ORIGINAL ARTICLE

The Efficacy of Mechanical Rotary, Chemical Solvent and Laser-Activated Irrigation to Remove Intracanal Obturation Material with Various Types of Sealer in Retreatment Endodontic

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ABSTRACT

Introduction: This research evaluates the efficacy of Protaper Universal Rotary Instruments (PTUR) combined with chloroform and Laser-Activated Irrigation (LAI) for removing intracanal obturation materials from extracted human premolars during retreatment. Objectives include assessing residual filling volume via Micro-CT. **Methods:** An in vitro study used extracted, obturated premolars retreated with PTUR, chloroform, and LAI. Teeth were divided into four groups based on retreatment method and sealer type: AH Plus, MTA Fillapex, or CeraSeal. Effectiveness was assessed through Micro-CT. **Results:** The combination of PTUR, chloroform, and LAI (Group 4) showed the least residual material ($p = 0.0037$). MTA Fillapex left more debris than AH Plus and CeraSeal. These findings suggest that combining solvent and laser irrigation with PTUR improves retreatment effectiveness. **Conclusion:** PTUR with chloroform and LAI demonstrated superior efficacy in removing intracanal obturation materials, leaving significantly less residue than other techniques. MTA Fillapex showed the most remaining debris, while AH Plus and CeraSeal yielded cleaner canals. This highlights the clinical value of integrating mechanical, chemical, and laser-assisted irrigation in retreatment.

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INTRODUCTION

The primary goal of root canal retreatment is to eliminate infection by removing debris, filling materials, and microorganisms causing apical periodontitis (1). This can be achieved using chemical solvents to dissolve Gutta-Percha (GP) and mechanical tools such as hand files, rotary, reciprocating, or ultrasonic instruments (2). Laser-Activated Irrigation has also been explored to enhance filling removal (3). However, in vitro studies show that remnants often remain in dentinal tubules, acting as reservoirs (4). Mechanical devices are faster than hand files, and chloroform helps soften GP in hard-to-reach areas like isthmuses and lateral canals (5).

The type of root canal sealer also influences retreatment outcomes. AH Plus, an epoxy resin-based sealer, is known for its sealing ability, dimensional stability, and low solubility (6). MTA is widely used due to its sealing ability, biocompatibility, and potential to promote mineralized tissue formation (7). CeraSeal, a calcium silicate-based bioceramic, has gained attention for its penetration into dentinal tubules, enhanced bonding, biocompatibility with periapical tissues, and adaptability to different obturation techniques (8).

Differences in the physical and biological properties of sealers may affect retreatment efficiency, especially in material removal and clinical performance. However, no consensus exists on the most effective retreatment approach, as many studies have focused on single techniques or sealers. This study addresses these gaps

by evaluating a multimodal protocol combining PTUR, chloroform, and LAI for removing obturation materials with three sealers: AH Plus, MTA Fillapex, and CeraSeal. We hypothesize that this combined approach will enhance material removal and support better clinical decisions in retreatment.

MATERIAL AND METHODS

Study Design

This in vitro experimental study evaluates and compares retreatment protocols for removing gutta-percha and sealers, aiming to identify the most effective combination of mechanical, chemical, and laser-assisted techniques to improve clinical outcomes.

Study Population

The study used freshly extracted permanent single-rooted premolars from healthy individuals (>12 years) at AMDI Dental Clinic, collected for orthodontic or periodontal reasons (ethical approval: USM/JEPeM/22070507). Included were intact single-rooted premolars, while multi-rooted teeth, previously treated canals, open apices, resorption, root stumps, and teeth from patients with systemic conditions were excluded. Informed consent was obtained from all participants, including guardians of minors, and specimens were discarded after research completion.

Sample Size and Selection

The sample size was calculated using G*Power v3.1.9.4 (9) with 80% power, 0.05 significance level, and effect size from Nouri et al. (10). The t-test (Wilcoxon-Mann-Whitney or one-sample) was applied, and objective three required ~37 teeth. Ultimately, 36 extracted single-rooted teeth were included and equally divided into four groups (9 each): PTUR only, PTUR + chloroform, PTUR + LAI, and PTUR + chloroform + LAI (Table I).

Table I: The number of extracted teeth and the grouping of the treatment involve in this study.

GROUP	TREATMENT	SUBGROUP A GP/AH Plus	SUBGROUP B GP/MTA Fillapex	SUBGROUP C GP/ CeraSeal
1	Protaper Universal Rotary Instrument (PTUR)	3 samples	3 samples	3 samples
2	Protaper Universal Rotary Instrument (PTUR) + chloroform	3 samples	3 samples	3 samples
3	Protaper Universal Rotary Instrument+ Laser-Activated Irrigation (LAI)	3 samples	3 samples	3 samples
4	Protaper Universal Rotary Instrument (PTUR) + chloroform+ Laser-Activated Irrigation (LAI)	3 samples	3 samples	3 samples

Research equipment and Materials

The equipment used in this study included a dental diode laser (DEASIN, China), an apex locator (Dentsply Apexlocator), and an endodontic micromotor machine (Dentsply Maillefer), all of which were located in the AMDI dental clinic. In addition, a Micro-CT scanner (Bruker Skyscan 1172 Micro-CT) was employed at the Abdullah Bugshan Research Chair for Dental and Oral Rehabilitation Laboratory, King Saud University, Saudi Arabia. The materials included three sealers: AH Plus (epoxy resin-based; Dentsply Maillefer, Switzerland), MTA Fillapex (calcium silicate with salicylate resin; Angelus, Brazil), and CeraSeal BC (bioceramic calcium silicate; Meta Biomed, USA). ProTaper Universal rotary instruments, ProTaper Next gutta-percha, and paper points (all Dentsply Maillefer, Switzerland) were used. Additional materials were chloroform (GuttaSoft, Diaa Products, Saudi Arabia), sodium hypochlorite (NaOCl; Parcan N, Septodont, UK), and 15% EDTA (Calsinase, Germany).

Preparation and obturation of the tooth samples:

Tooth preparation and obturation followed Suk et al. (11). Access cavities were prepared with a turbine handpiece, and pulp tissue was removed with a barbed broach. Apical sizes were checked with K-files; teeth with apical size >25 were excluded. Crowns were removed with a diamond disk (Keystone Industries, USA) to standardize root length at 17 mm. Working length (WL) was established with a size 10 Flexofile, set 1 mm short of the apical foramen (WL = 16 mm). Apical patency was confirmed following Agrafioti et al. (12) with a size 15 K-file.

Instrumentation used PTN rotary files (X1, X2, X3 to MAF 30/0.07) with an XSmart micromotor at 300 rpm. After each file, canals were irrigated with 1 mL of 2.5% NaOCl. Final irrigation included 1 mL 15% EDTA for 1 min, 1 mL 2.5% NaOCl for 30 s, and 1 mL saline for 30 s. Canals were dried with sterile X3 paper points.

Teeth were obturated with GP and either AH Plus (n=12), MTA Fillapex (n=12), or CeraSeal BC (n=12) using cold lateral compaction. Obturation quality was verified with periapical radiographs, and access cavities were sealed with Cavit (3M ESPE, USA). Samples were stored at 100% humidity for one month before retreatment. Filling volume was evaluated using Micro-CT .

Retreatment Procedure:

Group 1 (PTUR only): In Group 1, retreatment followed Bernardes et al. (13). PTUR instruments D1–D3 removed material from the cervical, middle, and apical thirds, followed by X3 to full working length (WL). WL was confirmed five times or regained with hand files. Canals were irrigated with 1 mL NaOCl and EDTA, then dried

with sterile paper points. Group 2 (PTUR + chloroform): Retreatment followed Takahashi et al. (14) using PTUR with chloroform. After D1, 0.1 mL chloroform softened the GP, which was removed with D2–D3 to WL. Preparation continued with X3 until all instruments reached WL five times. Irrigation and drying were done as in Group 1. Group 3 (PTUR + LAI): Retreatment followed Suk et al. (11) with PTUR plus laser-activated irrigation. After the mechanical phase, canals were irrigated with 5 mL of 2.5% NaOCl, activated by diode laser (5 s irradiation/10 s rest, repeated four times) to the apex. Group 4 (PTUR + chloroform + LAI):This group combined the techniques of Groups 2 and 3, using both chloroform and LAI in conjunction with PTUR instrumentation. Recapitulation was performed in all groups.

Micro-CT Analysis:

Root canal filling volume was assessed using Micro-CT at KSU, KSA, following (15). Scans with a 0.7 µm focal spot and 1.2 µm structural resolution at 80 kV and 60 µA showed a reduction in filling material on canal walls post-retreatment (Fig. 1).

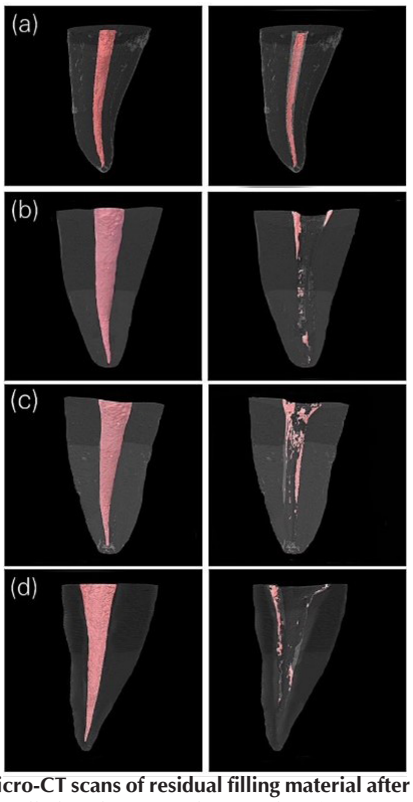

Figure 1: Micro-CT scans of residual filling material after retreatment. Canals were filled with CeraSeal BC sealer. (a) Group 1: PTUR (b) Group 2: PTUR and chloroform (c) Group 3: PTUR and LAI (d) Group 4: PTUR and chloroform and LAI.

RESULTS

Micro-CT Results

Two-way ANOVA revealed significant main effects of both treatment protocol and filling material on the volume of residual root canal filling material (Table II).

Table II: ANOVA Table for the Residual Volume of Root Canal Filling Material

Source	df	F	p-value
Treatment	3	3.05	0.0435*
Filling Material	2	11.09	0.0002**
Treatment x Filling Material	6	1.35	0.2652

Post-hoc Tukey HSD tests showed no statistically significant pairwise differences between treatment groups ($p > 0.1$), although there was a trend toward reduced residual volume when chloroform or laser-activated irrigation was added to PTUR.

Regarding the filling materials, GP/MTA Fillapex consistently presented higher residual volumes compared to GP/AH Plus and GP/CeraSeal, with differences approaching statistical significance ($p = 0.0502$ and $p = 0.0584$, respectively). These findings suggest that the resistance of GP/MTA Fillapex to removal may be clinically relevant.

DISCUSSION

This study evaluated the effectiveness of different retreatment protocols in removing root canal filling materials with various sealer types. The combination of PTUR, chloroform, and LAI (Group 4) showed the greatest efficiency, with Micro-CT analysis confirming significantly lower residual volumes ($p = 0.0435$). Two-way ANOVA also revealed significant effects of both retreatment protocol ($p = 0.0435$) and sealer type ($p = 0.0002$) on residual obturation material, supporting the advantage of multimodal approaches (16).

Among the tested sealers, MTA Fillapex exhibited the highest resistance to removal, likely due to its strong bonding to dentin and low solubility. CeraSeal was removed more effectively, particularly under the G4 protocol. Although AH Plus is known for strong adhesion, it was easier to remove than MTA Fillapex, contradicting previous reports that showed higher bond strength for AH Plus (17,18). These discrepancies may relate to methodological differences, laser parameters, or material properties.

Laser-Activated Irrigation played a significant role in enhancing canal cleanliness, consistent with studies by Preethee et al., Montero-Miralles et al., and Fahim et al. (19,20). Fahim et al. further confirmed that diode laser with NaOCl significantly reduced aerobic and anaerobic bacteria, highlighting its contribution to disinfection.

Clinically, the results support using multimodal retreatment protocols, particularly G4, in challenging cases. The findings also emphasize that the choice of sealer in initial treatment influences future retreatability, underscoring the importance of balancing sealing ability with removability. Despite limitations such as

the focus on single-rooted teeth, limited sample size, and evaluation of only three sealers, the standardized methodology enhances reliability. Future research should include multi-rooted teeth and newly developed sealers.

CONCLUSION

This study demonstrates that combining mechanical instrumentation (PTUR), chloroform solvent, and laser-activated irrigation significantly enhances the removal of root canal filling materials. This multimodal approach was the most effective across all tested methods, even for resistant sealers like MTA Fillapex, while the easier removal of CeraSeal underscores the importance of sealer selection for retreatment. These findings provide clinicians with a reliable strategy to improve retreatment outcomes and patient care. Further research on multi-rooted teeth and new sealers is recommended to advance endodontic treatment.

Conflict of Interest: No potential conflict of interest relevant to this article was reported.

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