Restoration of Endodontically Treated Teeth with Carbon Fibre Posts — A Prospective Study

(La restauration des dents traitées par endodontie à l'aide de pivots en fibre de carbone — une étude prospective)

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Sommaire

Historique : *C'est en 1995 que débuta une étude prospective pour mesurer le taux de réussite des pivots en résine époxyde renforcée de fibres de carbone (RRFC), qu'on utilise pour restaurer les dents traitées par endodontie. Toutes les dents étudiées avaient perdu plus de la moitié de leur structure coronaire.*

Méthodologie : *Cinquante-neuf pivots en fibre de carbone cimentés avec du Metabond et reconstruits à l'aide de Core Paste ont été insérés dans les dents de 47 patients. Chaque dent a été complètement restaurée (couronne céramo-métallique) et surveillée pendant 6,7 à 45,4 mois (moyenne = 28,0 mois; écart type = 10,7).*

Résultats : *Les résultats obtenus pour 52 dents réparties entre 42 patients ont été étudiés. On n'a constaté aucune fracture. Le taux d'échec s'élevait dans l'ensemble à 7,7 %, et le taux de survie cumulé était de 89,6 % à la fin de la période de suivi. Le seul élément d'importance statistique (p = 0,04) était que les pivots des prémolaires inférieures étaient plus susceptibles d'échouer.*

Conclusion : *Les pivots RRFC comptent parmi les systèmes les plus prévisibles d'aujourd'hui. On peut associer l'utilisation de ces pivots dans les dents antérieures supérieures à un taux de réussite et à une longévité plus élevés que pour ceux placés dans les prémolaires, en particulier inférieures. Cette étude ajoute aux éléments de preuve grandissants qui appuient l'utilisation des pivots RRFC dans la restauration des dents traitées par endodontie.*

Mots clés MeSH : *carbon; dental prosthesis design; post and core technique*

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There is no consensus on the best procedure for restoring endodontically treated teeth. However, retrospective studies[1-6] do identify factors that affect the success rate. Tooth location in the arch,[1-3] type of occlusion,[2] amount of remaining dentin[3] and type of abutment[1] affect the selection of a restorative approach that will produce a favourable outcome. Yet in spite of this evidence, a recent survey[7] calls into question dentists' patterns of restoring endodontically treated teeth in the United States.

Failure rates averaging 2% per year have been reported[2-6] for both single crowns and retainers for fixed partial dentures. The 1992 Hatzikyriakos[1] study reported dramatic differences in failure rate over 3 years between complete coverage restorations functioning as single crowns (5.5%) and those functioning as fixed partial denture abutments (16.4%). The reported causes of failure were debonding, post fracture, caries and root fracture. Because of the excellent adhesion of dentinal bonding agents to tooth structure, when used with resin core build-ups or in conjunction with luting cements, the threat of fracture as the chief failure mode in endodontically treated teeth is increasing.[8]

Corrosion caused by dissimilar metals, area variation and stress, first reported in 1970[9] is just now being implicated as a source of fracture potential in post-endodontic restorations.[10] In addition to established factors, the composition of the post system may play a pivotal role in restorative success. To address this concern, a carbon fibre post system was introduced in Europe in 1990. A carbon-epoxy composite post was reinforced with long carbon unidirectional, high-performance fibres stretched parallel to the axis of the post.[11] The fibres represented 64% of the structural volume and the matrix, which bound the fibres together, was an epoxy resin.

King and Setchell[12] showed that prefabricated carbon fibre posts exhibit properties comparable with, and in some cases better than, those of prefabricated metal posts, and McDonald and

Figure 1: *Composipost and core paste showing 2.0-mm ferrule.*

Figure 2: *#1, #2, #3 Composiposts and matching drill sets.*

Figure 3: *ISO 90, ISO 100 and ISO 120 University of Montreal Endoposts and matching drill sets.*

colleagues[13] found no difference in fracture resistance among unrestored endodontically treated teeth, teeth with stainless steel posts and teeth with carbon fibre posts. However, in 1997, a laboratory-based study[14] demonstrated that teeth restored with a carbon fibre post system exhibited inferior strength compared with other established metallic post systems when subjected to a single-angled compression load. Subsequent studies of the carbon fibre post system[15-17] do not agree on its efficacy. This confusion led to the initiation of the study reported here to evaluate the success of a carbon fibre post system used to retain an intracoronal foundation to restore endodontically treated teeth.

Materials and Methods

Patients in this study were referred by their dentist or treating specialist. All those who received a carbon fibre post and resin core restoration followed by a full-coverage restoration (porcelain fused to metal) between September 21, 1995, and November 26, 1998, were enrolled in the study. However, 5 patients were later excluded because of relocation or inability to locate them. Patients were recalled annually, although some received more frequent recalls due to ongoing dental needs.

Success or failure of the restorative tooth complex was evaluated by the author. When a patient was unable to return, a follow-up visit was arranged with the referring dentist, who was provided with the criteria for judging success or failure by telephone. The classification of failure as either biological or mechanical was based on findings of an unpublished cast post pilot study, carried out in 1990-93.

The crown preparation varied from a full chamfer to a feather finish depending on the height and thickness of the remaining dentin, but there was always a minimum 2.0-mm ferrule of dentin[18] as measured with a periodontal probe (Fig. 1). Crown lengthening or extrusion procedures or both[18] were used when the height of the remaining supragingival dentin (ferrule) was < 2.0 mm. A biological width of 2.0 mm was the ultimate goal after periodontal surgery and/or orthodontics. Christensen's guidelines,[19,20] that a core needs post retention only when more than 50% of the tooth's coronal structure has been destroyed, were followed.

Removal of the gutta percha for post preparation[21] was accomplished with Gates Glidden drills (Premier Dental (Canada), Markham, ON) at least 48 hours after obturation.[22] This was followed by refining of the canal space using the drill sets provided in Composipost or University of Montreal Endo-post kits (Biodent, Québec, QC). A minimal apical seal of 5.0 mm of gutta percha filling was retained in the apical root portion.[21] Canals were not prepared to receive a predetermined size of post; rather the gutta percha was removed and the post that best fit the remaining space was used in each tooth.[23] For the Composipost no. 1 (Recherches Techniques Dentaire [RTD], Grenoble, France), which was used in most cases, slight refining at the top of the pulp chamber was required; no additional preparation was required for University of Montreal Endo-posts (RTD, Grenoble, France).

The Composiposts were cylindrical with grooves around the circumference and a 2-stepped shank section tapering to a conical seating face for stabilization (Fig. 2). The University of Montreal Endopost had a distinctive smooth conical profile (Fig. 3). The posts were placed in the canal to mark the length needed to project into the resin core, then removed and cut with a diamond disc. The head of the carbon post should extend through the composite resin core to the surface of the preparation to prevent thin, unsupported areas of resin from fracturing during provisional restoration or on removal of the final impression.[24]

In preparation for the subsequent core build-up a copper band (Moyco Industries, Inc. Philadelphia, PA) was selected to fit snugly around the remaining dentin and its height was marked so that the carbon fibre post projected 1.0 mm beyond the edge of the band. It was then cut with scissors to the correct height. The opposing arch was prepared to ensure proper retention and resistance according to Shillingburg.[25]

The root canal was scrubbed for 10 seconds with C&B Metabond (Parkell, Farmingdale, NY) dentin conditioner on a felt brush (Pinnacle Products Inc., Lakeville, MN). The canal was then washed with water and dried with air and paper points (Henry Schein, Port Washington, NY). C&B Metabond was mixed according to the manufacturer's instructions. (The powder chosen from the Metabond kit was the tooth-coloured radio-opaque product.) The post was moistened with the mixed liquid and the cement was quickly loaded into Accudose Needle Tubes (Centrix Inc., Shelton, CT), placed in a Centrix syringe and injected into the canal. Once the canal was filled with cement, a lentulo (Spiral Fillers RA, Caulk, Dentsply, Milford, DE) was inserted to the depth of the canal to ensure proper coating of the root canal walls. The carbon post was then placed to the precut depth. Brushes were dipped in fresh monomer and the coronal surface of the tooth was cleaned of excess cement.

The Metabond was allowed to set undisturbed for 10 minutes, then the copper band was placed around the tooth and the dentin was etched with 37% phosphoric acid. Two-step Tenure (Den-Mat Corporation, Santa Maria, CA) was placed on all tooth surfaces and light-cured for 30 seconds. Core Paste (Den-Mat Corporation, Santa Maria, CA) was mixed in equal amounts, and a Centrix syringe was used to extrude the resin core material within the copper band; undercuts helped retain the core material. Pressure was applied with a gloved finger over a mylar strip until the resin hardened.

After 10 minutes, the band was removed and final preparations were made with Gingitage burs (Vic Pollard Dental Diamond Drills, Westlake, CA). The Gingitage burs prepared the tooth and refined the tissue if more ferrule was needed. The final impression was made and the tooth temporized (Luxatemp, DMG, Zenith Brand Division, Foremost Dental Mfg. Co., Hamburg, Germany) pending delivery of the crown. All crowns were porcelain fused to metal and final cementing was completed with Flecks Crown and Bridge cement (Mizzy Inc., Cherry Hill, NJ).

The restoration was deemed successful if the complete crown was still cemented to the underlying tooth–core complex at follow-up, without any biological or mechanical breakdown. Biological failure was defined as the presence of pathology due to caries, periodontal disease or endodontic failure. Mechanical failure was the debonding of any part of the tooth–post–core–crown complex or the presence of fracture. The presence of periodontal disease was identified as increasing mobility and pocket depth in any of the 6 readings on the restored teeth. Radiographs were taken during annual recall.

All restorative procedures were completed by one investigator with over 30 years of clinical experience. In 6 cases, the success of the restorations was determined by the referring dentist; one of the failures was reported by the referring endodontist.

Statistical Methods

Data were analyzed using the SPSS statistical software system (SPSS Inc., Chicago, IL). Dates were entered as day, month, year, using the 15th of the month when only month and year were known. Variables were created for tooth type, event status (i.e., post failure vs. non-failure), and time to event, and were assigned numerical values. Time-to-event was defined as the time, in months, between the date of insertion of the post and either the date of failure of the restoration or the date of the last recall. If a patient was not seen at one or more recall appointments, he or she was excluded from the analysis. Censored observations were cases for which failure did not occur during the observation period. However, censored observations contributed time to the analysis.

The unit of analysis was the tooth and teeth were referred to as cases. Survival analysis, used to determine the probability of

Table 1 Sample characteristics

Patients	
Number	42
% Female	57.1
Age	
% under 45 years (*n* = 13)	31.0
% 45-65 years (*n* = 21)	50.0
% over 65 years (*n* = 8)	19.0
Mean age at date of post insertion (*n* = 52)	54.1 years (SD=14.4, range 17-83)
Teeth	
Number	52
% maxillary teeth	71.2
% mandibular teeth	28.8
% incisors	30.8
% canines	25.0
% premolars	44.2
Post type (*n* = 52)	
Composipost (%)	
#1 (*n* = 37)	71.2
#2 (*n* = 1)	1.9
Total (*n* = 38)	73.1
Endopost (%)	
size #90 (*n* = 10)	19.2
size #100 (*n* = 4)	7.7
Total (*n* = 14)	26.9

SD = Standard deviation.
Note: 7 cases were excluded from the analysis because they were not seen at follow-up.

Table 2 Distribution of cases by prosthetic status and tooth type

	Single	FPD abutment	
Maxillary	**Number of cases**	**Number of cases**	**Overall %**
Incisor	8	8	30.8
Canine	3 (1)	7	19.2
Premolar	5 (1)	6	21.2
Mandibular			
Incisor	—	—	0.0
Canine	2	1	5.8
Premolar	9 (1)	3 (1)	23.1
Total number	27 (3)	25 (1)	
Overall %	51.9%	48.1%	

( ) = No. of failed carbon fibre posts
FPD = fixed partial denture

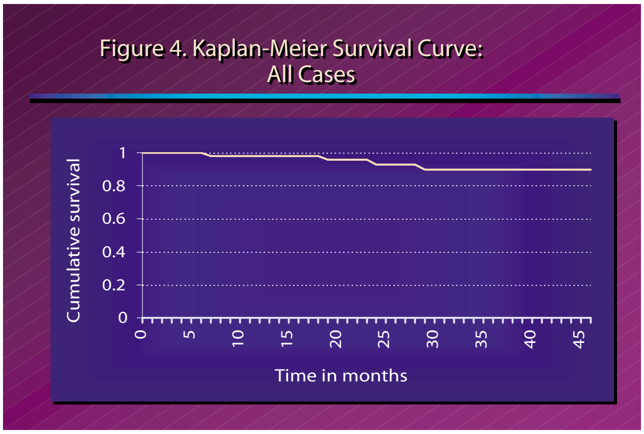

Figure 4: *Kaplan-Meier survival curve for all cases.*

failure or the survival rate, was performed at 3 levels (univariate, bivariate and multivariate) using the Kaplan-Meier method, the log-rank test, the Breslow (or generalized Wilcoxon) test and Cox regression. At the bivariate and multivariate levels, the following independent variables were assessed: patient's sex and age, tooth type and location, post type and prosthetic status.

It was assumed that subjects were treated similarly whether they entered the study early or late, that hazard rate did not change with time, and that those lost to follow-up were not significantly different from those included in the analysis.

Results

Characteristics of the Sample

A total of 59 carbon fibre reinforced epoxy resin posts with extracoronal coverage were placed in the mouths of 47 patients. Of these, 5 patients and 7 "cases" were excluded from analysis. Patients were monitored by recall for 6.7-45.4 months (average = 28.0 months, standard deviation [SD] = 10.7 months). The first post was inserted on September 21, 1995, and the last on November 26, 1998. Table 1 shows the distribution of cases by patient characteristics, tooth and post type. Table 2 shows the distribution by prosthetic status and tooth type together with the number of failed restorations. Upper incisors were the most commonly treated tooth type, followed by lower premolars and upper premolars. No molars required posts during the 3.75 years of the study.

Failure occurred in 3 teeth with single crown restorations and one fixed partial denture abutment. Of these, 2 were in lower premolars, one in an upper premolar and one in an upper canine (Table 2).

Univariate Analysis

For the 4 failures reported (7.7% of all cases), 2 were biologic (periapical pathology) and 2 were mechanical (1 core debonding and 1 crown debonding). Average time to failure was 20.0 months (SD = 9.5, median = 21.9, range 7.0-29.3).

The Kaplan-Meier survival curve for all cases is shown in Fig. 4. The cumulative survival rate at the end of the follow-up period was 89.6%, with a mean survival time of 43.4 months (95% confidence interval [CI], 41.0-45.8).

Bivariate Analysis

Table 3 summarizes the mean survival times and confidence intervals for bivariate analyses using the Kaplan-Meier method. Although survival rates for carbon fibre posts placed in anterior teeth in the maxillary arch (canines in particular) and fixed partial denture abutments were higher than for those placed in posterior teeth (premolars in particular), in the mandibular arch and in single teeth, the differences were not statistically significant (Table 4). Similarly, gender and age differences in carbon fibre post survival rates were not statistically significant. However, mean survival time was shorter for premolar teeth (39 months) than for anterior teeth (45 months). Pairwise comparisons of the different tooth types, carried out using the log-rank test, revealed a statistically significant difference in the 3-year survival rates of lower premolars compared with upper incisors.

Table 3 **Summary of Kaplan-Meier analysis**

Variable	Mean survival time in months (SE)	95% Confidence Interval
Sex		
male	41.0 (2.1)	37.0-45.0
female	43.9 (1.4)	41.1-46.6
Age		
< 45yrs	42.2 (1.9)	38.6-45.8
45-65 yrs	42.8 (2.1)	38.7-46.9
> 65 years	All observations censored	All observations censored
Tooth location		
Anterior	44.6 (1.3)	42.0-47.2
Posterior (premolar)	39.4 (2.2)	35.1-43.7
Tooth location (dental arch)		
Maxillary	44.0 (1.4)	41.3-46.6
Mandibular	38.7 (2.3)	34.2-43.2
Tooth type		
Incisor	All observations censored	All observations censored
Canine	42.9 (2.9)	37.3-48.6
Premolar	39.4 (2.2)	35.1-43.7
Prosthetic status		
Single	41.3 (2.0)	37.3-45.2
FPD abutment	44.9 (1.0)	42.9-46.9
Post type		
Composipost	41.5 (1.6)	39.4-45.7
Endopost	All observations censored	All observations censored

SE = Standard error of the mean.
Note: Survival estimates cannot be computed if all observations are censored.

Multivariate Analysis

Table 5 summarizes results from the Cox regression analysis to examine the joint influence of predictor variables on the carbon fibre post system. The following variables were included in the Cox regression model: sex, age, prosthetic status, post type and tooth type. Tooth type was found to be statistically significant, adjusting for other factors in the model. In other words, posts in lower premolars were at higher risk of failure than the other tooth types studied. None of the other variables was significant.

Discussion

This study may have lacked the power necessary to detect a statistical significance for the comparisons made. The results

Table 4 **Summary of log rank and Breslow tests**

Variable	Log-rank test statistic (*p* value)	Breslow statistic (*p* value)
Sex	0.07 (0.791)	0.19 (0.666)
Age (< 45 vs. 45-65 yrs)	0.02 (0.895)	0.04 (0.846)
Anterior-posterior (premolar) tooth location	2.22 (0.136)	1.11 (0.293)
Maxillary-mandibular tooth	1.03 (0.311)	0.61 (0.433)
Tooth type (canine vs. premolar)	0.51 (0.475)	0.07 (0.790)
Prosthetic status	1.02 (0.312)	1.46 (0.227)
Post type	1.42 (0.234)	1.36 (0.244)

Table 5 **Summary of Cox regression analysis**

Variable	Coefficient	SE	Significance
Sex (0 = male; 1 = female)	-0.73	1.13	0.518
Age (1 = 65 or younger; 0 = 65+ years)	13.34	406.80	0.974
Prosthetic status (1 = single; 2 = FPD abutment)	1.42	1.31	0.276
Post type (0 = Composipost; 1 = Endopost)	13.80	477.77	0.977
Tooth type (1 = upper incisor 2 = upper canine; 3 = upper premolar; 5 = lower canine; 6 = lower premolar)	0.50	0.24	0.040

suggest that the use of carbon reinforced resin posts in premolars, especially lower premolars, may be associated with a higher failure rate and shorter longevity than in anterior teeth. However, the ability to generalize these results is limited due to several factors: the length of follow-up was shorter than other similar studies; the number of cases was small; and post insertions took place over a long period (3 years). Nevertheless, the results indicate a 3-year survival rate of 90% for the carbon fibre-based post system used to restore endodontically treated teeth. Two of the 3 shortcomings of this study could be overcome by continuing to follow the cohort and reanalyzing the data in 5 and 10 years.

The mechanical failures included one resin core that debonded from the remaining dentin in an upper cuspid. The carbon post was replaced using the special removal system available from the manufacturer, an advantage over many existing post systems.[26]

As a result of the use of techniques that minimize cement failure and have been shown to be retentive,[27,28] all of the carbon fibre posts used in this study remained cemented to the radicular dentin.

Clinical Implications

As in previous studies,[15-17] the CFRR post showed no fractures. The placement technique is less invasive than with some other post systems due to a shorter post length of 7.0-8.0 mm, with less chance of perforation, and posts may be replaced if biologic or mechanical failure occurs.

The greater biologic failure rate among premolars compared with anterior teeth may reflect a more complex root canal system. ◆

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