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Risk factors for failure of glass fiber-reinforced composite post restorations: a prospective observational clinical study

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Glass fiber-reinforced endodontic posts are considered to have favorable mechanical properties for the reconstruction of endodontically treated teeth. The aim of the present investigation was to evaluate the survival of two tapered and one parallel-sided glass fiber-reinforced endodontic post systems in teeth with different stages of hard tissue loss and to identify risk factors for restoration failure. One-hundred and forty-nine glass fiber-reinforced endodontic posts in 122 patients were followed-up for 5–56 months [mean ± standard deviation (SD): 39 ± 11 months]. Glass fiber-reinforced endodontic posts were adhesively luted and the core was built with a composite resin. Cox proportional hazards models were used to evaluate the association of clinical variables and failure rate. Higher failure rates were found for restorations of anterior teeth compared with posterior teeth [Hazard-Ratios (HR): 3.1; 95% confidence interval (CI): 1.3–7.4], for restorations in teeth with no proximal contacts compared with at least one proximal contact (HR: 3.0; 95% CI: 1.0–9.0), and for teeth restored with single crowns compared with fixed bridges (HR: 4.3; 95% CI: 1.1–16.2). Tooth type, type of final restoration and the presence of adjacent teeth were found to be significant predictors of failure rates in endodontically treated teeth restored with glass fiber-reinforced endodontic posts.

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There are many *in vitro* studies on various post materials in the scientific literature. However, owing to differences in experimental designs, these studies are not comparable, the results are often contradictory (1), and it remains questionable to what extent they are generalizable to the clinical situation. Some retrospective clinical studies show a relationship between the prognosis of postendodontic restorations and a variety of factors such as numbers of proximal contacts (2), occlusal contacts (3, 4), tooth position in the dental arch (5, 6), crown placement (7, 8) or type of abutment (5, 9). Even an influence of metal posts on the periodontal bone support (10), as well as on the apical status (11), has been stated. Whether or not the endodontic treatment *per se* affects the survival of restorations is controversial. Equivocal results have been reported regarding the moisture content of endodontically treated teeth compared with vital teeth (12, 13), and similar physical properties such as modulus of elasticity (Young's modulus), hardness or fracture strength have been observed (14). However, a retrospective study over 18 yr suggested that the endodontic treatment of abutment teeth increases the failure risk of cantilever bridges (9).

It is generally assumed that hard tissue loss owing to carious lesions, previous restorations or endodontic access determines the reduced load capacity of a restoration (15–19). Clinical trials on the effect of baseline characteristics, such as defect extension, on the prognosis of post-based postendodontic reconstructions are missing.

Few clinical studies have evaluated the survival of fiber-reinforced posts. For carbon-fiber posts, failure rates of 2% after 32 months (range 27–41 months) (20) and 5% after 4 yr (21) of clinical service have been found in retrospective clinical studies. In a prospective study, the overall failure rate was 7.7% (22) after 28 months (range 7–45 months) at risk. After a period of clinical service ranging from 1 to 6 yr, 3.2% of carbon- and glass-fiber posts failed in a retrospective clinical study (23). In a prospective clinical trial comparing a carbon fiber-reinforced endodontic post ($n = 16$) with a conventional gold alloy cast post and core ($n = 11$), a failure rate of 25% and 9%, respectively, was found (24). Another study found a 30-month failure risk of 1.7% for quartz-fiber posts (25). The only published randomized controlled trial of postendodontic restorations investigated the survival of endodontically treated premolars with mesial-occlusal-distal (MOD)-cavities restored by either full cast coverage or with direct composite restoration. The crown build-up was performed using a carbon-fiber post and composite core. The overall risk of failure after 3 yr was 13% (8). The results of these clinical studies show a wide range of survival rates for fiber-reinforced post restorations. The reasons for this heterogeneity are unknown and it is uncertain which factors determine the survival rate of fiber-reinforced post restorations.

The aim of the present prospective cohort study was to identify factors associated with the survival of glass-fiber posts with a parallel-sided and tapered shape in teeth with varying cavity configurations.

Material and methods

Patient selection, tooth selection, and study design

Between June 2000 and February 2002, patients visiting the department of prosthetic dentistry with a need of restoring endodontically treated teeth were registered and screened for participation by the principal investigator. As described previously (26), the following inclusion criteria had to be met by the patient or by the tooth to be restored: (i) symptom-free root canal filling with a minimum apical seal of 4 mm; (ii) no untreated advanced periodontitis; (iii) tooth mobility not more than degree 2 (27); and (iv) the subjects' willingness to return at regular intervals for evaluation. There were no exclusion criteria based on the amount of hard tissue loss prior to restoration, for example, all types of defect extensions, including large defects with just one surface for adhesion or with excessively flared orifices (28) of the root canal, were included. Decisions for the maintenance of teeth were made according to the quality guidelines of the European Society of Endodontology (29). Each subject gave written informed consent before entering the cohort, which was approved by the local ethical committee of the Charité, Humboldt-University of Berlin.

Variables, treatment, and review procedure

The following data were collected at the baseline examination: patient age and gender, the date of post insertion, tooth type, post diameter (in mm), number of proximal contacts (0, 1 or 2), type of antagonistic contact (periodontal support, no periodontal support, no antagonist), tooth mobility (yes/no), post length (in mm), numbers of surfaces providing adhesion for core build-up ($n = 1$–5), as well as the type of final restoration (single crown, bridge, combined fixed and removable). The functional status was determined by the degree of attrition (no attrition, degree I or more) (30). Over the course of the study, three types of posts were used consecutively. A tapered post (Luscent Anchors; Dentatus, Hägersten, Sweden) was placed in the first group of patients. This was followed by a parallel-sided post with a serrated surface configuration (FiberKor; Jeneric Pentron, Wallingford, CT, USA) and another tapered post (DentinPost; Komet, Gebr. Brasseer, Lemgo, Germany). Each of these was available in three sizes (coronal diameter 1.0, 1.25, or 1.5 mm). Adhesive post placement and composite build-up was performed according to the manufacturers' instructions. Details of the treatment protocol have been published previously (26). The final restorations were made by dental students of the dental clinic of Charité, Berlin, as part of their clinical training in prosthodontics, within 3 months after post placement.

Follow-up procedures

Post placement was considered as the baseline for the analysis of the present study. Time until failure or censoring (i.e. last follow-up examination) was recorded in months. Patients were recalled after 6 months, and thereafter at least yearly, for a clinical examination. Clinical evaluation of success or failure was performed by one examiner who was not the operator. Follow-up examinations were performed with a dental probe and mirror in order to detect marginal gap formation of the restorations. One year after restoration placement, a radiograph was taken to exclude the possibility of radiographic symptoms of failure such as, for instance, a periodontal lesion as a symptom of root fracture. A failure was defined as loss of post retention, a vertical or horizontal root fracture, post fracture, endodontic failure, changes in the treatment planning, as well as a failure of the core build up that required a new restoration.

Statistical analysis

For descriptive purposes, frequencies and percentages of measured baseline characteristics, as well as frequencies and percentages of different failure types, were tabulated (Table 1).

For the primary statistical analyses, time until any failure was the dependent variable. Kaplan-Meier survival plots were constructed for descriptive purposes. As the hazard rate appeared to be constant over time, we calculated the average annual failure rate (number of failures/tooth-yr*100%). Because the sample size, and in particular the number of failures, was limited from a statistical perspective, multiple categories of several variables were collapsed to reduce the number of parameters. To evaluate the association of baseline factors with restoration failure, Cox proportional hazards models were fit. To account for the clustering of posts within patients, robust standard errors based on the marginal approach were calculated (31). The appropriateness of the proportional hazards assumption was graphically assessed using log-log plots. Crude associations between baseline characteristics and time until failure were calculated by fitting separate models for each baseline characteristic as the independent variable. Factors associated with time until failure ($P < 0.4$) in these models were then entered in a multivariate model. We then separately entered each of the variables that were not included based on the crude association ($P = 0.4$) in the multivariate model and checked whether this changed any of the other coefficients substantially. In separate secondary analyses, teeth that required a revision of the endodontic treatment were not classified as failures, and post fractures (the most common type of failure) were analysed separately. Hazard-Ratios (HR) and two-sided 95% confidence intervals (CI) were derived from the regression coefficients of the Cox models using STATA 7.0 statistical software (STATA, College Station, TX, USA).

Results

A total of 157 posts were placed in 128 patients. No follow-up information could be collected for 8 posts (6 patients). Hence, 149 posts in 122 patients (53 men, 69 women) aged 15–98 yr [mean ± standard deviation (SD): 53 ± 15 yr] followed-up for 5–56 months contributed a total of 5,531 tooth-months of follow-up.

Table 1

Frequency, number of failures and tooth-time of teeth included in the study, as well as bivariate Cox proportional hazards regression analysis of time until failure by categories of each baseline characteristic

	Frequency (%)	No. of failures	Tooth-time (months)	HR	95% CI	*P*-value
Tooth type						
Premolars/molars	86 (58%)	11	3,329	1.0	Reference	
Incisors/canines	63 (42%)	20	2,202	2.8	1.3–6.2	0.008
Type of post						
DentinPost	54 (36%)	13	1,849	1.0	Reference	
FibreKor	48 (32%)	10	1,830	1.8	6.3–5.0	0.280
Luscent Anchors	47 (32%)	8	1,852	1.4	0.5–3.9	0.556
Post diameter						
1.0 mm	60 (40%)	14	2,181	1.0	Reference	
1.25 mm	52 (35%)	10	1,849	0.9	0.4–1.8	0.671
1.5 mm	37 (25%)	7	1,501	0.7	0.3–2.0	0.521
Number of proximal contacts						
1–2	133 (89%)	25	4,965	1.0	Reference	
None	16 (11%)	6	566	2.1	0.9–5.2	0.091
Final restoration						
Bridge	40 (27%)	3	1,568	1.0	Reference	
Single crown	79 (53%)	19	2,839	3.5	1.0–12.8	0.055
Combined fixed-removable	30 (20%)	9	1,124	4.3	1.1–17.1	0.041
Type of antagonistic contact						
Other	137 (92%)	27	4,614	1.0	Reference	
Periodontal supported	12 (8%)	4	917	1.3	0.4–5.0	0.676
Functional status						
No parafunction	78 (52%)	16	2,783	1.0	Reference	
Parafunction	71 (48%)	15	2,748	0.9	0.4–2.0	0.827
Tooth mobility (score)						
0	128 (86%)	28	4,763	1.0	Reference	
≥ 1	21 (14%)	3	768	0.7	0.2–2.3	0.523
Number of surfaces for adhesion						
> 2	40 (27%)	6	1,452	1.0	Reference	
1–2	109 (73%)	25	4,079	1.5	0.5–4.1	0.444
Post length						
< 10 mm	80 (54%)	18	2,915	1.0	Reference	
≥ 10 mm	69 (46%)	13	2,616	0.8	0.4–1.7	0.564

CI, confidence interval; HR, Hazard-Ratios.

We observed 31 failures, resulting in an average annual failure rate of 6.7%. Post fracture was the most frequent (n = 14, 45%), and loss of retention the second most frequent (n = 9, 29%), type of failure observed. In all of these cases, the tooth could be restored in the same manner as before. One vertical and two horizontal root fractures resulted in three fatal failures. The vertical root fracture occurred in the mesial root of a lower first molar, where the post had been placed in the distal root. Furthermore, 3 failures of the core were observed. Finally, two endodontic failures (one upper first molar and one lower second premolar) required access to the root canal for revision of the root canal filling. Failure rates appeared to be constant over time (Fig. 1).

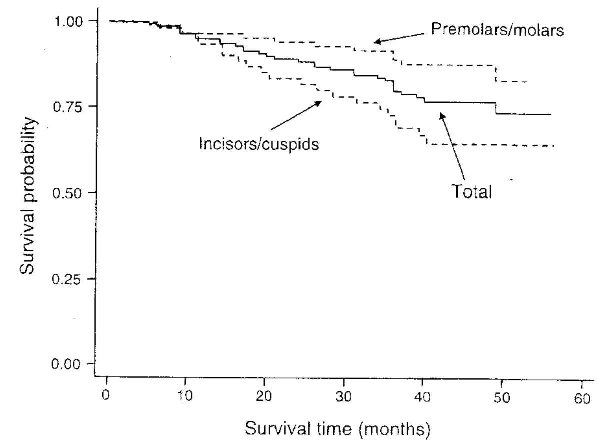

Fig. 1. Survival probabilities for the entire sample and by tooth type.

Crude analysis and multivariate model

Crude associations between the different baseline characteristics, and time until failure, are given in Table 1. Tooth type (incisors/canines compared with premolars/molars) was strongly associated with an increased failure rate, with an HR of 2.8 (95% CI: 1.3–6.2). In comparison with bridge restorations, combined fixed-removable partial dentures showed a significantly increased failure rate (HR = 4.3; 95% CI: 1.1–17.1; P = 0.041). Furthermore, lack of proximal contacts (HR = 2.1, 95% CI: 0.9–5.2, P = 0.091) and type of restoration (bridge vs.

Table 2

Multivariate Cox proportional hazards regression analysis of time until failure as a function of baseline characteristics, identified as described in the text

Multivariate model	All failures			Excluding endodontic failures		
	HR	95% CI	*P*-value	HR	95% CI	*P*-value
Tooth type						
Premolar/molar	1.0	Reference		1.0	Reference	
Incisor/canine	3.1	1.3–7.4	0.009	3.8	1.5–9.7	0.005
Restoration						
Bridge	1.0	Reference		1.0	Reference	
Combined	2.4	0.5–11.0	0.277	2.2	0.5–10.5	0.325
Single crown	4.3	1.1–16.2	0.033	3.9	1.0–15.1	0.050
Proximal contact						
Any	1.0	Reference		1.0	Reference	
None	3.0	1.0–9.0	0.051	3.1	1.0–9.5	0.043
Post type						
DentinPost	1.0	Reference		1.0	Reference	
Luscent Anchors	1.3	0.5–3.6	0.642	1.6	0.5–5.2	0.412
FibreKor	2.1	0.7–6.7	0.190	2.8	0.8–10.3	0.112

CI, confidence interval; HZ, Hazard-Ratios.

single crown: HR = 3.5, 95% CI: 1.0–12.8, $P = 0.055$) were associated with time until failure in crude analyses with borderline significance.

The results of the multivariate model, including tooth type, presence of proximal contacts, type of restoration, and post, are shown in Table 2. Compared with premolars and molars, restorations of incisors and canines had 3.1 (95% CI: 1.3–7.4) times higher failure rates.

Similarly, restorations in teeth with no proximal contacts had 3.0 (95% CI: 1.0–9.0) times higher failure rates than teeth with at least one proximal contact. Teeth that were restored with single crown restorations, or combined fixed-removable partial dentures, had 4.3 (95% CI: 1.1–16.2) and 2.4 (95% CI: 0.5–11.0) times higher failure rates than teeth with fixed bridges, respectively. Finally, compared with the tapered DentinPost, cylindrical serrated FibreKor posts tended to have higher failure rates (HR = 2.1; 95% CI: 0.7–6.7), although this was not statistically significant.

Restriction of the analysis to restorative failures (i.e. excluding endodontic failures) resulted in a somewhat higher estimate for the HR for tooth type (incisors/canines vs. premolars/molars) of 3.8 (95% CI: 1.5–9.7) as well as post type (e.g. FibreKor vs. DentinPost: 2.8; 95% CI: 0.8–10.3).

A separate analysis of post fractures yielded HR estimates similar to that of the full analysis. Finally, entering any other of the baseline variables to the multivariate model yielded very similar results.

Discussion

The present study investigated the influence of several baseline parameters on the survival of postendodontic restorations using fiber-reinforced posts. A total of 149 posts placed in 122 patients were restored according to a prosthodontic treatment plan and followed-up for 5–56 months. We found tooth type, type of final restoration, and presence of proximal contacts to be significant predictors of failure rates.

The glass fiber-reinforced composite posts inserted in the present study have become increasingly popular for the reconstruction of endodontically treated teeth. A wide variety of posts are available, which include parallel-sided, tapered, smooth, and serrated post geometries. Compared with other known post materials, such as carbon fibers, gold or other alloys and dental ceramics, the Young's modulus of glass-fiber posts is stated to be closer to that of dentin (structural compatibility), which is considered to be a major advantage of these systems (32, 33). It is thought that fiber posts flex under load and, as a result, distribute stresses between the post and dentine (34). This is expected to result in favorable clinical behavior (35, 36).

Restorations placed in incisors or canines had a failure rate about three times higher than that of restorations placed in premolars or molars. Restriction to restorative failures yielded an even higher HR as all endodontic failures occurred in posterior teeth, which is arguably unrelated to the reconstructive procedure (37). These findings may be explained by the higher horizontal forces causing tension stress acting on anterior teeth compared with a more perpendicular compressive force vector for posterior teeth. Fatigue fractures are caused by tension stress and not by compression (38). Therefore, the maxillary anterior region can be considered to be a high-risk area for technical failures, which is supported by other clinical studies (38). Most failures of postretained crowns occur in the maxillary anterior region (3, 39–41). A favorable prosthesis design may improve the survival of fixed prosthodontics, because non-axial forces are seen as the mean biomechanical factor for the fracture risk of compromised endodontically treated teeth (42).

The failure rate was three times higher for teeth with no proximal contact. This could be explained by a better stress relief as a result of support by neighboring teeth, while single-standing teeth might suffer under jiggling forces during chewing, leading to an early failure. These results are similar to previously published results, which describe a three times increased failure rate (rate of tooth loss) for endodontically treated teeth with less than 2 proximal contacts (2, 7, 43). Caplan and co-workers stated a protective effect of proximal teeth (44) because neighboring teeth may help to distribute occlusal forces (2).

Teeth restored with single crowns had four times higher failure rates than teeth restored with fixed bridges. Again, the explanation could be that, on single crowns, forces can still act in a vestibular-oral direction, even if two proximal contacts are present. The type of abutment (fixed partial denture superior to removable partial denture) has been shown to significantly impact the failure risk over 3 yr in a prospective clinical study of 154 endodontically treated teeth (5). In the present study, combined fixed-removable partial dentures had intermediate failure rates compared with single crowns and fixed bridges. The forces acting on abutment teeth of combined fixed-removable partial dentures during chewing and insertion/removal are expected to be higher than those acting on single crowns or bridges because of the leverage. However, most of the dentures in this category used precision attachments, and each abutment had to be composed of at least two teeth connected through a fixed bridge.

The post shape – tapered vs. a parallel-sided serrated shape – was not a statistically significant factor in the present study. However, the parallel-shaped serrated posts (FibreKor) had a failure rate that was almost three times higher than a tapered post system (DentinPost). Hence, we cannot rule out that the type of post may be an important determinant of the failure rate.

The major limitation of this study is a relatively small sample size and a small number of failures. Therefore, confidence intervals are wide and estimates have to be interpreted cautiously. Furthermore, the study is lacking power to detect moderate, yet clinically significant, relative risks. For example, our results indicate a trend for posts with larger diameters to be less likely to fail. This would make intuitive sense given that the majority of failures were post fractures. Similarly, the amount of hard tissue loss, measured as remaining surfaces for adhesion in this study, may be an important determinant of failure risk. Even with the relatively high failure rate observed in this study, much larger studies are necessary to evaluate such factors. For the example of hard tissue loss, assuming an HR of 1.5 and an annual failure rate of 6% among the unexposed group (> 2 surfaces for adhesion), an exposed/unexposed ratio of 2 : 1 (as found in the present study), and a follow-up for each subject of 5 yr (no loss to follow-up), one would have to enrol approximately 750 and 1000 subjects (assuming one tooth per subject) to have 80% and 90% power, respectively. This clearly illustrates that large, well-designed observational studies are necessary to further our knowledge of the determinants of success and failure of restorative procedures. Given the high number of restorative procedures performed in dental practice, the identification of a moderate modifiable risk factor that increases the failure rate by, for example, 50%, could have a large impact on a population level.

For logistic reasons, we did not randomize the allocation of teeth to different post types. However, the different posts were used consecutively and, hence, selection of post types was unrelated to tooth or patient-related criteria, which should minimize bias.

Compared with previous clinical studies on survival of fiber-reinforced post restorations (8, 20–25), the annual failure rate of 6.7%, as observed in the present study, is high. Although comparisons across studies are always difficult, the characteristics of our sample may explain these differences. Possible reasons include the fact that 59% of teeth had fewer than two proximal contacts and that the proportion of anterior teeth was relatively high (42%). By comparison, one previous study that reported that 13% of failures over 3 yr included only premolars with MOD-cavities (8).

There is a growing body of data from *in vitro* investigations suggesting that a 2-mm ferrule dramatically increases fracture resistance of post restorations (45–50). The load capacity is a function of the ferrule height (51). In the present study, a ferrule of 2 mm height was prepared whenever possible. However, we did not perform crown-lengthening procedures to ensure a ferrule in every case. Given the high proportion of teeth with little remaining tooth substance, the proportion of teeth with circumferential ferrules of at least 2 mm may, in fact, be low.

In conclusion, the results of the present study suggest that the risk of failure of glass fiber-reinforced post restorations is higher in anterior teeth. Furthermore, the number of proximal contacts and the type of final restoration are important determinants of restoration failures.

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