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Long-term survival of adhesively post-endodontically restored teeth

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Abstract

Introduction: The objective of this prospective clinical study was to investigate survival for endodontically treated teethrestored with adhesively luted prefabricated rather dentin-like or rigid posts.

Methods: Data were recorded for glass-fiber posts (GFP II) and compared to historical controls evaluating glass-fiber (GFP I) and titanium posts (TP) for 128 patients. Three groups were defined based on type of post system used: #1 GFP I (n=41), #2 GFP II (n=41) and #3 TP (n=46). Posts were adhesively luted with self-adhesive resin, adhesive composite-core build-ups were performed and all teeth were restored with full-coverage restorations. Primary endpoint was restoration survival at recall. Clinical and radiographic outcome was assessed after 6, 12, 24 and up to 178 months. Data were analysed by Kaplan-Meier log-rank test and Cox-regression analysis.

Results: After up to 178 months of observation 26 restorations failed (GFP I: 10, GFP II: 9, TP: 7) and 49 (GFP I: 18, GFP II: 12, TP: 19) were *in situ*. Cumulative survival probabilities were 57.1% for GFP I, 56.5% for GFP II and 71.8% for TP. In bivariate Cox regression the factors ‘tooth type’ and ‘grade of abrasion’ were significantly associated with failure. In multivariate Cox regression, none of the investigated factors were significantly associated with failure. The post system had no significant impact on tooth survival ($P > 0.05$).

Conclusions: Comparing glass-fiber and titanium posts the post system had no impact on tooth survival after up to 15 years. This study indicates that effect size of post material on survival is low.

Keywords [MESH]: Dental Caries/Dental cements/Dental Restoration Failure/Dental Restoration/Endodontically-Treated Tooth

Introduction

There is a consensus that success and survival of restoration of endodontically treated teeth (ETT) are dependent on a wide range of factors as the presence or absence of an apical lesion (1), the final prosthodontic restoration (2, 3) as well as the amount of residual tooth structure (3-5). Anterior teeth are at a higher risk of failure than posterior teeth (6), while ETT with two proximal contacts show significantly higher survival rates than teeth with one or no proximal contacts (7). Furthermore, a 1.5-2mm circumferential ferrule design preparation is considered crucial for long-term success of the restoration (8). During the past decades various post systems with different mechanical properties such as gold alloy casts (9), stainless steel (10), titanium (11), zirconia (12) and glass-fiber posts (4) have been researched extensively (13). The concept of a monoblock system implies the restoration of ETT with a structural unit of materials with mechanical properties that resemble dentine and therefore lead to a favorable stress distribution within the root (14). Based on the number of involved interfaces adhesive post and core build-up of ETT may be regarded as secondary monoblocks (15). Although the available clinical data suggest a positive effect for the secondary monoblock (16), long-term data on the clinical performance are not available.

There are no uniform treatment guidelines and dental practitioners use different post-and-core materials (17).

While laboratory studies indicate favorable failure modes for fiber posts in vitro due to their dentin-like Youngs' Modulus (18, 19), clinical studies report a wide range of failure patterns when comparting glass-fiber and metal posts (20, 21). Clinical long-term data is lacking and especially comparative studies are scarce (22). A systematic review calls for long-term clinical, well-designed standardized trials due to the heterogeneity in reported studies (20).

Hence, the primary objective of the study was to evaluate long-term survival of post-endodontic restorations with glass-fiber reinforced posts. Data were to compare with controls from a randomized controlled clinical pilot trial investigating survival of glass-fiber versus titanium posts (23). Factors affecting success and survival served as secondary endpoints of this clinical study.

Material and Methods

Experimental Design

A prospective clinical observational study design was selected to assess the long-term survival of post-endodontic restorations with glass-fiber post systems cemented with a self-adhesive resin cement. The design is intended as an extension of the published randomized controlled trial of glass-fiber (GFP I) versus titanium posts (TP) after self-adhesive cementation (23). In the third study cohort (GFP II) a different glass-fiber post was placed. GFP IIwas compared to the two already existing patient groups serving as historical controls. Data analysis for GFP I and TP was performed with the last recall data in 2018 (23). The treatment protocol remained unchanged.

Subject population

Between January 2003 and April 2004 study participants were recruited for GFP I and TP and between November 2006 and April 2008 for GFP IIfrom patients requiring prosthodontic rehabilitation at the Charité-Universitätsmedizin Berlin, Germany, at the Department of Prosthodontics, Geriatric Dentistry and Cranio-mandibular Disorders. The local ethics committee approved the study (approval number: EA2/148/06) and all participants provided written informed consent after being informed about risks, complications, and therapy alternatives by one operator. This research was conducted considering the STROBE (Strengthening the reporting of observational studies in epidemiology) statement for observational studies as applicable. The study was registered at DRKS (German Clinical Trials Register, registration number: DRKS00027063).

Subjects of 18 years and older were assessed for eligibility. Following inclusion criteria were defined for study participation:

- Final restoration with single crowns, fixed and/or removable partial dentures
- Presence of a ferrule-design preparation of at least 2mm
- Defect size: 2 or fewer remaining cavity walls of abutment tooth (cavity wall: presence of more than 50% of the respective crown height at the buccal, oral, mesial or distal aspect)
- Sufficient endodontic root canal filling in symptom-free teeth with no periapical translucencies
- Endodontic root canal filling with a residual apical gutta percha of 4mm

- No or treated periodontitis with a maximum probing depth of 4mm and no bleeding on probing
- Tooth mobility </= II resulting from a primary horizontal bone loss
- Patients willing to appear for recall appointments for at least five years
- Proper compliance and oral hygiene

The exclusion criteria were teeth with a residual dentin wall thickness of < 1mm, patient exhibiting signs of bruxism, teeth with periodontal pathologies and a consecutive tooth mobility > Score I, and patients with teeth presenting symptoms after initial root-canal treatment. Each participant received only one post retained restoration in one tooth within this study.

Treatment procedures

In all cases caries therapy and endodontic treatment were performed by dental students at Charité-Universitätsmedizin Berlin, Germany, at the Department of Operative Dentistry, Endodontics and Preventive Dentistry. Prior to treatment, probing depths, tooth mobility as well as a pre-operative radiographic image were evaluated. Two single operators (GS and MN) performed all post-endodontic restorations. After initial root canal treatments and a cure time of 24 hours minimum, Gutta-percha was removed with the aid of Gates-Glidden burs. Post spaces were prepared with a parallel-tapered post-system leaving residual Gutta-percha of 4mm in the apical region for apical seal. After preparation, the root canals were cleaned with an air abrasion system (DentoPrep Aluminium Oxide Microblaster, Rønvig Dental, Daugaard, Denmark and Cojet, 3MEspe, Seefeld, Germany), rinsed with 2 ml 99.6% ethanol solution and dried with paper points. The posts were cleaned with acetone (GFP I: Fiberpoints Root Pins Glass, Schuetz Detnal Group, Rosbach, Germany; GFP II: RelyX Fiber Post, 3MEspe; TP: Fiberpoints Root Pins Titanium, Schuetz Dental Group). Self-adhesive resin was inserted with the aid of the elongation tip under continuous pumping movement (RelyX Unicem 2, 3M Espe) inside root canal in a one-visit appointment. Teeth were etched with phosphoric acid for 15sec (Total Etch, Ivoclar Vivadent, Schaan, Liechtenstein), built up with composite based materials (Clearfil Core, Kuraray Noritake, Osama, Japan) and an etch-and-rinse adhesive (Clearfil NewBond, Kuraray Noritake) with the aid of transparent strip crowns (Frasaco Strip Crown, Frasaco GmbH, Tettnang, Germany) as matrices and light-cured according to manufacturers' instructions. Posts and cores were shortened after

cementation under constant water-cooling. Whenever posts were exposed, they were sealed with bonding to avoid water penetration. After preparation, the location of the restoration margin was critically evaluated in order to achieve a 2mm ferrule. Therefore 38% of all patients received surgical crown lengthening performed by one operator (GS) prior to restorative procedures in order to re-establish biologic width and to ensure a proper ferrule design preparation. Surgical crown lengthening was performed via a full-flap preparation and reduction of the marginal bone to residual 4mm tooth structure above alveolar bone level.Conventional impressions were taken for fabrication of single crowns, fixed dental prostheses or removable prostheses. The maximum time period between post placement and impression taking did not exceed three months. Final prosthetic rehabilitation was performed by dental students at the Department of Prosthodontics, Geriatric Dentistry and Craniomandibular Disorders. All prostheses were self-adhesively cemented using RelyX Unicem (3M Espe).

Follow-up Procedure and Outcomes

The date of post placement was defined as baseline. The primary endpoint was restoration survival, defined as a sufficient restoration *in situ* at recall. Secondary endpoints were loss of restoration, post fracture or debonding, horizontal or vertical root fracture, tooth loss due to secondary carious lesions or to periodontal reasons, endodontic failures and changes in treatment planning. Patients were recalled after 12, 24, 60 months and up to 178 months after post insertion. Radiographic evaluation was performed at baseline, 12, 60 months and at the last recall. Follow-up examinations were evaluated by an independent dentist who was not the operator (MB). Information was collected to assess the frequency and reasons for failure via assessment of probing depths by a periodontal probe, testing tooth mobility and other clinical findings. The periapical root status, possible secondary carious lesions, fracture lines, perforations and root resorptions were assessed with the aid of radiographic images at recall.

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Sample Size Calculation

There was no a priori sample size calculation. A mean exponential failure time with parameter λ=0.00219 month^{-1} (dropout comprises loss to follow-up and death of the patient) was assumed. Further, the accrual time was T_{acc}=63 months and the maximal length of follow up was T=178 months. The rates λ and λ_C, and the periods T_{acc} and T were estimated from study data. The two-sample log-rank test has a power of 80% if the sample size is n=41 per group and the two-sided level of significance is α=0.05. The sample size calculation was carried out using the procedure STT2-1 of nQuery 9.1.0.0.

Statistical analysis

Quantitative parameters were described with mean values and standard respective deviations. Kaplan-Meier statistics and log-rank tests were performed for calculation of significant differences between groups ($P < 0.05$). The annual failure rate (AFR) was calculated from life tables. For testing the impact of baseline parameters on survival of restorations, Hazard Ratios (HR) were calculated using Cox-regression analyses (24). Descriptive statistics, Kaplan-Meier survival-tables and plots were generated with means of IBM SPSS Statistics (SPSS 25 Inc, Chicago, IL).

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Results

A total of 128 patients with a mean age of 52.9 years (SD, 14.9 y) at baseline were included. Forty-one participants were recruited for the third study cohort (GFP II). Data were compared to control groups (TP: n=46; GFP I: n=41). For 20 patients no follow-up information was collected due to reason of no valid contact information (n=16) or death (n=4) resulting in a drop-out rate of 49% (GFP I: 32%; TP: 44%) (Table 1). For 21 patients of GFP II the number of events were recorded (GFP I: n=28; TP: n=26).

Overall the majority of teeth included in the study were premolars (46%) followed by incisors (24%), canines (16%) and molar teeth (13%). In GFP I (53%), GFP II (83%) and TP (48%) most teeth presented no remaining cavity wall. 59% of teeth in GFP I, 64% in GFP II and 61% in TP were restored with single crowns. Final restorations had mostly two proximal contact points (GFP I 60%, GFP II 59%, TP 61%). For descriptive purposes, detailed information is given in Table 2.

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Kaplan-Meier Survival Graphs and Log-rank Test

The overall mean observation time was 101 months for GFP I (SD: 41; min./max. 24/148), 82 months for GFP II (SD: 64; min./max. 12/178) and 95 months for TP (SD: 46; min./max. 12/154). Kaplan-Meier survival curves are presented in Figure 1.

Following cumulative survival probabilities were calculated: GFP I=57.1%, GFP II=56.5% and TP=71.8%. The Log-rank test did not show significant differences between groups ($P > 0.05$). Over the whole examination period annual failure rates of 3.6 for GFP II, 3.0 for GFP I and 2.0 for TP were calculated.

Cox Regression analysis and failure modes

Bivariate associations between the baseline characteristics and an increased failure rate are presented in Table 3 ($P < 0.25$). Data suggest a lower failure rate for canines with a hazard ratio (HR) of 0.3 (95% confidence interval [CI], 0.07-1.624; $P < 0.25$). There was no significant difference between anterior and posterior teeth. Furthermore, teeth with an abrasion grade III were significantly associated with a higher failure rate (HR=2.5, 95% CI, 0.5-11.4; $P < 0.247$). In multivariate Cox proportional hazards regression, none of the investigated factors were significantly associated with the failure rate. Failure modes and characteristics as secondary endpoints for all groups are displayed in Table 4.

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Discussion

This is the first comparative study on survival of ETT with titanium and two different glass-fiber post restorations with clinical data of up to 15 years in a total of 128 patients. GFP II was compared to TP and GFP I, that served as control groups published before (23). An adhesive approach was selected for all study cohort groups. The effect of different baseline parameters on survival rate was evaluated. Overall, rather low survival rates could be observed in all experimental groups. Data of the present study suggest that the type of post system had no impact on tooth survival. With respect to the investigated study population, tooth type, i.e. a higher survival rate for canines, and abrasion Grade, i.e. a higher failure rate for abraded teeth, are predictors for tooth survival.

Results of the presented study should be interpreted with caution due to the relatively small sample size. For identification of a significant difference in survival of 60% versus 70% at $\alpha = 0.05$ with 90% power, assuming a drop-out of 35%, would require participation of 1094 patients (n = 547 per group) (23). Furthermore, the high drop-out rate of 48.8% poses a common problem in clinical in long-term trials (25). A slightly higher drop-out rate in GFP II may be due to a longer time of observation. Patients were not recalled on a routine basis. In the majority of cases, patients were finally restored in the student's course and returned to private practice after treatment. Therefore, most drop-outs are attributable to a lack of valid contact information. For a standardized data collection, a university-based setting was chosen. All post-endodontic treatments were performed by two calibrated operators who due their active participation in the randomized controlled trial were considered as highly experienced and qualified for this clinical study.

For 20% of teeth it was necessary to perform a surgical crown lengthening prior to restorative treatment in order to achieve a proper ferrule design preparation (8). There was no statistical correlation between this surgical pre-treatment and tooth survival. In contrast to another clinical study, the procedure did not affect survival (26). However, it was shown that an increase of a crown-root-ratio over 1:1 is associated with a higher failure rate (26).

In this study, the parameters of tooth characteristics are evenly distributed throughout all study groups: The majority of teeth were premolars, followed by incisors, canines and molars. In all groups, most of the teeth retained no coronal walls and had two

proximal contact points at final restoration. The majority was restored with single crowns, followed by fixed dental prosthesis and removable partial dentures. Even post length of 9mm was equally distributed. As the study population for all study groups was recruited from consecutive patients in need of prosthodontic rehabilitation in the student's course demographic characteristics as well as base line data were similar. This even distribution of variables between groups results in highly comparable and, therefore, relevant long-term data for post-endodontic restorations. Outcome was defined as survival. Therefore, data on possible biological and technical complications were not recorded. Cumulative survival rates with 57% were nearly identical between the two glass-fiber post groups. Results are comparable to a clinical prospective observational study reporting a cumulative survival rate of about 60% for glass-fiber retained restorations over ten years of observation (4).

There was no significant association between the variable "post system" and "failure". These findings indicate that the choice of post system may be less relevant than commonly assumed for prefabricated adhesively cemented posts. It is in accordance with a clinical study of up to 9 years of follow-up comparing glass-fiber and cast-metal post retained restorations. No significant differences were found between the two post systems (27). Another clinical study comparing three different glass-fibre posts with a shorter observation time found no significant differences (28). Data are also in line with a practice-based, multicenter clinical study reporting a cumulative survival rate of 78% after a mean follow-up period of 91 months (29). The choice of post system had no significant impact on tooth survival as well. Ferrari et al. report a survival rate of 94% after six years of clinical function (30). However, the observation time was shorter and the study included teeth with significantly more coronal tooth structure (up to 4 coronal walls) while the present study focused on deeply destroyed teeth with 2 or less coronal walls. It was shown that residual tooth substance significantly influences survival (3). For adhesively cemented zirconia posts promising results with a survival probability of 81% are reported after 10 years of observation (12). In contrast, significantly lower survival rates were published for metal-screw posts with 50% in comparison to glass-fiber reinforced posts with 72% after 5 years of clinical function (31). The authors conclude that indication for metal-screw posts must be carefully considered due to increased risk of unfavourable complications.

Data suggest a lower failure risk for canines, which may be explained by an increased root length and –surface compared to other teeth in the dentition. Further studies have attributed a higher risk of failure for anterior teeth, since non-axial shear forces occur compared to rather compressive forces in the posterior region (4). Results suggest that teeth with an abrasion grade III exhibit more failures as they are exposed to a higher degree of functional forces. In the present study, the number of residual walls and the type of final restoration had no significant impact on tooth survival. This observation, however, is in contrast to findings of a prospective observational study for glass-fiber supported post-endodontic restorations with clinical data of up to 132 months (4). Ultimately, there is no unequivocal scientific evidence to support significant benefits of post insertion even for teeth with no remaining cavity walls (32). It was not within the scope of this study to provide evidence for a post placement as such. Failure patterns vary across groups and follow no consistent pattern, a finding, which concurs with the results of a systematic review (33). Reasons for failure vary and are dependent on other factors than the chosen post system or the restoration itself as caries or changes in treatment planning due to failures elsewhere in the dentition.

Despite the conclusion, that ETT exhibit lower survival rates compared to vital teeth (34), post-retained post-endodontic restorations may be a suitable treatment option before choosing dental implant installation (35).

Within the limitations of this study as the relatively small sample size, comparing two different glass-fiber posts and a more rigid titanium post the post system had no significant impact on tooth survival of post-endodontic restoration. After up to 15 years using glass-fiber or titanium posts result in survival rates of about 57% and 72% in the present long-term clinical study. Further studies with a larger study population are required to identify possible effects of post materials.

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Table 1. Primary outcome at final follow-up

Table 2. Descriptive data for participants and tooth characteristics

Figure 1. Kaplan-Meier survival graphs for post-restored teeth according to post system (blue GFP I, orange TP, red GFP II)

Table 3. Results of the bivariate Cox regression analysis including Hazard ratios calculated for baseline parameters

Table 4. Failure modes in intervention groups

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Table 1. Primary outcome at final follow-up.

	GFP I (n=41)	GFP II (n=41)	TP (n=46)
Month of follow-up (mean [SD]; min/max)	101[41]; 24/148	82.2[64]; 12/178	95[46]; 12/154
Restoration in situ (n; [% per group])	18; [44]	12; [29]	19; [41]
Drop-out (n; [% per group])	13; [32]	20; [49]	20; [44]
Reasons for drop-out (n)			
Death	1	4	3
Illness allowing no further participation	0	0	1
Not willing of further participation	5	0	6
Not available/no valid contact data	5	16	10
Lost tooth due to changes treatment planning	2	0	0
Primary endpoint loss of restoration (n; [% per group])	10 [24]	9 [22]	7 [15]
Cumulative survival probability [% per group]	57.1	56.5	71.8
P value of Log-Rank Test		0.496	

SD, standard deviation

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Table 2. Descriptive data for participants and tooth characteristics.

Patient, tooth, and treatment characteristics	GFP I	GFP II	TP
No. of patients	41	41	46
Age (years, mean ± SD)	49.4 ±14.6	54.5±15.4	52.3 ±14.2
Women (% of group)	19 (46)	16 (39)	25 (54)
Men	22 (54)	25 (61)	21 (46)
Tooth characteristics			
Tooth type (% of group)			
Incisor	13 (32)	9 (22)	12 (26)
Canine	6 (15)	5 (12)	10 (22)
Premolar	17 (42)	24 (59)	19 (41)
Molar	5 (12)	3 (7)	5 (11)
Remaining cavity walls (% of group)			
0	20 (49)	34 (83)	22 (48)
1	8 (20)	7 (17)	15 (33)
2	13 (32)	0 (0)	9 (20)
Treatment			
Surgical crown lengthening	2	15	11
Post length within root canal (mean mm/SD)	9.3/1.2	9.5/1.8	9.3/1.4
Final restoration (% of group)			
Single crown	24 (59)	26 (63)	28 (61)
FDP	13 (32)	11 (27)	10 (22)
Single crown and RPD	1 (2)	3 (7)	3 (7)
FPD and RPD	3 (7)	1 (2)	5 (11)
No. of proximal contact (% of group)			
0	4 (10)	2 (5)	3 (7)
1	13 (32)	15 (37)	15 (33)
2	24 (59)	24 (59)	28 (61)

FDP = fixed dental prosthesis; RPD = removable partial denture; SD = standard deviation.

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Table 3. Results of the bivariate Cox regression analysis including Hazard ratios calculated for baseline parameters.

Baseline parameter	Frequency [n (%)]	Failures [n (%)]	P value	HR	95% CI	Mean Survival	95% CI
Age [years]							
>60	48 (38%)	10 (21%)		1.0	Reference	143.3	126.8 – 159.8
41-60	51 (40%)	12 (24%)	0.725	0.9	0.371 – 1.994	150.1	136.1 – 164
≤40	29 (23%)	4 (14%)	0.480	0.7	0.206 – 2.103	154.1	133 – 175.2
Gender							
male	68 (53%)	12 (18%)		1.0	Reference	150.1	136.1 – 164.2
female	60 (47%)	14 (23%)	0.583	1.2	0.573 – 2.69	146.7	134.1 – 159.2
Post							
GFP I	41 (32%)	10 (24%)		1.0	Reference	127.7	115.7 – 139.6
TP	46 (36%)	7 (15%)	0.326	0.6	0.234 – 1.621	139.8	129.3 – 150.3
GFP II	41 (32%)	9 (22%)	0.898	1.1	0.425 – 2.652	143.6	124.2 – 163
Tooth type							
incisor	31 (24%)	7 (23%)		1.0	Reference	129.8	105.9 – 153.8
canine	21 (16%)	2 (10%)	**0.175**	0.3	0.07 – 1.624	161.4	143.9 - 179
premolar	59 (46%)	12 (20%)	0.416	0.7	0.266 – 1.729	150.5	137.2 – 163.8
molar	17 (13%)	5 (29%)	0.675	0.8	0.247 – 2.474	136.9	122.2 – 151.5
Tooth type pooled							
anterior tooth	52 (41%)	9 (17%)		1.0	Reference	146.3	129.5 – 163.1
posterior tooth	76 (59%)	17 (22%)	0.971	1.0	0,452 - 2,283	150.8	139.7 – 161.9
Proximal contacts							
No contact point	9 (7%)	4 (44%)		1.0	Reference	137.9	106.5 – 169.2
1 contact point	43 (34%)	9 (21%)	0.312	0.5	0.167 – 1.771	148.9	134.1 – 163.7
2 contact points	76 (59%)	13 (17%)	0.283	0.5	0.175 – 1.662	150.4	137 – 163.8

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Antagonistic dentition							
Natural/fixed	114 (89%)	22 (19%)		1.0	Reference	149.7	139.3 – 160.2
Periodontal-mucosal	14 (11%)	4 (29%)	0.471	1.5	0.509 – 4.3	130.3	117 – 143.5
Abrasion							
No	55 (43%)	10 (18%)		1.0	Reference	140.2	131.5 – 148.8
Grade I	42 (33%)	8 (19%)	0.934	1.0	0.378 – 2.445	151.9	135.5 – 168.3
Grade II	24 (19%)	6 (25%)	0.256	1.8	0.651 – 5.03	124.8	106 – 143.6
Grade III	7 (5%)	2 (29%)	**0.247**	2.5	0.534 – 11.404	119.4	55.6 – 183.2
Tooth mobility							
Grade 0	113 (88%)	21 (19%)		1.0	Reference	151.0	140.7 – 161.2
Grade 1-3	15 (12%)	5 (33%)	0.402	1.5	0.572 – 4.03	139.8	114.4 – 165.1
Number of remaining cavity walls							
0	76 (59%)	16 (21%)		1.0	Reference	148.1	135.5 – 160.8
1	30 (23%)	5 (17%)	0.629	0.8	0.285 – 2.134	138.7	123.7 – 153.6
2	22 (17%)	5 (23%)	0.948	1.0	0.354 – 2.641	129.0	110.5 – 147.5
Final restoration							
Single crown	78 (61%)	16 (21%)		1.0	Reference	146.6	133.3 - 160
FDP	34 (27%)	4 (12%)	0.271	0.5	0.18 – 1.617	159.9	146 – 173.8
Singe crown-RPD	11 (9%)	4 (36%)	0.554	1.4	0.465 – 4.177	133.0	119.6 – 146.4
FDP-RPD	5 (4%)	2 (40%)	0.448	1.8	0.405 – 7.721	109.9	76.9 – 142.8
Surgical crown lenghtening							
no	102 (80%)	21 (21%)		1.0	Reference	149.7	138.9 - 160.4
yes	26 (20%)	5 (19%)	0.966	1.0	0.383 – 2.723	150.0	129.3 – 170.7

HR = hazard ratio; CI = confidence interval; FDP = fixed dental prosthesis; RPD = removable partial denture. Underlined and bold characteristics of baseline parameter are reference within the test between the characteristics. Non-bold *p* values show if there is a significant difference compared to the reference; bold *p* values indicate of the total baseline parameter has a significant impact.

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Table 4. Failure modes in intervention groups.

Failure mode	GFP I	GFP II	TP
Fracture	6	3	1
Secondary caries	1	1	0
Endodontic failure	2	1	4
Combined endodontic and periodontal lesion	0	1	1
Extraction due to tooth mobility	1	0	0
New restoration due to changes in treatment planning	2	0	0
Extraction for other reasons	0	3	1
Overall	12	9	7

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Table 1. Primary outcome at final follow-up.

	GFP I (n=41)	GFP II (n=41)	TP (n=46)
Month of follow-up (mean [SD]; min/max)	101[41]; 24/148	82.2[64]; 12/178	95[46]; 12/154
Restoration in situ (n; [% per group])	18; [44]	12; [29]	19; [41]
Drop-out (n; [% per group])	13; [32]	20; [49]	20; [44]
Reasons for drop-out (n)			
Death	1	4	3
Illness allowing no further participation	0	0	1
Not willing of further participation	5	0	6
Not available/no valid contact data	5	16	10
Lost tooth due to changes treatment planning	2	0	0
Primary endpoint loss of restoration (n; [% per group])	10 [24]	9 [22]	7 [15]
Cumulative survival probability [% per group]	57.1	56.5	71.8
P value of Log-Rank Test		0.496	

SD, standard deviation

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Table 2. Descriptive data for participants and tooth characteristics.

Patient, tooth, and treatment characteristics	GFP I	GFP II	TP
No. of patients	41	41	46
Age (years, mean ± SD)	49.4 ±14.6	54.5±15.4	52.3 ±14.2
Women (% of group)	19 (46)	16 (39)	25 (54)
Men	22 (54)	25 (61)	21 (46)
Tooth characteristics			
Tooth type (% of group)			
Incisor	13 (32)	9 (22)	12 (26)
Canine	6 (15)	5 (12)	10 (22)
Premolar	17 (42)	24 (59)	19 (41)
Molar	5 (12)	3 (7)	5 (11)
Remaining cavity walls (% of group)			
0	20 (49)	34 (83)	22 (48)
1	8 (20)	7 (17)	15 (33)
2	13 (32)	0 (0)	9 (20)
Treatment			
Surgical crown lengthening	2	15	11
Post length within root canal (mean mm/SD)	9.3/1.2	9.5/1.8	9.3/1.4
Final restoration (% of group)			
Single crown	24 (59)	26 (63)	28 (61)
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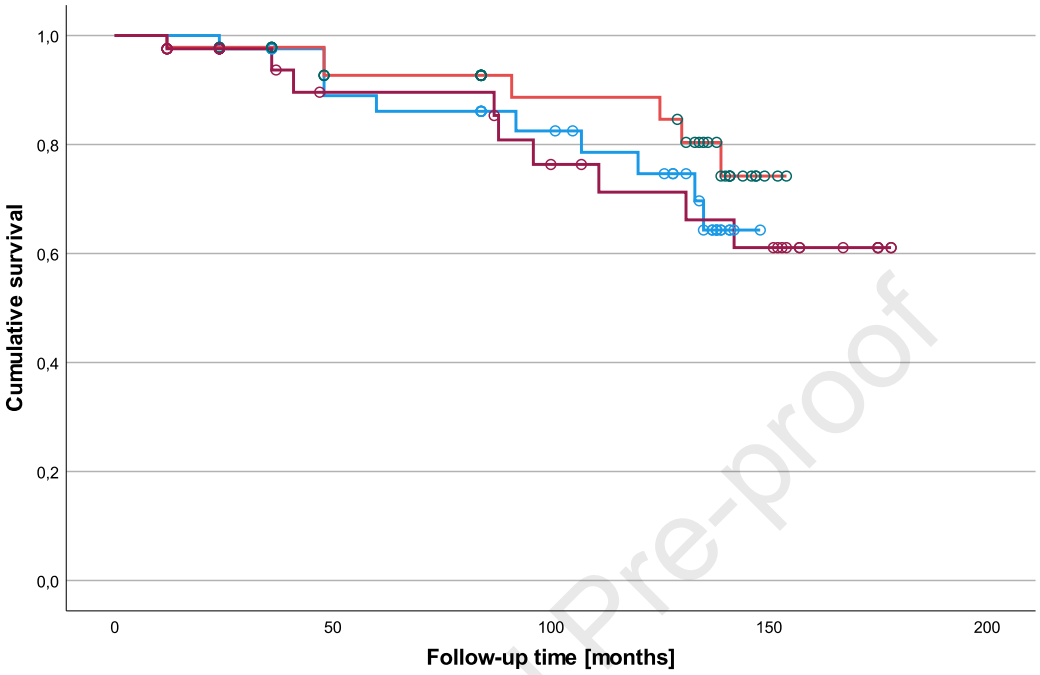

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Author contributions

MB: contributed to methodology, investigation, analysis, interpretation and drafted the manuscript

RJW: contributed to methodology, analysis, interpretation, performed all formal analyses and critically revised the manuscript

MSL: contributed to methodology, investigation, interpretation and critically revised the manuscript

HML: contributed to conceptualization, methodology, data interpretation and critically revised the manuscript

FB: contributed to conceptualization, methodology, data interpretation and critically revised the manuscript

MN: contributed to supervision, funding acquisition, conceptualization, methodology, investigation, interpretation and drafted the manuscript

GS: contributed to supervision, funding acquisition, conceptualization, methodology, investigation, interpretation and drafted the manuscript

All authors gave final approval and agree to be accountable for all aspects of the work.

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