A comparison of effectiveness of conventional and rotary NiTi instruments in the removal of Gutta-Percha during root canal retreatment: a randomized ex-vivo study

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Abstract:

Aim: To compare the effectiveness of conventional and rotary NiTi files in the removal of Gutta-Percha (GP) in straight roots during root canal retreatment (reRCT), using manual Hedstorm files (H-files) and ProTaper Universal Retreatment System, respectively.

Methods: It was an ex-vivo study using non-probability consecutive sampling. *Sixty* extracted single rooted maxillary and mandibular permanent anterior teeth, with straight canals were selected for this study. Following preparation, the root canals were filled with GP along with a sealer and kept for two weeks in a moist environment at room temperature. Thirty teeth were randomly allocated to the study and control groups each. GP removal was accomplished with Hedstrom files and ProTaper retreatment files in group 1 and group 2, respectively. Digital radiographs were obtained using Carestream (Kodak) RVG digital radiography system software version VER.6.10.8.3-A and analyzed for the difference of opacities representing residual GP. AutoCAD 2006 software was used to outline the root canal and the residual root filling. Independent sample t test was used to compare the total residual GP in both groups.

Results: No significant differences in the residual root filling were observed between GP removal with conventional Hedstrom files and ProTaper universal retreatment files. In both groups, the residual GP was confined to the apical third of the roots.

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Conclusion: ProTaper Universal Retreatment files and manual Hedstrom files are equally effective in the removal of GP in straight canals.

Keywords: Endodontics, Gutta-Percha ; Retreatment. Root canal

Introduction: Root canal treatment (RCT), also called endodontic treatment, involves removal of diseased or damaged dental pulp (core) of a tooth followed by instrumentation and filling of the root canals to achieve an apical seal.[1] Although root canal therapy has a high success rate in contemporary dentistry, failures may results from a variety of causes including but not limited to poor assessment (such as, inadequate crown structure, root caries, inadequate periodontal support, endo-perio lesions), anatomical variations (such as, accessory canals, pulp calcifications, root dilaceration, accessory roots, and open apex) and errors in access opening (inadequate access or gross destruction of tooth structure), instrumentation (such as inadequate cleaning and/or shaping, iatrogenic canal perforation, and instrument separation) and root filling (such as inadequate apical seal, underfilled or overfilled root canals, and inadequate coronal seal).[23] However, presence of micro-organisms in the root canal system and peri radicular tissues is a fundamental reason underpinning various causes of root canal treatment (RCT) failure [4].

Depending on individual factors which contribute to RCT failure, the management options include retreatment[5], surgical endodontics[6] or extraction as a last resort. A non-surgical root canal retreatment is, to-date, the preferred treatment option in contemporary endodontics, as it preserves the tooth, is more conservative, and minimizes the morbidity and complications associated with surgical endodontics. A primary objective of retreatment endodontics is to minimize bacterial contamination of the root canals. Complete removal of the existing root filling is required to facilitate cleaning and debridement, and placement of new root filling three dimensionally.

Gutta-Percha(GP) is the most commonly used root canal filling material. Its removal can be achieved with a wide range of instruments such as hand files[7], engine driven rotary files, ultrasonic tips and files, solvents and heat carriers etc.[8]

Traditionally, Hedstrom (H) files in combination with K type files have been used for the removal of GP from the root canal, facilitated by solvents such as, chloroform, eucalyptol[9], xylene, halothane, and solvents such as, turpentine[10,11]and orange[11]. Hedstrom files are milled from round stainless-steel blanks. They are recognized as efficient instruments for translational strokes and effective dentine cutting. They have been used in endodontics for removal of separated instruments[12] from the root canal and also for retrieval of fractured root tips. Their sharp cutting ability makes Hedstrom files useful for the retrieval of GP from the root canal while as part of retreatment[13].

ProTaper is a unique multipurpose universal system marketed for shaping, finishing and retreatment with a changing taper over the full length of the cutting blade. Extending from the tip to the end of the cutting flutes, the shaping files have an increasing taper while the finishing files show a decreased taper from the tip to the opposite end of the instrument.

The ProTaper Universal Retreatment system consists of three retreatment files[14] (D1, D2 and D3). They are convex in cross section, with taper/ tip diameter of 0.09/0.30, 0.08/0.25, and 0.07/0.20 mm, respectively. D1 is designed for use in the coronal portion of the canal, with a length of 16 mm, D2; for use in the middle third, with a length of 18 mm, while D3 is designed for use in the apical third of the canal, with a length of 22 mm. The D1 file features an active tip for easy engagement of the obturation material, while D2 and D3 feature a non-active rounded tip adapted to closely follow the root canal lumen.

A variety of methods have been used to assess the efficacy of various instruments for removal of root filling materials. The most commonly used technique is radiography[15] since it is non-invasive, quick and easy. However, radiographs only offer two-dimensional images of three-dimensional objects. These limitations can be mitigated by cone-

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beam computerized tomography (CBCT)[16] or by obtaining simultaneous radiographic images from bucco-lingual and proximal views. Digital radiography is preferred over the conventional radiographic system because it has the advantage of yielding an immediate view, which offers improved resolution, is timesaving, and minimizes problems associated with chemical processing of radiographic films.

Longitudinal sectioning prior to photographic or microscopic analysis has also been suggested previously[17]. Although direct visual access to the root canal is achieved, tooth sectioning may be unpredictable and may disturb the root structure. Clearing of the teeth by demineralization has been commonly employed in previous studies and entails the use of chemicals such as, nitric acid. Once processed, the teeth are rendered transparent and this method appears to be cost effective, and suitable to identify small areas of residual root filling material and sealer. The amount of residual material can be quantified by capturing an image and taking measurements using a computer software[18]. However, clearing teeth is time consuming and it may result in the degeneration of certain root filling materials and sealers and thus affecting the accurate analysis.

Other methods like projection of photograph onto a screen, stereomicroscopy, scanning electron microscopy[19], evaluation of digitalized images using a scanner[20], micro computed tomography (MCT)[21] and computed tomography (CT)[22] have also been used in many studies. The development of newer tomography techniques such as MCT allows for a more effective means of assessing the residual root filling materials in the canals as the exact remnants can be determined in a noninvasive three dimensional way and then quantified using a computer software.

The present study was aimed at comparing the effectiveness of manual Hedstrom files with the ProTaper Universal Retreatment files in the removal of GP during endodontic retreatment.

Materials and Methods: Riphah International University's institutional Review Board exempted this research for oversight. A sample consisting of 60 permanent human anterior teeth with straight, single roots and canals were collected, which were extracted for non-study related purposes. Teeth extracted due to unrestorable periodontal disease, as well as orthodontic and prosthodontic prescriptions were collected at the Oral Surgery Department of Riphah University's Islamic International Dental College & Hospital. There was no gender or age specification for the teeth collected. All the teeth had fully formed apices. Teeth with curved roots were excluded. Also, teeth with intra canal calcifications/obstructions, internal resorption, previously treated teeth and teeth with root caries were excluded from the sample.

All teeth were prepared by a single experienced endodontist. The teeth were decoronated at the cementoenamel junction using a high-speed air turbine, leaving 15-16 mm of the root. Root canals were cleaned with a size 15-K (Dentsply Maillefer, Ballaigues, Switzerland) type file and 1% sodium hypochlorite (NaOCl) until the apical foramen was negotiated. The anatomical length of the root canal in each tooth was recorded, followed by establishing the working length.

The canals were prepared with a step-back technique to a size 40 K files (Dentsply Maillefer, Ballaigues, Switzerland) at working length at the apex, stepping back with subsequent K file instruments (45, 50, 60). A Positive Pressure irrigation with 1% NaOCl was conducted with an irrigating needle placed 3 mm shy of the working length followed by recapitulation with a 15 K file to the working length after the use of each file. Irrigation with 2 mL of 1% NaOCl was used before moving to the next file. Following completion of root canal instrumentation, 17% Ethylene Diamine Tetra acetic Acid (EDTA) gel was applied for 3 minutes for removal of the smear layer. The canals were flushed again with 1% NaOCl before drying with paper points. The root canals were obturated with GP(DiaDent®) and an AH plus sealer® (Dentsply Sirona USA) using warm vertical technique using System B® (Kerr Dental) for apical part of the canal and obtura II® (Obtura Spartan)

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as back fill. The roots were stored in a damp gauze for 2 weeks at 37˚C to facilitate setting of the sealer.

The teeth were randomly allocated to two groups with 30 specimens in each group, based on tables of random numbers. GP removal was conducted with either Hedstrom files (control group) or ProTaper files (experimental group) employing chloroform as a solvent. For group I, The removal of GPwas completed using 25 to 40 Hedstrom files (Dentsply Maillefer, Ballaigues, Switzerland). In the second group, ProTaper Universal Retreatment files (Dentsply Sirona) in an electric motor were used for the removal of GP.

Evaluation

Digital radiograph of each tooth was taken from the bucco-lingual and proximal direction and each tooth was analyzed for the difference of radio opacity indicating residual GP by the same operator. Kodak RVG digital radiography system using Kodak dental imaging software version VER.6.10.8.3-A was done at the end of the last file used in the canal, to look for any radio opacity, which showed the remnants of the root filling material. The root canal and residual filling material was outlined using AutoCAD 2006 software by a trained operator.

Removal time was recorded using a stopwatch. The stopwatch was started with the use of first instrument for removal of GP and stopped when the instrument was finally withdrawn after GP removal was considered complete.

Data Analysis

Data were entered and analyzed using SPSS Statistics software (IBM) package V25. Mean ± SD was calculated for residual GP in coronal + middle + apical = total for both groups in both the bucco-lingual and proximal directions. Independent sample t-test was used to compare the total residual GP. P value < 0.05 was regarded as significant

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Results

The mean length of root canal in both groups combined was 15.005 mm ± 0.34 mm (Table 1). There was no statistically significant difference (p>0.5) between the two groups.

Table 1: Root lengths of the teeth (mm)

Groups	Mean (mm)	Standard deviation
Group 1 (Hedstrom)	15.03	0.30
Group 11 (ProTaper)	14.98	0.38
Total	15.005	0.34

Evaluation of residual root filling material

Complete removal of GP from the root canals was not achieved with either of the two techniques. No residual GP was observed in the coronal and middle thirds of the root canal in either group. The residual GP was confined to the apical third of teeth in both groups. The mean percentage volume of the residual GP imaged in bucco-lingual (Figure 1) and proximal direction (Figure 2) was higher for the manual Hedstrom files than for the rotary NiTi ProTaper retreatment files. These results are summarized in Table 2. However, the differences between the two groups were not significant (p>0.5).

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Table 2. The percentage volume of residual root filling material recorded on bucco-lingual and proximal radiographs (mean ± SD).

Groups	Bucco-lingual		Proximal	
	Mean	*S.D*	*Mean*	*S.D*
Hedstrom files	1.86	3.09	0.86	1.73
ProTaper files	0.11	0.47	0.06	0.23

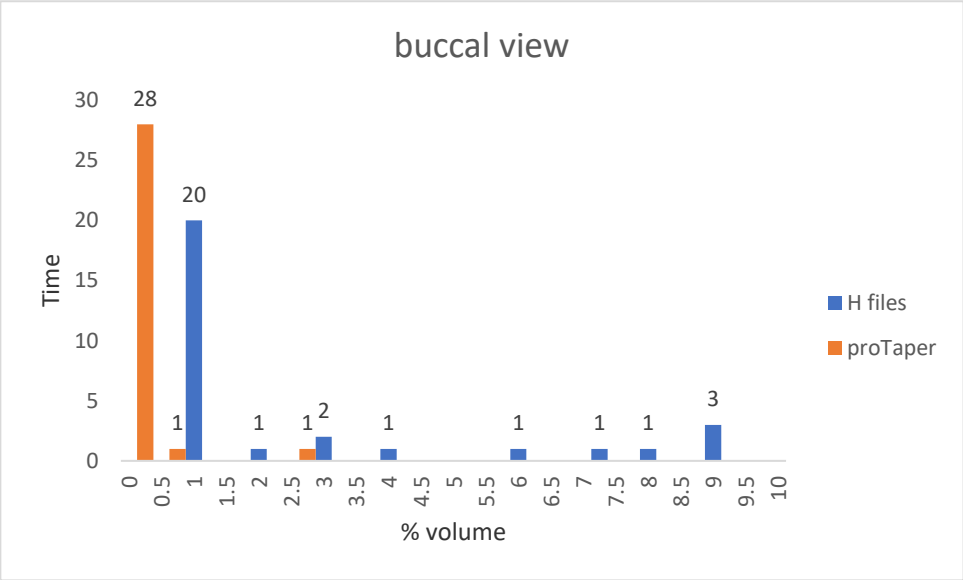

Figure 1 Mean percentage volume of the residual GP imaged from a bucco-lingual direction

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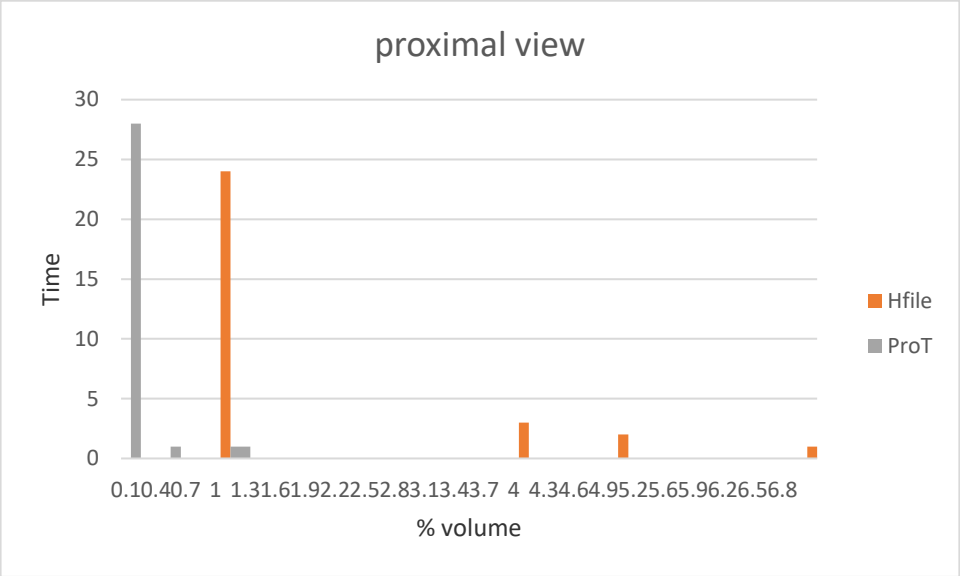

Figure 2. Mean percentage volume of the residual GP imaged from a proximal direction.

Removal Time

Hedstrom files took more time for the removal of filling material as depicted in Table 3. However, the differences between the study and control groups were not significant (p>0.5)

Table 3. Time required for the removal of root filling material .

Groups	**Time (minutes)** (Mean ± SD)
Hedstrom files	8.93 ± 1.18
ProTaper files	6.18 ± 1.32

Procedural errors

For all groups, none of the NiTi rotary instruments or hand files showed intracanal failure or visible signs of plastic deformation. Furthermore, no perforations, blockages or ledging were recorded for both the groups.

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Discussion

Despite being a difficult and time-consuming procedure, endodontic retreatment is undoubtedly the first choice for the management of endodontic failures when access to the root canal is possible. Removing the old filling material is important to reach the remnants of necrotic pulp or bacteria that may be responsible for periapical infection. [21]

In endodontic retreatment, it is important to remove gutta-percha and sealer efficiently followed by adequate canal re-instrumentation. These steps ensure better access to the necrotic tissue remnants and microorganisms responsible for causing persistence of periapical inflammation. However, previous studies have reported that it is not possible to achieve completely clean canal walls with any of the techniques. [23]

The purpose of this study was to compare the effectiveness of a conventional method against the rotary NiTi retreatment files system for the retrieval of GP from the root canals during the retreatment procedures. In spite of the procedural challenges and time required, endodontic retreatment is still widely considered the preferred option for the management of endodontic failures[24]success rates for retreatment procedures vary anywhere from 40% to 100%.[25]

The difference in the outcome of endodontic retreatment results depends on several factors like, the age of the patient, types of teeth being treated[26], altered anatomy of same teeth in different individuals, the seal of the coronal restorations[27], the possibility of removing the coronal restorations to access pulp chamber, the techniques used to remove the existing filling materials, and the possibility of repairing defects; iatrogenic or pathologic.

Removal of existing root filling material is essential to gain access to the remnants of necrotic pulp or bacteria that contribute to periapical infection[28,29]. Although there are various types of root canal filling materials, e.g. Resilon, SmartSeal, which seal the root canals three dimensionally, Gutta-Percha still remains the most popular choice among endodontists for root canal filling.

GP is by far the most widely accepted root filling material over the decades and therefore, the bulk of studies was on the removal of this material. GP is a thermoplastic root canal filling material in conjunction with various sealers[30]. Gutta-percha root filling material has been placed using either lateral condensation, with or without the application of heat. Access to residual necrotic pulp remnants and microorganisms warrant efficient removal of GP and sealer followed by appropriate canal re-instrumentation. [31] However, previous studies have reported that none of the available techniques ensure complete cleaning of the root canal walls.[16],[32]

In present study, decoronation of the teeth was done at the cementoenamel junction leaving 15 – 16 mm of roots. Although decoronation does not simulate retreatment in clinical conditions, it allows specimen standardization by controlling variables, such as crown morphology, and access to the root canal, thus providing a more reliable comparison of different techniques for retreatment endodontics.

Measuring instruments for this study were standardized and the procedures performed by the same operator to eliminate operator-dependent confounders. The use of NiTi rotary retreatment files activated by a 200-rpm low-speed electric motor with low torque was established according to the manufacturer's protocol. These factors enhance tactile feedback and minimize the risk of file separation.

A variety of techniques have been employed to evaluate the removal of root filling materials experimentally. The most commonly employed technique is the radiographic assessment[33, 34], as for the present study. Radiography is noninvasive, quick and easy. However, dental radiographs are not suitable for to distinguish sealer from the GP and can be distorted by magnification during assessment. These limitations were addressed by exposing radiographs from both the bucco-lingual and proximal views. However, the subjective nature of evaluation and variations in observer performance can be a source of bias. Therefore, digital images were evaluated with the aid of AutoCAD 2006 software for reliable quantification of residual filling material.

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Sectioning of the root and subsequent evaluation is more accurate in detecting residual root filling material. Residual root filling material left *in situ* will result in an over optimistic impression about the efficacy of the removal procedure.[15] On the contrary, radiography avoids the need for longitudinal sectioning, during which sealer or root filling material may be lost.[35] Tooth sectioning may be unpredictable and may disturb the root structure. Nevertheless, direct visual access to the root canal is achieved. In an attempt to improve the reliability of assessing residual GP, some studies have combined both radiographs and longitudinal sectioning.[36] Another commonly employed method is to 'clear' the teeth by demineralization in, for example, nitric acid prior to assessing the residual root filling material. Once processed, the teeth are rendered transparent and this method appears to be cost-effective, non-invasive and sensitive enough to identify small areas of residual root filling material and sealer on the canal walls[37]. The amount of residual material can be quantified by capturing an image and taking measurements using computer software. However, clearing teeth is time consuming. Only the residual volume of material is measured, and the chemicals used may result in the degeneration of certain sealers and root filling materials, thereby distorting accurate analysis.[38]

To quantify the amount of residual filling material and hence the efficacy of the removal technique, different scoring systems have been used. Hülsmann and Stotz[39] have devised scores for assessing residual material after longitudinal sectioning. A root canal is divided into coronal, middle and apical sections and the residual material placed into six different categories, ranging from complete removal to several residual (gutta-percha) masses greater than 2 mm. Others have used similar scoring systems with fewer categories, such as severe (>75%), moderate (50-75%), mild (25-50%) or no residual debris (0-25%)[19]. Unfortunately, analysis of sectioned teeth is also a time consuming process. It does not provide an idea about the volume of the residual root filling material and it can not detect whether the canal is transported as a result of retreatment procedures, which influence outcome.[40]

The development of newer computed tomography techniques allow for a more effective means of assessing the residual root filling material in the canal as the exact remnants can be determined in a non-invasive, three dimensional way.[22] . This is then quantified using computer software. This technique overcomes many of the deficiencies of other assessment techniques in that it measures the volume of residual material, and the tooth can be scanned before and after retreatment to determine the effect of removal procedures on canal morphology. This technique; though the best, was not used because of the unavailability of the required equipment.

The choice of using a solvent in this study was informed by the existing literature and the clinical relevance to simulate current clinical practice. The relative efficacy of various solvents has been investigated extensively[41]. Solvents have been advocated for many years to soften GP and facilitate its removal. Historically, chloroform has been the solvent of choice for GP due to its proven effectiveness[42]. However, cytotoxicity and potential carcinogenicity remain major concerns especially following its extrusion into the periapical tissues. In order to explore less-toxic alternatives, several other solvents have been used. The removal of root filling with rotary NiTi files with or without a solvent has also been reported.[43] For the purpose of this study, chloroform was used in the coronal third of the canal for 5 minutes before inserting the endodontic instruments for retrieval of the GP filling material.

Although the present study did not show significant differences between the two groups, other investigations have found that the rotary instruments can be used to prepare cleaner dentine walls when compared to manual techniques[44]. Hullsman and Blum found a lower volume of residual filling material in the middle and apical thirds when using ProTaper and Flexmaster files compared to hand instruments.[45] When considering the root canal thirds separately, a higher percentage of filling material was found in the apical third. This is consistent with the findings of other studies[46] as observed in both radiographic and microscopic analysis of samples and underscores the view that the apical third is a critical zone which requires meticulous instrumentation.

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Although teeth with a single, straight root may be chosen to reduce variables, considerable variations may still be encountered in root canal anatomy making strict standardization difficult. Therefore, removal of coronal portion of the root to achieve a consistent root length for instrumentation and obturation seems appropriate. To better simulate clinical conditions, a uniform temperature (37°C) and humidity (100%) were maintained during storage of the sample following obturation.[21]

Extracted teeth have been used to assess residual GP in most studies . However, in one study, resin blocks were used as an alternative[47]. Resin blocks are easier to obtain and standardize, but the nature of the substrate is different from tooth tissue, and they do not reproduce the inherent intricacies of the root canal system of natural teeth.

Time is also used as a measure of efficacy of root filling removal[48]. Recent studies have compared the time taken to remove root filling materials using different rotary file systems[49] or comparing rotary files with hand files**.** Given the popularity of rotary NiTi systems in contemporary endodontics, the findings of this study are relevant to support informed clinical-decision-making. Determining when the root filling removal procedure has been completed is difficult, both clinically and experimentally. There is no scientific method of measurement, so it relies primarily on the operator making a subjective decision. As a result, this can present problems with standardization, both within a study and also when comparing with other studies, as different criteria may have been applied. There is considerable variation with some operators stopping when canals were deemed clean[50] or when no residual root filling material (e.g., GP) was visible on the last instrument used[20]. Other studies have chosen the endpoint as; when the full working length of the canal has been reached and no further filling material can be removed[51] , or when none is visible within the canal with the naked eye[15]. In addition to the above, in some older studies it was suggested that the canals should be smooth and clean dentine chips should be present during instrumentation. Perhaps a more scientific method of assessing the end point is by using radiography. The removal of root filling material may be deemed to have been completed when there is no material visible on check radiograph[45].

Most studies only investigate the residual amount of root filling material in the canal after the removal procedure is deemed to have been completed. The amount of residual material is compared to other canals which have been treated with a different removal method or in which a different root filling material has been removed. However, other variables were also analyzed either in combination with residual material or in isolation. Some limitations of the current study need to be acknowledged. The study small sample was small and only utilized natural teeth. Although, the study sample was restricted to teeth with straight canals only, all variations in the canal morphology could not be ruled out fully. Future studies involving a larger sample size with use of artificial teeth are recommended for better standardization of canal anatomy.

Conclusion: This ex-vivo study compared the efficacy of GP removal with Hedstrom and ProTaper rotary files during retreatment endodontics. Evaluation of digital radiographic images showed presence of residual GP in the apical third of teeth in both groups. Although ProTaper appeared to be more efficient in GP removal, differences between the study and control group were not significant. Nevertheless, full working length was achieved in all root canals. Under similar conditions, ProTaper retreatment and Hedstrom files were equally effective in removing GP during retreatment involving teeth with straight canals.

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