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Marginal Adaptation of Root-end Filling Materials: An *In vitro* Study with Teeth and Replicas

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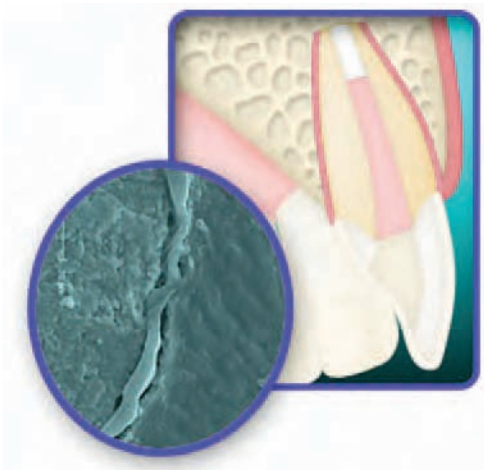

Abstract

Aim: The purpose of this investigation was to evaluate the marginal adaptation of five root-end filling materials.

Methods and Materials: Fifty human single-rooted teeth were resected 3 mm from the apex. Root-end cavities were then prepared using an ultrasonic tip and filled with one of the following materials: silver amalgam without zinc, white MTA-Angelus, white Portland cement (PC), Vitremer™, and GC Fuji Ortho™ LC. The apical portion of the roots was then sectioned to obtain two 1 mm thick transversal sections. Epoxy resin replicas of these apical sections were fabricated for an analysis of marginal adaptation. Scanning electron microscopy (SEM) was used to determine gaps in the adaptation of the root-end filling materials at the interface between them and the dentin. The Kruskal-Wallis test and a multiple comparison test were used for statistical data analysis. The Spearman correlation coefficient was used to determine the correlation between the results found for teeth and replicas.

Results: Materials containing calcium oxide (MTA and PC) showed similar results. Resin modified glass ionomer cements (GICs) presented similar variations in marginal adaptation, but Vitremer™ showed significantly greater marginal adaptation when compared to GC Fuji Ortho™ LC.

Conclusion: A positive and significant correlation was observed between marginal adaptation values found in the teeth and their replicas.

Clinical Significance: The use of ionomers as root-end filling materials may improve clinical outcomes in periradicular surgery.

Keywords: Dental materials, marginal adaptation, oral surgery, root-end filling, laboratory research

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Introduction

Surgical endodontic therapy, performed as an alternative to endodontic retreatment, requires several procedures, such as periradicular curettage, root-end resection, and root-end filling.[1-3] Root-end fillings should seal the apical region to avoid bacterial infiltration and diffusion of bacterial products from the root canal system to periradicular tissues.[4]

Amalgam has been widely used as a root-end filling material. Some of its advantages are low cost, ease of manipulation, and success in clinical applications. However, due to the growing concern over environmental contamination by hazardous metals several other materials to replace amalgam have been studied.[1] These include modified zinc oxide eugenol-based cements (Super-EBA®, IRM), glass ionomer cements (GICs), calcium hydroxide cements, gutta-percha, composite resins, and, more recently, mineral trioxide aggregate (MTA). Several studies reported good results in the evaluation of MTA as a root-end filling material. Because of their chemical and physical similarities, MTA and PC, a material used in civil engineering, have been compared in recent studies.[4] Both materials are composed of calcium phosphate, calcium oxide, and silica. However, MTA also contains bismuth oxide, an element that is radiopaque.[5,6]

GICs have also been used in root-end fillings. GICs do not induce tissue inflammatory responses and offer the advantages of biocompatibility and low toxicity.[7] Their use as a conventional or root-end filling material is recommended because of their favorable chemical adhesion to enamel and dentin.[8]

Different properties of these materials, such as marginal adaptation and biocompatibility, have been evaluated in several studies. Scanning electron microscopy (SEM) at high magnifications has been used to analyze the interface between dentin and root-end filling material and to evaluate marginal adaptation.

Tooth replicas manufactured with epoxy resin have been used to eliminate possible artifacts related to the use of high-vacuum SEM.[3,9-14] Gondim Jr. et al.[15] compared tooth images and their replicas at high magnifications and found no loss of detail in hard tissues when using replicas.

The aim of this study was to evaluate the marginal adaptation of the following materials: white MTA-Angelus, white Portland cement (PC), Vitremer™, GC Fuji Ortho™ LC, and silver amalgam without zinc; as well as compare the results obtained in the evaluation of teeth and their replicas.

Methods and Materials

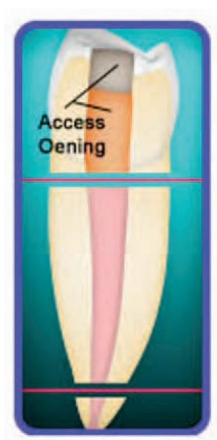
This study was approved by the Committee on Ethics of the School of Dentistry at the Pontifícia Universidade Católica do Rio Grande do Sul, Porto Alegre, Brazil.

Specimen Selection

Fifty human single-rooted teeth were selected. Teeth with root fractures, periradicular resorption, apical dilacerations, and previous endodontic therapy were excluded.

Specimen Preparation

All teeth were treated endodontically by a trained professional using Walton's technique. Root canals were accessed and instrumented first with #10 or #15 endodontic Kerr files (Moyco Union Broach, York, PA, USA) introduced to working length of the canal filled with 1% sodium hypochlorite (Biodinâmica Química e Farmacêutica Ltda. Ibiporã, Paraná, Brazil). Canals were instrumented with Kerr files introduced to the root length with rotating (enlarging) movements under irrigation. Progressively larger #25 K-files were introduced up to 0.5 to 1 mm short of the dental apex. Canals were enlarged to a diameter corresponding to a #40 file. After cleaning and shaping, the canals were irrigated with 10 ml 1% sodium hypochlorite using a disposable syringe and needle and aspirated using metal suction cannulas. After that, the canals were dried with absorbable paper points (Endopoints® Indústria e Comércio Ltda).



Canals were filled with laterally condensed gutta-percha (Tanari™, Manacapuru, AM, Brazil) using zinc-oxide eugenol (Endofill®/Dentsply e Comércio Ltda, Petrópolis, RJ, Brazil) as a sealer which was prepared according to the manufacturers' instructions. Crowns were sectioned at the cemento-enamel junction to standardize the length of the specimens at about 16 mm.

The apices were resected perpendicular to the long axis of the tooth at 3 mm from the end of the root with a diamond bur at high rotation. Root-end cavities 3 mm deep were then prepared using a Satelec S12/S90D (diamond coated) ultrasonic retrotip (Gnatus, Ribeirão Preto, SP, Brazil).

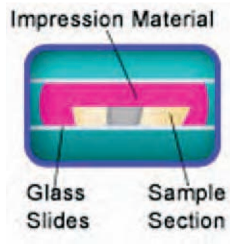
After preparation, the teeth were randomly divided into five groups of ten specimens each and root ends were filled as follows:

- Group A – silver amalgam without zinc (Logic+™ SDI, Bayswater, Vic., Australia)
- Group F - GC Fuji Ortho™ LC (GC America Inc., Alsip. IL, USA)
- Group V - Vitremer™ (3M ESPE, St. Paul, MN, USA)
- Group M – white MTA (Angelus, Londrina, PR, Brazil)
- Group P – white Portland cement (CPB40, Votorantin, São Paulo, SP, Brazil)

All materials were prepared according to manufacturers' instructions except for the PC which was prepared using the same powder-to-distilled water ratio as the MTA. The modified resin glass ionomer cements (MRGIC), Vitremer™ and Fuji Ortho™ LC, were placed into the root-end cavities using a Mark lll p syringe (Centrix Inc., Shelton, CT, USA) and light-cured for 40 seconds. No conditioning of the root-end cavity was performed in the Fuji Ortho™ LC group.

Evaluation of Marginal Adaptation

Two 1 mm transverse sections of the root ends were cut with a slow-speed diamond saw and labeled Section 1 (apical) and Section 2 according to their distance from the apex. Impressions of the sections of root surfaces and cavities were obtained using an addition-type silicone dental impression material (Express™, 3M ESPE, St. Paul, MN, USA) poured over the slices previously fixed to glass slides. Another glass slide was placed over the impression material to press it down and ensure a better impression of thin slices. After the material set, the upper glass



slide was removed together with the impression material providing a negative mold of the slices.

The replicas were made with epoxy resin (Embed 812™, EMS, Hatfield, PA, US) and poured into the negative molds of the slices. The resin was prepared according to the manufacturer's instructions.

Each section and its replica were mounted on stubs and placed in a desiccator with silica gel for two weeks. Stubs were sputter-coated with gold and examined at 230X magnification using a Philips XL30 SEM (Philips, Eindhoven, Netherlands) fitted with a secondary electron detector (SE).

The visualization and identification of the entire root-end filling surface was not possible at 230X magnification. The images were divided into two parts (upper and lower), marked at the division point, and recorded electronically. The ImageTool 2.0 custom software (UTHSCSA, San Antonio, TX, USA) system was used to identify and measure the gaps on the interface between dentin and root-end filling material. The values of all gaps of the same specimen were added so that one single gap value was obtained for each specimen.

Statistical Analysis

The tooth sections and their replicas were evaluated to establish a correlation between data obtained in both analyses.

The nonparametric Kruskal-Wallis test was used to evaluate the incidence of marginal gaps and the differences between groups. When differences were found, a multiple comparison test was used to evaluate each section of the tooth (Sections 1 and 2) separately. The Spearman correlation coefficient was used to establish the correlation between the results found for teeth and their replicas. The Statistical Package for the Social Sciences (SPSS) for Windows™ (SPSS Inc., Chicago, IL, USA) was used for data analysis, except for the multiple comparison tests which were analyzed with the BioStat 2.0 (AnalystSoft, Vancouver, Canada).

Results

The Kruskal-Wallis test revealed significant differences between the groups when the two sections were analyzed ($p \geq 0.05$). The results of the multiple comparison test showed Groups M and P had larger marginal gap areas, but the difference was not statistically significant. Groups P, V, and A had intermediate results with no significant differences between them. The marginal gap values for Section 2 were similar to those found for Section 1.

The multiple comparison test results revealed differences between mean ranks in some groups, however, these differences were not considered statistically significant.

Results showed a positive and significant correlation between marginal adaptation values of teeth and their replicas.

Discussion

Several studies have used SEM to evaluate the marginal adaptation of materials because it provides higher image magnifications. Different methods can be used to measure marginal gaps on the interface between dentin and root-end filling material such as gap measuring on the interface,[12,13,16,17] percentage in gap formation, and qualitative analysis of the surface.[4]

Bidar et al.[18] carried out a comparative SEM study of the marginal adaptation of white and gray MTA and PC in which the Kruskal-Wallis test results revealed gap formation in all cases. However, no statistically significant differences were observed between the materials used.

Since the deepest portion of the root-end cavity is conical only 2 mm of root-end fillings were analyzed in the present study as proposed by Xavier et al.[17] In that study investigators found gutta-percha on the interface between dentin and root-end filling material in this deepest portion which invalidates the analysis of marginal gap. As a result, the third section was discarded in the present study because it corresponded to the deepest third millimeter of the root-end cavity.

Marginal gaps on the interface between dentin and root-end filling material were calculated according to the method described by Gondim et al.[9] The system used in the present study to measure marginal gaps automatically provided total gap area values.

Shipper et al.[16] described the use of high- and low-vacuum SEM techniques to compare results of marginal adaptation of MTA and amalgam root-end fillings. Both wet and dry samples can be used at room temperature with the low-vacuum technique. However, all sample humidity should be removed using a desiccator with silica gel when using the high-vacuum technique. They found fewer gaps when using the low vacuum technique and humid samples. However, the high vacuum technique demonstrated larger marginal gaps because artifacts can look like microfractures. The authors of that study pointed out teeth did not have to be pretreated for the low-vacuum technique and visualization conditions were similar to those found *in vivo* studies.

The high-vacuum technique was used in this study. The teeth were kept in a desiccator with silica gel for two weeks. Since the technique used to prepare specimens for SEM may cause dentin microfractures the use of replicas reduces the number of teeth required for the study and avoids distortions of the results.[9,15]

Stabholz et al.[12] and Torabinejad et al.[13] found good material adaptation to dentin in both teeth and replicas. Microfractures were only found in teeth. Waplington et al.,[14] Weston et al.,[3] Gray et al.,[10] and Gondim Jr. et al.[9] analyzed only replicas.

The present study analyzed tooth sections and their replicas to establish the correlation between the techniques. Although statistical results showed a correlation between teeth and replicas, it is suggested marginal gaps be evaluated only in replicas to avoid artifacts. In several cases microfractures were caused by the microscopic technique itself. Some replicas showed larger gaps than the teeth. In these few cases, residues of the impression material were believed to be incompletely removed after impression making and filled the gaps which was then visualized at higher magnifications and confirmed by energy dispersive spectroscopy (Figure 1).

No significant differences were found in the adaptations of the two sections or their replicas for the different materials as shown in Tables 1 and 2. Group M had significantly greater adaptation gap values than groups A, V, and F in the analysis of Section 1 and their replicas, and worse results than groups F and A for Section 2 and their replicas. Group P, conversely, had statistically more marginal gaps than Section 1 in group F and Section 2 in group A. No significant differences were found between Group F and the other groups in the analyses of Section 2 and their replicas. These results differ from those reported by Xavier et al.,[17] who observed better marginal adaptation for MTA than for Vitremer™. All tested materials showed some degree of gap formation in agreement with the results reported by Stabholz et al.[12] and Fogel and Peikoff.[4]

Like Torabinejad et al.,[13] in a study in which specimens were sectioned longitudinally, the present study led to a belief material adaptation was affected when specimens were sectioned. One possible explanation for a better adaptation of RMGICs than other materials may be the type of chemical adhesion to dentin which may hinder the dislocation motion of materials during sectioning.

Conclusion

Marginal adaptation and varying degrees of gap formation on the interface between dentin and root-end filling material were found in all teeth. Materials containing calcium oxide (MTA and PC) showed similar results. While RMGICs presented similar variations in terms of marginal adaptation, Vitremer™ showed significantly greater marginal adaptation when compared to GC Fuji Ortho™ LC which had the greatest gap formation. A positive and significant correlation was observed between marginal adaptation values found in the teeth and their replicas.

Clinical Significance

Several factors can jeopardize the success of endodontic treatment. Persistent contamination of the apical region is an indication for periradicular surgery. Root-end fillings should seal the apex against diffusion of bacterial products from the root canal system to periradicular tissues. New materials have been tested to improve clinical outcomes in periradicular surgery. When treatment planning for the correction of a failed endodontic procedure, clinicians might consider the use of the GIC Vitremer™ as a clinical option for root-end filling due to its favorable chemical adhesion to enamel and dentin.

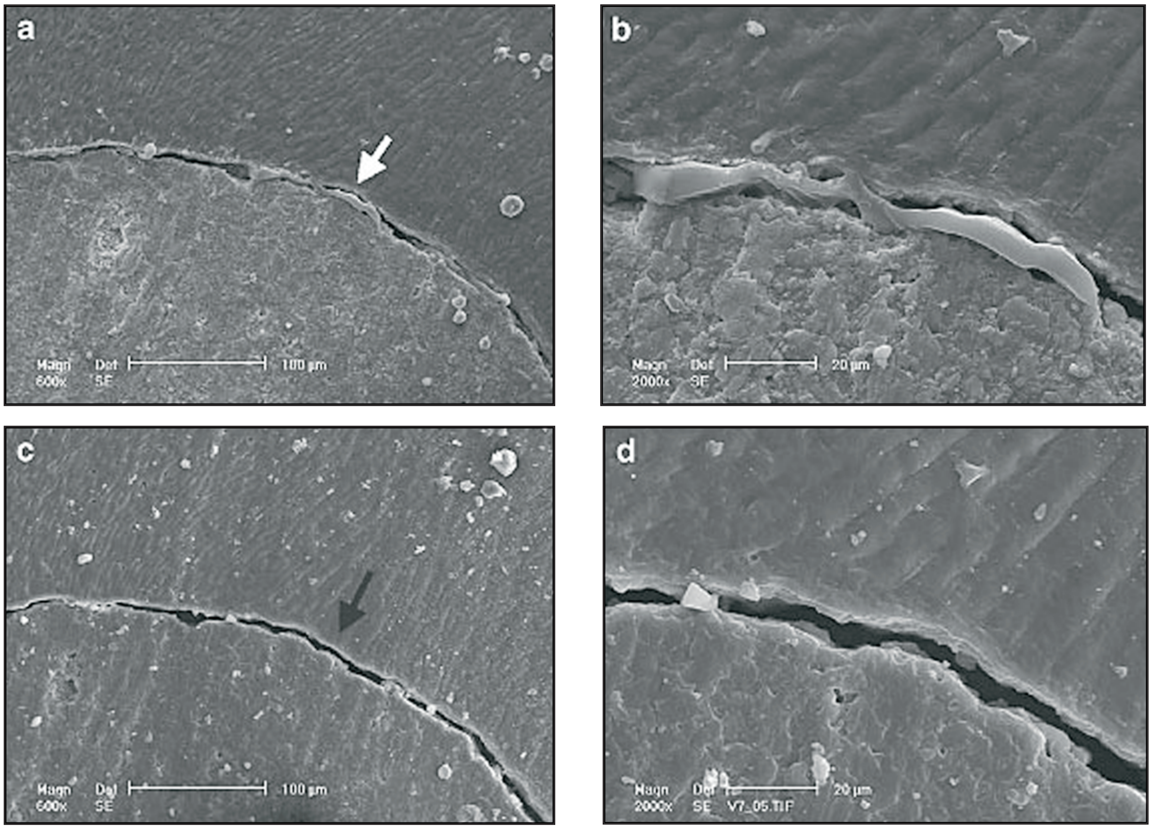


Figure 1. SEM photomicrograph. **A.** Replica of section 2, tooth 47, Group V (SE, original magnification 600X); impression material inside gap (white arrow). **B.** Same replica at higher magnification (SE, original magnification 2000X). **C.** Section 2 (SE, original magnification 600X) with marginal gap; no impression material seen inside gap at corresponding replica site (black arrow); **D.** Section 2 at higher magnification (SE, original magnification, 2000X) confirming lack of material in the gap.

Table 1. Comparison of marginal adaptation of section 1 between groups of teeth and replicas.

Group	N (teeth)	Mean rank*	p	Group	N (replicas)	Average rank*	p
M	9	35.11^{a}	0.005	R/M	9	35.11^{a}	0.006
P	10	28.50^{ab}		R/P	10	33.50^{ab}	
V	9	20.50^{bc}		R/A	10	21.60^{bc}	
A	8	20.31^{bc}		R/V	10	21.10^{bc}	
F	10	13.30^{c}		R/F	10	14.70^{c}	

A=Amalgam; F= Fuji Ortho™ LC; M=MTA; P=Portland cement; V=Vitremer™.
*Means followed by the same letter do not differ from each other (PUCRS; 2006).

Table 2. Comparison of marginal adaptation of section 2 between groups of teeth and replicas.

Group	N (teeth)	Mean rank*	p	Group	N (replicas)	Average rank*	p
M	10	33.20^{a}	0.049	R/M	10	36.20^{a}	0.0438
P	10	29.70^{ab}		R/P	10	26.60^{ab}	
V	9	26.33^{abc}		R/V	10	25.50^{ab}	
F	10	19.40^{bc}		R/F	10	23.00^{b}	
A	10	16.50^{c}		R/A	10	16.20^{b}	

A=Amalgam; F= Fuji Ortho™ LC; M=MTA; P=Portland cement; V=Vitremer™.
*Means followed by the same letter do not differ from each other (PUCRS; 2006).

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