Journal of Oral Science, Vol. 49, No. 2, 121-128, 2007

Original

Negative influence of continuous wave technique on apical sealing of the root canal system with Resilon

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(Received 27 November 2006 and accepted 30 March 2007)

Abstract: The aim of this study was to investigate apical microleakage after use of the Resilon system in comparison with gutta-percha. The materials used were 54 mesial roots of mandibular molars with an apical curvature of 20-40°. The root canals were instrumented with the Prosystem GT^R and obturated with: Group I: Gutta-percha + Sealer by lateral condensation (n = 25); Group II: Gutta-percha + Sealer, complemented by System B and Obtura II (n = 25); Group III: Resilon + System B and Obtura II (n = 25); Group IV: Resilon by lateral condensation (n = 25). After immersion in India ink, the specimens were demineralized and rendered transparent. Apical dye leakage was analyzed with a stereomicroscope and a digital camera connected to a computerized system. All groups showed different degrees of apical dye microleakage. The Kruskal-Wallis test revealed that the largest leakage occurred in Group I ($P < 0.05$), whereas the other groups presented a similar pattern of microleakage ($P > 0.05$). Thermoplastification negatively influenced the apical sealing ability of Resilon. Gutta-percha points and conventional sealer yielded the highest values of apical leakage, especially when the lateral condensation technique was used. Regardless of the obturation technique employed, the Resilon system provided the lowest mean values of apical leakage, but did not provide hermetic sealing of the root canal system. (J. Oral Sci. 49, 121-128, 2007)

Keywords: gutta-percha; leakage; Resilon.

Introduction

The main pathways of communication between the pulp cavity and the oral cavity are carious lesions, coronal fractures and failures in the cementoenamel junction, whereas the lateral, secondary and accessory root canals and foraminal openings establish communication between the root canal system and the periodontal ligament. Thus, if the biological barriers that assure cavity pulp integrity and maintenance of dental pulp vitality are disrupted, endodontic treatment is required. After adequate cleaning, shaping and antisepsis, obturation is performed for achievement of three-dimensional sealing of the root canal system, thus eliminating the penetration of oral fluids, microorganisms and periodontal fluid (1).

From clinical, radiographic and histological standpoints, the success rates of endodontic treatment vary depending on several factors, for example, teeth with pulp necrosis associated with periapical pathologies are usually associated with lower success rates, especially when they are obturated in the presence of positive microbiological culture (1-3). Nevertheless, longitudinal studies have revealed success rates of 80-95% in such cases (1,4,5). Even though there are variations in the methodologies of endodontic treatment and interpretation criteria, the reported success rates are not consistent with the outcomes of cross-sectional studies (6-8), suggesting a strong tendency for reduction of endodontic success in the long term. Within this context, one of the main associated factors is progressive loss of sealing of the root canal system (9,10). Thus, maintenance

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of endodontic success rates is closely related to permanent improvement of the quality of sealing of the root canal system.

Essentially, obturation is performed using gutta-percha, together with a smaller amount of sealer to eliminate the empty spaces at the gutta-percha/dentin wall interface. Thus, from a radiographic and physicochemical perspective, the main indicators of excellence of root canal obturation might be defined as follows; 1: regular progressive taper in an apical to cervical direction, 2: homogeneous density throughout its extension, 3: apical level slightly below the radiographic apex, and 4: micromechanical and chemical interlocking of obturation materials to each other and to the tooth structure (11-13). Obturation by the active lateral condensation technique with accessory gutta-percha points juxtaposed to the master gutta-percha point, associated with conventional endodontic sealers, is considered the gold standard of endodontic obturation (14,15). However, it is often criticized because of limited uniformity, density and quality of three-dimensional sealing of the root canal system in comparison with gutta-percha thermoplastification, as developed by Schilder (16). In an attempt to simplify the warm vertical condensation of gutta-percha, Buchanan (17) suggested the continuous wave condensation technique using the System B machine. Even though several techniques are available, it is believed that the excellence of obturation sealing is primarily related to the cohesive and adhesive interaction of obturation materials to the root canal walls. More recently, a new obturation system composed of a dentin adhesive, sealer and points made of a synthetic resin polymer was developed, allowing adhesion of a monoblock to the dentinal walls (18,19). Considering that the performance of marginal obturation sealing is influenced by the materials and techniques employed (13,20), this study evaluated the sealing ability of an adhesive system, Resilon, by the active lateral condensation technique or continuous wave condensation technique, using linear measurement of apical dye leakage, in mesial roots of mandibular molars, by rendering the roots transparent.

Materials and Methods

Sampling and root canal instrumentation

The study materials were 54 mandibular first molars with curvature ranging from 20 and 40 degrees (21) and independent mesial foraminal openings, comprising a total of 108 root canals. After radiographic evaluation and coronal opening, the pulp chamber was filled with 2.5% sodium hypochlorite and the root canals were instrumented with #08 or #10 Kerr files until the apical foramen was reached, to establish the patency length (PL) of each root canal. The working length (WL) was established at 1 mm short of the PL. Biomechanical preparation was performed by rotary instrumentation with nickel-titanium files, Prosystem GT (Dentsply/Tulsadental, Okulahoma, USA), with an engine AEU-20 Endodontic System (Dentsply/Tulsadental), and irrigation with 2.5% sodium hypochlorite at each file change using a syringe and 27-gauge needle. Crown-down preparation was performed using #20 GT files with a taper of 0.10, 0.08 or 0.06 mm/mm. Apical preparation was performed with #20 and 30 GT files, taper 0.04 mm/mm, at a speed of 300 rpm. Thus, the pattern of apical enlargement was equivalent to diameter #30, maintaining the foraminal patency with a #15 K file. For removal of the smear layer, 2 ml of 17% EDTA was used for 3 min after completion of instrumentation and a final rinse with NaOCl, followed by 2 ml of distilled water for 1 min before root canal obturation.

Root canal filling

The root canals were dried with #30 paper points with a taper of 0.04. The root canals were then divided randomly and obturated using a lateral condensation technique or the continuous wave condensation technique (System B associated with an Obtura II system), using natural gutta-percha points (Odous, Belo Horizonte, Brazil) with Pulp Canal Sealer-EWT (Kerr Sybron Dental Specialities, Romulus, USA) or the new endodontic sealer Resilon (Pentron Clinical Technologies, Wallingford, USA), which is composed of a self-etching primer, Epiphany sealer and resin points (Table 1), thus constituting four experimental groups, as presented in Table 2.

For the lateral condensation technique with gutta-percha (Group I), the initial diameter (D_0) of the master gutta-percha point size #30 taper 0.04 was standardized with a calibrating ruler (Angelus Intermedium, Londrina, Brazil) at gauge #30, and its point was regularized with a #15 blade. The cone was fitted to the working length with tug-back, followed by orthoradial and mesioradial radiographic confirmation. After application of sealer to the root canal walls with aid of a #30 K file, the master gutta-percha point coated with sealer was fitted apically into the root canal to the working length followed by active lateral condensation using secondary gutta-percha points and digital lateral spacers (Dentsply/Maillefer, RJ, Rio de Janeiro, Brazil) inserted into the canal until resistance was felt. The process was repeated until the canal was completely filled. The excesses at the root canal opening were removed with a heated plugger, vertical condensation was performed, and a radiograph was obtained to evaluate the quality of obturation.

For the continuous wave condensation technique (Group

Table 1 Average composition of the obturation system Resilon, according to [Barnett (18)]

Material	Composition
Epiphany primer™	Sulphonic acid, hema, water and polymerization initiator
Epiphany sealer™	BisGMA, ethoxylated BisGMA, UDMA, hydrophilic methacrylate, barium sulfate, silica
Resilon™ core material	Bioactive glass, bismuth oxychloride, barium sulfate
Solvent	Chloroform-based

Table 2 Distribution of experimental groups according to the obturation materials and techniques

Groups	Root canal obturation	
	Materials	Techniques
I (n = 25)	Gutta-percha points + Pulp Canal Sealer	Lateral condensation
II (n = 25)	Gutta-percha points + Pulp Canal Sealer	Continuous wave condensation
III (n = 25)	Resilon™ system	Continuous wave condensation
IV (n = 25)	Resilon™ system	Lateral condensation

II), the master gutta-percha point was standardized with a calibrating ruler followed by radiographic confirmation of its apical adaptation, as in group I, and a System B plugger with similar taper was selected so that it easily penetrated up to 5 mm short of the WL. The endodontic sealer was applied in the root canal as described previously, followed by the gutta-percha point covered by the same sealer until the WL was reached. At this point, the System B plugger heated at 200°C was placed through the obturation with mild apical compression to the previously established length for nearly 10 sec. Backfill with Obtura gutta-percha was performed using the Obtura II System (Spartan, Fenton, USA) with 23-gauge needle tips, followed by radiographic evaluation. For obturation with the Resilon system (Pentron Clinical Technologies, Wallingford, USA), after selection of the master gutta-percha point, the Epiphany self-etching Primer was applied to the root canal with a microbrush, and excess primer was removed with paper points. Dual Epiphany Sealer was then placed in the root canal with a Lentullo spiral. The master size #30 taper a 0.04 Resilon master cone (Resilon Core Material) coated with sealer was inserted into the canal until the WL.

At this step, in Group III, the obturation was downpacked by the continuous wave condensation technique (System B, SybronEndo, Orange, USA) at a reduced temperature of 150°C and power setting of 10 sec, as recommended by the manufacturer. Backfilling was performed with Obtura II at a temperature of 150°C. Light curing was then performed for 40 sec on the obturation surface to polymerize the surface of the dual-cured methacrylate sealer.

In Group IV, the adaptation of the master gutta-percha point and sealer utilization were the same as in group III, and the lateral condensation technique was the same as in group I. The space created was filled with a fine Resilon accessory point coated with Epiphany sealer. The process was repeated until the canal was completely filled. Light curing was performed after removal of excesses from the pulp chamber.

Clearing process and apical microleakage

Immediately after obturation, the distal roots of all teeth were removed with a diamond disc and the cervical 3 mm of the mesial root canals was sealed with Cavit (ESPE America Inc., Norristown, USA). All specimens were stored at 37°C and 100% relative humidity for 7 days to ensure complete setting of the sealer. The roots were then covered with two layers of nail varnish, so that only the apical foramen remained exposed. The specimens were immersed in India ink for five days under vacuum. After removal from the dye, the roots were rinsed in tap water and the nail varnish was completely removed by scraping with a Bard-Parker number 11 scalpel. The clearing process was completed with nitric acid, alcohols, and methyl salicylate (22).

The transparent specimens were examined with the aid of a stereoscopic glass (GSZ, Zeiss, Germany) with a digital camera connected to a computerized system for quantitative analysis (Image-Proplus, Media Cybermetics, USA) at 20× magnification. Images of the mesiobuccal and mesiolingual canals of each root were captured in a buccolingual direction, and only the largest measurement in millimeters between the gutta-percha point and the maximum dye leakage in the obturation or at the obturation/root canal wall interface in the cervical direction was recorded.

The root canals of the control groups were treated as described for Group III, except for a positive control group (n = 4), which did not receive the endodontic sealer, and a negative control group (n = 4), in which the roots were rendered completely impermeable.

The results were tabulated and the mean values of dye leakage for each group were calculated. Data were subjected to the Kruskal-Wallis for multiple comparisons, at a significance level of $P < 0.05$, to determine if there were any significant differences between groups.

Results

The patterns of apical microleakage in the four experimental groups are displayed in Table 3. Figs. 1, 2, 3 and 4 show the different magnitudes of apical microleakage for all groups. The active lateral condensation technique using gutta-percha points together with the Pulp Canal Sealer (Group I) provided the highest leakage values, which were significantly higher than those with the other treatments ($P = 0.023$). The best performance was observed for the combination of Resilon with the active lateral condensation technique (Group IV), but there was no significant difference in the pattern of apical leakage between Groups II, III and IV ($P > 0.05$). The mean apical dye leakage in Groups I, II, III and IV was 1.49, 0.97, 0.88 and 0.76 mm, respectively.

Discussion

Several studies have demonstrated the influence of poor root canal obturation on endodontic treatment failure (10,23,24). Thus, detailed interpretation of this correlation requires analysis of the geometrical, biological and physicochemical aspects of the obturation. From a geometrical standpoint, the shaping of the root canal in terms of the apical limit, enlargement and flaring (taper), basically follows the principles established by Schilder (16), in which the configuration is reproduced by obturation. Biologically, there may be different periapical tissue responses according to the apical level of obturation and chemical composition of the materials employed, with special emphasis on endodontic sealers (25). From a physicochemical standpoint, the goal is to achieve a homogeneous and dense obturation impermeable to fluids and microorganisms, considering the three-dimensional concept of the root canal system (12,13). Emphasis has been placed on apical foramen microleakage because the apical foramina represents the main connection between the root canal and the apical periodontium, and the dye leakage method is one of the approaches employed most often (14,20,26,27).

It has been observed that, regardless of the chemical composition of endodontic sealers (which may contain zinc oxide and eugenol, calcium hydroxide, resin or glass ionomer), cervical and apical microleakage is unavoidable (10,24,28,29) and occurs due to adhesive failure between the gutta-percha/sealer and dentin wall. Dentin bonding occurs by mechanisms involving mechanical microretention and/or intermolecular interaction (30) and is sometimes associated with tensil resistence, shear bond strength and sealing capacity. Endodontic sealers that are zinc-oxide-eugenol-based, glass-ionomer-based or calcium-hydroxide-based demonstrate reduced union with dentin and gutta-percha. On the other hand, sealers based on methacrylate-resin exhibit superior levels of dentin bonding, with values ranging from 2.06 to 7.9 MPa (30-33), as well as bonding to gutta-percha (32). Neverthless, these values are considerably larger when dental union agents are used in combination, and may reach up to 20-25 MPa (34).

Therefore, similar to restorative procedures with composites, dentin hybridization before root canal obturation has been suggested (35-37). In this capacity, removal of the smear layer, followed by application of primer and a bonding agent, have increased the bond strength of resin cements to dentin (38) and reduced microleakage (39). Removal of the smear layer allows penetration of endodontic sealers into the dentinal tubules at different depths, with better outcomes for resin sealers (40). It has been emphasized that, even if there is no chemical bond between these sealers and dentin, the sealer plugs penetrating into dentinal tubules provide mechanical interlocking, which may enhance the sealing ability of the obturation. Primers greatly increase the penetration of sealer into dentinal tubules (41). Adhesive agents significantly improve the apical sealing of glass ionomer cement and composite resin (42) and resin sealers, e.g. AH26 (30), with better performance for self-etching adhesives (43). *In vitro* studies have demonstrated a similar performance with regard to apical sealing, regardless of the presence of etching agent, primer or adhesive in single or multistep presentations (30,42).

With regard to strategies involving dentin adhesives for bonding during root canal filling, preliminary studies with Resilon have shown great promise. Thus, the lateral condensation and vertical compactation of softened Resilon have been equally effective *in vitro* for forming a monoblock highly resistant to penetration of *Streptococcus mutans* and *Enterococcus faecalis* (29). SEM has revealed adhesion between Resilon, Epiphany sealer, primer and the dentin wall, with formation of resin tags that penetrate the dentinal tubules. Another study has also revealed the superiority of the Resilon system for preventing apical periodontitis by blockage of microorganisms from the dental plaque inoculated into the pulp chamber of dogs, regardless of the obturation technique employed (44).

On the other hand, all experimental groups in the present

Table 3 Descriptive and comparative measurements for the four experimental groups as to linear dye leakage at the apical segment of obturations

Groups	Descriptive measurements (mm)					
	N	Minimum	Maximum	Median	Mean	Standard deviation
I	25	0.43	3.38	1.28	1.49	0.89
II	25	0.00	2.31	0.81	0.97	0.51
III	25	0.00	2.23	0.76	0.88	0.68
IV	25	0.00	1.90	0.77	0.76	0.66

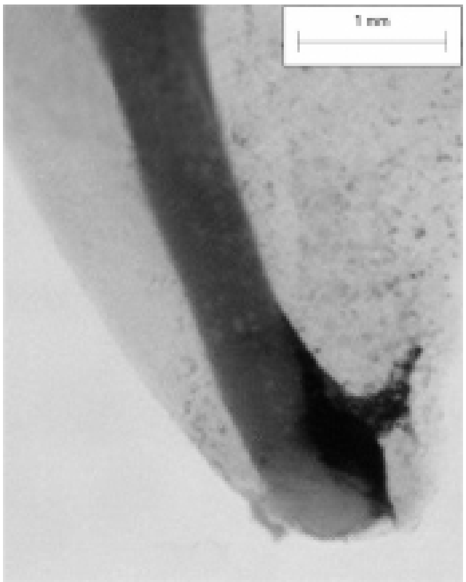

Fig. 1 Group I: Large marginal apical microleakage at the obturation/root canal wall interface.

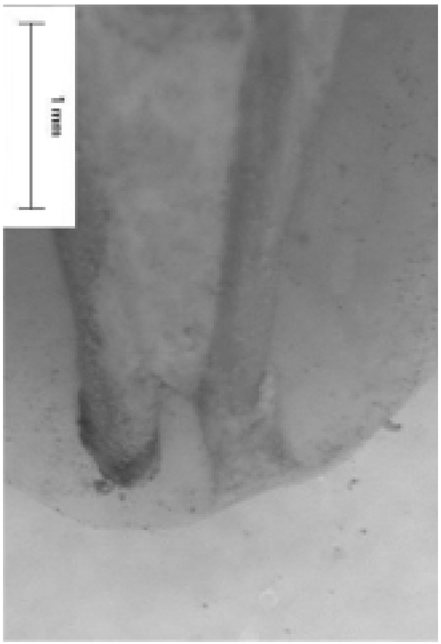

Fig. 2 Group II: Large microleakage in the apical 2 mm at the gutta-percha point/dentin wall interface.

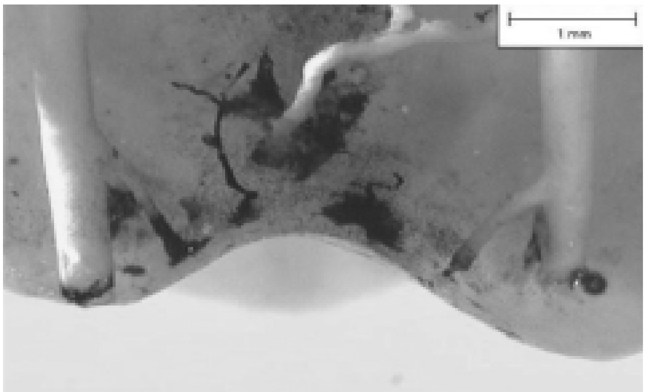

Fig. 3 Group III: Note the reduced microleakage at the obturation/dentin wall and secondary canal interface.

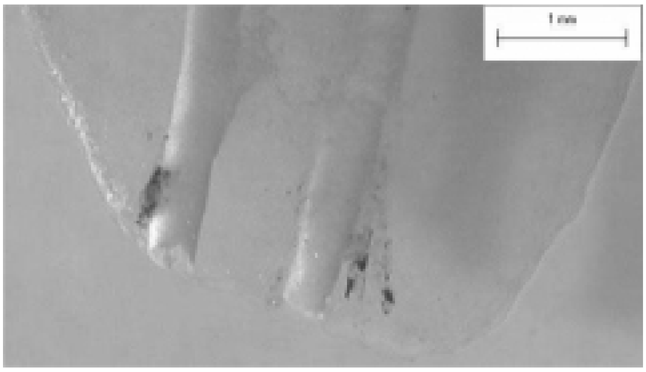

Fig. 4 Group IV: Absence of microleakage in root canal obturated by the Resilon system.

study showed different degrees of apical dye leakage. Considering that all the root canals underwent similar cleaning and shaping, it was revealed that different obturation materials and techniques resulted in different degrees of apical dye leakage. Thus, lateral condensation of gutta-percha exhibited a higher mean apical leakage, corroborating studies that compared it with thermoplastification (11,45-47). Although with system B thermoplasticization occurred about 5 mm short of the apical terminus, utilization of the continuous wave condensation technique allowed a significant reduction in apical microleakage, possibly due to the simultaneous plastification and condensation of the master gutta-percha point in the apical segment of the root canal. A favorable response involving micromechanical interlocking of the Pulp Canal Sealer to the dentin structure by the condensation forces and temperature afforded by System B could also be assumed. On the other hand, lateral condensation combined with the Resilon system provided the lowest apical leakage values. Because this is a simple, easy and economical technique, its association with the Resilon system was very promising with this new adhesive obturation system, since it significantly reduced the main negative aspect of the technique, namely poor apical sealing (30). Due to the reduced action of stainless steel pluggers at the apical third of the root canals, the results obtained by the lateral condensation technique might be related more to the physicochemical properties of the new sealer than to the condensation itself.

Unexpectedly, it was observed that the Resilon system had a different response to continuous wave condensation than gutta-percha. Since resin cements have an epoxy ring that becomes reactive after being opened, initiating polymerization and reactions, and also reacting with amine groups of collagen to form adhesive covalent bonds with dentin (30), a possible explanation might be increased chemical polymerization shrinkage of these synthetic compounds due to the heat generated by System B, as well as the heat inducing physical or stereochemical alterations to the Resilon. Banding of collagen fibrils beneath the hybrid layer after thermoplastification of Resilon following possible denaturation of collagen in the peritubular dentin during warm vertical compaction cannot be ignored (37).

The Resilon system failed to provide complete hermetic apical sealing, and recent studies have also showed that microleakage may occur at all the interfaces of the supposed monoblock. In fact, microleakage was observed in 9 of 10 Resilon-filled, and in all gutta-percha-filled, root canals (37). Another study has also observed gap-containing regions along the sealer/dentin interface (48). This microleakage in the Resilon system may be attributed to several different physical and chemical factors involved in the adhesion mechanisms between the components and the dentin wall. The thermoplasticity of Resilon is attributed to the incorporation of polyprolactone, a synthetic, biodegradable, semi-crystalline aliphatic polyester that has a low melting point of 60°C. Although high decomposition of Resilon occurs at a temperature of 350°C (49), in the present study its thermoplasticity at 150°C was utilized. Bondability is derived from inclusion of difunctional methacryloxy groups into the resin (49), and recently it was suggested that the amount of dimethacrylate incorporated into filled areas leads to a phase separation of polymeric components in Resilon with a significative reduction of its bondability to Epiphany (48).

It has been demonstrated that some irrigants, such as sodium hypochlorite solution, hydrogen peroxide solution, or a combination of both, cause deep changes in the collagen structure by dehydration and/or removal of fibrils that form the hybrid layer, thus reducing monomer penetration into dentin, and consequently bond strength. The release of oxygen originating from substances applied to the root canal should also be considered, since it acts as an inhibitor of polymerization (43,50), as well as the possible enzymatic hydrolysis of Resilon (37). Considering these variables, we are currently conducting SEM studies to evaluate apical dye microleakage and dentin hybridization with various irrigants, e.g. chlorhexidine digluconate and EDTA, followed by utilization of self-etching primers and obturation with resin sealers by several techniques. Our preliminary results, though promising, demonstrate that hermetic sealing of endodontic obturations is still a challenge with current bonding techniques and systems.

Acknowledgments

The authors wish to thank Dr Mario Lúcio Talarico, Elaine Reis and CETEC (Centro de desenvolvimento tecnológico de Minas Gerais) for technical support.

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