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Research Article

Effectiveness, Efficiency and Apical Extrusion of Different Instruments in Removing Filling Material During Endodontic Retreatment

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Abstract

Introduction: The key phase in root canal retreatment is removal of the obturation material, which facilitates reinstrumentation, disinfection and refilling of the root canal system. During retreatment, microorganisms, necrotic tissue, filling material or irrigating agents, pushed through the apical foramen may cause postoperative tenderness or periapical lesions. The success of endodontic retreatment may depend on effective removal of filling materials and apically extruded debris.

Aim of the Study: To compare the amount of apically extruded debris, time and efficiency of different endodontic instruments during retreatment.

Materials and Methods: 45 extracted single canal human teeth were instrumented up to 25.08 and obturated with Ah plus sealer and gutta-percha points using the lateral condensation technique. The samples were randomly divided into three groups (n = 15) depending on the retreatment technique: Hedstrom files; Reciproc; ProTaper. Apically extruded debris was collected in pre-weighed Eppendorf tubes and the assessment was performed using an analytical balance. During retreatment the time needed to obtain the working length was measured. The teeth were then split axially into halves and the residual material from the canal walls was evaluated using a stereomicroscope (x40) and graded from 1 (clean canal walls) to 5 (completely covered walls). Data were statistically analyzed using analysis of variance (ANOVA) and Scheffé post-hoc test.

Results: There was no statistically significant difference in the amount of extruded debris between the examined groups. However, the highest amount of apically extruded debris was recorded with the Hedstrom files (0.0046g) and the lowest with the Reciproc system (0.0035g).

The shortest time for the removal of filling material from the canals was found for Reciproc Blue system (110 sec.), followed by ProTaper R (125.5 sec.) but without statistically significant difference. Retreatment by hand instruments needed 229.3 sec., which was significantly longer in comparison to groups 2 and 3. The least amount of residual material was found for Reciproc Blue group, followed by ProTaper group ($p > 0.05$). Hand files group had the most residual filling material on canal walls, which was significantly more in comparison to other two groups ($p < 0.05$).

Conclusion: The research showed that apical extrusion was present in all examined retreatment techniques. The tested rotary systems produced less extruded debris compared to hand files. The fastest and most successful technique was using the Reciproc blue instruments. None of the techniques were able the fully remove the obturation material from the root canal walls.

Keywords: *Debris; Extrusion; Retreatment; ProTaper; Reciproc Blue*

Abbreviations

AP: Apical Periodontitis; NiTi: Nickel-Titanium; NaOCl: Sodium Hypochlorite; PTN: ProTaperNext; CGRP: Calcitonin Gene-Related Peptide; SP: Substance P

Introduction

Root canal treatment can be unsuccessful even when performed under the highest standards. The main cause of treatment failure is bacterial persistence within the root canal system or coronal leakage after treatment [1]. The developement or persistence of apical periodontitis (AP) after root canal treatment has been widely documented [2]. AP is common in the general population, with a prevalence rate of 39% in root-filled teeth [3].

When root canal therapy is unsuccessful, the available treatment choices include conventional retreatment, periradicular surgery or extraction. Decisions should be made based on the clinician's experience and in the patient's best interest [3]. Nonsurgical endodontic retreatment is the initial approach for addressing failed root canal therapy [4]. However, the removal of material from the root canal is a more time-consuming and technically demanding process than the initial endodontic treatment. Gutta-percha combined with an epoxy-resin sealer are considered the gold-standard endodontic materials for root canal obturation. AH Plus is most used because of its good sealing ability and adhesion and low solubility and disintegration [5,6].

The primary objective of retreatment is to restore access to the apical foramen by thoroughly eliminating the root canal filling material, thereby ensuring effective cleaning, reshaping, and proper final obturation of the canal system. It is essential to remove as much sealer and gutta-percha as possible from an inadequately treated and obturated root canal system to expose residual necrotic tissue or bacterial remnants that may contribute to periapical inflammation and treatment failure.

The cleanliness of the canal walls during retreatment is a crucial factor in ensuring the success of the therapy. Residual debris, sealer remnants, or bacterial biofilm adhering to the dentinal walls can serve as a source of persistent infection, hindering periapical healing and leading to further complications. Therefore, effective removal of filling materials and thorough decontamination of the canal walls are essential steps in achieving long-term clinical success.

Complete removal of the obturating material remains unattainable with current retreatment techniques. NiTi instruments were introduced as alternatives to manual techniques for removing filling materials from root canals. They are available in different designs, varying in tip and taper geometry, rake and helical angles, pitch, and the presence of radial lands. Studies indicate that NiTi instruments are efficient, fast and safe [7,8].

During endodontic retreatment, irritants such as filling materials, necrotic tissue, microorganisms, and irrigants may inadvertently be introduced into the periapical tissues [9].

Apical extrusion is regarded as an undesirable consequence of shaping procedures, as it can trigger inflammation, post-operative discomfort, and delay periapical healing [10,11]. The inflammatory reaction caused by debris extrusion depends on the type of instrument used and its motion pattern; however, no instrumentation system currently available can entirely prevent extrusion [12-18].

Rotary nickel-titanium instruments are widely recommended for endodontic retreatment due to their efficiency, speed, and safety. The friction generated during instrumentation softens gutta-percha, facilitating its removal [19].

The ProTaper Next (PTN) system (Dentsply Maillefer, Ballaigues, Switzerland) consists of five instruments made from an M-wire nickel-titanium (NiTi) alloy, which undergoes a thermal treatment process. Its variable taper design enhances both flexibility and strength. During canal preparation, the instruments exhibit a snake-like motion due to their unique design [20].

The introduction of single-file reciprocating systems has offered new possibilities for root canal preparation, with studies suggesting that in certain aspects, they surpass traditional continuous rotary NiTi instruments. Reciprocating movement reduces the stress on the instrument through alternating counter-clockwise (cutting) and clockwise (release) actions, increasing its resistance to fatigue compared to continuous rotation [21,22].

Reciproc Blue (RB; VDW, Munich, Germany) is a single file system designed to be used with reciprocating motion. It is manufactured from an M-wire alloy with special heat treatment. This technology shows increased file flexibility and improved cyclic fatigue resistance [23]. RB file is intended for use in initial treatment and retreatment [24].

Some studies have found that reciprocating motion results in greater debris extrusion compared to continuous rotation, while others have reported the opposite [25-27]. Nevertheless, it is worth noting that motor-driven rotary instruments have been linked to reduced dentinal debris extrusion [14,18].

Aim of the Study

The aim of this study was to compare remaining filling material after retreatment, time required for gutta-percha and sealer removal and examine and compare the amount of apically extruded debris during endodontic retreatment of teeth using hand files and two different rotary systems.

Materials and Methods

Tooth selection

The study was approved by the Ethics Committee of the Faculty of Dentistry (N° 36/6). The study included 45 human single root teeth that were extracted for reasons unrelated to this study. Teeth with calcifications or open apices were excluded, while those with a single apical foramen, fully developed apices, and similar curvatures between 0-10 degrees were included. Digital radiographs in buccal and proximal views were taken to confirm the presence of a single canal. The samples were subjected to cleaning in an ultrasonic bath with sodium hypochlorite for 15 minutes.

The crowns of the theeth were shortened, so the samples were standardized to a length of 21 mm.

Root canal preparation and filling

Access cavities were prepared using high-speed diamond burs under water cooling. Apical patency was verified using a size-10 K-file (Dentsply Maillefer, Ballaigues, Switzerland). The working length was set 1 mm shorter than the point at which the size-10 K-file became visible at the apical foramen. Canal preparation was carried out using the Reciproc Blue system with an R25 file.

During instrumentation, the canals were irrigated with 2 mL of 1% sodium hypochlorite (NaOCl). Once the instrumentation phase was completed, 10% citric acid was applied for one minute to eliminate the smear layer, followed by a final rinse with distilled water. The canals were obturated with gutta-percha and AH Plus sealer (Dentsply De Trey, Konstanz, Germany) using technique of lateral condensation. The access cavities were temporarily sealed using Cavit (Espe, Seefeld, Germany). The quality of obturation was assessed on retroalveolar radiographs. All specimens were stored in a humid environment at 37°C with 100% humidity for two weeks to allow the sealer to fully set.

Experimental design for apically extruded debris

The experimental model used to evaluate debris extrusion is illustrated in figure 1. Small openings were made in the caps of 45 Eppendorf tubes, and teeth were inserted under pressure through these openings, which were then sealed with cyanoacrylate.

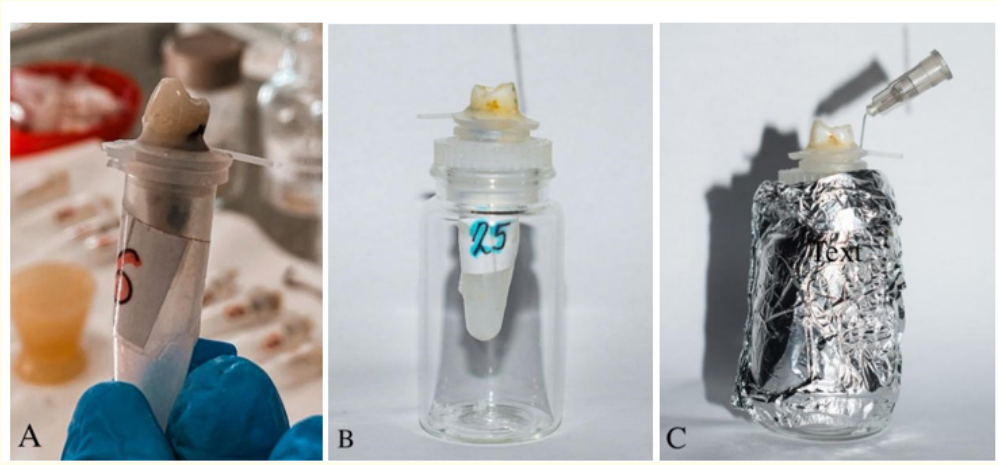

Figure 1: *A: Eppendorf tube with inserted tooth; B: Eppendorf tube placed in glass vial; C: Glass vial wrapped in aluminium foil.*

A bent 27-gauge needle was inserted alongside the stopper to function as a drainage channel and equalize air pressure inside and outside the centrifuge tubes. The Eppendorf tubes were placed within larger vials, and all vials were wrapped in aluminum foil to prevent the operator from visually assessing debris extrusion during the retreatment process. At no point did the technician's fingers come into contact with the interior of the Eppendorf tubes.

Before retreatment, each Eppendorf tube was weighed using a microbalance (Acculab Sartorius Group, Germany). Three consecutive measurements were recorded for each sample, and the average value was documented.

Upon completion of the retreatment, the Eppendorf tubes were removed from their vials. Any debris adhering to the external surface of the root apex was carefully scraped and collected into the corresponding tube. The Eppendorf tubes were then placed in an incubator at 37°C for 21 days to allow moisture to evaporate before weighing the dried debris. The tubes, now containing only dried debris, were reweighed using a microbalance. The same weighing protocol was consistently followed, and the weight of the extruded debris was calculated by subtracting the pre-measured weight of the empty tube from the weight of the tube with the dried debris.

Retreatment technique

The samples were randomly divided into three groups (n = 15) according to the retreatment instruments. Group 1: hand files-Hedstrom files (Dentsply Maillefer); Group 2: Reciproc Blue R40 (VDW Dentsply Sirona); Group 3: ProTaper R (D1-D3) (Dentsply Sirona).

No solvents were used in this study to avoid their influence on the removal of the filling material and the assessment of residues on the root canal walls.

The first group (Hedstrom files)

Hand instrumentation was performed with Hedstrom files from size 40-20, in a circumferential quarter-turn push-pull motion and by pushing against the root canal walls until the working length was reached. The final apical preparation was done with a K#40 file.

The second group (Reciproc blue)

Reciproc Blue R40 (40/.06) instrument was used with pecking movements until the working length was reached.

The third group (ProTaper)

ProTaper Retreatment instruments were used. D1 file was used for removing filling material from the coronal portion of the root canal. Material from the middle and apical thirds was removed using D2 and D3 files, respectively, with a brushing action and lateral pressing movements. D3 (20.07) was taken to the working length. The final apical preparation was done with the ProTaper X4 (40.06) instrument.

Throughout the procedure, 2 mL of 1% sodium hypochlorite (NaOCl) was used for irrigation after each instrument change. After retreatment, all teeth were radiographed again.

Time for retreatment

To calculate the total time required for retreatment, a stopwatch utilized. When the instrument was removed from the canal, the stopwatch was stopped, then restarted, and the instrument was reintroduced into the root canal. The total time for removing the filling material was defined as the time elapsed from the moment the instrument was first inserted into the root canal to the moment the working length was reached.

Canal wall cleanliness

Grooves were formed on the vestibular and oral surfaces of the roots using a turbine and round diamond bur, after which the teeth were split into halves along the longitudinal axis using a chisel and hammer, so that the root canal walls were accessible for analysis under a stereomicroscope with an integrated digital camera (Boeco BSZ-405, Germany) at x40 magnification. Digital images were saved in JPG format for further analysis and processing in the appropriate software program (Scopeimage 9.0 software; Telescope, Austria). The remaining filling material (mm^2) in the coronal, middle, and apical thirds was evaluated according to the Hulsmann [28] scoring system (1-5):

1. Canal walls are clean
2. Minimal or sporadic traces of material
3. Presence of material on less than 50% of the canal walls
4. Presence of material on more than 50% of the canal walls
5. Entire canal wall is covered with filling material.

Results

The amount of the extruded debris

The Reciproc group produced less extruded debris than the ProTaper and Hedstrom-file groups, but there was no statistically significant difference in the amount of extruded debris between the examined groups ($p < 0.05$) (Figure 2). However, the highest amount of apically extruded debris was recorded with the Hedstrom files (0.0046g) and the lowest with the Reciproc system (0.0035g). During retreatment, one perforation occurred with Hedstrom files.

The percentage of the remnants of root canal filling

No instrument was able to remove all obturation material from the root canal (Figure 3-6). The least amount of residual material was found for Reciproc Blue group, followed by ProTaper group ($p>0.05$). Hedstrom files group had the most residual filling material on canal walls (Figure 3), which was significantly more in comparison to other two groups ($p>0.05$).

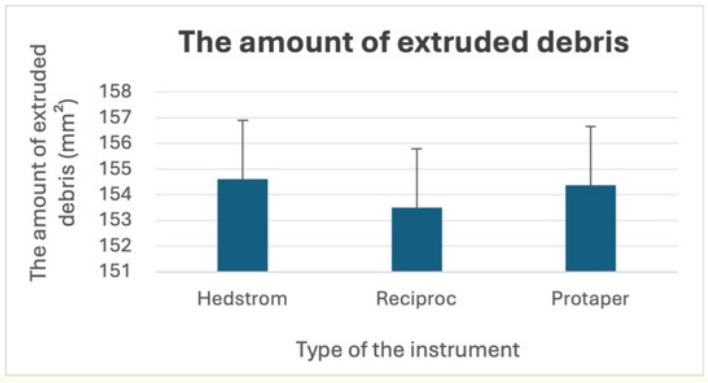

Figure 2: *Comparison of the extruded debris between the different groups.*

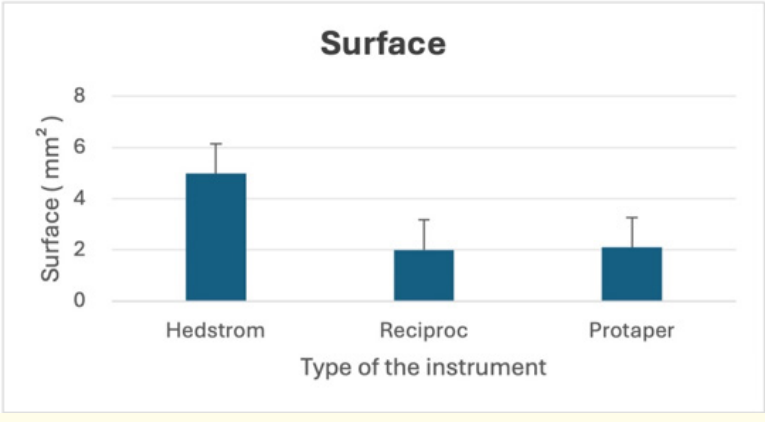

Figure 3: *Comparison of residual material between the different groups.*

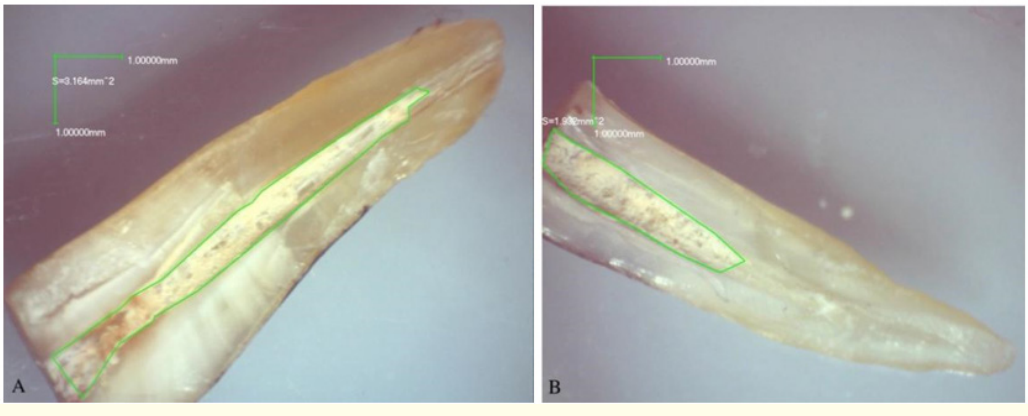

Figure 4: *ProTaper group had the most residual filling material on canal walls.*

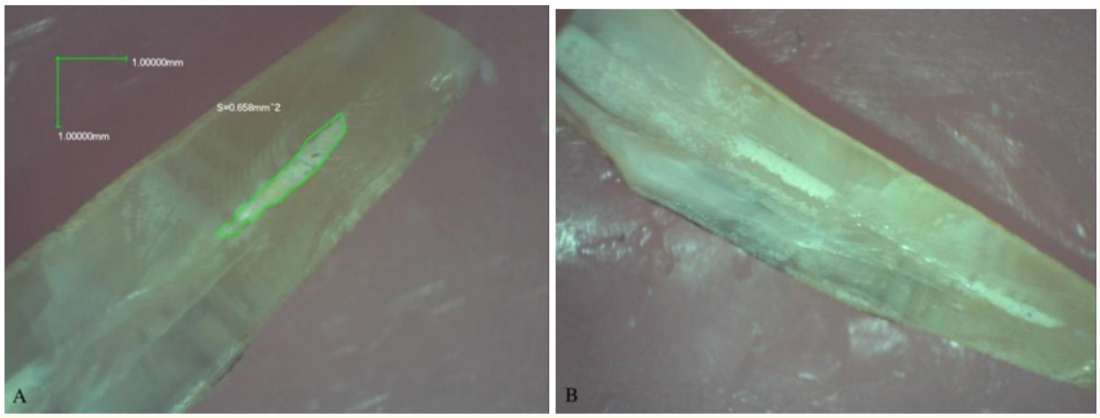

Figure 5: *The least amount of residual material was found for Reciproc Blue group.*

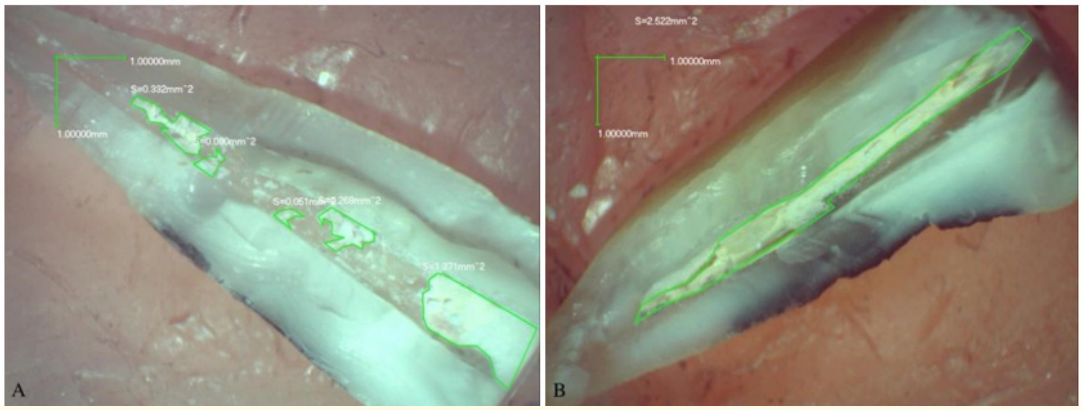

Figure 6: *Residual filing material on canal walls in the Hedstrom files group.*

Time for retreatment

The mean time to reach a working length was significantly longer in Hedstrom file group (229.3 sec.) than in other groups ($p>0.05$) (Figure 7). The shortest time for the removal of filling material from the canals was found for Reciproc Blue system (110 sec.) followed by Pro Taper R (125.5sec.) but without statistically significant difference ($p<0.05$).

Discussion

Apically extruded material is clinically associated with postoperative inflammation, flare-ups, and in some cases, failure of apical healing [9]. The extent of debris extrusion is influenced by several factors, including working length, tooth anatomy, file size, instrument type, and instrumentation technique [8,9,14,26,27].

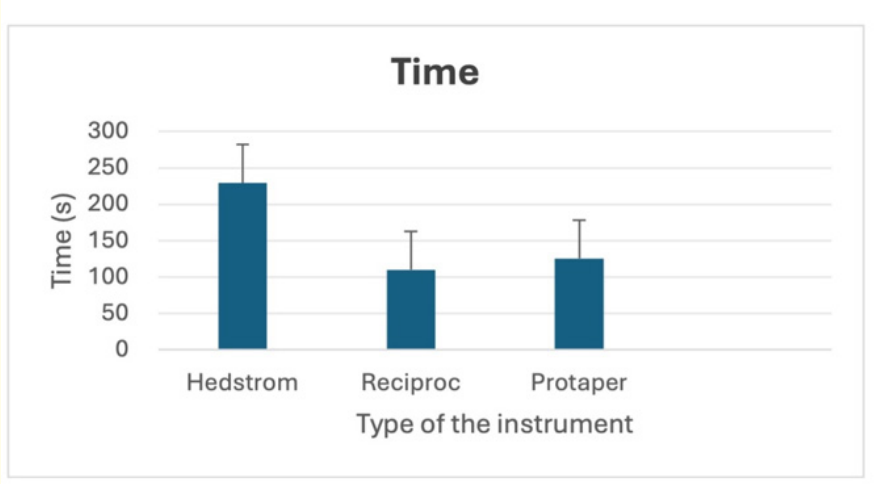

Figure 7: *Comparison of the times required to complete retreatment between the different groups.*

Studies have demonstrated that limiting the working length to 1 mm short of the apical foramen can significantly reduce the amount of extruded debris [29,30]. Tanalp and authors confirmed that instrumentation extending into the apical foramen results in substantially greater apical debris extrusion compared to instrumentation that remains 1 mm short of it [14].

When using extracted teeth *in vitro* studies, the absence of periapical tissues eliminates natural resistance, increasing the likelihood of debris extrusion. Therefore, in this study, the working length was maintained at 1 mm short of the apical foramen. However, these findings may not be directly applicable to clinical scenarios. Some studies suggest that using materials that simulate periapical tissues, such as agar, alginate, or floral foam, may absorb some of the debris and thus underestimate actual extrusion levels [31,32]. Such materials were not utilized in this study.

The selected tooth type also plays a crucial role in influencing debris extrusion. In this study, teeth were carefully chosen based on their type, canal size, and curvature, ensuring that only the instrument design affected the amount of debris extruded.

Our results align with previous studies showing that rotary NiTi instruments extrude less debris during retreatment compared to manual instrumentation with Hedstrom files [27,33]. This may be attributed to the early flaring of the coronal portion when using rotary instruments, which enhances control during preparation of the apical third. Additionally, the rotational motion of NiTi instruments directs debris coronally rather than compacting it within the canal, unlike Hedstrom files, which remove gutta-percha in small increments. The greater apical debris extrusion observed with manual instrumentation could be due to the piston-like action of the file in the apical third, which pushes debris beyond the foramen while leaving limited space for coronal flushing [27]. Reddy and Hicks indicated that the step-back technique resulted in significantly greater debris extrusion compared to engine-driven instrumentation [33]. Based on the findings, all retreatment techniques resulted in apical debris extrusion; however, rotary NiTi systems were associated with lower extrusion levels than manual instrumentation.

All file motions contributed to some degree of apical debris extrusion. Some researchers have suggested that reciprocating motions with 150° counterclockwise (CCW) and 30° clockwise (CW) or 270° CCW and 30° CW movements are linked to less debris extrusion compared to continuous rotation [26]. Conversely, other studies have reported that full-sequence rotary instrumentation results in less extrusion compared to reciprocating single-file systems [30,34]. The increased debris extrusion observed with reciprocating systems may be attributed to the substantial volume of dentin removed in a short time, as well as the reciprocating motion's tendency to compact debris toward the apical foramen [22].

Apical debris extrusion has been implicated as a contributing factor in symptomatic apical periodontitis, as it triggers the release of neuropeptides in the periodontal ligament. *In vivo* studies support this by demonstrating increased neuropeptide expression as a response to post-instrumentation irritation. Specifically, elevated levels of Substance P (SP) and Calcitonin Gene-Related Peptide (CGRP) have been observed following the use of ProTaper Universal and WaveOne, both of which share a similar triangular cross-section, active or semi-active tips, and a large central mass [34]. In contrast, instruments like Mtwo and Reciproc, which feature S-shaped cross-sections, non-active tips, and a reduced core mass, exhibit neuropeptide expression levels comparable to baseline values in the periodontal ligament [1,27,31]. This suggests that differences in instrument design may influence the degree of neuropeptide release. However, it is essential to recognize that neuropeptide expression is not solely attributable to debris extrusion. Other factors, including motion type, instrumentation speed, and additional inflammatory responses within the periodontal ligament, can contribute to symptomatic apical periodontitis.

Further laboratory studies with rigorous bias control, along with *in vivo* investigations quantifying inflammatory mediators, are required. Such studies should establish a stronger correlation between apical debris extrusion and inflammatory processes in the periodontal ligament, ultimately improving our understanding of the causes of symptomatic apical periodontitis.

In this study, a stereomicroscope (X40) was used to monitor the effectiveness of instruments for removing previous fillings. This is one of the numerous techniques and methods used to track the amount of residual material in the canal. A longitudinal cross-section of the root was found to be better than the two-dimensional representation obtained by radiographic techniques [35-38]. This study also observed that retroalveolar radiograph after retreatment indicate a well-cleaned canal, but under the microscope, a large amount of residual material was visible on the canal walls. As previously emphasized, the study included teeth with a simple canal system for easier standardization of samples. However, no technique was able to completely remove the filling material, as shown by numerous studies [24,37,39,40].

Although Reciproc Blue instruments were not initially designed for retreatment, the manufacturer recommends them because their special design and reciprocating motion probably present a potential benefit for removing filling material [41-43], which this study confirmed, as there was no statistically significant difference compared to ProTaper instruments for retreatment. This has also been confirmed by other studies [38,44]. It is important to note that apical patency was re-established in all samples in this study. In this study, the Reciproc Blue instrument was the most efficient with an average rating of 2.1 according to Hulsman's methodology [28], compared to ProTaper R (2.7), but without statistical significance. Reciproc Blue was also the most effective in removing material in the apical third. Similar results were found by Iriboz., *et al*. and DeDeus., *et al.* [41,42]. Numerous authors emphasize the necessity of processing the apical third with an instrument two sizes larger than the primary preparation to control infection and prevent apical periodontitis, while also ensuring that the root's resistance is not weakened and to prevent vertical fractures [35,40,42,43,47]. Roggendorf., *et al.* emphasize that removing residual material increases 10-20 times if the canal is further processed with two additional instruments [45]. Mechanical resistance of the root, besides excessive apical processing, is also compromised during canal preparation with NiTi instruments. It has been observed that reciprocating systems create defects/cracks in the root dentin more than the ProTaper R system, while such damage was not observed when using hand instruments. To reduce pressure and the danger of crack propagation, passive obturation techniques are recommended, such as the monoconical technique with tapered gutta-percha, which was used in this study [46].

The Hedstrom file, with a rating of 3.9, was the least efficient in root canal retreatment. This result aligns with other research [46]. One-third of the samples were rated 5 (almost the entire root was covered with sealer and/or gutta-percha). Residual material on the walls was observed in all thirds of the root. Hand instruments were found to be the least effective in other studies as well, although some studies used solvents [39,41, 6], while others did not [36]. In the present study, no solvent was used to prevent any interference with the removability of the sealers and its evaluation. Some studies emphasizes that the efficiency of hand instruments is comparable to that of ProTaper R instruments [35,40]. Surprisingly, in the ProTaper R group, the most residual material was observed in the middle third of the root, while other authors underline the coronal third [38]. The inefficiency of instruments for processing and cleaning canals is often explained by the mismatch of the round cross-section of NiTi instruments with the diverse internal morphology of the canals, such as oval canals, making enhanced and activated irrigation more significant [42]. For efficient removal of residual filling from the canal walls, it is often necessary to combine techniques and materials. Rodig., *et al*. [40] emphasize that the ProTaper R D3 instrument has a tip size of 20 with a 0.07 taper and cannot adequately clean the apical part without additional instrumentation. Abramovitz., *et al.* emphasize that using SAF after ProTaper R significantly reduces the amount of residual filling [48], while Aksel., *et al*. XPEndo Finisher [41,47]. An adequate is also the combination of rotary files for initial gutta-percha removal and Hedstrom instruments with a larger diameter than the primary apical preparation [36].

Retreatment is a long and demanding process, often determined by the therapist's ability, patience, and the motivation of the patient. The use of rotary systems has greatly facilitated this process. Except for being the most efficient, Reciproc Blue instruments were significantly faster than Hedstrom files at removing the filling material from the root canals. This is consistent with other research [24,41,49].

Conclusion

Owning the limitations of this study the Reciproc instruments subjected to blue thermal treatment, which is a procedure that improves the flexibility of the instrument, were associated with less debris extrusion during retreatment procedures.

They were also the most efficient and the fastest in removing the root canal filling material.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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