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Randomized Clinical Comparison of Endodontically Treated Teeth Restored with Amalgam or with Fiber Posts and Resin Composite: Five-Year Results

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Clinical Relevance

Within the limits of this study, restorations with fiber posts and composite were found to be more effective than amalgam in preventing root fractures but less effective in preventing secondary caries; the overall failure rate was not significantly different for the two kinds of restorations.

SUMMARY

Prospective clinical studies comparing the results of different types of restorations of endodontically treated teeth are lacking. This study compared the clinical success rate of endodontically treated premolars restored with fiber posts and direct composite to the restorations of premolars using amalgam.

Premolars with Class II carious lesions were selected and randomly assigned to one of two experimental groups: (1) restoration with amalgam or (2) restoration with fiber posts and composite. One hundred and nine teeth were included in Group 1 and 110 in Group 2.

Patients were recalled after 1, 3 and 5 years.

No statistically significant difference was found between the proportion of failed teeth in the two experimental groups. Significant differences were observed between the proportion of root fractures (p=0.029) and caries (p=0.047), with more root fractures and less caries observed in the teeth restored with amalgam at the five-year recall. Within the limits of this study, it can be concluded that restorations with fiber posts and composite were found to be more effective than amalgam in preventing root fractures but less effective in preventing secondary caries.

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INTRODUCTION

Severely compromised root-filled teeth are often built up with a post and core before crown restoration. Sorensen and Martinoff (1984a,b) reviewed 1,273 endodontically treated teeth that had been restored from 1 to 25 years previously. Statistical analysis showed that coronal coverage did not significantly improve the rate of success for root-filled anterior teeth but did for premolars and molars.

In many cases where crowns are indicated, teeth are restored with metal-ceramic crowns. The preparation of a tooth for a metal-ceramic crown requires an interproximal and labial reduction of 1.5 mm (Sozio, 1977), an occlusal reduction of 2 mm (Preston, 1977) and a lingual reduction of 1.2 mm. The removal of tooth structure can be considerable, especially as many teeth have already sustained significant tooth structure loss due to caries, removal of old restorations and endodontic procedures.

Amalgam has traditionally been used for the restoration of endodontically treated posterior teeth and may be used either as the definitive restoration or as a core for a full coverage crown. The failure rate of endodontically treated and vital teeth was found to be of the same order when restored with extensive amalgam restorations without crown coverage in a 100-month prospective study (Plasmans, Creugers & Mulder, 1998). The only difference reported was that the failures observed in non-vital teeth restored with amalgam, metal dowels and retention in the pulp chamber more frequently led to tooth extractions compared to those of vital teeth; however, the difference between the fracture rate of vital and non-vital teeth was not compared.

Over the last four decades, the introduction of adhesive techniques has enabled the maximum amount of sound tooth structure to be preserved. Endodontically treated posterior teeth restored with amalgam (Hansen, Asmussen & Christiansen, 1990) or self-cured and light cured resin composite (Hansen & Asmussen, 1990) without crown coverage or post-placement have been studied retrospectively. No statistically significant difference was found between amalgam-restored MO/DO teeth and pooled MO/DO plus MOD resin restored teeth, whereas, teeth with MOD amalgam restorations had a higher failure rate than was found for resin-restored teeth. If a fracture occurred, the resin composite restored teeth failed less catastrophically and were more easily re-restored than teeth restored with amalgam. Endodontically treated teeth with complete loss of coronal tooth structure cannot be restored without the use of posts. The use of metal posts, which are much more rigid than the root, may result in an increase in the number of root fractures (Sorensen & Martinoff, 1984a,b). This led to a search for materials with an elastic modulus similar to that of dentin (Duret Reynaud & Duret, 1990a,b) and resulted in the development of fiber posts. A prospective study evaluated the success of 59 carbon-fiber post-composite core restorations covered with full ceramic crowns (Glazer, 2000); the average observation period was 28 months. There were no root fractures and the overall failure rate was 7.7%. Prospective studies comparing clinical results of different restorative techniques for endodontically treated teeth are lacking. The only prospective study on the restoration of endodontically treated premolars that is currently in the literature was conducted on fiber-post restored teeth (Mannocci & others, 2002). No similar study exists on the amalgam restorations of premolars. The only study providing information on premolars with similar loss of tooth structure restored with amalgam was a retrospective one (Hansen & others, 1990) where information on post reinforcement was not collected. Therefore, it was decided to compare these two types of restorations.

This study evaluated the clinical performance of endodontically treated teeth without crown coverage. Premolars restored with amalgam compacted into the root canals were compared with premolars restored with fiber posts and composite. The research hypothesis was that in endodontically treated teeth with limited loss of tooth structure, the placement of fiber posts using a resin composite luting agent would result in a lower failure rate and a different failure mode compared with teeth restored with amalgam.

METHODS AND MATERIALS

Written informed consent was obtained from each patient prior to participation in the study. The protocol of the study was approved by the appropriate institutional review board of the University of Siena. Patients were required to have one maxillary or mandibular premolar for which endodontic treatment was indicated. Patients had to be healthy and willing to return at regular intervals for evaluation. Only patients showing an orthodontic Class I occlusal scheme were included in the study. Only teeth without previous endodontic treatment presenting with a Class II carious lesion and intact cusp structure were included. The teeth were required to be in occlusal function following restoration and none were used as abutments for fixed or removable prostheses. Patients with shortened dental arches were excluded from the study. Patients wearing removable partial dentures were also excluded. Teeth were excluded if the periodontal attachment loss was greater than 40% of the root length. Patients were also excluded from the study if the Gingival Index score (Loe & Silness, 1963) was recorded as being greater than one. All patients received a course of oral hygiene instruction from a dental hygienist prior to commencement of the study.

A total of 219 patients referred to a private practice in Florence from January 1996 to August 1997 for the restoration of endodontically treated premolars was selected (116 women and 103 men). The age of the patients ranged from 32 to 63 years, with a mean age of 45. By tossing a coin, the selected patients were randomly assigned by an author different from the operator to one of the following two experimental groups. Teeth in Group 1 were endodontically treated and restored with amalgam. Teeth in Group 2 were endodontically treated and restored with fiber posts and composite; all participants assigned to either group received intended treatment: 109 teeth were included in Group 1 (26 first mandibular, 29 second mandibular, 28 first maxillary and 26 second maxillary premolars) and 110 teeth in Group 2 (28 first mandibular, 32 second mandibular, 24 first maxillary and 26 second maxillary premolars).

All mandibular premolars had one root canal and, of the maxillary premolars, 70 had one and 34 had two root canals.

All clinical procedures were carried out by the same operator; the teeth were isolated with a rubber dam both for root canal filling and restorative procedures.

Root Canal Treatment

Root canal treatment of teeth from both groups and the composite restoration of teeth from Group 2 were performed as described in a previous study (Mannocci & others, 2002). Root canal treatment was performed under local anesthesia with a chemo-mechanical technique. The root canal filling was performed with laterally condensed gutta-percha and endodontic sealer, (AH Plus, Dentsply De Trey, Konstanz, Germany).

All teeth were prepared and the roots filled at the same appointment. Teeth of both groups received a temporary filling with a zinc oxide, eugenol-free temporary filling composite material (Fermit, Ivoclar–Vivadent, Schaan, Liechtenstein).

Composite Restoration

One week after the root canal filling procedure, gutta-percha was removed to a depth of 7 mm or, whenever possible, to a depth equal to three quarters of the length of the root canal using Largo drills (Maillefer, Baillagues, Switzerland). The working length of the drills was controlled with silicone stops. The root canal walls were enlarged with low speed burs provided by the manufacturer for the preparation of a size 1 carbon fiber post (Composipost, RTD, St Egreve, France). Post diameter was 1.4 mm in the coronal part and 1.2 mm in the apical 2 mm. The depth of the post space preparation was the same as that of the gutta-percha removal. As a reference point, this depth was obtained by using a line painted on the shank of the burs at a distance 9 mm from the tip of the burs. The root canal

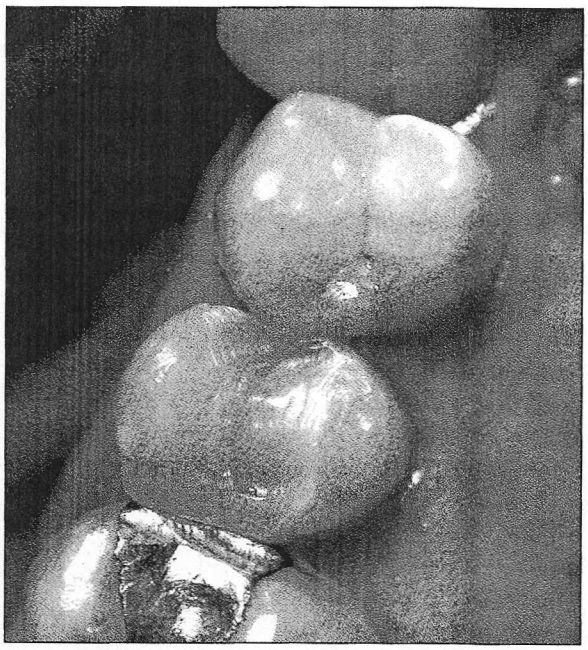

Figure 1. *Successful fiber-post + composite restoration of a maxillary second premolar at five-year recall. 1= fiber post + composite restoration.*

walls were etched with 32% phosphoric acid (All Etch, BISCO, Itasca, IL, USA) for 30 seconds, washed with water spray then gently air dried. Primer A and B (All Bond 2, BISCO) were mixed and applied in the canals. Dentin bonding material (All Bond 2 Pre-Bond Resin, BISCO) was applied in the canal. A layer of dentin bonding primer was applied on the carbon fiber posts, then equal volumes of base and catalyst of the luting composite (C&B, BISCO) were mixed for 10 seconds, according to the manufacturer's instructions. The cement was applied on the post surface, the post was inserted into the canal and the cement allowed to set for seven minutes. A number 1001 Tofflemire metal matrix band (Hawe Neos Dental, Bioggio, Switzerland) was positioned on the tooth; wooden wedges were used in order to improve the interproximal adaptation. Composite (Z100, 3M, St Paul, MN, USA) was placed incrementally in 2-mm layers. Each layer was exposed for 40 seconds with a visible light-polymerizing unit (Visilux 2, 3M) and no composite cusp coverage was performed (Figure 1).

Amalgam Restorations

One week after completion of the root canal filling procedure, the temporary restoration and gutta-percha were removed to a depth of 4 mm using Largo drills (Dentsply Maillefer, CH-1338 Ballaigues, Switzerland). A #1001 metal matrix band (Tofflemire) was placed around the tooth and wooden wedges were used to improve interproximal adaptation. The amalgam used was a palladium enriched, phase-dispersed amalgam alloy (Valiant PhD, Dentsply, Milford, DE, USA)

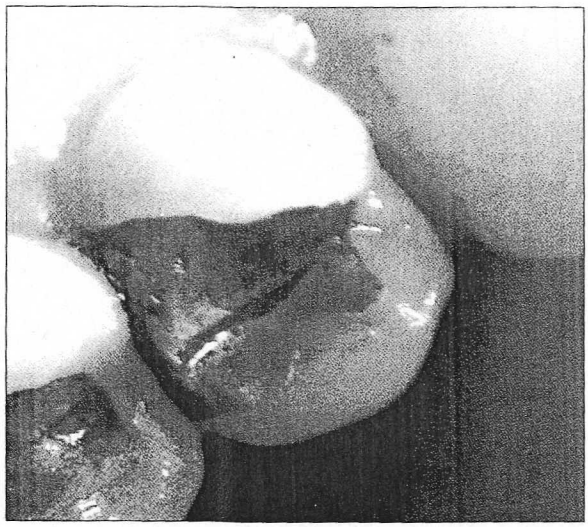

Figure 2. *Successful amalgam restoration of a maxillary first premolar at five-year recall.*

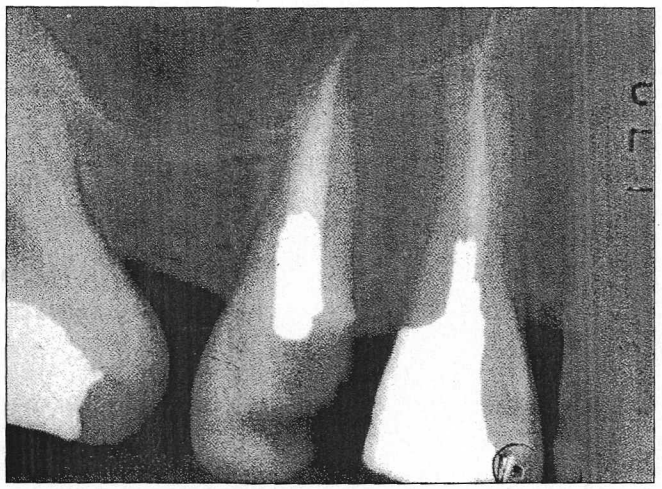

Figure 4. *Failed amalgam restoration of a second maxillary premolar at five-year recall. 3= Cervical fracture of the root. 4= Amalgam compacted into the root canal, this portion of amalgam remained into the root canal after tooth fracture.*

(Figure 2). No cavity liner was placed. In order to improve retention of the restoration, amalgam was compacted in the coronal third of the root canal from which the gutta-percha had been removed. A precise measurement of the diameter of the amalgam compacted into the root canal cannot be given, as the section of the coronal third of the root canals of mandibular and maxillary premolars is not circular but irregularly elliptical. In 70 teeth, the amount of dentin sustaining the buccal or lingual cusp was considered insufficient and, therefore, the cusp was covered with amalgam, the minimal cuspal reduction was about 3 mm.

Clinical Criteria for Success and Failure

The patients were recalled for examination after 1, 3 and 5 years. Causes of failure were categorized as root

Figure 3. *Failed fiber post + composite restoration of a maxillary second premolar at five-year recall. 2= Caries at tooth-composite margin.*

fracture, post fracture, post decementation, clinical and/or radiographic evidence of a marginal gap between the tooth and restoration and clinical evidence of secondary caries contiguous with the margins of the restoration. Failure caused by root fracture was noted when, after extraction of a fractured tooth fragment, a fracture line involving the root was evident at inspection; the other failure modes were defined as described previously (Mannocci & others, 2002).

Clinical, radiographic and photographic assessments were performed as described previously by two calibrated examiners (Mannocci & others, 2002). Visual inspection was conducted using loops with fiber-optic coaxial illumination (Zeon Illuminator; Orascoptic Research, Madison, WI, USA) at 3x magnification, examination of the continuity of the margins of the restoration with the tooth structure was accomplished using an explorer (EXS6; Hu Friedy, Leiman, Germany) and periodontal probing was performed using a periodontal probe (Perio-Probe, ASA Dental 1-2, Lucca, Italy). Color slides (1:1 mirror shots) of the restorations were taken using standard film (Kodak EliteChrome 100, Eastman Kodak Company, Rochester, NY, USA). Periapical radiographic examination was performed using a paralleling technique at 65 kV and 8 mA. A radiographic extension cone (Orix AET, Ardet, Buccinasco, Italy) was used in combination with a paralleling device (Rinn XCP, Rinn Corp, Elgin, IL, USA). Ultra-Speed periapical 31 ¥ 41-mm dental films (DF-57, Kodak) were used. Radiographs were projected onto a 60 ¥ 90 cm screen. The clinical, radiographic and photographic examinations were performed immediately before restoration, immediately after restoration and at 1-, 2- and 5-year recall. The assessment took place immediately before reconstruction, immediately after and at 1 to 3 and 5-year recall.

Table 1: *Results at One Year Showing the Differences Between the Groups in the Proportions of Failed Teeth with 95% Confidence Intervals*

	Amalgam (Group 1)	Composite + fiber post Group 2	Δ	95% CI		p
Recall	107	109				
Failure	1	2	-0.009	from-0.056 0.035	to	1.00
Fracture	1	0	0.009	from-0.026 0.051	to	0.50
Caries	0	2	-0.018	from-0.064 0.019	to	0.50

Table 2: *Results at Three Years Showing the Differences Between the Groups in the Proportions of Failed Teeth with 95% Confidence Intervals*

	Amalgam (Group 1)	Composite + fiber post Group 2	Δ	95% CI		p
Recall	105	105				
Failure	3	3	0.000	from-0.055 0.55	to	1.00
Fracture	2	0	0.019	from-0.019 0.067	to	0.50
Caries	1	3	-0.019	from-0.072 0.027	to	0.62

Table 3: *Results at Five Years Showing the Differences Between the Groups in the Proportions of Failed Teeth with 95% Confidence Interval*

	Amalgam (Group 1)	Composite + fiber post Group 2	Δ	95% CI		p
Recall	100	97				
Failure	9	10	-0.013	from-0.100 0.073	to	0.81
Fracture	6	0	0.060	from 0.010 0.125	to	0.029
Caries	3	10	-0.073	from-0.152 –0.002	to	0.047

Teeth lost due to trauma, endodontic or periodontal problems were considered as missing data. Patients who did not respond to one or more of the three recalls were excluded from the study.

Data Analysis

The proportion of fractures and failures between the two groups was compared using Fisher's exact test. The 95% confidence interval for the difference between the proportions was calculated using Wilson's method (Altman & others, 2000). The level of significance of 0.05 was used throughout the test.

RESULTS

Two patients from Group 1 and one patient from Group 2 failed to return at the one-year recall, two additional patients from Group 1 and four patients from Group 2 missed the three-year recall, five additional patients from Group 1 and seven patients from Group 2 failed to return at the five-year recall. These patients were excluded from the study.

No teeth were lost due to trauma, endodontic or periodontal problems. The only failure modes observed were due to caries (Figure 3) and root fractures (Figure 4). There were three failures (two from caries and one fracture) at one year, six failures (four caries and two fractures) at three years and 19 failures (13 caries and six fractures) at five years (Tables 1, 2 and 3). In the amalgam group, five of the six fractures involved cusps covered with amalgam. In three cases, the amalgam restorations remained intact and the cusp fractured; in the other three cases, the amalgam restorations also failed. In these cases, the amalgam compacted into the root canal and remained *in situ*, whereas, the remaining part of the restoration was involved in the fracture. No significant differences were found between amalgams and restorations with fiber posts and composite at the one- and three-year recall examinations (all $p>0.50$). At five years there were significant differences between the number of failures due to fractures ($p=0.029$) and the number of failures due to caries ($p=0.047$), with more root fractures in the teeth restored with amalgam and more caries in teeth restored with fiber posts and composite. No statistically significant differences were found for failure, fractures and caries when the analysis was conducted for maxillary and mandibular teeth separately (Table 4).

DISCUSSION

In this study, the recall rate after five years was 91.7% for Group 1 and 88.2% for Group 2. Similar recall rates have been reported in other long-term recall studies (Van Dijken, Olofsson & Holm, 1999). The 100-month survival rate of extensive amalgam restorations for both vital and non-vital teeth was found to be 88±2% in a study on extensive amalgam restorations (Plasmans

Table 4: *Results at Five Years Showing the Differences Between the Groups in the Proportions of Failed Teeth with 95% Confidence Intervals for Both Maxillary and Mandibular Teeth*

	Amalgam (Group 1)	Composite + fiber post Group 2	Δ	95% CI		p
Maxillary teeth						
Recall	47	52				
Failure	5	6	-0.009	from-0.138 0.125	to	0.88
Fracture	3	0	0.043	from -0.033 0.142	to	0.14
Caries	2	6	-0.052	from-0.173 0.073	to	0.36
Mandibular teeth						
Recall	53	45				
Failure	4	4	-0.13	from-0.140 0.103	to	0.82
Fracture	3	0	0.057	from 0.030 0.154	to	0.08
Caries	1	4	-0.070	from-0.189 0.027	to	0.12

& others, 1998). The survival rate of the amalgam group in this study was 91.3%; this higher survival rate may have been attributed to the selection of teeth with limited loss of tooth structure and to the shorter recall term. The survival rate of teeth restored with fiber posts and composite was 90%, this being somewhat less than that found in a previous two-year recall study (Glazer, 2000) on fiber post crown restorations (92.3%). This small difference might be explained by the longer follow-up time and supports the proposal that sound tooth structure should be preserved, if possible, and crown coverage avoided for premolars for the first five years after endodontic treatment. Post-core decementations may occur in crown-covered teeth restored with fiber posts and composite (Glazer, 2000; Mannocci & others, 2002). The absence of decementations in this study is another factor that favors the avoidance of coverage of composite cores with crowns, if possible. It has been demonstrated that fiber posts become more flexible after water immersion (Torbjoner & others, 1996; Mannocci & others, 2001a); contact of fiber posts with water may occur if there is leakage at the interface between the composite and the dentin (Mannocci & others, 2001b). In this case, it might be speculated that, for crown-covered teeth, rigid metal ceramic crowns transfer stress to fiber posts that have become more flexible. The flexion of fiber posts results in debonding of the adhesive from the tooth structure and post-core decementation. In teeth are left without crown-coverage, the less rigid composite restoration will probably wear more than the crowns and amalgam and, therefore, might transfer less stress to the fiber posts and the remaining tooth structure. This could account for the absence of post-core decementations and the absence of root fractures in fiber-post-restored teeth left uncovered. On the other hand, the wear rate was not included among the failure modes in this study, which might affect the long-term clinical performance of composite restorations without crown coverage.

The absence of root fractures in teeth restored with fiber posts and composite concurs with previous retrospective (Ferrari & others, 2000) and prospective (Glazer, 2000; Mannocci & others, 2002) studies on fiber post restorations. All failed teeth in this group were re-restored with adhesive techniques and maintained in clinical service, whereas, three teeth from the amalgam group had to be extracted due to root fractures. In accordance with Hansen and Asmussen (1990), it can be concluded that the failure mode of adhesively restored teeth was more favorable.

Cusp coverage of amalgam-restored teeth has been suggested in order to prevent root fracture (Robbins, 1990), but, to date, no controlled prospective study has demonstrated the effectiveness of cusp coverage for the prevention of root fractures. For this reason, in this study, only cusps with an amount of dentin considered to be insufficient were covered.

Procedures for finishing contact points and interproximal spaces were found to be less effective for composite restorations than for amalgam since they are performed on a less plastic material. This may lead to the formation of gaps that are difficult to detect and may result in plaque retention, hence, the higher incidence of secondary caries observed in the composite filling group.

Statistical analysis of the results did not support the first part of the research hypothesis—that in teeth with limited loss of tooth structure, endodontic treatment and build-up using fiber posts and composite results in a lower failure rate compared with endodontically treated teeth restored with amalgam. The second part of the research hypothesis—that the failure modes of the two groups were different—was upheld, as the number of root fractures was found to be significantly higher in teeth restored using amalgam and the number of teeth with caries was higher in teeth restored with fiber posts and composite.

CONCLUSIONS

It can be concluded that within the limits of this study conducted on endodontically treated premolars with limited loss of tooth structure, adhesive restorations were found to be more effective than amalgam in preventing root fractures but less effective in preventing secondary caries.

(Received 29 January 2004)

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