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Research Article

Efficiency of Different Tapers of Rotary Files and Complementary Cleaning Method in the Removal of Bio-ceramic Based Obturation (*In Vitro* Study)

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Abstract

Aim: The aim of the study is to assess the effectiveness of different tapers of rotary files in removal of gutta percha with bio-ceramic sealer with and without complementary method.

Methods: This comparative in vitro study will include 48 extracted permanent human mandibular molars. Teeth will be assigned randomly into 4 groups according to taper used for removal of filling material and ultrasonic activation use. All teeth will be prepared to 25.04%. Teeth will be divided into the following groups: Group I-A: Removal of gutta percha by using the continuous rotary Edge X7 file 4% taper without ultrasonic activation. Group I-B: Removal of gutta percha by using the continuous rotary Edge X7 file 4% taper with ultrasonic activation. Group II-A: Removal of gutta percha by using the continuous rotary Edge X7 file 6% taper without ultrasonic activation. Group II-B: Removal of gutta percha by using the continuous rotary Edge X7 file 6% taper with ultrasonic activation. The teeth will then be evaluated under stereomicroscope to evaluate the amount of remaining obturation material.

Results: The area of the remaining filling material was significantly reduced by the use 0.04 and 0.06 taper. Nevertheless, the root canal filler material was not entirely eliminated from the canals by any of the utilized taper (0.04 or 0.06) either with and without the use of US commentary method. The 0.04 taper left much more root canal filling material than the 0.06 taper either with or without the use of US complementary method as a direct comparison. Except with the use of 4% with ultrasonic activation which produced better results than 6% taper without ultrasonic activation but not statistically significant. The apical area showed the higher remnant followed by the middle area and then the coronal area in all groups. Furthermore, the results showed that the use of US complementary method decrease significantly the remaining obturation material.

Conclusion: Complete removal of bio-ceramic root canal filling material was not achieved with any of the retreatment protocols tested. The 6% taper rotary file removed significantly more obturation material than the 4% taper, with or without ultrasonic activation, in all root canal thirds. Ultrasonic activation significantly enhanced the removal of remaining filling material. The combined use of a 6% taper and ultrasonic activation resulted in the lowest amount of residual filling material overall. The use of 4% with ultrasonic activation produced better results as 6% taper without ultrasonic activation but not statistically significant.

Keywords: EDGE X7; Taper; Retreatment; Gutta Percha; Bioceramic Sealers; Ultrasonic

Introduction

The prevention or eradication of apical periodontitis of endodontic origin is considered the main objective of root canal therapy, and the desire to measure the effectiveness of endodontic treatment go hand in hand. Primary root canal therapy continues to have high success rates, and endodontic treatment is generally a trusted and effective way to preserve the natural dentition [1].

Nevertheless, primary root canal treatment tends to fail. Retreatment or apical surgery are frequently recommended when the initial root canal treatment is unsuccessful. Nonsurgical root canal retreatment's (NS-RCRT) main goal is to re-establish healthy periapical tissues. The conditions for successful retreatment can only be met if the filler material can be entirely removed and the negotiation of the canal to the apical foramen [2].

Multiple techniques have been deployed through-out the years. The most commonly used are rotary files designed for removal of gutta percha and intra canal remnants. This is because the process is faster and easier as compared to using hand files alone. A study compared the effectiveness of different nickel-titanium (Ni-Ti) instruments with different tapers in removing gutta-percha during root canal retreatment. It aimed to assess the cleanliness of root canal walls and the time required for gutta-percha and sealer removal. The study concluded that there was a significant difference in the cleanliness of root canal walls after retreatment using different NiTi systems [3].

Currently, there is no agreement in the literature on the optimal strategy for removing gutta percha with bio-ceramic sealers in retreatment procedures. The remnants of gutta percha and sealer after retreatment procedures reduces the success rate of retreatment due to presence of bacterial film and improper cleaning and disinfection or root canal space. Therefore, it is important to remove all filling material from the root canal. Conducting a study comparing different tapers during retreatment and supplemental technique for removal of filling material would be of clinical importance.

Materials and Methods

After applying exclusion criteria including severe root curvature, root caries, visible cracks, internal or external root resorption, and root canal classification other than Vertucci Type IV, Type II. Forty-eight mandibular molars' mesial canals with little or no mesial root curvatures (0˚-15˚) according to Schneider [4] were used in this study. Molars that met the criteria were collected from the oral surgery department in Misr International University (MIU).

The molars were occlusally flattened by a diamond disc to standardize the length to 16 mm [5], using a contra-angle high-speed handpiece, conventional access cavity preparation was performed by a round bur in all teeth. DG16 Explorer was used to find the canal orifices.

The teeth were accessed and mesio-buccal canal was prepared, the canals were explored with a size 10 K-type file (Figure 1) until the instrument tip was visible at the apical foramen and 1 mm was subtracted from the length to get the working length.

The mesiobuccal canal was cleaned and shaped using the following protocol:

- Crown down technique using the manufacturer recommended setting for the files (speed 350 rpm, torque 2 N-m) using Bomedent Wismy endomotor starting with 17/0.04 Edge X7 then to a final canal size of 25/0.04 with Edge X7.
- All canals were irrigated by 20 ml of 2.6% sodium hypochlorite using a side vented needle 30G throughout the whole root canal preparation and patency was done using a manual 10#k file between different files. The flutes of the files were cleaned after every two in and out pecks and was checked for unwinding and was discarded if unwinding was noticed. After preparation, final irrigation protocol of 2.6% sodium hypochlorite, 5 ml of 17% EDTA solution, and 10 ml of distilled water were used as a flush for the canals. This was followed by paper points dryness [6].
- All the root canals were obturated using hydraulic condensation technique with single cone. CeraSeal was delivered inside

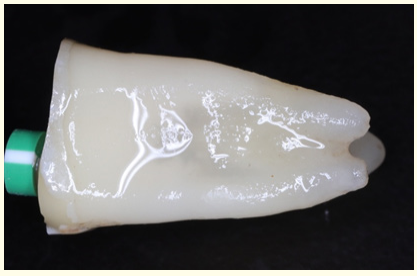

Figure 1: Exploration with 10k file.

the canal using delivery tips and a master cone of size 25 0.04% was used. A plugger of size 30# was used to compact the gutta percha. Teeth were then placed at an incubater at 37 Celsius for 1 week.

Teeth grouping

All teeth were numbered then randomly divided into two equal groups according to rotary taper used for retreatment, 24 teeth in each group (Group I, Group II). A randomization list was provided for the 24 samples of each group using excel sheet and generated by a specialized software (www.randomizer.org)

- **Group I-A:** Removal of gutta percha by using the continuous rotary Edge X7 file 4% taper without ultrasonic activation.
- **Group I-B:** Removal of gutta percha by using the continuous rotary Edge X7 file 4% taper with ultrasonic activation.
- **Group II-A**: Removal of gutta percha by using the continuous rotary Edge X7 file 6% taper without ultrasonic activation.
- **Group II-B**: Removal of gutta percha by using the continuous rotary Edge X7 file 6% taper with ultrasonic activation.

Retreatment of teeth

A notch was created using an ultrasonic tip before beginning of the retreatment process facilitate penetration of the file.

- **GP-1A:** 25/0.04 X7 file (Figure 2) was used in a continuous rotation motion (speed 350 rpm, torque 2 N-m) as a single file to remove the gutta percha. The file was inserted for 2 mm then pulled out to remove the debris collected on the file from the root canal filling then the file was cleaned on a clean gauze. Sodium hypochlorite irrigation was utilized between every 2-3 pecks with the file to ensure removal of the debris and clearing the way for the file. The procedure was carried on until the file reached the working length. Once the working length was reached, 10 vertical strokes were applied along the entire canal length by brushing against all of the canal walls [7].
- **GP-1B:** 25/0.04 X7 file was used in a continuous rotation motion (speed 350 rpm, torque 2 N-m) as a single file to remove the gutta percha. The file was inserted for 2 mm then pulled out to remove the debris collected on the file from the root canal filling then the file was cleaned on a clean gauze. Sodium hypochlorite irrigation was utilized between every 2-3 pecks with the file to ensure removal of the debris and clearing the way for the file. The procedure was carried on until the file reached the working length. Once the working length was reached, 10 vertical strokes were applied along the entire canal length by brushing against all of the canal walls. To guarantee the cleanness of the canal, a final irrigation was carried out and activated by an ultraX ultrasonic irrigation activation system. Irrigation and activation were repeated twice, resulting in a total of 10 mL of sodium hypochlorite and 2 min of activation [8].
- **GP-2A:** 25/0.06 X7 (Figure 3) file was used in a continuous rotation motion (speed 350 rpm, torque 2 N-m) as a single file to remove the gutta percha. The file was inserted for 2 mm then pulled out to remove the debris collected on the file from the root canal filling then the file was cleaned on a clean gauze. Sodium hypochlorite irrigation was utilized between every 2-3 pecks with the file to ensure removal of the debris and clearing the way for the file. The procedure was carried on until the file reached the working length. Once the working length was reached, 10 vertical strokes were applied along the entire canal length by brushing against all of the canal walls [7].
- **GP-2B:** 25/0.06 X7 file was used in a continuous rotation motion (speed 350 rpm, torque 2 N-m) as a single file to remove the gutta percha. The file was inserted for 2 mm then pulled out to remove the debris collected on the file from the root canal filling then the file was cleaned on a clean gauze. Sodium hypochlorite irrigation was utilized between every 2-3 pecks with the file to ensure removal of the debris and clearing the

way for the file. The procedure was carried on until the file reached the working length. Once the working length was reached, 10 vertical strokes were applied along the entire canal length by brushing against all of the canal walls. To guarantee the cleanness of the canal, a final irrigation was carried out and activated by an ultra X ultrasonic irrigation activation system. Irrigation and activation were repeated twice, resulting in a total of 10 mL of sodium hypochlorite and 2 min of activation [8].

Methods of evaluation

Stereo-microscope analysis

Figure 2: Edge X7 file 25/04.

Figure 3: Edge X7 file 25/06.

Canal orifices were sealed off with damp cotton pellets. Each root sample was grooved and wedged apart into two halves [9]. Any samples that were unviable were discarded and replaced. The two halves were examined under the stereomicroscope to determine which half was the most representative of the two. The selected half was marked into coronal, middle, apical thirds and inspected under stereomicroscope at magnification 20X (figure 4). Images were captured using a digital camera fitted on the microscope, then images were transferred to desktop and saved as JPEG format. Image analysis with Image J software was used to calculate the percentage area of the residual filling material within each third separately. The mean percentage value for each third and for the whole canal length was calculated. The Stereo-micrographs demonstrated the steps of the image analysis using ImageJ software (version 1.53a National Institutes of Health, USA). Images were processed using photographic editing software (Adobe Photoshop 7.0, Adobe Systems Inc., San Jose, California, USA).

Photoshop software was used for the segmentation of each tooth by its outline, using the semi-automatic outline selection tool. In that way the root canal was isolated from the rest of the image and divided into three thirds (cervical, middle, and apical).

After that, the areas with remnant (stained in white or orange color) were automatically detected and highlighted with blue color, and then separated from the rest of the image. Using image j software, the entire visible third area (coronal, middle, or apical) was automatically measured in mm^2.

From the images of isolated sealer which separated in step 1 and applying a threshold, the stained area in each third was automatically measured in mm^2. It was then calculated as % of the total third area using the following equation:

Statistical analysis

Categorical data will be represented as frequency (n) and percentage (%) and will be analyzed using chi square test. Numerical data will be explored for normality by checking the data distri-

$$\boldsymbol{Area\ \%\ of\ remaining\ filling\ material} = \frac{Area\ of\ remaining\ filling\ material\ (mm2)}{Area\ of\ root\ canal\ (mm2)} \times 100\%$$

Figure 4: The original SEM image after automatic correction of brightness and contrast.

bution, calculating the mean and median values and using Kolmogorov- Smirnov and Shapiro-Wilk tests. If the data was found to be normally distributed, it will be presented as mean and standard deviation values and two-way ANOVA will be used for the analysis followed by Tukey post-hoc test. If the assumption of normality was found to be violated; the data will be presented as median and range values and will be analyzed using Kruskal-Wallis test followed by Mann-Whitney U test. The significance level will be set at p ≤0.05 for all tests. Statistical analysis will be performed with IBM® SPSS® Statistics Version 26 for Windows.

Results

The remaining RC filling material (Stereomicroscope results)

Normality assumption

The Shapiro-Wilk test results assumed that the values of Group I-A (4% without US) and II-A (6% without US) is normally distributed (P-value >0.05). Moreover, the Shapiro-Wilk test results assumed that the values of Group I-B (4% with US) and II-B (6% with US) is normally distributed (P-value >0.05). So, the relevant parametric test (the independent (unpaired) t-test) was used.

Comparison of the remaining RC filling material area without ultrasonic activation

Comparison regarding the taper

Apical (area %)

The independent t-test results showed that the Group I-A (4% without US) had the significantly (P<0.0001) higher mean of the remaining RC filling material (76.13 ± 2.81 mm^2), however, the Group II-A (6% without US) had the significantly lower mean value (66.22 ± 3.05 mm^2) at the apical area.

Middle area (%)

The independent t-test results showed that the Group I-A (4% without US) had the significantly (P=0.0005) higher mean value of the remaining RC filling material (63.00 ± 5.18 mm^2), however, the Group II-A (6% without US) had the significantly lower mean value (54.86 ± 4.68 mm^2) at the middle area.

Coronal area (%)

The independent t-test results showed that the Group I-A (4% without US) had the significantly (P=0.0007) higher mean value of the remaining RC filling material (49.10 ± 4.73 mm^2), however, the Group II-A (6% without US) had the significantly lower mean value (42.72 ± 3.04 mm^2) at the coronal area.

Total area (%)

The independent t-test results showed that the Group I-A (4% without US) had the significantly higher mean total value of the remaining RC filling material (65.96 ± 2.55 mm^2), however, the Group II-A (6% without US) had the significantly lower mean total value (57.44 ± 2.35 mm^2) at significant level of (P<0.0001).

Table 1: Comparison of the remaining RC filling material between 4% and 6% taper without US activation.

Variables	4% Taper without US		6% Taper without US		t-value	P-value
	Min.-Max.	Mean ± SD	Min.-Max.	Mean ± SD		
Apical	72.25-80.38	76.13 ± 2.81	61.60-69.93	66.22 ± 3.05	8.290	<0.0001*
Middle	53.48-69.82	63.00 ± 5.18	47.50-63.31	54.86 ± 4.68	4.038	0.0005*
Coronal	41.27-55.84	49.10 ± 4.73	38.89-46.42	42.72 ± 3.04	3.928	0.0007*
Total	53.39-60.31	65.96 ± 2.55	60.12-69.80	57.44 ± 2.35	8.500	<0.0001*

*; Significant at P≤0.05. Min.= Minimum; Max.= Maximum.

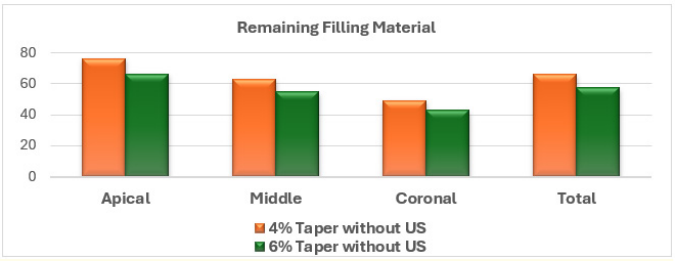

Figure 5: Bar chart showing the mean remaining filling material between 4% and 6% Taper without US activation.

Comparison regarding the root site for 4% taper without US activation

The One-Way ANOVA results showed that the difference between the sample averages of some groups is big enough to be statistically significant (P<0.001). Moreover, the results of the Tukey test for the intergroup comparison revealed that the means of the all groups are significantly different (P<0.0001).

The apical third had the significantly higher mean area of the remaining RC filling material (76.13 ± 2.81 mm^2), followed by the middle third (63.00 ± 5.18 mm^2), however, the coronal third had the significantly lower mean area of the remaining filling material area (49.10 ± 4.73 mm^2).

Table 2: Comparison of the remaining RC filling material for the 4% taper without US activation at different root sites.

Variables	Min.-Max.	Remaining area (Mean ± SD)	F Statistic	P-value
Apical	72.25-80.38	76.13 ± 2.81^{A}	115.05	<0.0001*
Middle	53.48-69.82	63.00 ± 5.18^{B}		
Coronal	41.27-55.84	49.10 ± 4.73^{C}		

*; Significant at P≤0.05. Min.= Minimum; Max.= Maximum. Different letters mean statistically significant.

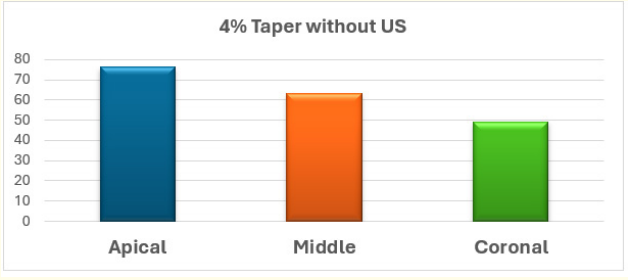

Figure 6: Bar chart showing the mean remaining filling material for the 4% taper without US activation at different root sites.

Comparison regarding the root site for 6% taper without US activation

The One-Way ANOVA results showed that the difference between the sample averages of some groups is big enough to be statistically significant (P<0.001). Moreover, the results of the Tukey test for the intergroup comparison revealed that the means of the all groups are significantly different (P<0.0001).

The apical third had the significantly higher mean area of the remaining RC filling material (66.22 ± 3.05 mm^2), followed by the middle third (54.86 ± 4.68 mm^2), however, the coronal third had significantly lower mean area of the remaining RC filling material area (42.72 ± 3.04 mm^2).

Table 3: Comparison of the remaining RC filling material for the 6% taper without complementary at different root sites.

Variables	Min.-Max.	Remaining area (Mean ± SD)	F Statistic	P-value
Apical	61.60-69.93	66.22 ± 3.05^{A}	122.97	<0.0001*
Middle	47.50-63.31	54.86 ± 4.68^{B}		
Coronal	38.89-46.42	42.72 ± 3.04^{C}		

*; Significant at P≤0.05. Min.= Minimum; Max.= Maximum. Different letters mean statistically significant.

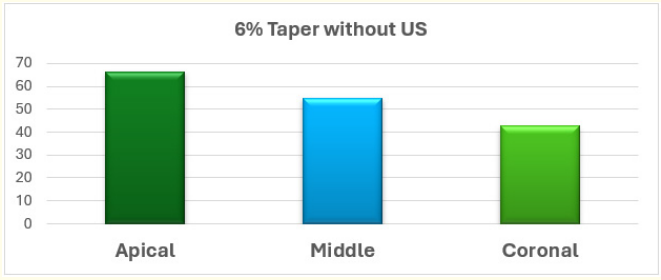

Figure 7: Bar chart showing the mean remaining RC filling material for the 6% taper without complementary at different root sites.

Comparison of the remaining RC filling material with US activation

Comparison regarding the taper

Apical (area %)

The independent t-test results showed that the Group I-B (4% with US) had the significantly (P<0.0001) higher mean value of the remaining RC filling material (61.16 ± 3.29 mm^2), however, the Group II-B (6% with US) had the significantly lower mean value (49.93 ± 4.19 mm^2) at the apical area.

Middle (area %)

The independent t-test results showed that the Group I-B (4% with US) had the significantly (P<0.0001) higher mean value of the remaining RC filling material (56.21 ± 2.17 mm^2), however, the Group II-B (6% with US) had the significantly lower mean value (40.15 ± 2.64 mm^2) at the middle area.

Coronal (area %)

The independent t-test results showed that the Group I-B (4% with US) had the significantly (P<0.0001) higher mean value of the remaining RC filling material (47.40 ± 3.12 mm^2), however, the Group II-B (6% with US) had the significantly lower area value (31.67 ± 2.33 mm^2) at the coronal area.

Total (area %)

The independent t-test results showed that the Group I-B (4% with US) had the significantly higher mean total area value of the remaining RC filling material (56.23 ± 1.53 mm^2), however, the Group II-B (6% with US) had the significantly lower mean total area value (42.64 ± 2.33 mm^2) at significant level of (P<0.0001).

Table 4: Comparison of the remaining RC filling material between 4% and 6% taper with US activation.

Variables	4% Taper with US		6% Taper with US		t-value	P-value
	Min.-Max.	Mean ± SD	Min.-Max.	Mean ± SD		
Apical	57.44-67.00	61.16 ± 3.29	43.29-55.84	49.93 ± 4.19	7.29	<0.0001*
Middle	52.07-58.90	56.21 ± 2.17	35.51-44.42	40.15 ± 2.64	16.26	<0.0001*
Coronal	43.49-51.95	47.40 ± 3.12	27.97-35.26	31.67 ± 2.33	13.98	<0.0001*
Total	52.96-58.42	56.23 ± 1.53	37.84-46.06	42.64 ± 2.33	16.85	<0.0001*

*; Significant at P≤0.05. Min.= Minimum; Max.= Maximum.

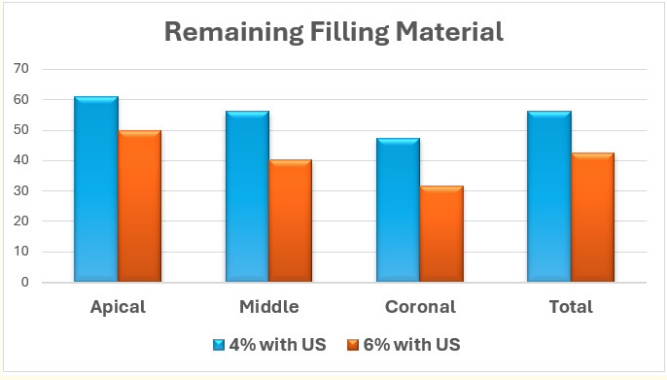

Figure 8: Bar chart showing the mean remaining RC filling material between 4% and 6% Taper with US activation.

Comparison regarding the root site for 4% taper with US activation

The One-Way ANOVA results showed that the difference between the sample averages of groups is big enough to be statistically significant (P<0.001). Moreover, the results of the Tukey test for the intergroup comparison revealed that the means of the all groups are significantly different (P<0.05).

The apical third had the significantly higher mean area of the remaining RC filling material (61.16 ± 3.29 mm^2), followed by the middle third (56.21 ± 2.17 mm^2), however, the coronal third had the significantly lower mean area of the remaining filling material area (47.40 ± 3.12 mm^2).

Table 5: Comparison of the remaining RC filling material for the 4% taper with US activation at different root sites.

Variables	Min.-Max.	Remaining area (Mean ± SD)	F Statistic	P-value
Apical	57.44-67.00	61.16 ± 3.29^{A}	69.05	<0.0001*
Middle	52.07-58.90	56.21 ± 2.17^{B}		
Coronal	43.49-51.95	47.40 ± 3.12^{C}		

*; Significant at P≤0.05. Min.= Minimum; Max.= Maximum. Different letters mean statistically significant.

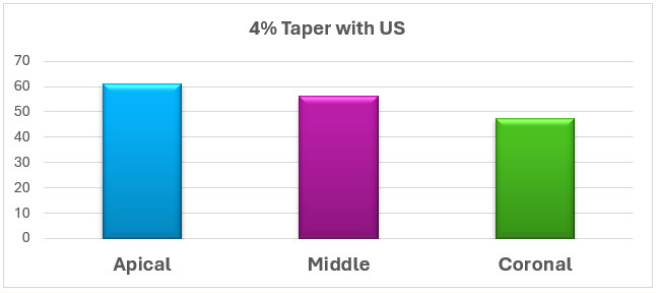

Figure 9: Bar chart showing the mean remaining filling material area (%) for the 4% taper with US activation at different root sites.

Comparison regarding the root site for 6% taper with US activation

The One-Way ANOVA results showed that the difference between the sample averages of groups is big enough to be statistically significant (P<0.001). Moreover, the results of the Tukey test for the intergroup comparison revealed that the means of the all groups are significantly different (P<0.0001).

The apical third had the significantly higher mean area of the remaining RC filling material (49.93 ± 4.19 mm^2), followed by the middle third (40.15 ± 2.64 mm^2), however, the coronal third had the significantly lower mean area of the remaining filling material area (31.67 ± 2.33 mm^2).

Table 6: Comparison of the remaining RC filling material for the 6% taper with complementary at different root sites.

Variables	Min.-Max.	Remaining area (Mean ± SD)	F Statistic	P-value
Apical	43.29-55.84	49.93 ± 4.19^{A}	100.16	<0.0001*
Middle	35.51-44.42	40.15 ± 2.64^{B}		
Coronal	27.97-35.26	31.67 ± 2.33^{C}		

*; Significant at P≤0.05. Min.= Minimum; Max.= Maximum. Different letters mean statistically significant.

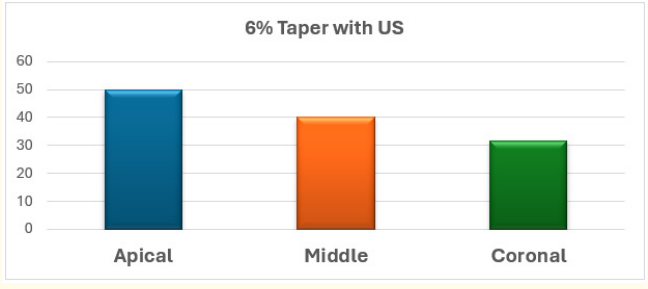

Figure 10: Bar chart showing the mean remaining RC filling material for the 6% taper with complementary at different root sites.

Comparison of the remaining RC filling material with vs. without US activation

Comparison of the remaining RC filling material for 4% taper Apical (area %)

The independent t-test results showed that the Group I-A (4% without US) had the significantly (P<0.0001) higher mean area value of the remaining RC filling material (76.13 ± 2.81 mm^2), however, the Group I-B (4% with US) had the significantly lower mean area value of the remaining RC filling material (61.16 ± 3.29 mm^2) at the apical area.

Middle (area %)

The independent t-test results showed that the Group I-A (4% without US) had the significantly (P=0.0003) higher mean value of the remaining RC filling material (63.00 ± 5.18 mm^2), however, the Group I-B (4% with US) had the significantly lower mean (56.21 ± 2.17 mm^2) at the middle area.

Coronal (area %)

The independent t-test results showed that the Group I-A (4% without US) had the higher mean apical area value of the remaining RC filling material (49.10 ± 4.73 mm^2), however, the Group I-B (4% with US) had the lower mean (47.40 ± 3.12 mm^2) at the coronal area but without significant difference (P=0.310).

Total (area %)

The independent t-test results showed that the Group I-A (4% without US) had the significantly (P<0.0001) higher mean total area value of the remaining RC filling material (65.96 ± 2.55 mm^2), however, the Group I-B (4% with US) had the significantly lower mean value (56.23 ± 1.53 mm^2).

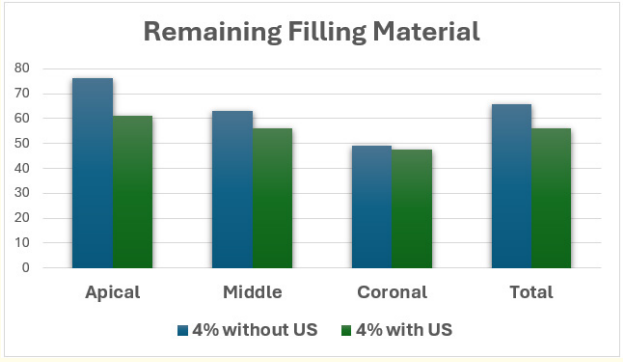

Figure 11: Bar chart showing the mean remaining filling material area percentage (%) for 4% taper with vs. without US activation.

Table 7: Comparison of the remaining RC filling material for 4% taper for with vs. without US activation.

Variables	4% without US		4% with US		t-value	P-value
	Min.-Max.	Mean ± SD	Min.-Max.	Mean ± SD		
Apical	72.25-80.38	76.13 ± 2.81	57.44-67.00	61.16 ± 3.29	11.98	<0.0001*
Middle	53.48-69.82	63.00 ± 5.18	52.07-58.90	56.21 ± 2.17	4.18	0.0003*
Coronal	41.27-55.84	49.10 ± 4.73	43.49-51.95	47.40 ± 3.12	1.03	0.310 NS
Total	53.39-60.31	65.96 ± 2.55	52.96-58.42	56.23 ± 1.53	11.32	<0.0001*

*; Significant at P≤0.05. NS; Non-significant at P>0.05. Min.= Minimum; Max.= Maximum.

Comparison of the remaining RC filling material for 6% taper

Apical (area %)

The independent t-test results showed that the Group II-A (6% without US) had the significantly (P<0.0001) higher mean value of the remaining RC filling material (66.22 ± 3.05 mm^2), however, the Group II-B (6% with US) had the significantly lower mean value (49.93 ± 4.19 mm^2) at the apical area.

Middle area (%)

The independent t-test results showed that the Group II-A (6% without US) had the significantly (P<0.0001) higher mean value of the remaining RC filling material (54.86 ± 4.68 mm^2), however, the Group II-B (6% with US) had the significantly lower mean value (40.15 ± 2.64 mm^2) at the middle area.

Coronal area (%)

The independent t-test results showed that the Group II-A (6% without US) had the significantly (P<0.0001) higher mean value of the remaining RC filling material (42.72 ± 3.04 mm^2), however, the Group II-B (6% with US) had the significantly lower mean value (31.67 ± 2.33 mm^2) at the Coronal area.

Total area (%)

The independent t-test results showed that the Group II-A (6% without US) had the significantly (P<0.0001) higher mean total area value of the remaining RC filling material (57.44 ± 2.35 mm^2), however, the Group II-B (6% with US) had the significantly lower mean total area value (42.64 ± 2.33 mm^2).

One-way ANOVA comparison of the remaining RC filling material between all groups

The one-way ANOVA demonstrated statistically significant differences among the four experimental groups at the apical, middle, coronal, and total root levels (P < 0.0001). Higher values represented a greater amount of remaining root canal filling material. The Group I-A (4% without US) exhibited the highest mean values, indicating the greatest amount of remaining filling material, whereas the Group II-B (6% with US) showed the lowest mean values, reflecting the most effective removal. Moreover, the Tukey test for intergroup analysis revealed that comparisons were statistically significant except for the comparison between the Group I-B (4% with US) and the Group II-A (6% without US), which did not show a statistically significant difference (P > 0.05).

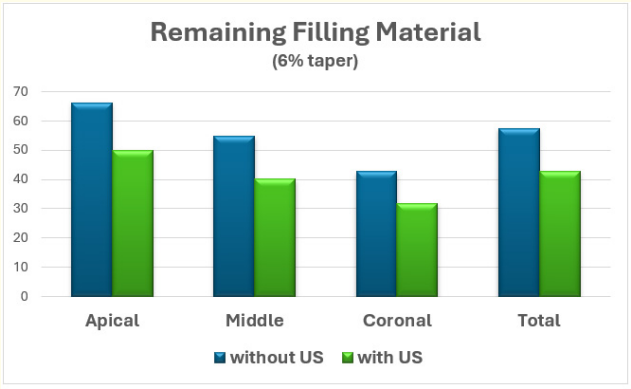

Figure 12: Bar chart showing the mean remaining RC filling material for 6% taper for with vs. without US activation.

Table 8: Comparison of the remaining RC filling material for 6% taper for with vs. without US activation.

Variables	6% without US		6% with US		t-value	P-value
	Min.-Max.	Mean ± SD	Min.-Max.	Mean ± SD		
Apical	61.60-69.93	66.22 ± 3.05	43.29-55.84	49.93 ± 4.19	10.88	<0.0001*
Middle	47.50-63.31	54.86 ± 4.68	35.51-44.42	40.15 ± 2.64	9.48	<0.0001*
Coronal	38.89-46.42	42.72 ± 3.04	27.97-35.26	31.67 ± 2.33	9.99	<0.0001*
Total	60.12-69.80	57.44 ± 2.35	37.84-46.06	42.64 ± 2.33	15.47	<0.0001*

*; Significant at P≤0.05. Min.= Minimum; Max.= Maximum.

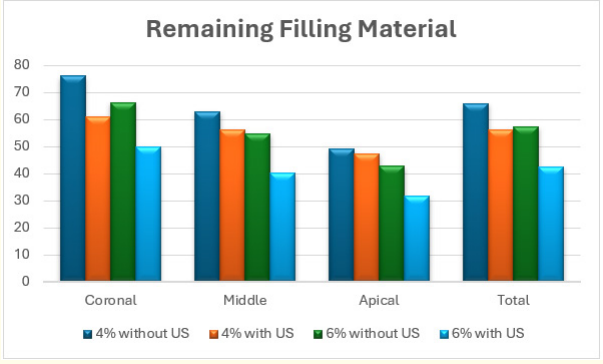

Figure 13: Bar chart showing the mean remaining RC filling material for all groups.

Table 9: Comparison of the remaining RC filling material for all groups.

Variables	4% taper without US (Mean ± SD)	4% taper with US (Mean ± SD)	6% taper without US (Mean ± SD)	6% taper with US (Mean ± SD)	F-statistic	P-Value
Apical	76.13 ± 2.81^{A}	61.16 ± 3.29^{C}	66.22 ± 3.05^{B}	49.93 ± 4.19^{D}	61.8	< 0.0001*
Middle	63.00 ± 5.18^{A}	56.21 ± 2.17^{B}	54.86 ± 4.68^{B}	40.15 ± 2.64^{C}	94.3	< 0.0001*
Coronal	49.10 ± 4.73^{A}	47.40 ± 3.12^{A}	42.72 ± 3.04^{B}	31.67 ± 2.33^{C}	89.6	< 0.0001*
Total	65.96 ± 2.55^{A}	56.23 ± 1.53^{B}	57.44 ± 2.35^{B}	42.64 ± 2.33^{C}	176.2	< 0.0001*

*; Significant at P≤0.05. Min.= Minimum; Max.= Maximum. Different letters mean statistically significant.

Two-way ANOVA comparison of the remaining RC filling material with vs. without US activation for 4 and 6% taper

Factor A: (Regarding taper)

The results revealed that the 4% vs. 6% taper had statistically significant difference (P<0.0001) in case of with and without the use of the US activation.

Factor B: (Regarding US activation)

The results revealed that with vs. without the use of US activation there was a statistically significant difference (P<0.0001) between the 4 and 6% taper.

Interaction: Factor A X Factor B:

The results revealed the use of US activation as well as the differ in taper resulted in statistically significant difference (P=0.0003) regarding the removal of the remaining filling material.

Discussion

Endodontic failure is defined as a situation in which a treated tooth exhibits clinical symptoms and radiographic periapical lesion after endodontic therapy. This often requires endodontic retreatment [10]. The main goal is removing the filling material, debris and microorganisms that are causing the periapical pathosis [11].

Removing the material from the canal is difficult and, in most cases, it is not possible to be completely removed. This can hinder the chemo-mechanical debridement of the root canal system [12]. Therefore, the aim of the study was to assess the effectiveness of different tapers of rotary files in removal of gutta percha (GP) with bioceramic (BC) sealer with and without ultrasonic (US) activation.

BC sealers are hydrophilic sealers that require moisture to set [13]. They have showed to be highly flowable and can bond to the canal walls [14]. This makes them hard to remove from the canals, for this reason they were the sealer of choice for this study.

Regular nickel-titanium (Ni-Ti) files designed for canal preparation were used to remove the filling material. This was shown in previous research to have no significant difference on their effectiveness in root canal filling removal and un-instrumented surface area compared to retreatment files [15]. In this study EDGE X7 files was used for retreatment because they are readily available and is made of a high quality, flexible metal alloy which will allow reaching for parts of the canal [16].

Prior research has demonstrated that file systems designed for retreatment alone are unable to fully eliminate the root canal filling materials [17-19]. It was claimed that the US activation aided in removal of more material from the root canals. Therefore, one of the aims of the present study is to assess the effectiveness of rotary files in removal of GP with BC sealer in combination with US activation.

Mandibular molars were chosen as they are the most frequently treated teeth in root canal therapy [20]. Only mesial roots having Vertucii Type IV, II were chosen as they are the most common configurations in Egyptian population [21,22]. For standardization purposes, the mesiobuccal canal of the teeth were prepared.

The canals were prepared to a size 25.04 followed by obturation using a single cone 25.04. CeraSeal was selected because it is one of the most popular used sealers. Research showed that it has high flowability and dentinal tubule penetration [23].

Furthermore, because previous studies showed that the use of solvents increased the quantity of GP and sealer residue on the root canal walls and inside the dentinal tubules, therefore solvents were not used in this study when the filling material was being removed [24-26].

Teeth were wedged apart [9]. This is because the isomet blade thickness (0.3 mm) [27]. which may result in displacement of filling material giving false measurements.

In this study, the evaluation of the remaining dentin filling was done with the use of a stereomicroscope because its readily available and is sensitive enough to detect a little patch of residual GP or sealer on the canal wall [28]. A range of stereomicroscope magnifications are used, most commonly between 4x and 40x. For this study 20x was used in accordance with previous studies [29-32]. This allows us to examine the whole root section. On the other hand, studies have done evaluation using Micro-CT [25,26,33,34]. They may have varying degree of effectivity, but they are not readily available and expensive.

The current study's findings demonstrated that the 0.06 taper file produced noticeably better results in the coronal, middle, and apical thirds than the 0.04 taper file. This could be explained by the fact that the obturation is performed using a 25.04 master cone, and 6% taper file has a larger taper size than the master file. The dentin wall that is next to the GP root filling material has therefore also been removed [35].

Furthermore, the results of this study demonstrated that the filling removal results were significantly better in the coronal and middle thirds of the canal as opposed to the apical thirds. This result can be explained by the fact that the apical third exhibited greater compaction and deeper penetration of the obturating material into the dentinal tubules, resulting in increased residual filling [36-39].

Some studies have reported an opposite distribution of remaining filling material, with the coronal third showing significantly greater remnants than the apical third after retreatment. This has been attributed to the higher initial bulk of obturation material coronally and the tendency of rotary of instruments to plasticize and smear softened GP against the coronal canal walls. Additionally, it was suggested that limited access design and may further contribute to increased coronal residue [40-42].

The larger file size of 0.06 taper file could also explain the significantly higher total root filling material removal when compared with 0.04 taper file. Furthermore, a significant amount of frictional heat may be produced by the rotational motions of 0.06 taper files bigger than 0.04 taper files, potentially plasticizing GP. Therefore, the plasticized GP would be easier to remove and exhibit less resistance [43,44].

The current study's findings also showed that using a US irrigation with 0.04 can give almost similar filling removal as 0.06 taper alone. The apical third demonstrated better filling removal with the 0.04 taper with US. This highlights the critical role of US activation in enhancing irrigant penetration and effectiveness in narrow and anatomically complex apical regions [45].

The better removal of filling material could also be due to the fact that US causes acoustic streaming which produces small, powerful, circular fluid movement. With an apically directed flow at the tip, the acoustic streaming happens closer to the tip than in the coronal end of the file. By using hydrodynamic cutting power, this acoustic streaming, enhances the irrigant's cleansing action inside the canal. The US vibration from the US tip also encouraged the displacement of filling material from the root canal walls, making it easier to remove the filling material [46,47].

In the coronal third, the 0.06 taper without US demonstrated superior removal of filling material compared to the 0.04 taper with US, likely due to greater canal enlargement and increased instrument-filling contact. While US activation enhances irrigant penetration and loosens remnants through acoustic streaming and cavitation. This is consistent with *in-vitro* studies showing that activation aids removal but does not completely eliminate sealer remnants [48,49].

Some studies have reported contrasting results regarding the effectiveness of US activation during endodontic retreatment. In certain *in-vitro* investigations, the application of passive US irrigation following mechanical removal did not result in a statistically significant reduction in residual filling material when compared with instrumentation alone [50,51]. These findings have been attributed to differences in experimental protocols, including limited US activation time, insufficient irrigant volume. All of which may reduce the potential effectiveness of US activation.

According to the current study, using US as a complementary technique in conjunction with rotary files during endodontic retreatment was better than using rotary files alone. The GP plasticization brought on by the rotary instrument's rotation and the US tip's photoacoustic stream is most likely the reason of this [52,53].

Overall, the results showed that complete removal of GP and BC sealer was not achieved with any technique, regardless of taper or US activation. Files with a 0.06 taper demonstrated significantly greater filling removal, while US activation enhanced removal efficiency when used with a 0.04 taper. Accordingly, the null hypothesis was rejected, as instrument taper and US activation significantly influenced both filling removal and remaining dentin thickness.

Conclusions

Considering the limitations of this study, the following conclusions may be drawn:

- Complete removal of bioceramic root canal filling material was not achieved with any of the retreatment protocols tested.
- The larger taper rotary file removed significantly more obturation material than the 4% taper.
- Ultrasonic activation significantly enhanced the removal of remaining filling material.
- Interplay of taper and ultrasonics is valuable especially in the apical area where 4% taper with ultrasonic gave better results than 6% without ultrasonic.

Recommendations

- Ultrasonic irrigation is a valuable adjunct that enhances filling material removal without increasing dentin loss.
- Further research for different modalities in complementary methods for removal of filling material should be investigated.

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