



Adaptation of a Resin-Based Endodontic Sealer to Dentin in the Apical Third of Root Canals Using Two Thermoplasticized Gutta-Percha Systems or a Cold Lateral Compaction Technique: An *Ex Vivo* Scanning Electron Microscopy Study

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Received: February 25, 2026; **Published:** March 12, 2026

Abstract

Objective: To evaluate *ex vivo* the adaptation of a resin-based endodontic sealer to the root canal walls using three different obturation techniques, as observed by scanning electron microscopy.

Materials and Methods: Thirty (n = 30) extracted single-rooted human mandibular premolars were prepared to the working length with the WaveOne Gold System. The samples were divided into three groups of 10 (n = 10) teeth each. Group 1: The canals were filled with the Calamus continuous-wave filling system; group 2: The canals were filled with the GuttaCore system; and group 3: The canals were filled with the cold lateral compaction of gutta-percha cones technique. In all groups, AH Plus was used as the sealer. An horizontal cross-section was made at 3 mm from the working length and the samples were observed with a scanning electron microscope. In each sample, the adaptation of the sealer to the root canal walls was evaluated at four predetermined locations. Data were recorded and statistically analyzed.

Results: One-way ANOVA did not show significant differences between the three filling techniques in terms of the presence of voids and adaptation to the root canal walls. However, Gutta Core presented less sealer-dentin separation and fewer voids than Calamus or the lateral compaction technique.

Conclusion: Both thermoplastic techniques and the cold lateral compaction technique revealed an acceptable three-dimensional obturation of the canals when observed at 3 mm from the working length. GuttaCore resulted in a more homogeneous gutta-percha mass and showed a better adaptation to the irregularities of the root canal walls.

Keywords: Endodontics; Filling; Resin-Based Sealant; Scanning Electron Microscopy; Thermoplasticized Gutta-Percha

Abbreviations

CCWS: Calamus Continuous Wave Filling System; GUCO: GuttaCore Obturation System; LCGP: Cold Lateral Compaction of Gutta-Percha Cones; WL: Working Length

Introduction

It is generally accepted that after complete debridement and disinfection, the key factor for successful endodontic therapy is the total obliteration of the root canal space with biocompatible materials [1]. In this respect, the outcome of endodontic treatment indicates the extent to which these conditions have been achieved [2]. Historically, various materials have been advocated for filling root canals, with gutta-percha and sealer cement being the most widely used [3]. For many years, the cold lateral compaction of gutta-percha cones technique (LCGP) along with a sealer has been considered the “gold standard” for filling the root canal system [4]. However, Dhangar, *et al.* [5] reported that voids and gaps are frequently observed with the use of the gutta-percha cones as well as between the gutta-percha and dentin walls, leading to a deficient three-dimensional obturation of the root canal space. In this respect, the introduction of thermoplasticized gutta-percha to endodontics was a turning point for endodontic therapy. Various innovative systems use the plasticity of warm gutta-percha to overcome these shortcomings and allow the material to move into irregularities, recesses, or fins that are frequently present in root canals, thereby enabling a closer adaptation of the endodontic sealers to the dentin walls [4,6].

One of these innovative techniques is the Calamus Continuous Wave Filling System (CCWS), a thermoplastic delivery system that provides excellent flow of the gutta-percha for a three-dimensional filling of the root canal irregularities. The CCWS uses a hybrid procedure with a down-pack for the apical third and a back-fill for the rest of the canal space [7]. The system has a handpiece and an activation cuff for controlling the flow and temperature of the gutta-percha while the material is introduced into the root canal space. The temperature of the gutta-percha during extrusion through a needle ranges between 48 and 55°C, and the gutta-percha remains in its flow state for approximately 45 to 60 seconds [7,8].

Another filling technique, i.e. GuttaCore (GUCO; Dentsply, Tulsa Dental specialties, Tulsa, OK), involves a central core made of cross-linked thermoplastic gutta-percha, coated with a thermoplastic

soft gutta-percha material. According to the manufacturer the system provides a homogeneous, dense mass of gutta-percha and is quite effective in performing a three-dimensional filling of the root canal space, with high values for filling lateral canals and fins [9]. Previous reports have shown that these core carriers allow rapid and easy removal in cases of non-surgical retreatment [10].

Aim of the Study

The aim of the present *ex vivo* study is to evaluate the adaptation of a resin-based endodontic sealer to the root canal walls as produced by the use of the CCWS or GUCO filling systems and the LCGP technique. The null hypothesis of the study was that there would be no significant differences between the three filling techniques in terms of the presence of voids (GAP) and adaptation to the canal walls.

Materials and Methods

The protocol of the present study was approved by the CICUAL Institutional Ethics Committee at the Faculty of Odontology, School of Dentistry, University of Buenos Aires (Protocol RESCD-2025-314/UBA). The sample size was calculated using the F-family test, ANOVA, and G* Power 3.1 [11], after which a total of 30 teeth was indicated as the minimum sample size required for the present study. Thirty mandibular premolars with a single, slight, oval-shaped, straight root canal were then selected from the Tooth Bank of the University and stored at room temperature in a solution of 50% alcohol and 50% glycerin until they were used. Radiographs taken from the mesial and buccal aspects of the teeth confirmed that they had a single, slight oval canal. Teeth were assigned to three groups of 10 teeth each ($n = 10$). Teeth with root caries, canal obstructions, open apices, cracks, and resorptive defects were excluded. To ensure that groups had teeth of similar average dimensions, a stratified sampling method was used (Minitab 10.1, Minitab Inc., StateCollege, PA, USA). The length of the teeth was standardized by cutting the crown perpendicular to the long axis at 15 mm from the apex using a low-speed saw (DHUC Micro Disc NH-6P, DHUC Co., Buenos Aires, Argentina) under constant water cooling. The working length (WL) was established by advancing a size 10 K-file into the canals until it was just visible at the apex under a stereomicroscope (Carl Zeiss, Oberkochen, Germany), followed by subtracting 1 mm.

Sample preparation and obturation

All canals were prepared with Wave One Gold instruments (Dentsply, Sirona, Switzerland) strictly according to the manufacturer's recommendations. Preparation of the canals was considered complete when a medium instrument (equivalent to a size #35.06) could be inserted to the WL without interference while maintaining apical patency. Throughout biomechanical preparation, the canals were irrigated with 5 mL of 5.25% NaOCl using a 30-G NaviTip needle (UltradentProductsInc, South Jordan, UT) placed 1 mm short of the WL without binding. Activation of the irrigant was performed with the instrument Gold from the system Ultra X (Eighteenth, Changzhou Sifary Medical Technology Co. Ltd, China) for 20s. After preparation, 5 mL of 17% EDTA solution was left in the canals for 1 minute while it was activated with the same instrument. Finally, the canals were copiously rinsed with saline and dried with paper points. After patency was confirmed with a size 10-K file, all canals were filled to the WL.

In group 1 (n = 10), the root canals were filled with the CCWS. In group 2 (n = 10), the obturation was completed with the GUCO. In group 3 (n = 10; the control group), the canals were filled with the LCGP technique. In all cases, AH Plus (Dentsply, Sirona, Switzerland) was used as the sealer. For groups 1 and 2, the filling procedures were performed according to the manufacturer's recommendations. For group 3, the LCGP technique was performed as described by Koçak and Darendeliler-Yaman [12]. Briefly, each tooth was filled to the WL with a matched-taper single gutta-percha cone to maintain consistency between samples. The canals were trial fitted with a gutta-percha cone sized and tapered to match the final shaping #35/.06 medium instrument. The cone was inserted to the WL using visual and tug-back control. After removing the cone, the sealer was gently applied to the canal walls with a size #20 K-file. Subsequently, the cone was dipped in the sealer and then firmly inserted to the WL. Additional accessory gutta-percha cones dipped in the sealer were also used and laterally compacted with finger spreaders until it was not possible to place one further than 2 mm. Immediately after obturation, excess material was removed flush with the canal orifice using a heated instrument. The gutta-percha was then vertically condensed with a plugger, and the orifice was sealed with a glass ionomer cement (FujiPlus; GC Corp, Tokyo, Japan). During the obturation procedures, the samples were kept moist by holding the roots in gauze moistened

with saline. All samples were properly identified and stored for 24h in an oven at 37°C and 100% humidity to ensure complete setting of the sealer. After the samples were removed from the oven, radiographs were taken from the mesial and buccal aspects of each tooth to check the quality of the root canal obturation. If there were radiographically visible voids, bubbles, or unfilled spaces, the tooth was excluded from the study and replaced by a new one. All teeth were then individually embedded in transparent acrylic resin and sectioned horizontally at 3 mm from the WL with the slow-speed saw. Subsequently, a 2-mm-thick slice, including the complete perimeter of the tooth and the root canal space containing the filling materials, was obtained from each tooth. The samples were then coded to allow for a blinded evaluation.

Scanning electron microscopy

In preparation for scanning electron microscopy (SEM), the slices were individually mounted on aluminum stubs, coated with 200 Å of gold-palladium, and examined at x350 and x750 magnifications in a Gemini SEM 560 scanning electron microscope (Carl Zeiss, Oberkochen, Germany) operated at 15.5 kV. For evaluation, the total area within the canal perimeters was examined and photographed at low magnification. Four standardized measuring points were established at the 3-, 6-, 9-, and 12-hour locations (Figure 1). At each measuring point, photographs were taken, and the adaptation of the sealer to dentin was analyzed by two calibrated evaluators. If there were areas of sealer separation, the space was measured using the micrometric ruler incorporated into the microscope. If there was a disagreement between the evaluators, the sample under discussion was analyzed jointly until a consensus was reached.

Statistical analysis

For each group, the average scores at the measuring points were recorded in an Excel data sheet. The images were transferred to a computer and analyzed using the Image J Software 1.38x program (National Institutes of Health, Bethesda, MD). For each sample data was obtained by summarizing the values registered at each of the four measuring points. Mean scores were calculated for each group and statistically analyzed with the Statistical Package for the Social Sciences software (SPSS; Inc, Chicago, IL). For between-group significance, a one-way analysis of variance (ANOVA) was used. The Shapiro-Wilk test was used to test the assumption of a normal distribution. The significance level corresponds to 5%.

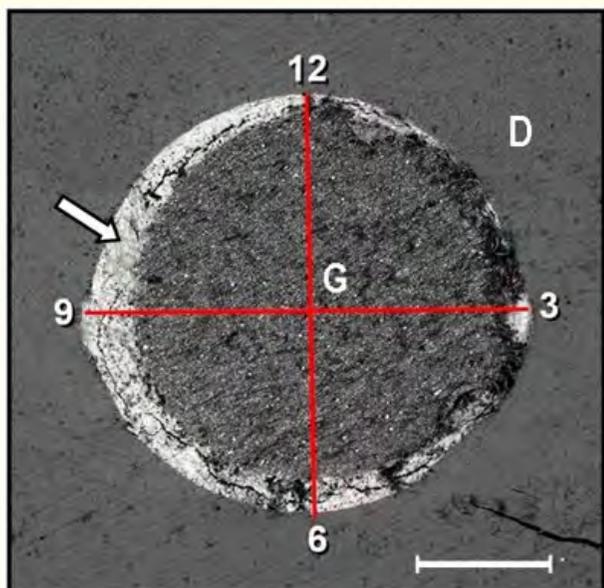


Figure 1: SEM microphotograph of a horizontal cross section taken 3 mm from the WL, showing the four measurement points at 3, 6, 9, and 12 hours. G: Gutta-percha. The white arrow indicates the sealer. Original magnification x300; Bar: 120 μ m.

Results

The evaluators' calibration exercise established an agreement ratio of 92%, which constitutes strong inter-observer agreement. Therefore, the scoring of the samples was considered reliable. The mean scores and standard deviations for all groups are shown in table 1. ANOVA revealed no significant differences between groups with respect to the presence of voids (GAP) or in adaptation to the canal walls. Therefore, the null hypothesis was accepted. In general, all samples showed close adaptation of the sealer to dentine but not to the gutta-percha mass. Artifacts such as dentin fracture lines or cohesive microfractures within the sealer were occasionally seen in specimens from all groups. The analysis of individual GAP values revealed that GUCO (Figure 2) had greater homogeneity, with a tendency to show lower deviations from the mean and better adaptation to the root canal walls. By contrast, CCWS (Figure 3) and LCGP (Figure 4) showed greater dispersion. The Shapiro-Wilk test (Table 2) revealed that CCWS and GUCO have a normal distribution, while LCGP did not.

	N	Mean	SD	Gap (minimum)	Gap (maximum)
Group 1	10	4.927,28 ^a	17.07	143.80	720.30
Group 2	10	3.438,60 ^a	2.05	125.30	405.75
Group 3	10	5.054,90 ^a	10.31	172.75	602.35

Table 1: Mean values (μ m) of groups measured at 3 mm from the WL.

SD: Standard Deviation. Same lowercase letters represent no significant differences between groups.

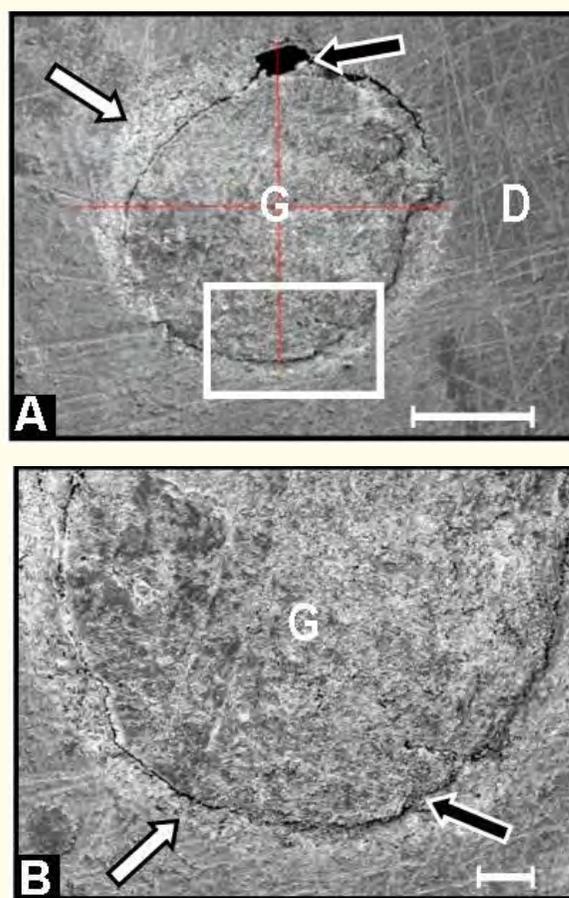


Figure 2: SEM microphotograph of a representative specimen from group 1. A: Low magnification showing gutta-percha (G) and the sealer (white arrow). Note the wide gap between the sealer and gutta-percha (black arrow). Original magnification x300; bar: 100 μ m. B: Higher magnification of the square area in A. Note that the sealer shows close adaptation to dentin (white arrow) but not to gutta-percha (black arrow). G: Gutta-percha. Original magnification x750; bar: 30 μ m.

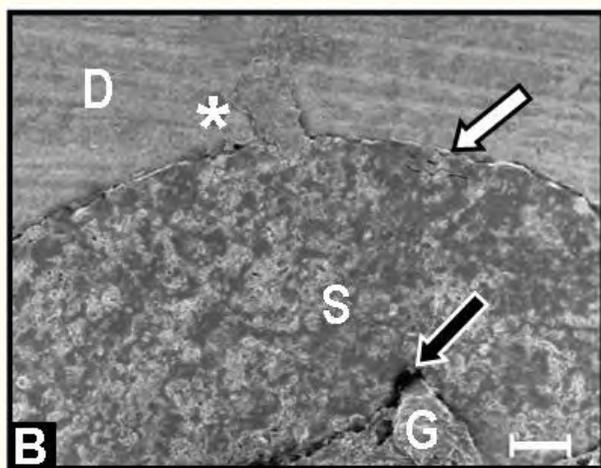
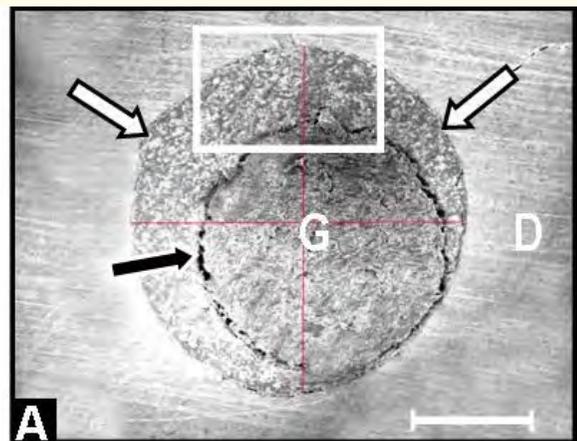


Figure 3: SEM microphotograph of a representative specimen from group 2. A: Low magnification showing the gutta-percha mass (G) surrounded by the sealer. Note the close adaptation of the sealer to dentin walls (white arrows). The sealer did not adhere to gutta-percha (black arrow). D: Dentin. Original magnification x300; Bar: 100 μ m. B: Higher magnification of the square area in A. The sealer shows close adaptation to dentin (white arrow) but not to gutta-percha (black arrow). Note the sealer entering an irregularity of the dentin wall (asterisk). D: Dentin; S: Sealer; G: Gutta-percha. Original magnification x750; Bar: 30 μ m.

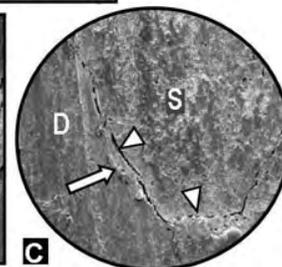
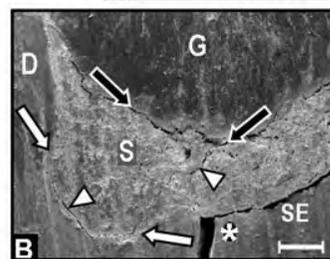
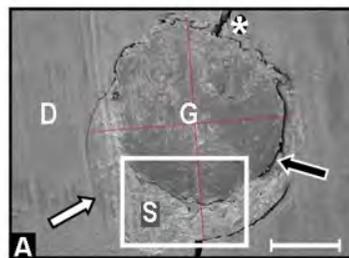


Figure 4: SEM microphotograph of a representative specimen from group 3. A: Lower magnification showing separation between the sealer and the master gutta-percha cone (black arrow). White arrow indicates close adaptation of the sealer to dentin. The asterisk indicates the presence of an artifact (dentin fracture). G: Gutta-percha cone; S: Sealer; D: Dentin. Original magnification x300; Bar: 30 μ m. B: Higher magnification of the square area in A. Note the separation between the gutta-percha cone and the sealer (black arrows) and the extensive area in which the sealer shows close adaptation to dentin (white arrows). The presence of an artifact, such as the gross dentin fracture (asterisk), appears to be responsible for the separation of the sealer from dentin (SE). Note also a thin cohesive microfracture within the bulk of the sealer (white arrowheads). G: Gutta-percha cone; S: Sealer; D: Dentin. Original magnification x850; Bar: 50 μ m. C: Higher magnification of the same area of B demonstrating a cohesive microfracture within the bulk of the sealer (white arrowheads) and the close adaptation of the sealer to dentin (white arrow). S: Sealer; D: Dentin. Original magnification x1500.

Group 1	P = 0,07918	Normally is accepted
Group 2	P = 0,01087	Normally is accepted
Group 3	P = 0,54104	Normally is rejected

Table 2: Normal data distribution (*Shapiro-Wilk test*).

Discussion

Three-dimensional obturation of the root canal system is essential to prevent reinfection of the root canal space and to create a favorable environment for healing of the periradicular tissues [4]. In this study, we evaluated the quality of obturation produced by two thermoplasticized gutta-percha systems and the cold lateral compaction technique. As per protocol, the evaluation focused specifically on a predetermined level within the apical third of the root canals. It has been demonstrated that the apical third is one of the more difficult areas to fill due to the presence of many anatomical variables and canal ramifications [13]. Our observations are in line with those of Gupta, *et al.* [14], who found gaps and empty spaces between the sealer and dentin or between the sealer and gutta-percha in teeth filled with different thermoplasticized gutta-percha systems, regardless of the filling technique used. In the present study, no significant differences were found between the three groups, a finding also supported by Jindal, *et al.* [8], Yadav, *et al.* [15], and Peng, *et al.* [16]. However, both thermoplasticized systems showed some advantages over the LCGP technique. They were less time-consuming (data not shown) and resulted in a more homogeneous mass of gutta-percha.

The tendency of GUCO to fill the root canal space better was not entirely unexpected. Migliau, *et al.* [10] reported that carrier systems that deliver soft thermoplasticized gutta-percha into the root canal produce a more uniform distribution of the material within the root canal space and a more favorable adaptation of the sealer to the irregularities of the canal walls. In line with this assumption, Raghuvanshi, *et al.* [2] and Aminsobhani, *et al.* [6] reported that although CCWS performed efficiently, the system frequently exhibited variations in material density along the entire length of the root canal, especially in the apical third, a finding that was also confirmed by the results of the present study. Dhangar, *et al.* [5] and Bhatia, *et al.* [1] indicated that although they found comparable outcomes in terms of the presence of gaps and adaptation to the canal walls, the warm thermoplasticized systems

exhibited superior flowability and more homogeneous lateral and apical compaction of the material than the conventional LCGP technique, a finding that was also supported by others [17,18]. Another important point to be considered is that irrespective of the material and filling technique used for each group, most samples of the study revealed that the sealer did not show adhesion to the gutta-percha mass and appeared almost completely separated from the gutta-percha surfaces. In this respect, we agree with Tanomaru-Filho, *et al.* [19] and Teixeira, *et al.* [20] in that initially, the heated natural state and brittle soft form (lower melting point) of the alpha-phase thermoplastic gutta-percha used in groups 1 and 2 often results in better adaptation and uniform mass with the sealer but it may suffer posterior contraction upon cooling. This phenomenon along with the presence of occasional microfractures within the sealer could be also influenced by the high vacuum present within the column of the microscope (Zmener and Domingues 1998; unpublished data). In contact with the manufactured processed flexible and stable form (high melting point) gutta-percha cones used in group 3, the adaptation of the sealer showed similar results. On the contrary, a close adaptation of the sealer to dentin was consistently observed in all samples of the study which is in agreement with the previous study of Nunes, *et al.* [21] who found that AH Plus adhered closely to dentin under different treatment conditions. Interestingly, Swathika, *et al.* [22] and Özer and Aktener [23] demonstrated that despite the aforementioned differences, the *in vitro* and long-term *in vivo* success rates obtained with the use of thermoplasticized gutta-percha did not differ significantly from those obtained with the LCGP technique. Nevertheless, due to the particular characteristic of both, the soft thermoplastic gutta-percha and the flexible gutta-percha cones, further studies are required to analyze the capacity of different types of gutta-percha filling techniques in adequately filling the root canal space.

Conclusion

Within the limits of the present study, we conclude that although there were no statistical differences between Calamus, GuttaCore, and the cold lateral compaction technique, GuttaCore showed a tendency to deliver a more homogeneous mass of gutta-percha and to adapt the sealer to the irregularities of the root canal walls more closely.

Acknowledgements

The authors wish to thank to Engineer Eduardo Coronel for his contribution to the statistical analysis. They are also grateful to the staff of the Department of Dental Materials at the Faculty of Odontology, School of Dentistry, University of Buenos Aires, for their technical collaboration.

Conflict of Interest

The authors declare no conflict of interest.

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Volume 8 Issue 3 March 2026

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