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THE EFFICACY OF DIFFERENT KINEMATICS IN THE REMOVAL OF GUTTAPERCHA FROM ENDODONTICALLY TREATED TEETH FILLED WITH BIOCERAMIC SEALER: AN IN-VITRO STUDY

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ABSTRACT

Endodontic retreatment is required when treatment failure is detected, typically due to residual bacteria or re-infection. The main objectives are to enhance patient quality of life and restore periapical tissues. This study evaluated the efficacy of different kinematic movements of two nickel-titanium systems and ultrasonic tips in retreating oval canals by assessing the relative amount of remaining gutta-percha using Protaper Gold, WaveOne Gold files and E6 Woodpecker ultrasonic tip. Non-carious extracted human lower second premolars with single straight oval canals were standardized to an 18 mm root length. They were instrumented, irrigated with sodium hypochlorite, and obturated with single-cone gutta-percha using Ceraseal sealer. Samples were divided into three groups: Protaper Gold F4 (group 1), WaveOne Gold Large File (froup 2), and ultrasonic tip Woodpecker E6 (group 3). The remaining root canal filling material was detected using a stereomicroscope. At the coronal third, the vibration and reciprocation groups had almost similar mean remaining material percentages (24.2% and 22.9%), the rotation group had a significantly lower mean value (16.4%). At the middle third, the vibration group had the highest mean remaining material percentage (22.2%), The reciprocation group (19.15%) and the rotation group had the lowest (16.5%). At the apical third, the vibration and reciprocation groups had comparable mean remaining material percentages (25.3% and 25.35%), while the rotation group showed a significant decrease (21.36%). ProTaper gold (rotation) was the most effective technique for removing root canal filling material, followed by the WaveOne Gold Large File and Ultrasonic vibration using the Woodpecker E6 tip.

KEYWORDS: retreatment, remaining gutta-percha, bioceramic sealer

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INTRODUCTION

Endodontic retreatment is a critical procedure that aims to address recurrent periapical pathologies following initial root canal therapy. One of the primary challenges in endodontic failed cases is the effective removal of the previous root filling material, such as sealer and gutta-percha, which facilitate thorough cleaning, shaping, and subsequent obturation of the canal system [(1)]. The removal of these materials completely is essential to eliminate residual infection and ensure the success of the retreatment procedure [(2)].

Gutta-percha, a thermoplastic material commonly used in conjunction with various sealers, has been the gold standard for root canal obturation for decades. However, the advent of bioceramic sealers has introduced new complexities in retreatment due to their superior adhesion properties and ability to form a chemical bond with root dentin. These properties, despite being beneficial for initial obturation, but pose significant challenges during retreatment, necessitating the exploration of effective techniques for their removal [(3)].

Various kinematic techniques have been developed to increase the efficiency of sealers and gutta-percha removal. Rotary instruments, such as ProTaper Gold, utilize continuous rotation to mechanically debride the canal walls [2]. Reciprocating systems, like WaveOne Gold, employ a back-and-forth motion that has been shown to improve debris removal and reduce the risk of instrument fracture[(4)]. Additionally, ultrasonic activation, using devices such as the Woodpecker E6 ultrasonic tip, leverages cavitation and acoustic streaming to disrupt and dislodge filling materials [(5)].

Therefore, this study aimed to assess the efficacy of various kinematic movements of two different nickel titanium systems (Protaper gold and Waveone gold files) and ultrasonic tips in the retreatment of oval canals by evaluating the amount of remaining gutta-percha**.**

MATERIALS AND METHODS

Study Settings and Ethical Considerations:

The study protocol was approved by the Institutional Review Board (IRB) of Misr International University (MIU) with a given approval # (MIU-IRB-2324-049). The study was performed at the dental labs of the Restorative Department, Faculty of Dentistry, MIU.

Sample Size Calculation:

A power analysis was designed to have adequate power applying a statistical test of the null hypothesis which was that there was no difference between different tested groups for remaining filling material. By adopting alpha (α) level of (0.05), beta (β) level of (0.05) (power=95%) and effect size (f) of (1.05) calculated based on the results of a previous study [(2)]. The minimal required total sample size (n) was found to be 20 teeth (6 samples per group). Sample size was increased 20% to compensate for any complications to be 24 teeth 8 teeth per group. Sample size calculation was done by version 4.3.2 for Windows R statistical analysis software [(6)].

Specimens Selection:

24 mandibular second premolars were collected from Misr International University (MIU) teeth bank. Samples were stored in 0.5% chloramine-T at 4°C until used. Each tooth was inspected at 20x magnification to ensure that they met the study's eligibility criteria.

Eligibility Criteria:

Permanent mandibular second premolars with exposed carious lesions, free of any other defects, not subjected to prior endodontic treatment or with minimal restorations were selected with similar dimensions and morphology. The chosen teeth length's measures were 21-23 mm with an average length of 22 mm. Teeth with large restorations, root resorption, cracks, or calcifications were excluded.

Specimens Preparation:

A mark was placed on the root surface to facilitate measuring the tooth length. The samples' occlusal surfaces were flattened to obtain a reproducible coronal reference and to standardize tooth length of 18 mm with a double coated diamond disc by KG Sorensen, Barueri, Sao Paulo, Brazil.

An oval-shaped access was prepared using a 21 mm endo-access bur (Dentsply Sirona, United States) and a finishing diamond stone. The working length was measured with a size 10 k-File (MANI) and confirmed for apical patency. Hyflex EDM files, (Coltene, Switzerland) were used for cleaning and shaping. Irrigation was done with 2.6% sodium hypochlorite, activated with SLP EndoActivator Tips Dentsply Sirona, United States, and finally rinsed with 17% EDTA solution to remove the smear layer.

After cleaning and shaping, gutta-percha cones were calibrated and used for canal obturation. Gutta-percha 25/.06 and CeraSeal sealer were employed with single cone technique. Radiographs were taken to ensure uniform and void-free root canal filling. Samples were stored in an incubator for three weeks to ensure proper sealer setting.

Samples Grouping:

The selected, prepared and obturated mandibular second premolars were split into three groups, according to the motion of the retreatment system used:

Group 1 (n=8): Full rotational motion using protaper gold F4.

Group 2 (n=8): Reciprocal motion through Waveone gold files.

Group 3 (n=8): Vibrational motion using E6 ultrasonic tip

Retreatment Procedure:

The obturated teeth were instrumented with the different retreatment methods, according to their corresponding group, using a pecking motion for this step. Canals were irrigated with 5 ml of 2.6% sodium hypochlorite.

Methods of Evaluation:

Relative percentage of residual root canal filling material:

Under continuous water cooling, the teeth were grooved longitudinally in a buccolingual direction just before reaching the canal lumen using the Isomet 4000 (BUEHLER, Germany) with a double-coated diamond disc. The teeth were then sectioned using a chisel, splitting them into two halves. Both halves were photographed under a stereomicroscope (Euromex microscopes holland, Netherlands) attached to a digital camera and were transferred to the computer.

The sections were analyzed using version 1.37v image J software (National Institute of Health, Bethesda, MD, USA). residual obturation material was selected for stereomicroscope scanning and analysis at coronal, middle, and apical sections at magnification (20x). The procedure involved the meticulous division of the specimens into three distinct and precisely equal segments using a marker, each has a uniform measurement of 6 mm.

On these digital images, calculation of the remaining filling material was as a relative percentage. In each third, the area around the root canal was cleared out. The total root canal area and total remaining area of the root filling material were measured in pixel. Then, percentage of the remaining canal filling material was calculated in each third with the following equation [14]:

$$\text{Area \% of remaining canal filling material} = \frac{\textit{Area of remaining filling material}}{\textit{Area of canal wall}} = 100$$

Statistical Analysis

The recorded values were subjected to testing for normality with Kolmogorov-Smirnov test and

Shapiro-wilk's tests, which revealed normally distributed data of the study groups (the P-value >0.05). The Kolmogorov-Smirnov test showed that the P-value was 0.20 in vibration and rotation groups but was recorded to be 0.0 in reciprocation group. The Shapiro-Wilk test showed that P-value was 0.80 in vibration group and 0.88 in Rotation groups, while it was shown to be 0.0 in reciprocation group.

One way Anova was used as a parametric test for multiple groups comparison and it showed a statistical significance difference regarding the relative percentage for the remaining filling material in the coronal third, middle third and apical portions between three groups as recorded (P-value =0.0). A tukey Post hoc test for pair wise comparison revealed a statistical significance difference between study groups except for vibration and reciprocation groups in coronal and apical portions.

RESULTS

This study results' (Table 1, figure 1) showed that, there was a statistical significant difference between mean relative percentage of the remaining obturating materials of all groups at different root canal thirds; coronal third (p=0.001), middle third(p=0.001) and apical third(p=0.003).

At the coronal third, the mean material relative percentage was comparable in the vibration and reciprocation groups, 24.2 (2.96) and 22.9 (2.8), respectively, while the rotation group showed a decrease in the mean value of the material relative percentage which was statistically significant 16.4 (2.41).

At the middle third, the mean material relative percentage was statistically significant between all groups with a greatest mean value of 22.2 (1.7) for the vibration group followed by 19.15 (2.3) mean value for the reciprocation group, while the least mean value was at the middle third of a mean value of 16.5 (1.8) for the rotation group.

At the apical third, the mean material relative percentage was comparable in the vibration and reciprocation groups, 25.3 (2.6) and 25.35 (2.45), respectively, while the rotation group that showed a decrease in the mean value of 21.36 which was statistically significant (1.9).

The vibration group resulted in no statistical significant difference comparing the mean values of the remaining material relative percentages at the coronal third 24.2 (2.96), at the middle third 22.2 (1.7), and at the apical third 25.3 (2.6) at p=0.062.

However, both reciprocation group and rotation groups showed a difference between the mean relative percentages of the remaining material at p=0.001 which was statistically significant.

In the reciprocation group, the mean percentages of the remaining material were comparable at the coronal 22.9% (2.8) and at the apical thirds 25.36 (2.45) while the mean percentage of the middle third decreased to 19.16% (SD 2.3).

The rotation group also demonstrated a comparable mean remaining material percentage at the coronal 16.4% (2.41) and at the apical thirds ds 21.36 (1.9). Similar to the reciprocation group, the mean percentage of the middle third dropped to 16.5 (1.8).

TABLE (1) One-Way Anova results testing the inter and the intra-group comparisons of mean and standard deviation of the % of the remaining obturating material with-in different teeth thirds (coronal, middle and apical) for each tested group.

Study groups	Remaining material % in coronal portion Mean (SD)	Remaining material % in middle portion Mean (SD)	Remaining material % in apical portion Mean (SD)	P-value
Vibration	24.2 [a] (2.96)	22.2[a] (1.7)	25.3 [a] (2.6)	0.062
Reciprocation	22.9 [a] (2.8)	19.16[b] (2.3)	25.36 [a] (2.45)	0.000*
Rotation	16.4 [b] (2.41)	16.5 [c] (1.8)	21.36 [b] (1.9)	0.000*
P-value	0.000*	0.000*	0.003*	

**** The significance level is at the 0.05.***

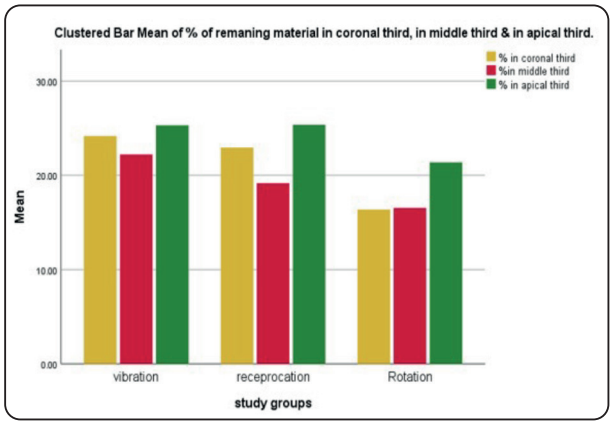

Fig. (1) Bar chart illustrating remaining material % between vibration, reciprocation and rotation at the different root thirds.

DISCUSSION

The chief goal of endodontic treatment is to clean, shape and three dimentionally seal the canal system, to prevent reinfection and to have a durable outcome. In some cases, although initial endodontic therapy is shown to be successful, failures can occur often due to procedural and non-procedural errors. In such cases, endodontic treastment is indicated. The major objective in retreatment is to create favorable conditions that promote healing of the periapical tissues. This necessitates the through removal of sealer and gutta percha together with cleaning the root canal system to allow the endodontic irrigant to affect the bacteria contained in dentinal tubules and canal space [7]. Various techniques were used to remove root canal fillers, as stainless-steel manual files, Ni-Ti rotary or reciprocating files, ultrasonic files, Gates Glidden, and lasers. Although complete root filling material removal is still doubtful, many studies demonstrated that rotary instrumentation showed more efficiency than hand files in removing root canal filling [8-13]. In this study, rotary instruments were used to retrieve bio-ceramic sealer due to their ease of use and efficiency.

The advent of nickel-titanium (Ni-Ti) engine-driven instruments, either rotating or reciprocating, in endodontics revolutionized root canal preparation. These instruments simplified the mechanical shaping of root canals and reduced treatment time by using fewer instruments [14]. NiTi engine driven systems were designed for retreatment procedures, aiming to enhance the efficiency of root canal filling removal while minimizing procedural errors. However, despite their purpose, these systems did not demonstrate superiority over conventional NiTi systems. On the other hand, NiTi single-file systems have shown efficacy in mechanical preparation when compared to multiple-file systems. Their improved mechanical properties contribute to their effectiveness [15]. There is now two heat-treated Gold NiTi systems available in the market with different geometric designs and movement kinematics which are the WaveOne Gold and ProTaper Gold [16].

Moreover, the use of an ultrasonics for the mandibular premolars retreatment effectively removes gutta-percha and sealer from root canals in a short time with minimal possible extrusion of filling material. The frictional heat generated by the those instruments synergistically softened and gutta-percha removal within the canal [6] .

Endodontic engine driven instrumentation could be classified into five different groups according to the kinematics of the instrumentation as follows: rotary, rotational reciprocating, vertical vibration in addition to rotational reciprocating motion, and adaptive motion in the form of vertical vibration and rotary plus rotational reciprocating motions [17]. In the current study, three strategies for extracting material from root canals with varying kinematics were compared to determine the efficacy of various endodontic instrumentation techniques; vibration, reciprocation and rotation [4].

Single-rooted lower second premolars with straight oval canals were deliberately chosen for standardization, minimizing confounding variables, ease of handling, and due to the difficulty in removing root canal fillings from larger canals [18,19]. This anatomical complexity of large canals could pose challenges for endodontic instruments to access all areas. Consequently, complete removal of filling material within these canals might become more difficult. Additionally, most experimental research evaluating the effectiveness of retreatment techniques has focused on straight root canals, which simplifies the process of standardizing specimens [20–22].

A conventional oval-shaped access cavity was prepared to optimize the chemo-mechanical preparation, filling methods, and retreatment. The filling material removal is influenced by adequate coronal access. It also avoided complications associated with changed connect cavities, such as orifice position, quality of canal preparation, disinfection, filling procedures, and iatrogenic mishaps[23]. According to research, minimally invasive access cavities lead to more filling remnants compared to traditional cavities.

Ceraseal bio ceramic sealer was the sealer of choice for obturation. Bioceramic materials are highly regarded as effective sealing materials in dentistry [24] . Single cone technique was the obturation method of choice. This technique was recently advocated for use with the introduction of bioceramic sealers. This was to have the benefit of better bonding of the sealer with the dentine walls thus decreasing microleakage that might occur due to the gap formation.

In the current study, no solvent was employed due to the challenges associated with removing chemically softened gutta-percha from the canal. Several studies demonstrated that the use of canal filling solvents results in increased gutta-percha and sealer remnants on the canal walls [9].

Stereomicroscope analysis was employed to identify the remaining obturating material percent. It is recognized as a crucial tool for evaluating the filling quality, which is considered a safe method showing all adaptation gutta-percha and sealer details, including inadequately filled areas during canal treatment [25].

None of the tested instruments completely removed the canal filling material, consistent with findings from other studies on efficacy of retreatment using various instruments [6,18]. Statistically a significant difference was found, in all retreatment group, when analyzing each root third individually. Specifically, the apical portions exhibited highest percentage of the remaining filling using the three techniques. This could be due to complex root canal anatomy in the apical third, characterized by lateral and accessory canals which poses challenges for complete removal [26]. These results were consistent with other study showing higher remaining obturation material in the apical thirds using E6 ultrasonic tip [6].

The results of this study showed that statistically significant difference was found between the three groups at various root canal thirds. This indicates that the choice of technique significantly impacts the efficacy of filling material removal across coronal, middle, and apical thirds of the canal.

In this study, highest percentage of remaining material was found in apical third in the vibration group (25.3), the coronal third followed (24.2), with lowest percentage found in middle root third (22.2). The two potential reasons account for the highest value of the remaining filling materials in the apical portion of canals within vibration group. First, ultrasonic tips lack cutting action; their vibrations disintegrate the root filling, expelling them coronally towards the canal orifice. Additionally, ultrasonic tip is thicker coronally. Second, using EDTA for irrigation protocol will open the dentinal tubules, promoting the bio-ceramic sealer to bond and forms of hydroxyapatite tags helping with the monoblack concept. Consequently, creating exceptionally strong bonds with the root canal walls, making bio ceramic sealer retreatment challenging. Breaking this bond requires higher cutting efficiency instruments [27].

Wave One Gold Large File utilizes a reciprocating motion, showing comparable performance compared to the Ultrasonic E6 tip. The reciprocating motion enhances cutting efficiency and reduces the risk of instrument fracture [4]. Reciprocating motion results in a broader movement in the counterclockwise direction compared to the clockwise direction, aiding in better centralization of the instrument within the canal. Additionally, files with reciprocating motion possess a significant taper, which, along with the increased friction between the root canal filling and the instrument, makes reciprocating as effective in removing fillings as continuous rotating files [22]. WaveOne Gold emerges as a viable option for removing filling material in curved canals. Low apical transportation (AT) suggests that tested instruments are safe to be used in retreatment procedures [28]. The reciprocation group's performance in the middle third, with a mean material percentage of 19.16%, showed the least remaining material. Those findings suggests that the WaveOne Gold Large File is effective in this section. Allows for better adaptation to the canal walls and enhancing debris removal. Although, another study stated that reciprocating motion is particularly effective for removing the filling material, especially in apical portions[27].

ProTaper Gold F4 demonstrated highest efficacy in removing canal filling material. In spite of, they are not especially intended for retreating cases, the use of thermal treatment to traditional Nickel titanium alloys enhanced the resistance to cyclic fatigue, which is beneficial during retreatments [25]. Files specially designed for retreatment do not offer significant privileges over heat-treated ones, which, in contrast, provide greater torsional resistance and flexibility [29] . The stereomicroscope analysis revealed that ProTaper Gold F4 was more effective in coronal (16.6%) and middle (16.5%) portions of the canal but less effective in the apical third (21.36%). This came in alignment with other studies that ProTaper gold removed significant higher amount of resin in the middle and coronal thirds, attributed to its larger diameter and greater taper [30] . Removing filling material from the apical third poses difficulties upon using rotary instruments. In contrary, another study showed that remaining obturation material was more at coronal and middle thirds of canals and least at the apical portion [31].

For the total remnant of filling material, studies showed no difference statistically between rotary instruments and reciprocating ones [32] . However, some studies found that reciprocating instruments are significantly more efficient than rotary ones [27].

The finding of this study disagreed to those of Agrawal et al [33] who found that ultrasonic tip used during retreatment was more effective than Mtwo and R-Endo retreatment file systems. This might

be attributed to the use of different type of sealers as they used zinc oxide eugenol sealer compared to Ceraseal bioceramic sealer used in this study. A limitations of this study was using one obturation technique. Other studies have compared various techniques, including single cone technique [(34)].

This study found a significant clinical implications for endodontic retreatment procedures. The superior performance pro Taper Gold file suggests that clinicians should consider incorporating pro taper gold for more efficient removal of canal filling material, particularly in challenging apical regions. The Wave One Gold Large File also presents a viable option, offering a balance between efficiency and ease of use. Clinicians using Ultrasonic E6 should be aware of its limitations.

CONCLUSION

According to the constraints of this in vitro study, we can conclude the following: none of those available techniques completely removed the gutta percha. ProTaper Gold (Rotation) was the most efficient for the root filling material removal, showing the least material percentage among all thirds of the canals. Followed by wave one large files (Reciprocation) and finally the Ultrasonic endodontic tip E6 (vibration) was the least efficient in the removal of filling material. Those findings tend to provide valuable insights for clinicians in selecting the appropriate technique for endodontic retreatment procedures, emphasizing the importance of thorough removal of filling material to ensure a successful outcome.

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