dentures. J Prosthet Dent 1997;78:127–131.
36. Zidan O, Ferguson G. The retention of complete crowns prepared with three different tapers and luted with four different cements. J Prosthet Dent 2003;89:565–571.
37. Foster L. The relationship between failure and design in conventional bridgework from general dental practice. J Oral Rehabil 1991;18:491–495.
38. Walton J, Gardner F, Agar J. A survey of crown and fixed partial denture failures: Length of service and reason for replacement. J Prosthet Dent 1986;56:416–421.
39. Foster L. Failed conventional bridgework from general dental practice: Clinical aspects and treatment needs of 142 cases. Br Dent J 1990;10:199–201.
40. Palmqvist S, Söderfeldt B. Multivariate analyses of factors influencing the longevity of fixed partial dentures, retainers and abutments. J Prosthet Dent 1994;71:245–250.
41. De Backer H, Van Maele G, De Moor N, Van den Berghe L, De Boever J. An 18-year retrospective survival study of full crowns with or without posts. Int J Prosthodont 2006;19:136–142.
42. Coornaert J, Adriaens P, De Boever JA. Long-term clinical study of porcelain-fused-to-gold restorations. J Prosthet Dent 1984;51:338–342.

Literature Abstract

In vitro microleakage of luting cements and crown foundation material

The purposes of this study were to *(1)* evaluate microleakage of zinc phosphate cement and resinous cement under ideal (dry) and contaminated (wet) conditions, and *(2)* compare the microleakage of foundations subjected to both ideal and contaminated conditions. One hundred forty intact, extracted, caries-free human molar teeth were mounted with autopolymerizing acrylic resin. A mesial surface Class II cavity preparation was prepared for each tooth. Seven restorative groups were formed. Silver amalgam with cavity varnish, silver amalgam with a dentinal bonding agent, and composite with a dentinal bonding agent were inserted under both ideal and contaminated conditions. The seventh group consisted of Class II cavity preparations without foundations. All groups were restored with type III gold crowns cemented with dry and contaminated zinc phosphate cement and dry and contaminated resin reinforced glass-ionomer cement. The teeth were sectioned mesiodistally and standard photomicrographs were made, and the microleakage on them was measured and digitized. Within the limits of this in vitro study, the following conclusions were drawn: *(1)* less leakage was observed with resin-reinforced glass-ionomer cement than with zinc phosphate cement; *(2)* the least microleakage was recorded under a crown foundation with silver amalgam or composite when a dentinal bonding agent was used in ideal conditions; and *(3)* an interaction was discovered between cements and crown foundation materials.

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