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A laboratory analysis of gutta-percha-filled area obtained using Thermafil, System B and lateral condensation

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Abstract

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Aim To determine the percentage of gutta-percha-filled area (PGFA) in the apical third of root canals when filled with either Thermafil, System B or lateral condensation.

Methodology Sixty extracted human maxillary central incisor teeth were root filled as following: G1: lateral condensation ($n = 20$), G2: System B ($n = 20$) and G3: Thermafil system ($n = 20$). A horizontal section was cut 2 and 4 mm from the apical foramen of each tooth. The samples were prepared for microscopic analysis and photomicrographs of each apical surface were taken at a magnification of 50×. Through digital image analysis, the cross-sectional area of the canal and the gutta-percha was measured. The PGFA was calculated. The PGFA data obtained in the three groups were analysed using a nonparametric Friedman and Wilcoxon signed-rank tests.

Results Significant differences in PGFA were found between the Thermafil System (G3) and both System B (G2) and lateral condensation (G1) ($P < 0.01$). The greatest PGFA occurred in the Thermafil group. No significant statistical difference was found between System B and lateral condensation ($P > 0.05$).

Conclusions The coated carrier gutta-percha system Thermafil produced significantly higher PGFAs than lateral condensation and System B techniques.

Keywords: apical third, filling techniques, gutta-percha-filled area.

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Introduction

Endodontic sealers play an important role in the sealing ability of root fillings; without using sealer, root fillings leak (Kontakiotis *et al.* 1997, Wu *et al.* 2000a). The sealer is capable of filling imperfections and increasing the adaptation of gutta-percha (Wu *et al.* 2000a). However, it has also been confirmed that leakage may occur within the sealer or by its dissolution, either in the interface between sealer and the dentine, or between sealer and the gutta-percha (Kontakiotis *et al.* 1997). Consequently, the areas filled by sealer are more vulnerable because gutta-percha is dimensionally stable whilst the sealer can dissolve over time (Peters 1986, Georgopoulou *et al.* 1995).

The confirmed solubility of sealers implies the necessity to limit its presence to a thin film and increasing the mass of the gutta-percha (Peters 1986, Kontakiotis *et al.* 1997, De Deus *et al.* 2003). Sealer film thickness and the gutta-percha component may be of particular relevance when the apical root filling is analysed. The apical root filling should provide a seal, especially because after post-space preparation only the apical root filling of 3 or 4 mm in length remains (Wu *et al.* 2002). Moreover, studies have shown that numerous lateral canals are present in the apical third. Rubach & Mitchell (1965) detected lateral canals in 45% of the 74 teeth they studied, the majority of them located in the apical third. De Deus (1975) found lateral canals in 27% of 1140

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teeth: in 17% of the teeth they were located in the apical third, 9% in the middle third and 2% in the coronal third.

The warm gutta-percha technique was promoted by Schilder (1967). Modifications to the technique have been advocated to improve its efficacy and efficiency (Silver *et al.* 1999). The System B endodontic heat source unit (EIE/Analytic, Redmond, WA, USA) was designed to fill the apical root canal system with a single continuous wave of thermoplasticized gutta-percha (Buchanan 1996).

Johnson (1978) reported the use of a gutta-percha-coated carrier to fill canal that was later produced as the Thermafil System (Dentsply; Tulsa Dental, Tulsa, OK, USA). Such systems consist of a flexible central carrier coated with a layer of α-phase gutta-percha. The device is heated to soften the gutta-percha before insertion into the root canal. The Thermafil System can produce a homogenous mass of gutta-percha in the canal unlike lateral condensation (Gençoglu *et al.* 1993a). Leakage studies have shown Thermafil root fillings provide a seal that is better than (Dummer *et al.* 1993, Gençoglu *et al.* 1993b), equal to (Gutmann *et al.* 1993) or worse than (Lares & ElDeeb 1990) that obtained with the lateral compaction of gutta-percha. However, Fan *et al.* (2000) investigating leakage along the apical portion of curved canals found that vertical condensation of warm gutta-percha used with Kerr Pulp Canal Sealer (Kerr Manufacturing Co., Romulus, MI, USA) resulted in less leakage than Thermafil obturators and AH26 sealer (Dentsply, Konstanz, Germany).

Leakage tests have been used widely to evaluate the quality of root fillings (Wu & Wesselink 1993); as well as cross-sections of filled roots (Kersten *et al.* 1986, Wu & Wesselink 2001) and the association of both (Ardila *et al.* 2003). The methodological model used in this study was introduced by Eguchi *et al.* (1985) and thoroughly explored by other authors (Silver *et al.* 1999, Wu *et al.* 2001, 2002, Wu & Wesselink 2001, Gençoglu *et al.* 2002, Gençoglu 2003).

The purpose of this investigation was to evaluate the percentage of gutta-percha-filled area (PGFA) in the apical third of root canals when filled either with Thermafil, System B or lateral condensation.

Materials and methods

Instrumentation

This study was revised and approved by the Ethics Committee, Nucleus of Collective Health Studies, Rio de Janeiro State University, Rio de Janeiro, Brazil. Sixty straight maxillary central incisors were selected from the tooth bank of Rio de Janeiro State University. The teeth were stored in 10% neutral formalin. Access to the root-canal system was made and the patency of each canal was confirmed by inserting a size 15 file through the apical foramen (AF) before and after completion of the root canal preparation. The working length was determined by subtracting 1 mm from the AF. The coronal and middle third of each canal was prepared using Gates Glidden drills (Dentsply/Maillefer, Ballaigues, Switzerland), sizes 6, 5, 4 and 3. The apical third was prepared with Flexofiles® (Dentsply/Maillefer) sizes 60, 55, 50 and 45 in a balanced force technique (Roane *et al.* 1985). The canals were irrigated between each file with 2 mL of freshly prepared 5.25% NaOCl using a disposable syringe and 27-gauge needle. Sixty teeth received a flush of 10 mL of 17% EDTA (pH 7.7) for 3 min to remove the smear layer. After completion of the preparation a final flush of 3 mL of 5.25% NaOCl was performed. The canals were dried with paper points (Dentsply/Maillefer).

The prepared teeth were randomly divided into three equal groups ($n = 20$).

Canal filling

The canals were filled using either lateral condensation technique (G1); using the System B heat source (G2) (Buchanan 1996) or the Thermafil System (G3). No sealer was used (Wu *et al.* 2002).

In G1 (lateral condensation technique), a size 45 master gutta-percha cone (Diadent Group International, Chongchong Buk Do, Korea) was placed in the canal to the full working length. Lateral compaction was achieved in each canal by using 10 accessory gutta-percha cones (MF; Diadent Group International) and endodontic finger spreader size B (Dentsply/Maillefer). A heated instrument was used to remove the coronal gutta-percha excess.

The System B technique was used in G2 (model 1005; EIE/Analytic) as recommended by the manufacturer and by Buchanan (1996). The tip of a medium-sized nonstandardized gutta-percha cone (Diadent Group International) was trimmed back until tug-back was achieved at working length. A M plugger (Analytic), which penetrated to within 6 mm of the working length was selected and a rubber stop placed. The System B unit was pre-set to 200 °C during the condensation of the primary gutta-percha cone (down-pack), to 100 °C when adapting and condensing the apical portion of the secondary (backfill) gutta-percha cone, and finally to 250 °C to thermosoften the remainder of the secondary cone prior to vertical condensation.

In the G3, a size 45 Thermafil verifier was used to check the size of the canal and thus, the correct Thermafil Obturator. The Thermafil Plastic Obturator (Dentsply) was heated in a Thermaprep Oven (Dentsply) for 30 s according to the manufacturer's instructions. Firm apical pressure was used to insert the Thermafil obturator to the working length. A round diamond bur in a turbine handpiece was used to cut the plastic shaft at 1–2 mm within the access cavity; the excess gutta-percha was removed with an instrument.

The teeth with root fillings were then stored in 100% humidity and at 37 °C for 2 weeks.

Sectioning and image analysis

After this time, each sample was sectioned horizontally 2 and 4 mm from the AF using a low-speed saw (Isomet; Buhler Ltd, Lake Bluff, NY, USA) with a diamond disc (diameter 125 mm × 0.35 mm × 12.7 mm), with continuous water irrigation in order to prevent overheating. Subsequently, each sample was embedded in an epoxy resin cylinder (Arazyn 1.0; Ara Química, SP, Brazil) to facilitate manipulation and improve the metallographic preparation. The margins adjoining the epoxy resin and tooth were sealed with cyanoacrylate (Super bonder Gel; Lockite, Itapevi, SP, Brazil). The metallographic preparation was performed as described previously (De Deus *et al.* 2003). Specific sandpapering (DP-NETOT 4050014, Struers, Copenhagen, Denmark) for metallographic preparation was completed. The purpose of this procedure was to obtain a surface that was free from scratches and deformities. To achieve this result, the samples were sandpapered to remove damaged or deformed surface material whilst introducing as few changes as possible. To eliminate deformities from fine sandpapering and to obtain a highly reflective surface, the specimens were polished before they were examined under the microscope. The polishing was completed with diamante paste of 4–1 μm roughness (SAPUQ 40600235; Struers).

The samples were examined under a light optical microscope (Axiscoppe; Carl Zeiss Vision GmBH, Hallbergmoos, Germany) and photographed at a 50× magnification. The negatives were scanned by a 35 mm/medium format film scanner (Sprintscan 120, Polaroide, NY, USA) as TIFF images (Tagged Image File).

Image analysis and processing were completed using a Carnoy 2.0 image system for Windows (Laboratory of Plant Systematics, K.U. Leuven, Flanders, Belgium). Through this software, the cross-sectioned area of the canal and the gutta-percha was recorded and the PGFA was calculated. The measurements obtained by image analysis were repeated twice to ensure reproducibility.

Statistical analysis

A linear regression models (SPSS/PC + Statistics 4.0 software; SPDD International BV, Gorinchem, The Netherlands) were used and the data for PGFAs were analysed statistically by a nonparametric Friedman and Wilcoxon signed-rank tests. The level of significance was set at $P < 0.05$.

Results

The results for the cross-sectional area of the canal and PGFA at 2 and 4 mm are show in Table 1. At 4 mm from the AF, the cross-sectional area of the canal varied from 0.34 to 1.01 mm^2, with a mean of 0.54 ± 0.15 mm^2. The PGFA at 4 mm from the AF, varied from 67.9% to 98%, with a mean of 87.57 ± 12%. The comparison of the PGFAs obtained 4 mm from the AF in the three groups is described in Fig. 1. The Thermafil System group produced significantly higher PGFAs than the lateral condensation group and the System B group ($P < 0.01$). No statistically significant difference was found between the lateral condensation group and the System B group.

In the samples sectioned at 2 mm from the AF, the cross-section area of the canal varied from 0.16 to 0.68 mm^2, showing an average of 0.36 ± 0.13 mm^2. The PGFA 2 mm from the AF, varied from 55.4% to

Table 1 The canal area, gutta-percha-filled area, void area, PGFA and the standard deviation 2 mm from the apical foramen

Group	Canal area (mm^2)	Gutta-percha area (mm^2)	Voids area (mm^2)	PGFA	SD
G1 – lateral condensation	0.38	0.31	0.08	82.60%	±10.67
G2 – System B	0.28	0.24	0.04	85.69%	±8.96
G3 – Thermafil System	0.51	0.50	0.01	98.16%	±0.50

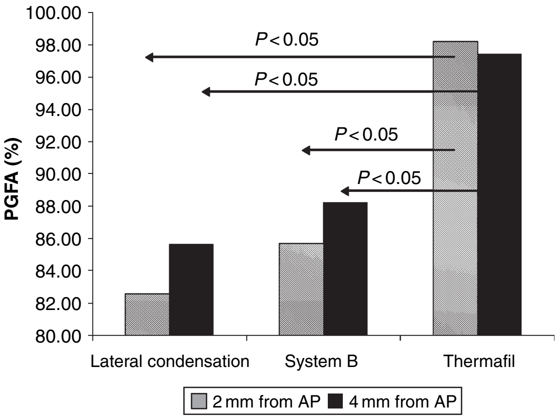

Figure 1 Graphic representation of the average values of the PGFAs found at 2 and 4 mm from the AF.

98%, with an average of 89.94 ± 15.75%. The comparison of the PGFAs obtained in the three groups was described in Fig. 1. The Thermafil system group produced significantly higher PGFAs than the lateral condensation group and the System B group ($P < 0.01$). No statistically significant difference was found between the lateral condensation group and the System B group.

The canal area was larger in the sections at 4 mm than 2 mm sections and this difference was statistically significant ($P < 0.05$). However, the differences between the averages of the PGFAs obtained in the sections at 4 and 2 mm was not statistically significant ($P = 0.068$) (Tables 1 and 2).

Discussion

The quality of canal filling in apical third is important and this study was designed to quantify the gutta-percha component and the area of voids on a percentage basis in order to provide a measure of quality.

In this experiment, samples were examined under an optical microscope and measurements were made through digital image analysis and processing. In this methodology, the quality of the images is important. The sample preparation for observation using an optical microscope is essential, as materials with different consistencies (gutta-percha and dentine) have to be polished in order to provide an even plane for observation.

Following the approach described by others (Smith *et al.* 2000, Wu *et al.* 2002), no sealer was used in the order to prevent methodological problems such as standardizing the volume of sealer.

Within the experimental design of this study, the lateral condensation group had a lower PGFA. Nevertheless, no significant statistical difference was found between lateral condensation and System B groups. These findings contradict those noted by Eguchi *et al.* (1985), where lateral condensation in the apical third was the technique with the lowest percentage of gutta-percha and the greatest amount of sealer. Normally used as a negative control for comparing the standards of other filling techniques, one of the main disadvantages of lateral condensation is its inability to replicate the inner surface of the root canal (Budd *et al.* 1991) (Fig. 4).

The Thermafil system group produced the highest PGFA at both 2 mm (PGFA = 98.2%) and 4 mm (PGFA = 97.4%) from the AF. It is also noteworthy that the minimum and maximum PGFA values are very close to the overall average in all Thermafil samples. Consequently, a minor standard deviation was found and indicates the excellent sampling homogeneity of this group. The Thermafil system used gutta-percha in the heated alpha-phase during the obturation process. This type of gutta-percha is endowed with specific characteristics: high radiopacity, excellent viscosity and fluidity, and enhanced adherence (Johnson 1978, Nguyen 1994). These characteristics are obtained through a process that upgrades its molecular array, making it better-balanced in chemical terms and modifying its physical properties.

One of the factors that might influence the poor performance of System B technique may be correlated to the anatomical variability of the teeth used. The oval canal shape may make it difficult to clean and fill (Wu *et al.* 2001, Wu & Wesselink 2001). Kersten *et al.* (1986) report that both the lateral condensation of gutta-percha cones as well as the vertical compacting of warm gutta-percha have been widely used in endodontic treatment, although their quality may differ

Table 2 The canal area, gutta-percha-filled area, void area, PGFA and the standard deviation 4 mm from the apical foramen

Group	Canal area (mm^2)	Gutta-percha area (mm^2)	Voids area (mm^2)	PGFA	SD
G1 – lateral condensation	0.57	0.48	0.09	85.62%	±15.62
G2 – System B	0.62	0.53	0.08	88.23%	±7.75
G3 – Thermafil System	0.51	0.49	0.01	97.43%	±1.88

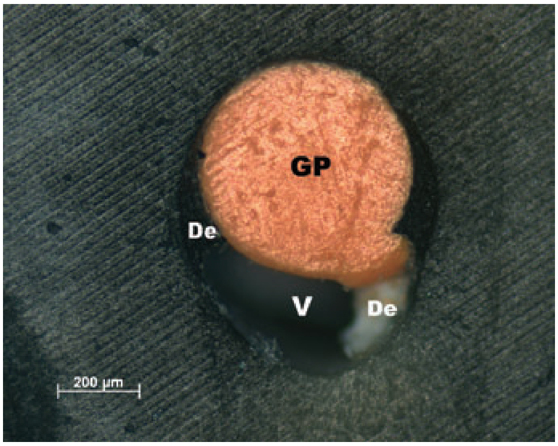

Figure 2 A cross-section of a specimen from System B group 2 mm from the AF.

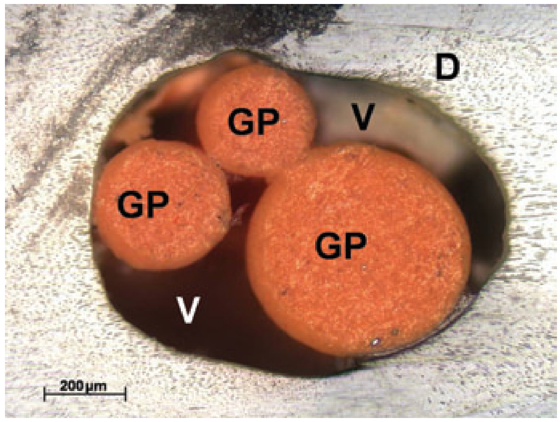

Figure 4 A representative cross-section of a specimen from lateral condensation group 2 mm from the AF.

in canals with different shapes. In their studies, Wu & Wesselink (2001) report a high percentage of oval canals in the apical portion of human roots (≥50%) with the diameter of these oval canals tending to decrease apically, which may well explain why various areas with no instrumentation appear less frequently at 3 mm (45%) than at 5 mm (65%) from the AF. Both the irregular canal shape and inadequate biomechanical preparation may negatively influence filling quality. It may be postulated that irregularly shaped canals may be filled more effectively by warm gutta-percha techniques, provided they are clean (Wu *et al.* 2001). Areas beyond the reach of the mechanical action of endodontic instruments in canals with irregular shapes can frequently remain unfilled when the lateral condensation technique is used (Wu *et al.* 2001). These findings corroborate with the results of the present study. In all samples with oval canals, the lateral condensation technique as well as System B performed poorly (Fig. 2). Only the Thermafil system was able to fill oval canals in a suitable manner (Fig. 3).

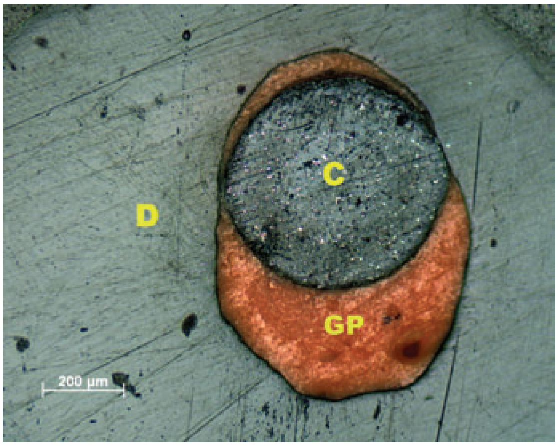

Figure 3 A representative cross-section of a specimen from Thermafil group 2 mm from the AF.

This present results confirm the findings of Gençoglu *et al.* (2002). The technique using a carrier-guided gutta-percha fill (Thermafil system) produced significantly higher PGFAs than the lateral condensation and System B techniques ($P < 0.01$). It indicates that the Thermafil system can reduce the sealer component (Fig. 4).

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