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THE EFFICACY OF DIFFERENT RETREATMENT PROTOCOLS IN THE REMOVAL OF ROOT CANAL FILLING MATERIALS FROM OVAL ROOT CANAL (AN IN-VITRO STUDY)

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ABSTRACT

Background: When a treatment failure is discovered following a clinical or radiographic evaluation, an endodontic retreatment process is carried out. The most significant etiological causes for failures are the existence of residual germs or re-infection in endodontically treated teeth.

Aim: To assess the efficacy of rotary and reciprocation kinematic movements of two different nickel titanium systems in the retreatment of oval canals by evaluation of the amount of remaining gutta-percha with or without solvent as well as crack formation using Edge XR and Reciproc Blue files**.**

Materials and Methods*:* Thirty-five non-carious extracted human lower second premolars with single straight oval canals will be selected. The occlusal table of the samples will be flattened to achieve a standardized tooth length. They will be randomly divided according to the retreatment system used. Group 1: Edge File XR with solvent, Group2: Edge XR file without solvent, Group 3: Reciproc Blue R25 with solvent, Group 4: Reciproc Blue R25 without solvent. The remaining amount of root canal filling material and evaluation of crack formation will be measured by stereomicroscope.

Results: More filling material was observed in the apical third, and there were no notable differences in the percentage of remaining filling materials and working time among the four groups.

Conclusion: Achieving the thorough removal of root canal filling material from oval root canals has proven to be challenging with any retreatment approach. Additionally, neither of the kinematics resulted in the occurrence of cracks during the retreatment procedure in oval root canals.

KEY WORDS: Retreatment, Reciprocation, Oval canals, Root canal filling.

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INTRODUCTION

Root canal treatment is one of the most common dental procedures nowadays with success rate between 86 and 96 percent.[1] Despite this high success rate, 14–16 percent of patients had treatment failure because of the lingering intra- and extra-canal germs. This infection is a major cause for post-treatment complains.

The main cause of persistent apical periodontitis is the survival of intracanal microorganisms after initial root canal treatment. This highlights the need for nonsurgical endodontic retreatment, aiming to eliminate filling material from the root canal and restore access to the apical foramen.[2] Thus, endodontic retreatment is indicated when the initial procedure fails,[3] and better root canal debridement and disinfection,[4] as well as 3D obturation to the root canal system is needed to achieve a fluid-tight seal.

Complete removal of root canal filling material from the root canals has proven elusive using any retreatment technique.[5,6] The root canal's remaining filling materials can have an impact on the outcome of endodontic retreatment. The gutta-percha that adheres to the dentin walls can shelter microorganisms that cause an intra-radicular infection and hinder the adhesion of new filling materials to the root canal walls.

Various techniques for removing filling materials are currently in use,[7,9] including rotary and manual instruments, which are preceded by softening the filling material with heat or solvents. Different instruments that provide access to root dentin can be used to mechanically remove infected root canal filling materials; therefore, instrumentation and irrigation may hinder the biofilm and expose microbes to the antiseptic effects of irrigants.

The RECIPROC blue instruments are intended for single-file shaping. Thus, in the majority of cases, a root canal can be completely prepared with only one reciprocating instrument - without the need for a glide path, because of its unique design, where the s-shaped cross-section moves smoothly and cuts efficiently.[10,11]

The Edge® XR retreatment rotary file has a noncutting tip and uses EdgeEndo® "FireWireTM NiTi - a heat-treated nickel-titanium alloy for cryogenic applications that allows maximum flexibility and strength that EdgeEndo® is known for without "screw-in" and or "picking".

Materials and Methods

Thirty-five non-carious human lower second premolars, collected for orthodontic research, were standardized for patient age (15-18 years), tooth morphology, and pulp chamber sizes. After ethical approval (IRB 0010118), the teeth were sourced from the Department of Oral and Maxillofacial Surgery at Misr International University and MIU Teeth Bank over 3 months.

Samples were stored in 0.5% chloramine-T at 4°C.[3] Each tooth was inspected at 20x magnification to ensure they met selection criteria: similar dimensions, morphology, absence of defects, and no prior endodontic treatment. The chosen teeth measured 21-23mm in length, averaging 22mm.

A mark was placed on the root surface to ensure a tooth length of 18mm. Samples were flattened to obtain a reproducible coronal reference and to standardize tooth length of 18mm using a double diamond disc (KG Sorensen, Barueri, Sao Paulo, Brazil).

An oval-shaped access was prepared using a 21mm endo-access bur (Dentsply Sirona) and a finishing diamond stone. The working length was established with a size 10 k-File (MANI) and confirmed for apical patency. Hyflex EDM files (Coltene) were used for cleaning and shaping. Canals were irrigated with 5.25% Sodium Hypochlorite, activated with SLP EndoActivator Tips, and finally rinsed with 17% EDTA solution to remove 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 warm vertical compaction. The technique was applied 6mm away from the apex to avoid sealer disruption. The rest of the canal was backfilled with plasticized gutta-percha. Radiographs were taken to ensure uniform and void-free root canal filling. Samples were stored in an incubator for three weeks for sealer setting.

Samples Grouping

Thirty-Five mandibular second premolars were divided into four main groups according to the motion used through the retreatment system and the presence or absence of solvent. (n=8) and One control group. (n=3)

Group 1 (n=8): Full rotational motion through Edge XR retreatment files with the application of solvent. **Group 2 (n=8):** Full rotational motion through Edge XR retreatment files without application of solvent. **Group 3 (n=8):** Reciprocal motion through Reciproc Blue files with the application of solvent. **Group 4 (n=8):** Reicprocal motion through Reciproc Blue files without application of solvent. **Group 5 (n=3):** Control group was left filled and received no further treatments.

Retreatment procedure

The temporary restorations were removed using round burs. Retreatment procedures were performed by removing the previous filling material from each canal using either full rotational motion through Edge XR or reciprocal motion through Reciproc Blue file in the presence or absence of a solvent.

Group 1: In a retreatment procedure using Edge XR file with a tip size of 25 and a constant taper of 0.08, an X-smart IQ Endo motor Endo motor was employed, following manufacturer-recommended settings of 300 g-cm torque and 400 rpm. Eucalyptol was applied for 5 minutes to soften gutta-percha, and NiTi rotary files were used with a 2-3 mm push-pull motion and gentle apical pressure. Removal started with light apical pressure, progressing from coronal to apical with a size 25/.08 file, ensuring no material adhered to the instrument or canal walls. Canals were irrigated with 5 mL of 5.25% sodium hypochlorite (NaOCl), and the process continued until no material was visible on the instrument. Final irrigation included NaOCl, saline, and EDTA solutions, followed by drying with paper points. The total procedure time was recorded in seconds. One operator conducted all procedures.

Group 2: Edge XR File (25/.08) were used for retreatment with an X-smart IQ Endo motor Endo motor, following manufacturer-recommended settings of 300 g-cm torque and 400 rpm. Filling material removal began with gentle apical pressure and progressed coronally. Obstructions prompted file removal, irrigation, and re-introduction. Continuous NaOCl irrigation ensured debris removal. Final steps involved EDTA and saline irrigation for smear layer removal, followed by saline rinse. Each file was used once, and the procedure was timed, with a single operator.

Group 3: In a retreatment procedure using Reciproc Blue file size 25 with 8% taper and X-smart IQ Endo motor. Files were operated following manufacturer's instructions concerning torque and speed. These settings are preinstalled on the application Endo IQ. Eucalyptol solvent applied before removal to soften gutta-percha. Canals instrumented using push-pull motion. Obstructions managed with irrigation, file cleaning, and brushing action. Final irrigation: NaOCl, saline, and EDTA solutions. Retreatments monitored until no debris visible. Each file used once and discarded for consistency.

Group 4: Root canals were retreated using Reciproc blue files (size 25, taper 8%) with X-smart IQ Endo motor. Files were operated following manufacturer's instructions concerning torque and speed. These settings are preinstalled on the application Endo IQ. Obstructions were managed by removing, irrigating, and re-introducing the file. Final irrigation included NaOCl, saline, and EDTA solutions. Retreatment was deemed complete when no debris confirmed when no gutta-percha/sealer residue remained. A single operator conducted all procedures, and the time was recorded from touching gutta-percha with the file.

Methods of evaluation

Percentage of residual root canal filling material

Under continuous water cooling, the teeth were grooved longitudinally in a buccolingual direction) using the Isomet 4000 (BUEHLER, Germany) **(Figure 1)** and a double-sided diamond disc. Both halves were photographed under a stereomicroscope (Euromex microscopes holland, Netherlands) (20x) magnification attached to a digital camera and were transferred to the computer.

The sections were analyzed using image J software (version 1.37v, National Institute of Health, Bethesda, MD, USA). The half of the root with the most 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 boasting a uniform measurement of 4mm from apex.

On these digital images, the remaining filling material was calculated as a percentage. In each third, the area around the root canal was cleared out. The total area of the root canal and total area of remaining root filling material were measured in pixel.

Then, the percentage of the remaining root filling material was calculated in each third according to the following equation:[12]

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

Evaluation of the presence of cracks

Root specimens were divided into thirds, soaked in methylene blue dye, and examined for presence of cracks using stereomicroscope at 20x magnification at MIU laboratory. Two operators, blinded to group allocations, assessed images for defects in the apical, middle, and coronal root segments. The evaluation of the dentinal defect was applied in a method previously described by Shemesh et al.[13,14] Defects were categorized as 'No defect' (no cracks), 'Incomplete defects' (lines not reaching the root surface), and 'Fracture' (lines from canal to root surface). Photos were reviewed in sets of 5 to reduce evaluator fatigue. Disagreements were resolved jointly, and results were expressed as percentages.

Working time

Root canal procedures' timing, excluding irrigation, was measured with a stopwatch from the start of instrument introduction to their removal at the working length. The recorded time covered the entire re-instrumentation process, omitting instrument handling, file changes, and irrigation.

Statistical analysis

The percentage of the remaining filling material and the mean time of filling material removal were evaluated and analyzed for all groups. The data of canal wall cleanliness obtained by the stereomicroscope and by direct digital radiographic evaluation, As well as the data concerning the operating time were considered for statistical analysis.

Data were presented as mean and standard deviation (SD) values. A low significance value (p-value less than 0.05) was considered statistically significant. They were explored for normality by checking the data distribution and by using the Shapiro-Wilk test. Data showed parametric distribution and were analyzed using one-way ANOVA followed by Tukey's post hoc test for intergroup comparisons and repeated measures ANOVA followed by Bonferroni post hoc test for intragroup comparisons.

RESULTS

Percentage of the Remaining filling material (%)

Inter, intragroup comparisons, mean and standard deviation values of the percentage of the remaining amount of root canal filling material for different groups and root sections.

The intergroup comparison showed no significant differences between different kinematics as shown in **table (1)**, **figure (2)** and **figure (3).**

In the intragroup comparison, mean and standard deviation values for the percentage of the remaining amount of root canal filling material (%) for different sections within each group as shown in **table (1)**, **figure (3)** and **figure (4).**

According to the stereomicroscopic images, the apical region exhibited the highest percentage of remaining filling material within all groups as shown in **figure (3)** and **figure (4).**

TABLE (1) Inter, intragroup comparisons, mean and standard deviation values of the remaining amount of root canal filling material (%) for different groups.

Section	Remaining amount of root canal filling material (%) (Mean±SD)				p-value
	Rotation with solvent	Rotation without solvent	Reciprocation with solvent	Reciprocation without solvent	
Coronal	20.23±0.59^{Ac}	20.03±0.88^{Ac}	20.48±0.92^{Ac}	21.01±1.29^{Ac}	0.216ns
Middle	22.59±0.68^{Ab}	22.82±2.13^{Ab}	23.31±1.35^{Ab}	23.43±1.73^{Ab}	0.677ns
Apical	24.72±1.27^{Aa}	26.74±2.59^{Aa}	25.89±1.39^{Aa}	25.55±2.08^{Aa}	0.227ns
p-value	<0.001*	<0.001*	<0.001*	<0.001*	

Different upper and lowercase superscript letters indicate a statistically significant difference within the same horizontal row and vertical column, respectively vertical column *; significant (p ≤ 0.05) ns; non-significant (p>0.05).

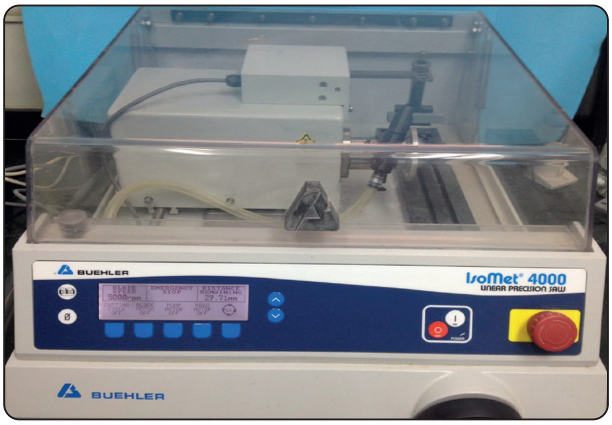

Fig. (1) Isomet machine.

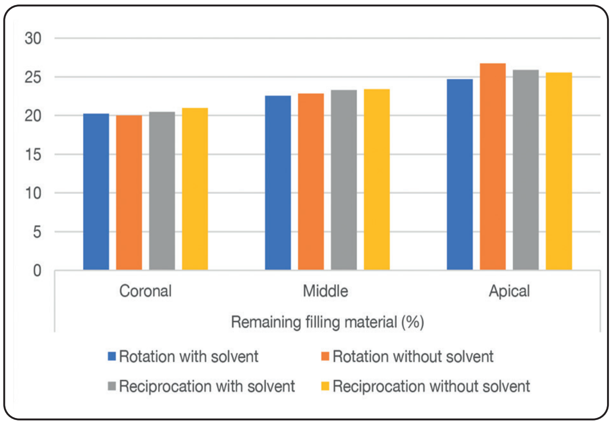

Fig. (2) Bar chart showing mean and standard deviation (error bars) values for the remaining amount of root canal filling material (%) for different groups.

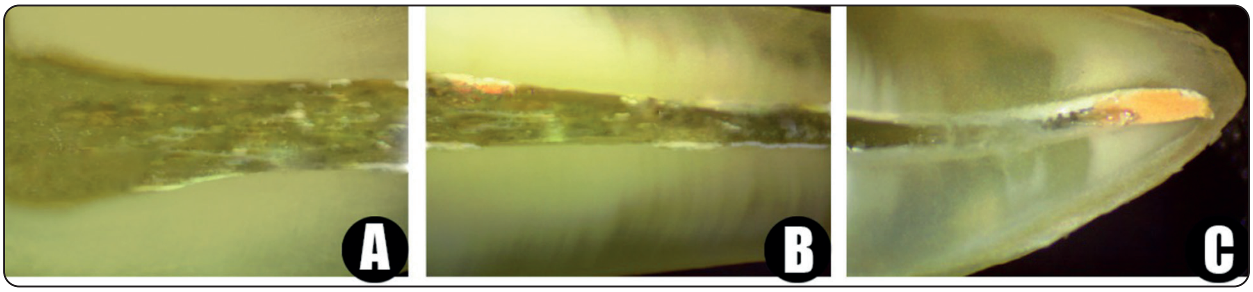

Fig. (3) Stereomicroscopic image for sample..

In the intergroup comparison, no significant differences were detected within the groups as shown in **figure (2).**

In the intragroup comparison, significant differences were detected within each group across the different sections, with higher values generally observed in the apical section as shown in **figure (4).**

After stereomicroscpic evaluation under magnification 20x and the utilization of methylene blue dye, Stereomicroscopic images showed no cracks in the samples from both the control group and the other four groups as shown in **figure (5)**.

Intergroup comparison, mean and standard deviation values of working time (mm: ss) for different groups are presented in **table (2)** and in **figure (6)**. Statistical analysis indicated no significant difference among the various groups (p=0.066).

TABLE (2) Intergroup comparison, mean and standard deviation values of working time (mm: ss) for different groups**.**

Working time (mm: ss) (Mean±SD)				p-value
Rotation with solvent	Rotation without solvent	Reciprocation with solvent	Reciprocation without solvent	
04:3200:39±A	04:2500:43±A	03:5200:28±A	03:5500:25±A	0.066ns

Different superscript letters indicate a statistically significant difference within the same horizontal row *; significant (p ≤ 0.05) ns; non-significant (p>0.05).

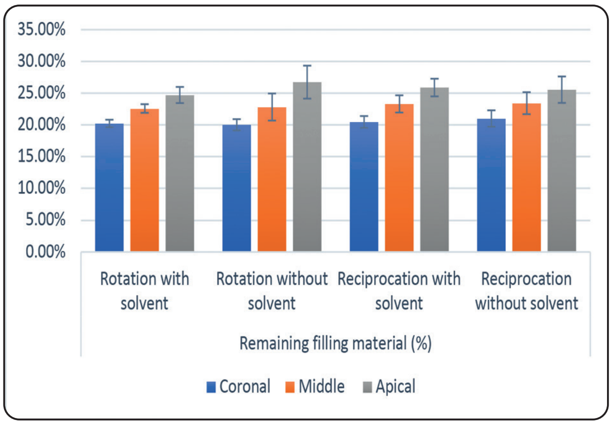

Fig. (4) Bar chart showing mean and standard deviation (error bars) values for the remaining amount of root canal filling material (%) for different sections.

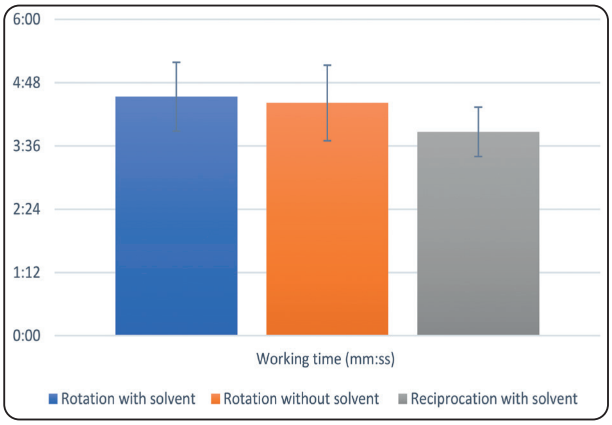

Fig. (6) Bar chart showing mean and standard deviation (error bars) values for working time (mm: ss) for different groups.

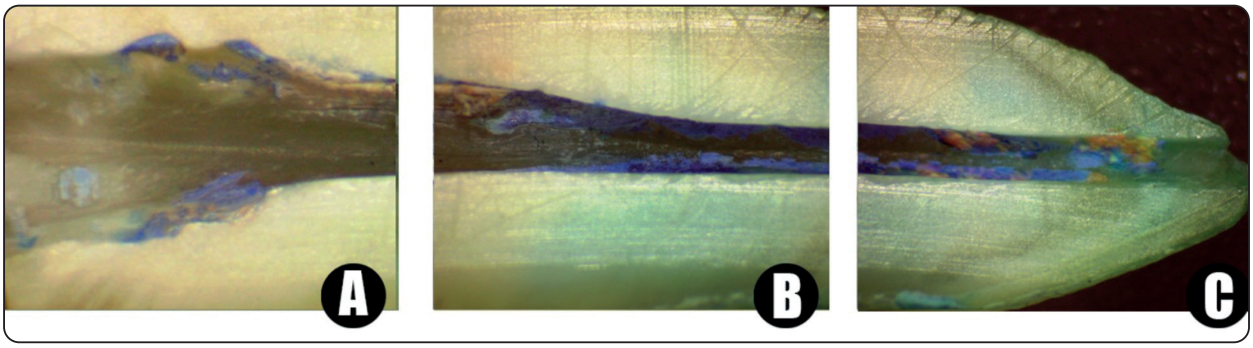

Fig. (5) Stereomicroscopic image for samples showed no cracks.

DISCUSSION

Nonsurgical endodontic retreatment of previously obturated root canals is the initial line of treatment for endodontic failures.[15] The retreatment process tends to have a lower success rate compared to initial root canal therapy due to factors such as the presence of a more enduring intracanal infection with stubborn bacteria, and the challenges associated with the removal of pre-existing filling material to access and eradicate the pathogens.[16]

Mandibular premolars were chosen due to their flattened, bucco-lingually larger shape, making it challenging for endodontic instruments. During retreatment, assessing canal morphology and the quailty of initial root canal filling, especially for oval root canals with limited instrument access.[17,18]

Teeth in the study were intentionally flattened to mimic clinical conditions, enhancing standardization. All specimens were set to a uniform length of 18mm to prevent length-based influences. [19] In contrast to previous studies, crowns were not decoronated at the cemento-enamel junction, acknowledging this deviation from clinical conditions. This ensures more reliable comparisons for retreatment methods. Rotary NiTi instruments are favored over manual files for endodontic retreatments due to reduced operator fatigue and time efficiency. However, they are more prone to file separation while offering advantages such as shape maintenance and shorter working time.[15]

Warm vertical compaction was used to obturate samples with Gutta-Smart cordless obturation system, ensuring effective sealing of oval canals. This technique enhances sealer penetration and minimizes heat exposure for patient safety.[3] CeraSeal, a premixed bioceramic root canal sealer, contains tricalcium and dicalcium silicate, radiopacifiers, and exhibits excellent sealing power with high calcium release and alkalizing activity.[20]

Some studies have used solvents in filling removal procedures, but few have compared removal procedures with and without them. Solvents like organic solvents have been used to soften various endodontic sealers. The use of solvents can aid in easier access to filled canals but may lead to a thin layer of filling material adhering to dentinal walls. In this study, solvents were deliberately excluded in two out of four groups to assess material removability without potential interference.

Different kinematics, including reciprocation and continuous rotation, are used in endodontic retreatment to remove root canal filling material. Reciprocation involves back-and-forth motion, reducing file separation risk, while reciprocating instruments offer flexibility and fatigue resistance. Reciproc Blue files, with heat treatment and superelasticity, follow canal curvature. Continuous rotation aids in precise debris removal.[21,22]

Edge XR retreatment files, made of Fire-WireTM NiTi alloy, improve flexibility and efficiency in retreatment.[23] Various techniques like radiography, digitized imaging, and cone-beam computed tomography are used to assess removal effectiveness, each with its limitations, affecting the precision of estimating remaining filling material.[12,24,25]

This study employed a precise vertical tooth splitting method, enhancing image standardization at 20X magnification. It's a reliable approach compared to 2D radiographs. Care was taken to avoid disrupting filling material during the cleaving process.[12] ImageJ software facilitated accurate measurements of canal and filler areas.[26]

Research comparing continuous rotational motion and reciprocating motion in endodontic retreatment has shown mixed results. In this study, neither technique completely removed root canal filling material. [6] The study found no significant difference between continuous rotation (Edge XR) and reciprocation (Reciproc Blue) with or without solvent. Standardizing file characteristics may have contributed to consistent results.

Diverse studies have shown mixed results in comparing different kinematics for endodontic retreatment. While Nawaf et al.[27] found no significant differences, Obaidi et al.[28] observed that reciprocating motion was more effective than rotational motions. These results could be attributed to the fact that the reciprocating file was utilized with a reciprocating movement involving changeable clockwise and counterclockwise rotations, which followed the reverse balanced force technique.

Interestingly, the use of a solvent in retreatment appeared to have no discernible impact on residual filling material, with both rotational and reciprocating methods yielding similar results.[17]

This study found that the utilization of solvent in endodontic retreatment doesn't significantly affect residual filling material. Both rotational and reciprocation methods yield similar outcomes.

This occurrence in the present study may be attributed to the fact that only a small quantity of eucalyptol was employed exclusively in the coronal third of the canal. Its purpose was to soften the filling material and enhance the ease of instrument penetration. Therefore, the potential impact of softening and dissolution effects may have been restricted in order to prevent the formation of a layer that adheres to the canal walls, thus creating difficulties during the removal process.[4,12]

Colombo et al.[17] conducted a study on the effectiveness of the rotary and reciprocation kinematics for gutta-percha removal, both with and without the use of a solvent. It was suggested that the utilization of a solvent aids in instrument penetration and might contribute to enhancing the overall cleanliness of the root canal system. In contrast, Galal et al.[29], who assessed the efficacy of reciprocating instruments versus continuous rotary instruments during root canal retreatment, with and without the use of a solvent. Their findings suggested that the utilization of a solvent may lead to an increase in residual material within the canals, attributed to the creation of a thin layer that strongly adheres to the canal walls.

In a trial to evaluate the remaining amount of root canal filling materials at different root thirds, the apical section had the greatest scores. The fact that anatomical complexities are larger in the apical third can explain this observation.[27] Furthermore, the middle and apical thirds of the canal showed higher obturating material compaction and penetration, resulting in more debris deposited in the dentinal tubules. [27] It is crucial to be able to clean this area of the canal because it is prone to be affected by more bacteria.

In this present study, an additional contributing factor to consider is that the retreatment files employed had the identical tip size as the files utilized in the initial root canal treatment. However, other research has suggested that for improved cleansing, it is advisable to use larger instruments for re-instrumentation, extending up to the working length, compared to the sizes used during the initial root canal treatment.[30] The coronal third had been thought to be the easiest area to clean during retreatment procedures and to have the lowest debris ratio of all the treatments employed.[25]

Nawaf et al.[27] found in their study that continuous rotational and reciprocation motion techniques for gutta-percha and sealer removal in root canals resulted in the majority of remaining material being in the apical third, followed by the middle third and the least in the coronal third. This was attributed to differences in tip sizes between the instruments utilized for the initial root canal preparation size 30 and those used for canal retreatment size 25. Furthermore, instrumentation and retreatment in this area are challenging due to the greater anatomical variation. In contrast, Matoses et al.[31] reported inconsistent gutta-percha removal across canal regions in straight root canals, with higher amounts in the coronal and middle thirds compared to the apical third, possibly due to the initial canal shaping was performed using ProTaper instruments sized 25/.08, while retreatment involved using files with an apical diameter and taper of 40/.06.

Samples from four groups and a control group showed no cracks, credited to the gentle Isomet machine used for sectioning. Freshly extracted intact teeth from young patients were employed, excluding any with prior cracks. Retreatments in wide oval canals reduced file stresses, and adherence to manufacturer guidelines ensured proper torque and speed. The study's meticulous criteria minimized risks of damage during specimen preparation and procedures.

Pradeepkumar's research,[32] corroborating findings, used micro-computed tomography to assess dentinal microcracks post root canal preparation, finding no significant impact from hand or rotary tools. However, the study's limitation included a narrow age range (15-30 years), and it's important to consider potential variations in root dentin strength in older individuals due to microstructural and chemical changes.

Contrastingly, Ustun et al.[33] who examined reciprocation versus rotational movement's impact on root defects during retreatment. Both nickel-titanium systems, ProTaper F4 and Reciproc R40, led to dentinal defects in extracted premolars. The use of multiple large-tip files induced cracks in root dentin during extensive instrumentation.

The study found no significant difference in retreatment performance between continuous rotation and reciprocation systems, consistent with Yigit et al.[4] who noted no significant differences in retreatment time between reciprocating and rotary systems. The absence of a substantial distinction can be ascribed to its singular file approach. However, Silva et al.[21] reported a faster performance with the reciprocating system, attributed to its use of a single file compared to the four files required by the rotary system.

Research studies, including the current one, found no significant reduction in retreatment time with solvent use.[17] Limited eucalyptol application in the coronal third aimed to soften filling material, potentially restricting its dissolving effects to prevent adherence to canal walls. This constraint might lead to challenges in removal, requiring more time for completion.[12]

CONCLUSION

Within the limitations of this study the following could be concluded;

- Complete removal of root canal filling material from oval root canals has proven elusive using any retreatment kinematic.
- Both kinematics presented a maximum percentage of residual filling material in the apical part of oval root canals compared to the middle and coronal parts.
- Solvents failed to decrease the remaining filling materials and time needed for the retreatment procedure.
- Both kinematics presented no cracks during the retreatment procedure in oval root canals.

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