JOURNAL OF DENTISTRY 37 (2009) 115–121

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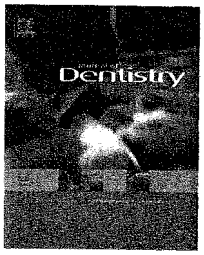

Long-term survival of endodontically treated, maxillary anterior teeth restored with either tapered or parallel-sided glass-fiber posts and full-ceramic crown coverage

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ARTICLE INFO

Article history:
Received 29 June 2008
Received in revised form
9 October 2008
Accepted 11 October 2008

Keywords:
Fiber post
Endodontically treated teeth
Full-ceramic crown
Build-up material
Survival analysis
Adhesion

ABSTRACT

Objectives: This retrospective study investigated the clinical effectiveness over up to 8 years of parallel-sided and of tapered glass-fiber posts, in combination with either hybrid composite or dual-cure composite resin core material, in endodontically treated, maxillary anterior teeth covered with full-ceramic crowns.

Methods: The study population comprised 192 patients and 526 endodontically treated teeth, with various degrees of hard-tissue loss, restored by the post-and-core technique. Four groups were defined based on post shape and core build-up materials, and within each group post-and-core restorations were assigned randomly with respect to root morphology. Inclusion criteria were symptom-free endodontic therapy, root-canal treatment with a minimum apical seal of 4 mm, application of rubber dam, need for post-and-core complex because of coronal tooth loss, and tooth with at least one residual coronal wall. Survival rate of the post-and-core restorations was determined using Kaplan–Meier statistical analysis.

Results: The restorations were examined clinically and radiologically; mean observation period was 5.3 years. The overall survival rate of glass-fiber post-and-core restorations was 98.5%. The survival rate for parallel-sided posts was 98.6% and for tapered posts was 96.8%. Survival rates for core build-up materials were 100% for dual-cure composite and 96.8% for hybrid light-cure composite.

Conclusions: For both glass-fiber post designs and for both core build-up materials, clinical performance was satisfactory. Survival was higher for teeth retaining four and three coronal walls.

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doi:10.1016/j.jdent.2008.10.007

1. Introduction

The choice of appropriate definitive restoration of endodontically treated maxillary anterior teeth should be guided by the amount of remaining hard tissues as well as functional and aesthetic considerations. Because of their aesthetic appeal, durability and biocompatibility, full-ceramic crowns have become a standard procedure in the treatment of anterior teeth.[1,2] However, in cases of inadequate remaining coronal structure, complete crowns often require the additional support afforded by a post-retained core.[3,4] For this purpose, a prefabricated root post or an indirect, custom-made post-and-core can be used. Custom-fabricated cast post-and-cores are still considered to be the gold standard for restoring extensively damaged endodontically treated teeth.[5,6] However, it has been reported that shape and rigidity of cast gold post-and-cores, and the rigidity of prefabricated metal posts, may pose a risk for root fracture.[7,8] Recent reports suggest that the rigidity of the post should be equal or almost equal to that of dentin, so as to distribute the functional forces evenly along the length of the root.[9,10] More recently, several new types of post material have been introduced, including fiber-reinforced posts (FRPs). The biomechanical properties of fiber posts have been reported to be close to those of dentin,[11,12] and clinical prospective and retrospective studies have reported convincing results.[13,14] In addition, for aesthetic considerations, dentin-colored post-and-core materials are now normally used for all-ceramic crown restorations.[15,16] The core should be built up with composite materials, but as yet there is no agreement regarding the best composite material to be used for the direct core build-up of endodontically treated teeth.[17,18]

Most existing longitudinal clinical studies of endodontically treated anterior teeth restored with glass-fiber posts, in combination with full-ceramic crowns, are on small series and with a follow-up of limited duration. The purpose of this longitudinal retrospective study, over up to 8 years, was thus to evaluate the survival rate of glass-fiber posts with parallel-sided or tapered shape in combination with either hybrid composite or dual-cure composite resin core material in endodontically treated maxillary anterior teeth, with various degrees of coronal tissue loss, restored with full-ceramic crowns.

2. Materials and methods

2.1. Study population

Between January 2000 and February 2008, patients attending the Department of Biophysics, Medicine and Dentistry of the University of Genoa (Italy) requiring aesthetic restoration of endodontically treated, maxillary anterior teeth were recruited for this study. The study protocol was conducted by four operators, after prior review and approval by the Ethical Approval Board of the University of Genoa. All patients provided written, informed consent and declared themselves willing to return at regular intervals for evaluation. The study population comprised 200 patients, 121 female (60.5%) and 79 (39.5%) male, who had received 538 FRPs in endodontically treated maxillary anterior teeth, with various degrees of hard-tissue loss. They were subdivided into four experimental groups, as described below. Four experimental groups were defined by post shape and composite core build-up material. Post-and-core build-up with parallel-sided post and dual-cure composite (group A), parallel-sided post and hybrid light-cure composite (group B), tapered post and dual-cure composite (group C), and tapered post and hybrid light-cure composite (group D).

Each tooth received one calibrated post only. Randomization of the FRPs was carried out with respect to root morphology but not with respect to tooth location. For clinical and anatomical reasons, tapered FRPs were selected for tapered roots with small residual root dentin walls. The abutment portion of teeth that presented with three or four residual walls was built up with a dual-cure composite material (group A or C); teeth that presented with one or two residual walls were built up with a hybrid composite material (group B or D). For all teeth, the final restoration was a single laboratory fabricated full-ceramic single crown.

Only teeth that had been previously endodontically treated by one of the four operators were included in this study. Other inclusion criteria were symptom-free endodontic therapy, root-canal treatment with a minimum apical seal of 4 mm, application of rubber dam, and the need for a post-and-core restoration because of coronal tooth loss. Only patients showing an orthodontic Class I occlusal scheme were included. Exclusion criteria were teeth that had lost all coronal walls or with failed endodontic therapy, tooth fractures and extensive caries under the margins of the free gingiva. Also teeth with deep periodontal pockets, no adequate periodontal support and poor oral hygiene or caries rates were not included in this trial. Patients with open or deep bite, with severe parafunction and shortened dental arches and patients wearing removable partial dentures were also excluded. All patients received initially a medical examination by one of the four operators to exclude medical contraindications to dental treatment. One patient suffered from Sjögren syndrome and two patient suffered from diabetes at time of examination, however, all were receiving treatment. Fifty patients (25%) declared themselves to be smokers. In addition to medical and demographic information, other data were collected at the baseline examination: tooth location, root morphology, number of residual walls, type of the post placed (either parallel-sided or tapered), and core build-up material.

2.2. Clinical procedures

All endodontic and restorative procedures were performed by one of the four dentists involved in the study, under standardized conditions and employing standardized techniques, using the same materials and adhesive procedures. Root-canal treatment was performed using a crown-down technique with nickel–titanium instruments (ProFile System; Denstsply Maillefer, Ballaigues, Switzerland) and 2.5% sodium hypochlorite irrigation. The canals were filled with vertically condensed warm gutta-percha (Guttapercha Points, Dentsply DeTrey, Konstanz, Germany) and endodontic sealer containing eugenol (Argoseal, Ogna, Laboratori Farmaceutici, Muggiò (MI), Italy). All teeth received a temporary filling with zinc phosphate temporary filling material (DeTrey Zinc, Dentsply DeTrey, Konstanz, Germany). At least 10 days later, roots were

prepared for post placement. Two prefabricated FRP designs were used: a parallel-sided glass-fiber post, the FibreKor Post (Pentron Clinical Technologies, Wallingford, USA); or tapered glass-fiber posts. Between 2000 and 2005 Luscent Anchors were used (Dentatus AB, Hägersten, Sweden); starting from 2005, Enaposts (Micerium, Avegno (GE), Italy) were used.

For adhesive procedures, the working field was isolated with a rubber dam.

The appropriate size of FRPs was selected and the root canal space was prepared with calibrated drills provided by the manufacturer, to a length of 8–9 mm; at least 5–4 mm of apical seal was maintained. The posts were tried in and if necessary shortened with a diamond separating disc. Before cementing, the FRPs received surface pre-treatment: posts were cleaned with acetone and silanized with a prehydrolyzed silane solution (Monobond S, Ivoclar Vivadent, Schaan, Lichtenstein). The post surface was then wetted with one-coat bonding resin (Mono, DMG Dental-Material GmbH, Germany). After that the resin was thinned with oil-free air, then light-cured by means of a halogen light-curing unit with light-intensity 800 mW/cm^2 (Spectrum 800, Dentsply, Konstanz, Germany) for 20 s. The root canal was rinsed and dried with sterile paper points (Absorbent Paper Points, Dentsply DeTrey, Konstanz, Germany). Etching gel 37% phosphoric acid (Total Etch, IvoclarVivadent, Schaan, Lichtenstein) was applied to the post space for 60 s and rinsed off with water using an endodontic syringe then dried with sterile paper points. A single coat of dual-cure adhesive system (All Bond 2; Bisco, Schaumburg, IL, USA) was applied following the manufacturer's instruction using Microbrush fine or Microbrush X (Microbrush International, Grafton, USA) and not light-cured. Excess bonding components were completely absorbed with sterile paper points. A dual-cure composite resin cement (LuxaCore-Dual, DMG Dental-Material GmbH, Germany) was applied to the post space with a Lentulo spiral (Dentsply Maillefer, Ballaigues, Switzerland) and on the post surface, and then the post was seated. After removing excess cement, the correct position of the post was verified and the resin was light-cured by means of a halogen light-curing unit with light-intensity 800 mW/cm^2 for 60 s. To reconstruct the coronal tooth structure, core build-up was performed using a hybrid composite (Ecusit Composite, DMG, Hamburg, Germany) in teeth with one or two residual coronal walls, while a dual-cure composite resin material (LuxaCore-Dual, DMG Dental-Material GmbH, Germany) was used in teeth with three or four residual coronal walls. To standardize adhesive procedures for all core build-ups, the same dentin adhesive system was used (All Bond 2; Bisco, Schaumburg, IL, USA).

For crown preparation, a circumferential shoulder with rounded internal line angles was created with diamond burs. Care was taken to prepare a 2.0-mm-height ferrule. However, in several teeth, non-uniform ferrules had to be prepared because of a loss of tooth structure. In this cases, the achieved ferrule height was newer below 1 mm. All-ceramic crowns were fabricated using the 3G OPC System (Pentron Clinical Technologies, Wallingford, CT, USA) and adhesively cemented. Occlusion was evaluated and excursive interferences in lateral, latero-protrusive, and protrusive excursions were removed.

All patients received hygiene instructions; complete plaque removal by mechanical scaling plus root planning was performed every 6 months.

2.3. *Follow-up procedures*

All patients were told to report to the Department of Biophysics, Medicine and Dentistry of the University of Genoa if they experienced any problems. Follow-up examinations were performed at the oral hygiene recalls. Patients were examined clinically and radiologically by two independent dentists from the Prosthetic Department of University of Genoa and were scored according to the pre-determined criteria for post-and-core survival. Radiographs of all restorations were taken with the standardized long-cone technique and examined at 4.3 × 400 with surgical head-worn loupe. Photographs, radiographs of the restorations and data sheets were used as documentation. Comparisons were made with photographs and radiographs obtained immediately after treatment. The criteria for survival were no root fracture, no post fracture, no post debonding, and no failure of the core build-up. Endodontic and periodontal failure, marginal discoloration, lack of integrity of the crown, and porcelain fracture were also noted but not included as non-survival in the statistical analysis.

2.4. *Statistical analysis*

Post-and-core restorations were defined as either surviving or not surviving according to the following criteria: survival was a positive, censored event, whereas non-survival was defined as the negative, uncensored event. Based on this definition, survival rates from time-related events were calculated using the non-parametric survival analysis (Kaplan–Meier).

Post placement was considered as analysis baseline for the present study. Time until failure or censoring (i.e. last follow-up examination) was recorded in months. The end of the observation time for a successful restoration corresponded to the re-evaluation date. The end of observation for a failed restoration was the date when this event was noted in the record or when the failed restoration was detected during the re-evaluation appointment. Statistical analysis was performed to determine the survival rate with the software SPSS version 13.0 (SPSS) for Windows. The null hypothesis, that there is no difference between the populations in the probability of an event (here failure of post-and-core restoration) at any time point, was tested by means of the Logrank test; analysis is based on the times of events.

3. Results

A total of 538 FRPs were placed in 200 patients. The study population comprised 121 women and 79 men. A total of 538 laboratory fabricated full-ceramic single crown were placed.

In this study no follow-up information could be collected for 12 (2.3%) post-and-core restorations, involving 8 (4.2%) patients (5 men and 3 women). Reasons for not attending recall were four patients could not be contacted (seven restorations), two were no longer interested in participating

Table 1 – Distribution and characteristics of the post-and-core restorations.

	Parallel-sided post, N (%)			Tapered post, N (%)		
	Central incisors	Lateral incisors	Canines	Central incisors	Lateral incisors	Canines
Dual-core composite build-up material ($n = 80$)	17 (21.3)	4 (5.0)	12 (15.0)	13 (16.3)	28 (35.0)	6 (7.5)
Hybrid composite build-up material ($n = 446$)	90 (20.2)	20 (4.5)	106 (23.8)	85 (19.1)	99 (22.2)	46 (10.3)

in the study (three restorations) and two had moved to another area (two restorations). Thus, 526 endodontically treated maxillary anterior teeth restored by means of post-and-core, in 192 patients (118 women, mean age 36.8 years, range 20–66 years; and 74 men, mean age 38.3 years, range 19–65 years) completed the follow-up. The restored maxillary teeth comprised 205 central incisors, 151 lateral incisors, and 170 canines, and were followed-up for a mean observation time of 5.30 years. Thirty-three post-and-core restorations were performed with parallel-sided post and dual-cure composite (group A), 216 with parallel-sided post plus hybrid light-cure composite (group B), 47 with tapered post and dual-cure composite (group C), and 230 with tapered post and hybrid light-cure composite (group D). The characteristics and distribution of the post-and-core restorations are shown in Table 1.

The results of the Kaplan–Meier analysis of cumulative survival are presented in Fig. 1. The overall 8-year survival rate of ceramic-crowned, endodontically treated maxillary anterior teeth restored with full-ceramic crowns and glass-fiber posts was 98.48%. Survival rate for groups A and C was 100%, while group B had a survival rate of 98.2% and group D of 95.72%. The Logrank test determined that there was no significant difference between the four groups, which led to acceptance of the null hypothesis.

Graphs representing the survival curves versus type of post and type of build-up material are presented for descriptive purposes in Fig. 2A and B. The survival rate for parallel-sided posts was 98.6% and that for tapered posts was 96.8%. The survival rate for core build-up materials was 100% for dual-cure composite and 96.8% for hybrid light-cure composite. The Logrank test detected no differences between these survival curves.

During the evaluation period, seven post-and-core restorations failed (1.33%). Failure mode was post debonding (five cases, 0.95%), traumatic post fracture (one case, 0.19%) and core build-up failure with fracture of the core and a small part of residual coronal dentin (one case, 0.19%). In three of the five post debonding cases, an asymptomatic periapical radiolucency was observed and endodontic re-treatment was performed. In all cases of failure, the tooth could be restored in the same manner as previously described and remained in service. No root fractures were observed.

During the evaluation period, eight full-ceramic crowns (1.52%) failed. Five (0.95%) with a fracture were replaced; the other three (0.57%) debonded crowns were immediately rebonded. The clinical performance of the full-ceramic crowns was not included in the longitudinal study.

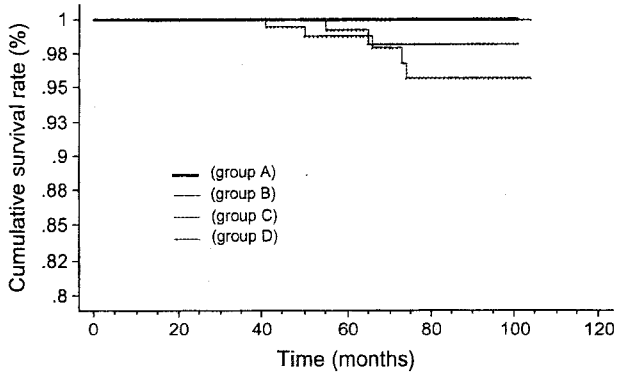

Fig. 1 – Kaplan–Meier survival curves for post-and-core restorations in maxillary anterior teeth.

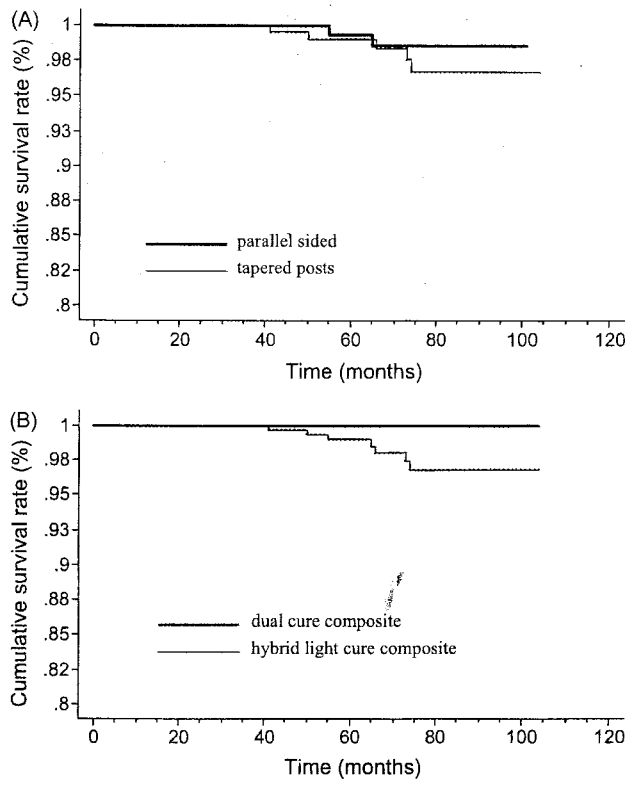

Fig. 2 – (A) Kaplan–Meier survival curves for parallel-sided and tapered posts. (B) Kaplan–Meier survival curves for dual-cure composite and hybrid light-cure composite core build-up materials.

4. Discussion

In the present study the cumulative survival rate was found to be 98.48%. Comparison across studies is always difficult due to

differences in inclusion criteria, study population, materials, methods, and observation period. An association between crown placement and the survival of endodontically treated teeth is known from numerous clinical investigations. However, most previous clinical trials were not restricted to the anterior dentition, but also involved premolars and molars, and nor were they restricted to full-ceramic crowns; this limits their comparability to the present study.[13,19–22] For that reason, in this investigation descriptions of materials and techniques and documentation of their performance are in sufficient detail to permit their inclusion in a meta-analysis.

Two investigations showed long-term clinical performance of three types of fiber posts in combination with composite build-up, over an observation period of more than 8 years, with a slightly lower survival rate than the present study.[6,23] This may be explained by the larger series and longer service period of fiber posts included in those trials.

According to the literature, the prognosis for endodontically treated teeth restored with FRP build-up depends on a wide range of factors, which have been examined independently or in combination, using in vitro studies or clinical reports. Various aspects have been considered, such as post material and design, post length and diameter, core build-up material, luting cement and adhesive system, ferrule height and amount of coronal tooth substance.[24–28] In the present study the success rate for groups A and C was 100%. The lack of failures in these groups, comprising teeth with three and four residual walls treated with dual-cure composite as build-up material, may be due to the relatively small sample size (group A = 33 teeth; group C = 47 teeth). We believe this result may be explained by the determinant role played by remaining tooth structure: a growing body of data from clinical and laboratory investigations shows that the more residual coronal dentin there is, the better the survival rate.[19,22–24,29] In agreement with previous clinical trials, in the present investigation loss of retention was the most frequent unfavorable event for direct post-and-core restorations.[21,22,30] FRP debonding may occur along either the cement/post or the cement/dentin interface. Pre-treatment of the post surface with coupling agents, silane and/or bonding resin can enhance adhesion;[31,32] bonding to intraradicular dentin is a challenging procedure that may impair optimal dentin hybridization.[33–35] In our study all cases of post debonding and the single failure of the build-up material occurred in teeth retaining only one or two residual coronal walls (groups B and D). These findings may be explained by the determinant role played by the remaining tooth structure rather than by the mechanical properties of the restorative materials: several studies have suggested the role of residual coronal dentin in post retention to be significant.[19,21,23,25,29] Nevertheless, the most common failure observed in previous investigations was post fracture, which may be related to low fatigue resistance of the post used.[36,37] Conversely, in the present clinical trial the single post fracture occurred as a result of trauma, with no fracture to the root. In agreement with these findings and with previous clinical trials it could be said that fiber post placement resulted in a low risk of root fracture.[12,22,38]

Another study indicated two other risk factors: the type of definitive restoration and the number of proximal contacts.[19] The present trial failed to identify the type of restoration as a risk factor, and did not record the number of proximal contacts.

In the present study the success rate for parallel-shaped posts was 98.6% and for tapered posts was 96.8%. The post assignment was randomized with respect to the root morphology by means of intraoral radiographic examinations performed during endodontic treatment. Thus, lateral incisors received more FRPs with conical shape (98 posts) than they did parallel-shaped posts (24 posts). The post shape was not a statistically significant factor in the present investigation. However, tapered posts had a higher failure rate than parallel posts, which is in disagreement with a previous study in which parallel posts had a failure rate three times higher than tapered posts.[19] According to these data, we cannot rule out that the shape of FRPs may represent a determinant factor in failure rate.

The different build-up materials were also compared in a range of clinical situations. The success rate for dual-cure composite material (groups A and C) was 100% and that of hybrid light-cure composite (groups B and D) was 96.8%. Although dual-cure composite exhibits lower flexure strength and a lower modulus of elasticity than hybrid composite materials, no statistically significant difference was found. It has been shown that where there is more residual dentin the mechanical qualities of the build-up material play a less significant role.[29,34]

Recently, clinical studies have suggested that post-retained single crowns placed in the maxillary anterior region had a failure rate about three times higher than that of restorations placed in premolars and molars.[19,39] According to other recent studies, it has been well documented that fracture resistance of non-vital teeth depends significantly on the angle of applied load, with axial forces being less detrimental than oblique forces.[40,41]

Further, the loading capacity of crowned post-and-core restorations is a function of the ferrule height.[21,42] Non-uniform ferrule results in lower fracture resistance than a uniform 2-mm-height ferrule.[29] In the present study a standard ferrule height of 2.0 mm was preferred, however, in some teeth this could not be obtained and ferrule were non-uniform depending on the amount of sound tooth structure. Although ferrule height was not one of the factors recorded at baseline in the present clinical trial. The authors speculate that the occurrence of non-uniform ferrules may have influenced the results.

With regard to the clinical performance of full-ceramic crowns, the survival rate, fracture resistance and failure pattern were excluded from this clinical trial for standardization purposes.

Finally, in three of the post debonding cases, an asymptomatic periapical radiolucency was observed and endodontic re-treatment was performed. It may be speculated that these endodontic failures were caused by re-infection due to loss of coronal seal, as has been described in other clinical trials.[28,30,43]

The present study has some limitations. All clinical procedures were performed by experienced clinicians and the post-and-core restorations were placed over a period of 8 years, rather than simultaneously. In addition, the study population was pre-selected, since tooth loss due endodontic

or periodontal failures was excluded; thus, the data only represent restorative failure. The study limitations include the fact that post assignment was randomized with respect to the root morphology but not with respect to tooth location. The inability of the statistical test applied to identify any significant differences may be related to the long observation period, the large number of restorations evaluated and to the relatively rare occurrence of failure. These limitations must be considered when interpreting the results.

Nevertheless, the study also possesses some major advantages compared to others: the sample size was large, and the follow-up period long; the trial was limited to anterior dentition, and all patients treated were serially accounted for at the end of the study. The clinical procedure for endodontic treatment and placement of restorations was performed under standardized conditions, which are described in detail so that they can be compared with other studies.

The study groups included in this trial are still under investigation, with the aim of collecting longer-term survival data, and this continuing long-term longitudinal study will provide additional data that may support the validity of our results.

5. Conclusion

It can be concluded, within the limits of this study, that over a mean observation time of 5.30 years the survival rate of glass-fiber posts with a parallel-sided or tapered shape in combination with either hybrid composite or dual-cure composite resin core material in endodontically treated maxillary anterior teeth was 98.48%. For both parallel-sided and tapered glass-fiber posts, as for the two different core build-up materials, the long-term clinical performance was satisfactory. With regard to the influence of residual coronal dentin, survival was longer for teeth with four or three coronal walls. The amount of coronal tooth destruction was identified as a variable that influenced the survival of post-and-core systems.

Acknowledgments

The authors are especially grateful to Prof. George Romanoss, Department of Dentistry, Rochester, NY, USA, for proof-reading the manuscript and for his contribution to the study, and to the Department of Health Sciences, University of Genoa, Italy, for the statistical analysis.

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