Effect of Different Obturation Techniques on the Amount of Debris Extrusion During Endodontic Retreatment Using XP Endo Retreatment Set Files (In vitro Study)

Pawan K. Mohamad Amin¹, Hawzhen M. Mohammed Saeed¹ *

Abstract

Objective: This study aimed to assess the effect of the cold and warm obturation techniques on the amount of apically extruded debris (AED) and time needed for the removal of filling material during endodontic retreatment using the XP endo retreatment files.

Methods: Sixty single-rooted lower premolars with round-shaped canals were selected for the study. The canals were prepared and obturated with one of four obturation techniques (N=15): cold lateral compaction (CLC), single-cone (SC), thermoplasticized gutta percha injection (TGP), and gutta core (GC) obturation techniques. All the root canal fillings were removed using XP endodontic retreatment files. The mean weight of the AED was estimated with an analytical balance to an accuracy of 10⁻⁴ g. AED data were subjected to Kruskal-Wallis and a one-way ANOVA, post hoc Tukey's test for the time factor, with a significance level ≤ 0.05.

Results: AED data revealed significant differences among groups (p=0.039). The CLC technique was significant compared to TGP, with a significance level of p=0.018, and significant compared to the SC technique, with a significance level of p=0.034. Also, there were highly significant differences between groups regarding the time needed for retreatment (p=0.000).

Conclusions: The obturation technique influences AED, and time for root canal retreatment. CLC resulted in less debris extrusion, while SC resulted in higher debris extrusion and TGP required the least time for root canal retreatment.

Keywords: Apical extrusion, Obturation techniques, XP endo files.

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1. Conservative Department, College of Dentistry, University of Sulaimani, Sulaimani, Iraq.

* Corresponding author: hawzhen.mohammed@univsul.edu.iq.
Introduction

Endodontics aims to prevent or treat apical periodontitis. Proper cleaning, shaping, and disinfection enable three-dimensional root canal obturation.1 Gutta-percha and a small amount of sealant are used to fill the root canal. Solid core, “cold gutta-percha,” softened core, or “warm gutta-percha,” or thermal techniques are applied to fill root canals.2 The most prevalent endodontic procedure is known as cold lateral compaction (CLC). The benefits of CLC include its comparatively simple usage, affordable price, predictable results, and controlled placement.3 The single-cone technique is becoming more popular among dentists since it is less technique-dependent, uses less equipment, is simpler, and inexpensive.4 Thermoplasticized gutta-percha obturation is used to fill root canals because it can better replicate the canal anatomy.5 A third-generation carrier, known as GuttaCore (Dentsply Tulsa Dental Specialties), was created; rather than plastic, it is made of cross-linked gutta-percha. This carrier is easy to remove, and the maker claims that it is firm enough to help guide the gutta-percha into the root canal.6

Epoxy resin sealer AH Plus (Dentsply Maillefer, Ballaigues, Switzerland) is often used with gutta percha. Its good adherence and minimal solubility and disintegration make it preferable for sealing.7

Non-surgical endodontic retreatment is essential when treatment fails. Non-surgical retreatment aims to restore healthy periapical tissues and predictability by completely removing the gutta-percha and sealer from root canal walls, re-establishing working length, disinfecting, and re-obturating the root canal.8 Endodontic hand files, nickel-titanium rotary instruments, Gates Glidden burs, heated instruments, ultrasonic instruments, lasers, and adjunctive solvents have been used to remove root canal filling materials.9

During retreatment, root canal obturation materials, dead pulpal tissue, irrigation solutions, and bacteria can push through into the periradicular tissues, causing pain, swelling, and a delay in periapical healing.10 Compared with manual files, studies showed that rotary NiTi files resulted in much less apical extrusion11 and that apical extrusion was much lower with systems using full rotation motion compared with those using reciprocal motion.12

XP-Endo Retreatment System (FKG Dentaire, La-Chaux-de-Fonds, Switzerland) consists of three endodontic rotary files: the DR1 has alternating cutting edges and a triangular cross-section, and the Shaper and Finisher R are made of NiTi MaxWire alloy (Martensite-Austenite Electropolish Flex), which increases root canal filling removal efficacy due to its shape memory and austenite.13

The objective of this study was to assess and compare the quantity of apical debris extrusion and the required time for gutta-percha removal using various obturation techniques. So, the null hypothesis tested was there is no difference between different obturation techniques in the amount of debris extrusion and there is no difference among obturation techniques regarding the time needed for the removal of obturation material.

Materials and methods

The present study was approved by the Ethics Committee of the Dentistry College at the University of Sulaimani (no. 21/66 on 9/11/2021). Based on the data from a previous study, the results of power calculations indicated that the sample size for each group should be a minimum of 12. This value was determined by projecting the power as 0.91, the effect size as 0.853, and the significance level as a = 0.05. Finally, 15 teeth were selected for each group for the study.

Teeth Selection

Sixty single-rooted lower premolars with round-shaped canals were selected for the study. For standardization, all teeth were scanned with a cone-beam computed tomography device, the CS 9600 (Carestream, Healthcare, France), to identify the roots with a round canal based on orifice configuration, and that had been extracted for orthodontic reasons in the last three months.

Orifice configuration: For determining round shaped canals, the axial section below the cementoenamel junction was used. The buccolingual length of the orifice was defined as R1. R2 was defined as the mesiodistal length in the middle part. The theoretical model to determine the shape of orifice is shown in Figure 1.A. According to this the orifice shape was determined as round if the R2/R1 was equal to 1 ± 0.4.14

The samples were stored in distilled water until use and examined using a stereomicroscope with a magnification of ×20 to ensure the presence of one foramen and mature apices (Figure 1.C). A periapical radiograph was taken at mesiodistal and buccolingual directions to exclude teeth with external and internal resorption and teeth with more than one canal, calcification, or other anatomic irregularities (Figure 1.B). Schneider’s method was used to select teeth with canal curvature less than 10 degrees.

Sample Preparation

All samples were immersed in 5.25% sodium hypochlorite NaOCl (AQUA, Turkey) for two hours and then thoroughly washed with running tap water to remove any remaining soft tissue on the root surfaces with scalers. Following that, digital calipers were used
to measure the lengths of the samples from the apex to the CEJ; for standardization purposes, at the cementoenamel junction (CEJ), all teeth were decoronated with a safe-sided diamond disk (0.2 mm thickness) used with a straight handpiece under water cooling to provide root lengths of 16 mm. Patency was checked with a size 10 K-file (Dentsply Maillefer, Switzerland).

**Root Canal Instrumentation and Obturation**

The working length was adjusted to 1 mm shorter than the root length (Figure 1A) and confirmed by radiograph. Instrumentation of root canals was done with ProTaper Next X1 (17/04) and X2 (25/06) files (Dentsply Sirona, Ballaigues, Switzerland) in the crown-down technique at 2 Ncm and 300 rpm. The files were operated according to the instructions of the manufacturer. During preparation, the canals were irrigated with 2 mL of 2.5% NaOCl using a syringe and a 27-gauge double-sided needle between each instrument. Following that, 5 mL of 17% Ethylenediaminetetraacetic acid was flushed in each canal for 1 minute. The canals were finally rinsed with 5 mL of distilled water and dried with a paper point (Dentsply Maillefer). The specimens were randomly divided into four groups (N = 15) according to the obturation techniques.

**Group I: Cold Lateral Technique**

A size 25.02 taper gutta-percha (GP) cone was pre-fitted into the canal at the WL. AH Plus sealer was used according to the instructions of the manufacturer. The sealer was applied with a lentulo spiral, and following that, the tip of the master cone was lightly coated with sealer and inserted into the canal. Then, a size 15 finger spreader was placed, rotated, and removed, and 15.02 taper GP accessory cones, coated with a thin layer of sealer, were placed into the space created by the spreader. The process was repeated until it was impossible to place another accessory cone beyond 2–3 mm into the root canal. Finally, a hot instrument was used to remove excess gutta-percha.

**Group II: Single Cone Technique**

The matched-taper gutta-percha cone X2 and sealer (AH Plus) were used to fill the root canals. Canal walls were covered with AH Plus sealer by lentulo spiral, and the sealer was used as directed by the manufacturer’s instructions. With a good tug back, the master GP cone was coated with sealer and inserted until the working length was reached. Excess gutta-percha was removed with a hot instrument.

**Group III: Thermoplasticized gutta-percha injection technique**

A layer of AH Plus sealer was applied to the canal walls with a lentulo spiral. The apical part of the pre-measured master cone X2 was coated with sealer and positioned at its full working length. A Fi-P Woodpecker pen with a tip adjusted 5 mm shorter than the working length was used to cut the gutta-percha. The Fi-P Woodpecker was heated at 160°C for 1 minute (per the manufacturer's instructions), and the gutta-percha was removed from the canal. After that, a Fi-G gun with 23-gauge needles was used for the backfill obturation, and the tip was placed 5 mm short of the working length. After heating the Fi-G gun unit to 200°C, the needle was placed at the desired length and injected passively to fill the remaining space of the canal. After each layer was applied, a hand plugger was used to press the gutta-percha. This technique was repeated until gutta-percha was observed at the coronal portion of the root.

**Group IV: Gutta Core Obturation Technique**

After instrumentation, the final working length measurement was confirmed using a size verifier (25/.04) (Dentsply Maillefer) to reach the apical constriction passively without significant resistance or twisting. A layer of sealer (AH Plus) was then applied into the canal with a lentulo spiral. A silicon stopper was used to set the working length at calibration marks on the ProTaper Next gutta-core obturator (Dentsply Maillefer). The ProTaper Next gutta-core obturator was softened in an oven and slowly inserted to working length. The carrier was twisted off, and canal filling was compacted at the orifice.

Consequently, the root canal obturation quality was confirmed radiographically, and any substandard obturation was replaced with another sample. The access cavities were sealed with a small piece of cotton and Cavit TM (3M ESPE, St Paul, MN, USA). All specimens were stored in a 37°C with 100% humidity incubator for two weeks to allow the sealer to set.

**Debris Collection and Retreatment**

This study used a modified experimental model described by Myers and Montgomery. Initially, the empty Eppendorf tubes were individually weighed three times with a microbalance with four decimal places in grams (Sartorius BP121S Analytical Lab Balance,
After removing the temporary filling material, the root canal obturation materials were removed with the XP-Endo Retreatment System (FKG Dentaire, La-Chaux-de-Fonds, Switzerland), beginning with a continuous rotation with the DR1 endodontic rotary file at 800 rpm and 1.5 N/cm torque inserted in the root canal obturating materials to create a 3-4 mm space. Subsequently, a drop of eucalyptol oil was applied to the space created for one minute. Afterwards, an XP-endo Shaper endodontic rotary file with 300 µm apical diameter and 4% taper was used at 1000 rpm and 1.0 N/cm torque; additional drops of eucalyptol were applied, as needed, to reach the WL. In all teeth, 0.1 mL of eucalyptol was used to dissolve the filling material. Once the file reached working length, the file was rotated until the root canal obturating material was entirely removed. Finally, the XP-endo Finisher R endodontic rotary file with 300 µm apical diameter and 0% taper was used at 1000 rpm and 1.0 N/cm torque throughout the working length as a supplementary cleaning approach to the root canal system; all files were used as detailed in the manufacturer's recommendations. All endodontic retreatment was carried out inside a cabinet with a heater maintained at 37°C.

During the removal, 15 mL of distilled water was used to irrigate each canal between files. A 27-gauge double-sided port needle delivered distilled water into each canal. The flutes of the files were cleaned after each file was removed from a canal. The procedure for removal of the obturating material was complete when the last file reached the WL and no filling material or debris was covering the instrument. After the retreatment process, the debris remaining on the apical portion of the root surface was washed with distilled water (1 mL) and added to the debris collected in the Eppendorf tubes. The required time to remove the obturating material was recorded by a digital watch, excluding the time needed for file cleaning, file changes, and irrigation. The distilled water was then evaporated in the Eppendorf tubes for five days at 70 °C before the dry debris was weighed (Figure 2.B). The tubes were weighed using the same analytical balance used earlier to obtain the weight of the tubes with extruded debris. Each tube was weighed three times, and the mean value was calculated. The debris dry weight was calculated by subtracting the empty tube (weight) from the (weight) of the tube with extruded debris. All the operations were completed by the same operator, thereby reducing the risk of inter-operator variability and ensuring uniform quality in the initial root canal instrumentation, canal filling, and removal of root obturating material. Uninformed of the group’s assignment, a second examiner calculated the weights and measured the time during the root canal retreatment.

**Statistical analysis**

The normality (Shapiro-Wilk) test revealed that data on AED was not normally distributed. Therefore, the non-parametric Kruskal-Wallis test was used to conduct the statistical analysis, followed by the Mann-Whitney test for detecting significant differences between the groups. Data on retreatment time was normally distributed; as a result, one-way analysis of variance (ANOVA) was used to conduct the statistical analysis, followed by Tukeys HSD post hoc test for detecting significant differences between the groups. The Statistical Package for Social Sciences SPSS 27 (IBM SPSS Inc., Chicago, IL) software was used in all the statistical analyses. The statistical significance level was set at P ≤ 0.05.

**Results**

Weight of apically extruded debris among all groups: The median values, interquartile range (IQR), Mean and standard deviation (SD) of the quantity of AED produced during endodontic retreatment for all groups are presented in Table 1. It was found that all techniques resulted in a measurable amount of debris, and there was a statistically significant difference between obturation techniques (p=0.039). Statistically, CLC resulted in the least amount of AED compared to the SC (p=0.034) and the TGP technique (p=0.018).

Retreatment time among all groups: The mean value and SD of retreatment times are shown in Table 2. There were highly significant differences between groups (F (3,56) =13.554, (p=0.000). TPG significantly required less time to remove root canal obturation material compared to CLC (p=0.007), GC (p=0.000), and SC
obturation techniques (p=0.000). SC required longer time to remove obturation material.

Figure 1: A: CBCT of lower premolar with round shaped canal. R1: Buccolingual length of orifice. R2: Mesiodistal length in the middle of the orifice. B: Buccolingual and mesiodistal radiographs of tooth. C: Stereomicroscopic evaluation of teeth to select the teeth with one mature apex.

Figure 2. A: Presentation of the apparatus used to obtain apically extruded debris. B: Extruded debris collected in the Eppendorf tube.
Table 1. The Median, Interquartile range, Mean and SD of the weight of apically extruded debris (mg) among the four groups.

<table>
<thead>
<tr>
<th>Groups</th>
<th>N</th>
<th>Median (25% - 75% IQR)</th>
<th>Mean (SD)</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>CLC*</td>
<td>15</td>
<td>0.0141 (0.0123 – 0.0153) a,b</td>
<td>0.0137 (0.0019)</td>
<td>0.039 &lt; 0.05</td>
</tr>
<tr>
<td>SC*</td>
<td>15</td>
<td>0.0162 (0.0133 – 0.0166) a</td>
<td>0.0149 (0.0021)</td>
<td></td>
</tr>
<tr>
<td>TGP*</td>
<td>15</td>
<td>0.0155 (0.0153 – 0.0157) b</td>
<td>0.0154 (0.0006)</td>
<td></td>
</tr>
<tr>
<td>GC*</td>
<td>15</td>
<td>0.0149 (0.0130 – 0.0152)</td>
<td>0.0140 (0.0022)</td>
<td></td>
</tr>
</tbody>
</table>

*CLC, cold lateral; GC, gutta core; SC, single cone; TGP, thermoplasticized gutta percha injection; S, significant. Similar lowercase superscript letters indicate statistically significant differences in each row.

Table 2: The Mean and SD time for endodontic retreatment in seconds among the four groups.

<table>
<thead>
<tr>
<th>Groups</th>
<th>n</th>
<th>Mean</th>
<th>Standard Deviation</th>
<th>ANOVA</th>
</tr>
</thead>
<tbody>
<tr>
<td>CLC*</td>
<td>15</td>
<td>224.60 a</td>
<td>54.874</td>
<td>F=13.554</td>
</tr>
<tr>
<td>SC*</td>
<td>15</td>
<td>273.07 b</td>
<td>70.552</td>
<td>P=0.000</td>
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<tr>
<td>TGP*</td>
<td>15</td>
<td>152.73 a,b,c</td>
<td>26.823</td>
<td>(Highly Significant)</td>
</tr>
<tr>
<td>GC*</td>
<td>15</td>
<td>265.47 c</td>
<td>68.783</td>
<td></td>
</tr>
</tbody>
</table>

*CLC, cold lateral; GC, gutta core; SC, single cone; TGP, thermoplasticized gutta percha injection; HS, high significance. Similar lowercase superscript letters indicate statistically significant differences in each row.

Discussion

When initial endodontic treatment fails, non-surgical endodontic retreatment is needed. Non-surgical retreatment removes gutta-percha and sealer from the canal, restores working length, disinfects, and re-obturates to regain healthy periapical tissues and predictability.8

Apically extruded debris produced during initial canal preparation and removal of obturation material from the canal leads to postoperative discomfort, such as pain and swelling.10

A limited number of studies have been conducted to assess the impact of distinct obturation techniques on the quantity of extruded debris formed during the removal of filling material.10,16,17 According to our knowledge, no study has compared the effect of two cold and two hot obturation systems on the amount of AED during endodontic retreatment using XP-endo retreatment set files; thus, in the current study, we aimed to evaluate four different obturation techniques (cold lateral CLC, single cone SC, thermoplasticized gutta percha injection TGP, and gutta core GC) during the retreatment of root canals by the non-surgical XP-endodontic retreatment file system.

At the cementoenamel junction, the teeth’s crowns were removed, and the root canal was standardized at 16 mm in length. Although decoronation misrepresents the clinical state, by removing certain variables like crown morphology and access to root canals, more accurate comparisons between the suggested retreatment approaches can be made.18

There are various obturation methods that can be implied for root canal treatment. The decision is based on the canal anatomy and the specific therapeutic goals in each case. The canals were obturated using four different obturation techniques. The lateral compaction method has served as the benchmark against which other methods have been measured. Excellent length control
is a benefit of the CLC process. Additionally, any suitable sealer may be used with it.\textsuperscript{3} Single-cone is considered the preferred procedure because it is less technique-dependent, employs less equipment, is more accessible, and is cheaper.\textsuperscript{4} Warm gutta-percha best fulfills the requirements of a root canal obturation technique because it provides homogeneity throughout the entire canal filling. Injectable, thermoplasticized gutta-percha and carriers covered with an alpha-phase GP are newer approaches.\textsuperscript{5} GC is a cross-linked gutta-percha-based root canal obturating material that is carrier-based on gutta-percha and has a hard-central core. In contrast to thermafil, the cross-linked gutta-percha in the rugged central core retains its physical properties when heated by the oven, making the root canal system removal process easier.\textsuperscript{6}

Clinically, retreatment procedures are generally completed using files that have a larger apical diameter than the master apical file that was used for the initial canal instrumentation. This has resulted in better apical cleaning and instrumentation during retreatment.\textsuperscript{19} As a result, apical enlargement was performed in this study using an XP-end Shaper XPS of size 30 and a 0.04 taper and a supplementary XP-end Finisher R instrument XPFR. The XPFR file is designed to reach the complex areas in the root canal to achieve complementary cleaning at the final stage of chemo-mechanical preparation.\textsuperscript{13} During the removal of filling material from the root canal, distilled water was employed as an irrigation solution to minimize NaOCl crystallization, which might affect dentin debris weight and impair outcomes.\textsuperscript{12}

The present research showed that the method used for obturation of the canals might impact how much AED was released after root canal obturating material removal. Therefore, the first null hypothesis was rejected in light of the current study’s findings. The groups filled with CLC revealed the least quantity of debris extrusion compared to groups filled with TGP. This may be because the Alpha (α) phase of gutta percha in the TGP technique is more flexible and highly flowable when heated, so it may flow through canal imperfections and dentinal tubules to seal the root canal walls better and produce denser obturation.\textsuperscript{20–22} However, the Beta (β) phase of GP employed in CLC cannot be compressed at room temperature. Hence, the fins, isthmus, and apical deltas of the canal’s accessory anatomy are inaccessible. In comparison to heated GP compaction, it leads to a weakened seal. A heated gutta-percha (GP) approach that enables the plasticized GP to adapt to the canal’s varied anatomy can result in a void-free filling.\textsuperscript{23} Consequently, it has a higher percentage of obturation volume and may result in more debris. This result is similar to other studies by Topçuoğlu et al. and Canakci et al.\textsuperscript{10,17} which reveal that warm gutta percha results in more debris than CLC.

The current study showed that the cold lateral significantly reduced debris extrusion compared to the single cone. In another comparable study by Türker et al.\textsuperscript{16} there was no significant difference between CLC and SC. In contrast to our findings, Topçuoğlu et al.\textsuperscript{10} found that SC produced less AED than CLC and WVC during endodontic retreatment. These contrary findings may be because ProTaper universal retreatment files have been used in later studies. These files differ from XP-end systems in file sequences, tip design, taper, cross-section, flexibility and manufacturing alloy. XP-end files have zero tapers, high flexibility, and NiTi MaxWire technology. They can navigate the root canal’s walls, corners, and scrape debris without deviating from their natural path.\textsuperscript{24,25} Another reason may be anatomical differences between these roots and apical pressure during retreatment, which is operator-related.\textsuperscript{26}

Research investigations have related the apically extruded materials to postoperative inflammation, flare-ups, and even failure of apical healing.\textsuperscript{27} According to reports, nearly all teeth with apical periodontitis exhibit some level of root resorption. Root canal retreatment has a poor prognosis when compared to initial root canal therapy, with a low success rate that may be caused by the extrusion of debris, particularly in teeth with periapical lesions. It was discovered that retreatment cases with apical periodontitis had a considerably high rate of postoperative discomfort (13.6%).\textsuperscript{28,29} Its presence is very uncomfortable for both the patient and the dentist and may negatively impact relationships between the two. Therefore, to prevent an interappointment flare-up from occurring, practitioners should take proper precautions and follow the right guidelines.\textsuperscript{30}

Furthermore, other findings of the study determined that the time requirement was affected by obturation techniques; therefore, the second null hypothesis was rejected. TGP significantly required less time than SC needed more time; this can be explained by the fact that SC root filling had a larger amount of sealer, removal of which caused more difficulty.\textsuperscript{31–33} AlOmari et al.\textsuperscript{14} found that XPS removed gutta-percha from most canals but not the sealer. In contrast to the current research, Topçuoğlu et al.\textsuperscript{10} claimed that WVC required more time than SC. Furthermore, Canakci et al. and Athkuri S et al.\textsuperscript{17,35} have
shown that retreatment for CLC was faster than for WVC or thermoplastized gutta percha obturation. The differences in file design, the number of files utilized, the variations in canal anatomy across the studies, and techniques for determining the overall retreatment time might be the causes of the conflicting findings.

One limitation of the study is the absence of physical back-pressure provided by the periapical tissue in vitro studies. An attempt was even made to mimic periapical tissue by placing a small holding template made of silicon impression material, despite the fact that this cannot represent the clinical condition 100%. However, standardization of methodology could provide information to compare the obturation techniques in terms of apical extrusion. In the present study, a round-shaped canal with a straight root canal was selected for standardization purposes; however, in clinical practice, endodontists may face other shapes of the canal, such as oval, C shape, etc., and roots with moderate to severe curves. So, there is an opportunity for further research on the effect of different obturation techniques on the amount of AED in curved root canals with different canal shapes.

Conclusion

Within the constraints of this in vitro experiment, the conclusions are as follows: All obturation techniques resulted in AED. CLC had the lowest amount of AED among other groups, while SC resulted in higher AED and needed more time during root canal retreatment. TGP required less time during root canal retreatment. Although apical debris extrusion is unavoidable, physicians should consider alternative methods that could be used to lessen it during the retreatment procedure, to lessen postoperative discomfort and increase the success rate.

References

16. Türker S, Uzunoğlu E, Sağlam B. Evaluation of the


