# INFLUENCE OF CHLOROFORM AND PASSIVE ULTRASONIC IRRIGATION ON REMOVAL OF ENDODONTIC FILLING MATERIAL DURING RETREATMENT (AN IN VITRO STUDY)

Shaimaa M. Aly[1]* *BDS*, Mahmoud R. Aboelseoud[2] *PhD,* Raef A. Sherif [3] *PhD*

## ABSTRACT

**INTRODUCTION:** Removal of initial endodontic filling material during retreatment is mandatory for favorable outcomes.
**OBJECTIVES:** This study aimed to assess the influence of chloroform and passive ultrasonic irrigation (PUI) on the retrieval of endodontic filling material during retreatment using CBCT for evaluation.
**METHODS:** Forty extracted single canaled lower premolars were decoronated, instrumented with ProTaper Next files (X3), and filled with lateral condensation technique. Samples were randomly distributed into two groups with further subdivision into four subgroups according to the use of chloroform and PUI as follows: Group A1 (chloroform/PUI), Group A2 (chloroform /without PUI), Group B1 (without chloroform/PUI), Group B2 (negative control) (without chloroform / without PUI). Retreatment was done with ProTaper Universal retreatment (PTU) files in all teeth. Before and after-retreatment CBCT-scans were done for all samples, and the residual volumes were measured. Statistical analysis was performed with a level of significance set at a P-value of 0.05.
**RESULTS:** Complete removal of endodontic filling material was not achieved by any tested techniques. However, the negative control group (B2) showed the least mean percentage of residual volume (5.95%), while chloroform with the PUI group (A1) showed the greatest mean percentage of the residual volume (17.98%), with no significant difference between the four study groups. The greatest mean residual volume was revealed at the coronal third in all study groups.
**CONCLUSION:** PTU-file without chloroform and PUI was the most effective in removing endodontic filling material.
**KEYWORDS:** CBCT, Chloroform, Endodontic retreatment, Passive ultrasonic irrigation.
**RUNNING TITLE:** Endodontic retreatment using chloroform and PUI.

1 BDS 2010, Faculty of Dentistry, Alexandria University, Egypt.
2 Professor of Endodontics. Department of Conservative Dentistry, Faculty of Dentistry, Alexandria University, Egypt.
3 Lecturer of Endodontics, Department of Conservative Dentistry, Faculty of Dentistry, Alexandria University, Egypt.

* *Corresponding Author:*
E-mail: drshaimaamohamed88@gmail.com

## INTRODUCTION

Apical periodontitis might emerge, persist or recur after primary root canal treatment, a condition that may need further intervention and retreatment (1). Endodontic retreatment may be done surgically or nonsurgically. Nonsurgical retreatment involves removal of initial endodontic filling material, further instrumentation and obturation to enhance periradicular tissue status. However, due to the complex root canal anatomy and different chemical and physical properties of root canal filling materials, it may be difficult to completely remove previous canal fillings (2-4).

During endodontic retreatment, solvents were commonly used to aid in removal of initial filling material (5). Although endodontic filling material may be removed with rotary files without the need for solvents, previous studies combined solvents and rotary files to evaluate their synergistic effect during retreatment (6-8).

Passive ultrasonic irrigation (PUI) was shown to be more beneficial than conventional needle irrigation regarding irrigant penetration and cleaning of the root canal apical part and untouched areas during the instrumentation procedure (9-11). Furthermore, it was shown previously that three PUI cycles may lead to better flushing of debris found in simulated untouched areas (11). Therefore**,** it seems necessary to understand the synergistic effect of solvent and irrigant activation with three PUI cycles regarding root canal filling material removal.

In endodontic studies, residual filling materials have been measured by different methods and techniques, including stereomicroscope, scanning electron microscope, microcomputed tomography,

teeth clearing, longitudinal tooth splitting, radiography, and digital images. However, CBCT has recently become available, allowing for a three-dimensional volume measurement without the need for splitting the specimens (12).

This study's aim was to assess the efficacy of a solvent (chloroform) and PUI with intermittent flushing method in improving endodontic filling material removal using CBCT for assessment.

The null hypothesis was that the tested techniques would not exhibit any difference concerning the removal of residual filling material.

## MATERIALS AND METHODS

This study was approved by the ethics committee of the Faculty of Dentistry, Alexandria University, Egypt (serial no. 0089-11/2019). It was conducted at the Faculty of Dentistry, Alexandria University, Egypt.

**Sample Size Estimation**

The sample size was measured using Gpower software, version 3.1.9.2 (13). The minimal required sample to achieve a power of 80% (β error) and an (α error) of 5% (p – 0.05) in order to detect a significant difference was calculated to be 40 teeth.

**Specimen Preparation**

Forty extracted lower premolars with single straight roots and single canals, mature apices, free from caries, cracks, calcifications, or internal resorption were included in this study. Manual K file size 15 was the first fitted file at the apex. The selected teeth were thoroughly cleansed from debris, calculus, and organic tissues and then preserved in saline solution up to the time of use to avoid dehydration. Teeth were initially examined with two digital radiographs in facio-lingual and proximal views to ensure the existence of one canal (Vertucci type I).

The crowns were removed at the cervical line with a diamond disc (KG Sorensen, Barueri, SP, Brazil) to establish a standardized length of 17 mm. A size 10 K-file was inserted into the canal until it was visualized at the apex, and 1 mm was deducted from the measured length to determine the working length. Glide path was created with manual K files up to size 15, then the canals were instrumented with ProTaper Next files (Dentsply, Sirona, Tulsa, USA) up to size X3(size 30/.07 taper). The files were operated with the XSmart plus rotary motor in continuous rotary motion at 300 rpm and a torque of 2 Ncm. Irrigation was performed at each instrument change with 1ml of 2.5% NaOCl (A.R.E Chemicals, Cairo, Egypt) bringing the total volume of irrigant into 5ml, using a 31 gauge luer lock syringe (DiaDent Group International, Burnaby, BC, Canada) positioned 1 millimeter shorter of the canal's working length. EDTA chelating gel (MD.ChelCream, MetaBiomed, Seoul, Korea) was used on the files as a lubricant throughout the preparation.

Canal patency was preserved during the preparation using k-file size 10. As a final rinse 2 ml of 17% EDTA solution (DHARMA Research, Miami, USA) was performed for 3 minutes, followed by 2ml of 2.5% NaOCL for 3 minutes. Roots were then dried with ProTaper Next absorbent paper points size X3.

**Obturation**

Roots were obturated with gutta-percha cones X3 (30/.07) as a master cone (Dentsply/Tulsa; Tulsa, Okla) and ADSEAL epoxy resin-based root canal sealer (META- BIOMED CO., LTD) using lateral compaction technique. A size 25 stainless steel finger spreader was inserted beside the master cone till resistance was felt and left for 30 seconds, followed by the placement of ISO size 25 gutta-percha cones. This step was repeated until the spreader could not exceed more than 2 mm inside the canal. Roots were imaged by digital x-ray from buccal and proximal views to verify the endodontic filling material's quality. All roots were sealed by Cavit temporary restoration (3M ESPE, St Paul, MN, USA) and stored in saline solution at 37°C for 48 hours to allow the sealer to be entirely set according to manufacturer instructions (14).

**Pre-retreatment CBCT**

Roots were placed in blocks of softened modeling wax, in groups of five roots per block, with one mm distance between each root. CBCT scans were taken for each block using J. Morita's Veraviewepocs 3D R100 scanner (J. Morita MFG Corp. Kyoto, Japan). The scans were taken with settings of 75 kVp tube voltage and one mA, with 9.4 seconds exposure time. Images were recorded with 80 x 80 mm FOV and a resolution of 0.125 mm.

The axial cut was positioned on the cervical line, while the sagittal cut was at the midline.

OnDemand3D software (CyberMed Inc, Daejeon, Korea) analyzed the images. Volume rendering and 3D reconstruction of the endodontic filling material were performed, and the material's volume was measured and recorded in cubic millimeters **(Figure 1)**.

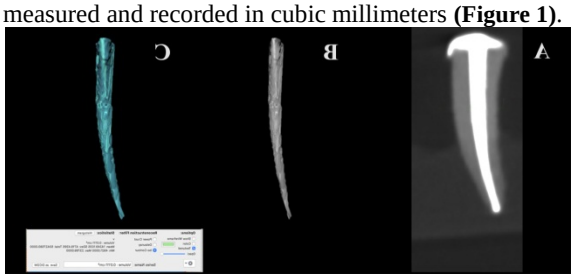


**Figure (1):** Pre-retreatment CBCT image, coronal view (A) and 3D volume reconstruction (B &C).

Retreatment protocol

For all specimens in both groups, after temporary filling material removal , 3mm of coronal gutta-percha were removed using size 2 Gates- Glidden drills, specimens were numbered, and an online

randomization tool (https://www.randomizer.org) (15) was used to divide the specimens into two groups (n=20) based on the method of using chloroform as a solvent or not during retreatment as follows: Group A (with chloroform) and Group B (without chloroform). Retreatment was performed with PTU retreatment files (Dentsply, Sirona, Tulsa, USA) in all specimens.

**Group A: (with chloroform)**

A drop of chloroform (0.1ml) was deposited into the coronal part of the canal after the previous removal of 3 mm of filling material, and then kept in place for 3 min before starting retreatment. Afterward, the softened gutta-percha was removed using D1 at the coronal third, D2 at the middle third, and D3 at the apical third, sequentially applying a crown-down technique until reaching the full working length (standardized to 17 mm). X-Smart plus endodontic motor was used at a constant speed of 500 rpm for D1 and 400 rpm for D2 and D3, with a torque of 3 Ncm for the three files.

After that, K-file size 10 was used to check the patency of the apical foramen. Irrigation was performed with 1 mL 2.5% NaOCl at each instrument change using a 31 gauge luer lock syringe (DiaDent Group International, Burnaby, BC, Canada). After completion of retreatment, 5 mL 17% EDTA was used to irrigate the specimens for 3 min , then was followed by a flush of 5 mL 2.5% NaOCl for 3 min.

After finishing retreatment procedures, specimens were further subdivided into two subgroups of 10 according to the use of PUI or not, using the previous randomization tool.

**Subgroup A1: (chloroform / PUI)**

After removal of GP using PTU retreatment files, chloroform (0.1ml) was deposited into the canal and left for three minutes. Then, activation was done using ultrasonic file IRRI

S21/25 (VDW GmbH, Bayerwaldstraße, Munich, Germany) for 20s operated with Satelec

P5 Newtron ultrasonic system (Satelec Acteon, Merignac, France), set at an endo power of 10 and positioned 1 mm from the WL. Afterward, 2ml of 2.5% NaOCL was deposited in the canal and activated for 20s. Activation of NaOCL was repeated for three cycles (20 s each) while replenishing the irrigant between each cycle using a suction tip.

**Subgroup A2: (chloroform / without PUI)**

The technique used in this subgroup was similar to that used in subgroup A1, but without activation by PUI for the solvent or the irrigant. Chloroform (0.1ml) was deposited into the canal and left for three minutes. Then, 2ml of 2.5% NaOCL was deposited in the canal for 20 seconds and was repeated for three cycles (20s each) while replenishing the irrigant between each cycle using a suction tip, bringing the total volume of NaOCL to 6ml for 1 minute.

**Group B: (without chloroform)**

The same retreatment steps were performed as group A, but without chloroform. The endodontic filling material was removed using PTU retreatment files. Specimens were further subdivided into two subgroups of 10 according to the use of PUI or not, using the randomization tool mentioned previously.

**Subgroup B1: (without chloroform / PUI)**

Activation was done for the irrigant by PUI following the same steps as for subgroup A1 but without using chloroform.

**Subgroup B2 (Negative control group): (without chloroform / without PUI )**

The technique used in this subgroup was similar to that used in subgroup B1, but without activation by PUI. In this subgroup, PTU retreatment files were used alone without chloroform or PUI. After endodontic filling removal, irrigation by 2ml of 2.5% NaOCL was done in the canal for 20s and repeated for three cycles (20s each), while replenishing the irrigant between each cycle using a suction tip, bringing the total volume of NaOCL to 6ml for 1 minute.

Retreatment accomplished when the D3 file reached the WL, remnants of the endodontic filling material were not detected between the file flutes and the presence of a clear irrigating solution. Finally, all the samples received a rinse with 5 ml of 17% EDTA followed by 5ml of 2.5% NaOCL solution and dried with paper points. Specimens were instrumented, obturated, and retreated by the same operator.

**Post-retreatment CBCT**

After retreatment was completed, the samples were once again scanned, repeating the same pre-retreatment scanning protocol. OnDemand3D software was used again to perform volume rendering and 3D reconstruction of the remaining obturation material inside each canal. The density of dentin and obturation material were measured, then the region of interest (ROI) tool was used to identify the residual filling materials. Once all areas of the remnants were marked, the total volume was computed **(Figure 2)**. The volume percentage of the remaining root canal filling was calculated as suggested by Khedmat et al. (16) according to the following equation:

$$\frac{\text{Remaining Volume}}{\text{Original Volume}} \times 100\% = \text{The Percent of remaining filling material}$$

Each canal's length was measured using the (Tapeline) tool in the software; the length was divided equally into three sections. The remaining root canal filling material volume in each third was then marked and computed in the same manner described previously.

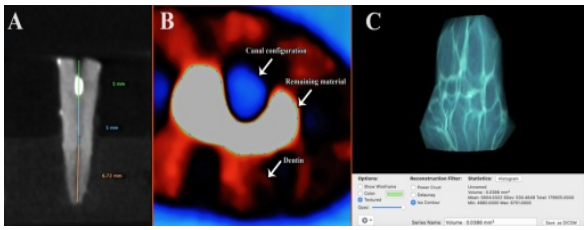


**Figure (2):** Post-retreatment CBCT image, coronal view (A), axial view (B) and 3D volume reconstruction (C).

**Statistical analysis**

Normality was checked using the Shapiro Wilk test, box plots, and descriptives. The residual filling material volume was presented using Mean, Median, Standard deviation, Inter Quartile Range (IQR), minimum and maximum.

Groups were compared regarding residual volume and percentage of the remaining filling material volume using the Kruskal Wallis test followed by pair-wise comparisons with Bonferroni correction. Before and after comparisons were done using the Wilcoxon Sign Rank test. Volume was compared among different root canal levels within each group using the Friedman test and followed by pair-wise comparisons with Bonferroni correction.

The significance level was set at a p-value of 0.05. All tests were two-tailed. Data were analyzed using IBM SPSS for windows version 23 (IBM, Armonk, New York, United States).

## RESULTS

None of the tested techniques was successful in entirely removing the endodontic material. Regarding the amount of endodontic material identified before and after retreatment, it was found that all techniques removed significant volume when comparing pre and post-retreatment CBCT scans (P<0.05) **(Table 1)**.

**Table (1):** Describes Mean, SD &Median of the volume in mm3 of the filling material in the four study groups before and after retreatment.

| | | Group A1 chloroform with PUI (n=10) | Group A2 chloroform without PUI (n=10) | Group B1 without chloroform with PUI (n=10) | Group B2 without chloroform without PUI (Negative control) (n=10) | Test (P value) |
|---|---|---|---|---|---|---|
| Before | Mean (SD) | 19.69 (3.04) | 19.54 (2.21) | 18.90( 3.67) | 19.11 (3.17) | 0.712 (0.870) |
| | Median (IQR) | 20.35 (5.50) | 20.30 (6.4) | 20.20 (6.5) | 20.20 (5.5) | |
| | Min - Max | 15.60 – 23.90 | 14.00 – 23.40 | 14.10_ 23.80 | 15.0 – 23.90 | |
| After | Mean (SD) | 3.53 (2.73) | 1.75 (1.30) | 1.73 (1.38) | 1.26 (1.35) | 6.924 (0.074) |
| | Median (IQR) | 2.72 (4.02) | 1.67 (1.46) | 1.62 (1.55) | 1.10 (1.64) | |
| | Min - Max | 0.80 – 9.47 | 0.00 – 4.70 | 0.00 – 4.78 | 0.00 – 3.82 | |
| Test (P value) | | 2.803 **(0.005*)** | 2.803 **(0.005*)** | 2.803 **(0.005*)** | 2.803 **(0.005*)** | |

*Statistically significant difference at P value≤0.05

The negative control group (B2) demonstrated the minimum mean percentage of residual volume (5.95%), while group A1 (chloroform / PUI) exhibited the maximum mean percentage of residual volume (17.98%) with no statistically significant difference between the four study groups **(Figure 3)**.

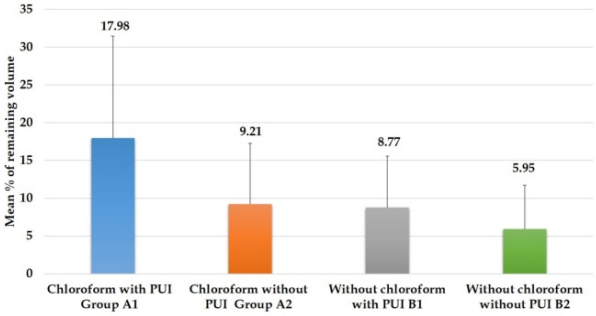


**Figure (3):** Bar chart showing the mean percentage of remaining filling material volume for the four study groups.

Regarding the mean volume of residual material among different root thirds, a statistically significant difference was found between the coronal and middle thirds within each study group (P1≤0.05). In addition, a statistically significant difference was found between the coronal and apical thirds within each study group (P2≤0.05) except for group B2 (negative control) (P2=0.221).On comparing the middle and apical thirds within each study group, no statistically significant difference was noted (P3=1.00) **(Figure 4)**.

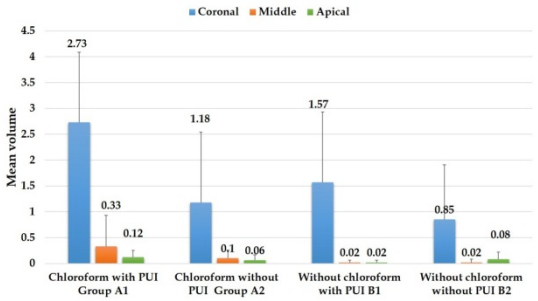


**Figure (4):** Bar chart showing the mean volume of remaining filling material for the four study groups regarding different root thirds.

## DISCUSSION

A great attention has been drawn recently toward non-surgical endodontic retreatment as a result of increased concern to preserve teeth with failed endodontic therapy. Numerous studies have reported that total removal of endodontic filling material is challenging with current instruments and techniques (3,17,18). The ability to achieve patent canal and clean its apical part has been identified as one of the prognostic markers for periapical healing. Nickeltitanium rotary and reciprocating files are insufficient to entirely remove sealer and

guttapercha remnants from root canal walls (6-8). As a result, additional methods for improving the removal of residual endodontic materials were developed.

A systematic review by Rossi-Fedele and Ahmed in 2017 (8) showed that when solvents were used at the initial retreatment stage, they may improve penetration of files but may prevent complete removal of gutta-percha, and if used after instrumentation, may reduce residual filling material. In addition, they stated that the role of irrigant agitation during retreatment is controversial. Accordingly, the aim of the present study was to evaluate the effectiveness of a solvent (chloroform) in enhancing the removal of endodontic filling material and the additional influence of PUI with intermittent flushing method using CBCT volumetric analysis for evaluation.

In the current study, mandibular premolar teeth have been chosen to standardize root canal cross-section and morphology. In addition, these teeth are available due to their frequent extraction during orthodontic treatment. This was in accordance with Mederios et al. (19), Kasam et al. (20), and Jain et al. (21).

In this study, the last file used during initial root canal treatment was PTN X3 file (30/.07), while the last retreatment file used was D3 file (20/.07) which is smaller than the last file used during the initial treatment. This was done to exclude the effect of mechanical instrumentation and evaluate the efficiency of chloroform and PUI on further removal of endodontic filling material. ProTaper retreatment files were used to the full working length during gutta-percha removal i.e.; at the same length during initial treatment.

Resin based sealers are considered as the gold standard sealers due to their enhanced physicochemical properties. These sealers have low solubility, disintegration and adequate dimensional stability (22). Thus, an epoxy resin-based root canal sealer ( Adseal) had been used in this study.

Lateral condensation technique was used in this study as it is the most common method for obturation and can be used in most clinical situation providing predictable length control during obturation (23). A study by Mahera et al. (24) reported no significant difference between warm vertical condensation and lateral condensation technique of ProTaper guttapercha for obturation of single canals. In addition, mandibular premolar teeth with oval cross section used in the current study might not be completely filled with a single PTN X3 GP cone with a circular cross section.

ProTaper Universal retreatment files have been used in the present study as an alternative to hand files in retreatment due to their convenience and efficacy in removing obturation materials (20). In addition, it was shown previously that PTU-retreatment files were more efficient than hand files regarding endodontic filling material removal due to their progressive taper in comparison to 2% taper of hand files (25).

Several solvents have been previously investigated during endodontic retreatment where chloroform has shown to be the most suitable one (26). Accordingly, chloroform has been selected in the current study. One drop (0.1 ml) was applied at the canal orifice for a period of 3 minutes to enable the advancement of rotary files through the softened guttapercha.

High concentration of NaOCl (5.25%) is highly toxic, affecting the dentin matrix components causing further degradation, thereby affecting the mechanical properties of teeth. Thus, 2.5% NaOCL irrigant had been used in this study during retreatment procedures.

Furthermore, since NaOCl is unable to dissolve inorganic materials, the smear layer was removed with 5ml of 17% EDTA (27).

Ahmed et al (28) showed that the application of three PUI activation cycles might result in improved cleaning of dentinal debris located in simulated untouched areas during root canal instrumentation. During PUI the file moves freely in the canal with minimal cutting action resulting in cavitation and acoustic streaming. Acoustic streaming is the movement of fluid rapidly in circular shapes around the file, while cavitation is the distortion of the existing bubbles in the irrigant (29). In addition, PUI during retreatment removes sealer and gutta-percha debris from areas that are inaccessible to conventional retreatment files. This could be attributed to gutta-percha plasticization caused by tip vibration that causes sealer de-bonding and the heat generated by the tip friction (30).

Cone Beam Computed Tomography technology provides high-resolution, nondestructive images, which allow accurate quantitative 3D analysis thus enabling measuring of the percentage of the residual endodontic materials adhered along canal length. This was in accordance with Khedmat et al. (16) and Aly et al. (31). However, the nondestructive micro CT analysis is the gold standard method, unfortunately it wasn't used in this study as it is not available in Egypt.

Results of the current study demonstrated that a statistical significant difference was found in the four study groups when comparing the mean percentage of residual volumes before and after retreatment. However, the mean percentage of residual volumes was not statistically significant between the four study groups. Therefore, the null hypothesis of the current study was accepted.

When comparing the use of PUI in conjunction with chloroform in subgroup A1, and without chloroform in subgroup B1, it was found that the mean percentage of residual volume was 17.98% and 8.77% in both groups, respectively. Furthermore, the mean percentage of residual volume in subgroup A2 (chloroform/without PUI) was 9.21%. These

findings demonstrate that the use of chloroform with PUI have hindered the removal of residual endodontic material successfully. This might be due to the softening and plasticization of GP by chloroform and PUI leading to its compression and squeezing along the canal walls. This was in accordance with Jain et al. (21), who noticed that the sole use of PUI leads to significantly cleaner canals and chloroform leaves a fine layer of softened GP into dentinal tubules. They reported that Chloroform should only be utilized in retreatment cases when mechanical methods of GP retrieval have failed. Bernardes et al. (32) and Mozo et al. (29) reported similar results that using PUI without solvent during root canal retreatment enhances the endodontic filling material removal by producing cleaner canal surfaces.

The results of the current study were in agreement with a systematic review by RossiFedele and Ahmed in 2017 (8), who concluded that when solvents are used at the initial retreatment stage, they enable the rotary files to penetrate easily through the endodontic material but may impede canal cleanliness. Contrary to our results, Cavengo et al. (33) found that when xylene was used after retreatment with D-RaCe files in the mesial roots of lower molars, more filling material was removed. This might be due to the use of roots with circular cross sections found in mesial roots of lower molars and different solvent than that used in the present study.

It is worthy to mention that the lowest mean percentage of residual endodontic filling material volume (5.95%) along the canal length was noted in the control group (subgroup B2) i.e. when using PTU files without additional use of chloroform or PUI. As mentioned previously, this might be due to that chloroform had increased the viscosity and adhesion of the obturation material along root canal length hindering its removal from oval shaped canals used in this study (34). In addition, the flute design as well as the rotary motion of the PTU retreatment files tends to pull the GP towards the file flutes and guide it towards the orifice of the canal. Moreover, the rotary motion produces frictional heat which plasticizes the GP, facilitating its removal (17). Previous studies by Kfir et al. (15) and Takahashi et al. (34) also noticed that PTU files without chloroform was faster during retreatment.

Regarding the mean percentage of residual endodontic filling material volume at different root thirds, the maximum mean percentage of residual material was found in the coronal third in the four study groups. In addition a statistical significant difference was noted between the coronal and the middle thirds in the four study groups, and between the coronal and apical thirds in all groups except for the negative control group (B2). These findings might be due to the oval shaped cross section of lower premolars used in this study at the coronal third and a relatively more round cross section at the middle and apical thirds. Moreover, retreatment was done using PTU retreatment files without the use of hand files to remove any residual root filling material on the buccal and lingual walls of these oval canals. This was in accordance with Dadresanfar et al (35) and Aly et al. (31). On the contrary, Reddy et al. (36) and Roshdy et al. (37) reported that the apical part revealed the maximum residual filling material. This might attributable to the use of xylene as a solvent and single rooted teeth in the first study, and the use of bioceramic sealer in the second study.

It should be kept in mind that direct comparison between the results of the current study among the previous studies was difficult due to several reasons. First, the selection of teeth which varied between central incisors, premolars, and curved canals in molars. The root canal volumes of human lower premolars used in this study differ from the root canal volumes of other teeth which may interfere with the amount of remaining filling. The second reason might be due to the type of rotary retreatment system used. Since PTU retreatment files were used in this study and no comparison has been made with other files/rotary systems, therefore the results cannot be applied to all types of retreatment systems.

One of the most common complications that may occur during endodontic retreatment is apical extrusion of debris or gutta-percha that may influence retreatment outcome in the form of postoperative pain or flare-up (38). The amount of extruded debris or gutta-percha during retreatment was not measured in the present study as this was not the main goal. However, the authors recommend that future studies should focus on this point using the tested retreatment techniques

It is necessary to mention that quick evaporation of chloroform during retreatment was noticed by the operator. This observation was also reported by Oyama et al (39), who stated that evaporation of chloroform almost occurred after one minute of its application necessitating further application to exert its dissolving action. This might be considered as a limitation of this study. Another limitation was the inability of the CBCT images to distinguish GP and sealer residues along root canal length. In addition the large amount of scattered radiation, thus producing noise in reconstructed images (40).

## CONCLUSION

Within the limitations of this study, it was concluded that none of the tested techniques was efficient in accomplishing the total removal of endodontic filling material along the root canal length. However, all the four retreatment techniques were efficient in removing significant volume of the filling material with no significant difference was found between them. Furthermore, it was shown that the additional use of PUI with or without chloroform didn't show an additional benefit compared to the sole use of ProTaper Universal retreatment system for removal of endodontic filling material.

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The authors received no specific funding for this work.

**CONFLICT OF INTEREST**

The authors deny any conflict of interests related to the current study.

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