EGYPTIAN DENTAL JOURNAL
www.eda-egypt.org
VOL. 69, 3155:3162, OCTOBER, 2023
PRINT ISSN 0070-9484 • ONLINE ISSN 2090-2360
CONSERVATIVE DENTISTRY AND ENDODONTICS
Submit Date : 12-06-2023 • Accept Date : 29-07-2023 • Available online: 20-10-2023 • DOI : 10.21608/EDJ.2023.213729.2575

EFFICIENCY OF FOUR RETREATMENT ROTARY FILE SYSTEMS IN REMOVAL OF FILLING MATERIAL FROM ROOT CANAL (IN VITRO STUDY)

Nourhan Hussien Sayed*, Shady Aly Hussein** *and* Tariq Yehia***

ABSTRACT

Aim: the aim of this study was to evaluate the amount of filling material left on root canal walls, amount of apically extruded debris, time to reach working length and number of fractured files by using four different nickel-titanium (Ni-Ti) retreatment file systems (Protaper universal, Rogin, Soco-pro, M3 progold).

Methods: Forty extracted human mandibular first molar with two separate mesial canals (type III) were prepared by manual k files taper 0.02% up to master apical file #25. Step back technique was performed up to size #40 and then obturated with gutta-percha and Adseal. Samples were equally divided into 4 groups according to the retreatment system used.

Results: Group (I) showed higher efficiency in removal of filling materials with statistically significant difference compared to other groups. Group (I) and Group (IV) extruded the least amount of debris with significant difference to other groups. Group (I) was significantly the fastest in reaching the working length and removal of filling materials. Three D3 in group (I), 3 D2 and 3 D3 in group (II), 2 D1,3 D2 and 5 D3 in group (III) and 1 D1, 3 D2 and 3D3 in group (IV) were broken.

Conclusions: Protaper universal retreatment file system (PTUR) has higher efficiency in removal of root canal filling material from different root sections, M3 pro gold and PTUR systems extruded the least amount of debris, PTUR system took the least time to reach the working length, Soco pro had the highest number of broken files while PTUR had the least number.

KEYWORDS: Nickel-titanium rotary instrument; root canal retreatment; scanning electron microscope; Apically extruded debris

* MSc Student, Endodontic Department, Faculty of Dentistry, Ainshams University
** Associate Professor, Endodontic Department., Faculty of Dentistry, Ainshams University.
*** Associate Professor, Endodontic Department, Faculty of Dentistry, Ain Shams University, Cairo, Egypt

INTRODUCTION

Despite initial root canal therapy being a predictable and highly successful treatment, failures can occur after treatment. Failures can be due to persistent intra radicular infections in uninstrumented root canals, dentinal tubules, or in the complex irregularities of the root canal or may be due to extra radicular causes such as periapical actinomycosis, extrusion of endodontic materials apically causing foreign body reaction[1].

The failure might be treated successfully by orthograde retreatment or, if that is not possible, by a surgical procedure.[2] Nonsurgical root canal retreatment is considered the safest and least invasive method in solving the problem. The main aim of retreatment is to create a direct pathway to the apex by complete removal of obturation material.[3]

Several difficulties can be faced during the retreatment process such as the type of obturating material that was used, the anatomy of the tooth and other factors that must be considered. Complications such as causing strip perforations, over-enlarging of the apical foramen, instrument breakage and extrusion of obturating material and debris through the apical foramen can all result in apical pathology or post-instrumentation pain.[4]

A lot of methods have been used to remove obturating materials such as heat pluggers, ultrasonic instruments, laser and manual files. But none of these methods proved its efficiency in removing root canal filling materials completely.[1]

Nickel-titanium rotary files have been used widely in retreatments, due to their effectiveness, and capability to remove obturating material in less time than manual files. Therefore, investigating the effectiveness of different retreatment files was thought to be of value.

MATERIALS AND METHODS

Eighty mesial canals type (III) with curvature < 25° based on Schneider's method in forty extracted human first mandibular molar teeth were selected. The teeth were collected from an archive of extracted teeth at Endodontic Department, Faculty of Dentistry, Ain Shams University. Teeth were radiographed from both the buccolingual and mesiodistal directions to be confirmed of having 2 patent separate canals and to rule out any abnormal canal morphology. Endodontic access cavities were prepared using round diamond burs size 2 and endo-z bur in high-speed handpiece under water cooling. Negotiation of the canals was done by using manual k- files #10 (Mani, Tochigi, Japan). The teeth were confirmed to be type (III) by introducing files into canals in mesial root and inspected to be extruded from different foramen. Samples were equally distributed into four groups of 20 root canals each. The mesial root was split from the distal root with a fissure surgical bur, and the teeth were cut with a 0.5mm diamond disc in straight hand piece, leaving a root segment with a length of 12 mm for standardization. The MB and ML canals were prepared and instrumented using manual k files taper 0.02% (Mani, Tochigi, Japan) up to master apical file #25. Step back technique was performed with K-file up to size #40. Sodium hypochlorite (NaOCl) solution 2.5% (JK dental vision, Mansourah, Egypt) was used as irrigating solution.

All canals have been obturated by 0.02/25 master cone guttapercha (Dentsply Maillefer, Ballaigues, Switzerland) and Meta-biomed adseal epoxy resin sealer (Meta-biomed, Cheongwon, Korea). Lateral condensation was done using #20 finger spreader and accessory cones size #20. After finishing obturation, coronal access was closed with temporary filling material. Mesiodistal radiographs were taken to confirm complete filling. The samples were stored for 14 days at 37°C to let the sealer set completely.

The amount of apically extruded debris was collected in a custom made apparatus. Each sample was inserted firmly into a rubber stopper. A hole was

created in the rubber stopper, a 27-G needle was inserted. Each stopper with the tooth and the needle was then attached to its Eppendorf tube. A needle was used alongside the stopper to equalize air pressure inside and outside the tubes. The tubes were fitted into vials. The entire apparatus was handled only by the outer vial. Before the root canal shaping procedure, the Eppendorf tubes were weighed to 10^{-5} precision using a microbalance (Sartorius Lab Instruments GmbH, Goettingen, Germany).

Obturation material was removed in a crown-down direction and pecking motion with the retreatment Kit sequence. Retreatment was done without the help of any solvent; irrigation had been carried by 1 mL of distilled water between every file. The file was taken out of the canal after three pecking motions and the canal was finally cleaned with irrigation.

- Group I: pro-taper universal retreatment system consists of 3 files D1(30/.09), D2(25/.08), and D3(20/.07) used respectively at 2-Ncm torque and 500-rpm speed.
- Group II: Rogin retreatment system consists of 3 files D1(30/.09), D2(25/.08), and D3(20/.07) used respectively at 2.5-Ncm torque and 300-rpm speed.
- Group III: soco pro retreatment system consists of 3 files D1(30/.09), D2(25/.08), and D3(20/.07) used respectively at 2-Ncm torque and 375-rpm speed.
- Group IV: Root canal filling materials were removed using M3 pro gold retreatment system consists of 3 files M3RT1 (30/.09), M3RT2(25/.08), and M3RT3(20/.07) used respectively at 2-Ncm torque and 350-rpm speed.

After instrumentation had been finished, each root segment was removed from the Eppendorf tube. The Eppendorf tubes were incubated at 37°C for 10 days, so that moisture can be evaporated, and the dried debris could be weighted by the microbalance. Weight of extruded debris was calculated by subtracting the weight of empty Eppendorf tube before instrumentation from its weight containing the dried debris after instrumentation.

To measure remaining filling materials left on canal walls, all samples were cut longitudinally into mesial and distal halves by using a chisel after being grooved with a diamond disc 0.5 mm buccolingually until the canal's shadow could be seen through a thin layer of dentin . The half of the roots that had the largest area of remaining obturation materials was selected for scanning using stereomicroscope. A stereomicroscope at a fixed magnification of x3.5 was used. Images were taken by using a digital camera attached to the microscope, and then were transferred to desktop and stored as JPEG format. Image J software was used to analyze the obtained images by measuring the percentage of area covered by remaining obturation material with no attempt to distinguish between residual filling material and sealer.

The time to reach working length is the time lapsed from the first file to the last file used to reach the working length. It was recorded using a stopwatch. Time required to change files and irrigation was not included. The number of fractured instruments was calculated. In case a file fractured, a new file was used, and new sample was introduced to the group.

RESULTS

Data were normally distributed and were analyzed using one-way ANOVA followed by Tukey's post hoc test for intergroup comparisons. The significance level was set at $p \leq 0.05$ within all tests.

Apical third was neglected during evaluation of remaining filling material due to difference in apical diameter between manual files during apical preparation and D3 file the last file in retreatment. (Fig.1)

TABLE (1) Intergroup comparisons and mean ± standard deviation (SD) values of remaining filling material (%) for different files.

Root section	Remaining filling material (%) (mean±SD)				p-value
	Group (I)	Group (II)	Group (III)	Group (IV)	
Coronal	1.81±0.38^{B}	2.38±0.99^{AB}	2.84±0.58^{A}	2.88±1.13^{A}	<0.001*
Middle	2.67±1.25^{B}	3.49±1.07^{AB}	4.30±1.11^{A}	3.55±1.34^{AB}	<0.001*

Means with different superscript letters within the same horizontal row are significantly different *; significant (p ≤ 0.05) ns; non-significant (p>0.05).

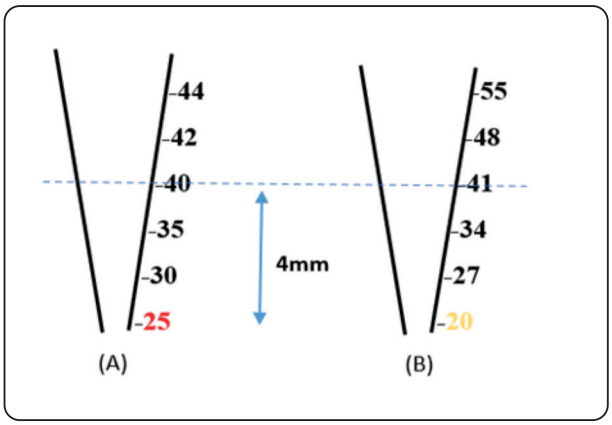

Fig. (1): Photograph showing difference in apical diameter between master apical file (used for initial preparation) (A) and D3 file (last file used in retreatment) (B).

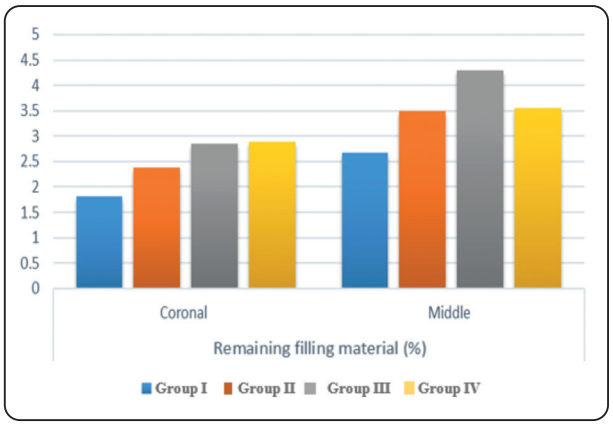

Fig. (2): A graph illustrating the mean remaining material for various files.

Group (I) protaper universal retreatment files system demonstrated efficiency in removing filling materials from the whole canal wall surface with significant difference to other groups ($p \leq 0.05$), followed by Group (II) Rogin retreatment files system followed by Group (IV) M3 pro-gold and Group (III) Soco pro retreatment files systems.

DISCUSSION

Root canal therapy has been a reliable, effective and also successful treatment for the maintenance of teeth when the rules of root canal cleaning and obturating are fulfilled. Consequently, failure to reach these rules results in persistent intracanal pathogens and treatment failure[5,6]. So, nonsurgical root canal (NSRC) retreatment and endodontic surgery are available choices.[7] Nonsurgical root canal retreatment is the first treatment option to eradicate infection as it is the least invasive method with favorable outcomes[8].

In this study, solvent wasn't used because soften gutta-percha could go deeper into root canal walls and dentinal tubules, making its removal more difficult[9,10,11]. Distilled water was recommended to be used as irrigant during retreatment procedure to eliminate the potential impact of sodium hypochlorite crystallisation.[12,13]

Retreatment was deemed finished when the last used file didn't have any obturating materials on it. Nevertheless, all the canals contained remnants of obturating materials, as proved by previous studies.[14,15] According to our results, absence of obturating materials on the file is not a reliable

measure to represent full removal of obturating materials from the canals, as found by Schirrmeister and others[9].

Different methods have been used to evaluate remaining material after retreatment procedure. Remaining obturation material was evaluated radiographically, or roots were divided longitudinally before subjected to photographic or microscopic analysis or using evaluation scales[10]. Recently, many studied preferred to use high resolution micro-CT scans in determining the amount of obturating material that was left after retreatment procedures were finished. This method allows for a noninvasive, accurate, 3D quantitative examination of the left filling material on the canal walls.[16,17].

Due to the limited availability of micro-CT scans, the amount of residual filling material in the current study was determined by longitudinal cleavage of the roots, followed by quantitative analysis. Root sections were imaged by stereomicroscope followed by analysis using ImageJ software. Two different parts of the root were evaluated: the coronal and middle parts. ImageJ software for analysis of stereomicrographs is a subjective method for evaluation of remaining filling debris. This method has been proven to be successful in determining the amount of obturating materials and to have reduced subjectivity in the scale-based scoring method.[18] According to Takahashi et al.[19] vertical splitting and viewing under stereomicroscope is considered a suitable method, since it is easy to use and provides advantages over other techniques.

Under the conditions of the current study, removal of filling material completely was impossible despite the retreatment method used. This is in full agreement with other studies[15,19,20,21].

In the current study, regarding the effect of file type on remaining filling material our results showed group (I) protaper universal retreatment files system showed efficacy in removal of obturating materials from the root canal walls with significant difference to other 3 groups. This is due to the design of PTUR. Its triangular cross-section allows removal of large amounts of obturating materials in spirals around the instrument, it has negative cutting angles and no radial land which permits cutting action instead of planning action. Furthermore, engine driven files rotary movements create frictional heat which plasticizes gutta-percha (GP). plasticized GP encounters less resistance to remove. Our results agree with Giuliani et al.[22], Takahashi et al.[19], Yilmaz et.al.[17], Japtag et.al.[5], Gu et al.[23]. But disagreed with somma et.al.[24] who found that manual retreatment technique removed obturating materials more successfully than NiTi rotary files and explained that due to the small size of master apical file used in rotary systems.

Group (III) Soco pro retreatment files system showed the highest amount of remaining filling material. Unfortunately, there are no studies regarding Soco pro retreatment files system, but it may be due to the type of wire used in these instruments which is controlled memory (cm) wire. This agrees with Topcuoglu et al.[25] who found less efficiency of files made of cm wire during retreatment compared to other wires so they stated that as the flexibility of the files increases, their performance in removal of obturating materials could decrease.

Regarding the percentage of remaining root filling material in different root sections, our results showed that the least percentage was observed in the coronal one-third. Because of the cutting tip of D1 file which allows more effective initial penetration in gutta-percha. Also, viewing the filling material in the coronal third is easier, especially with the help of clinical microscope. Our results agree with Takahashi et al.[19], Giuliani et al.[22]and Patil et al.[26] and Marques da Silva et al.[27]

While the greatest percentage of filling material was found in the middle one third. This agrees with Zmener et al.[28] who found that the rotary files were

used with pecking motion. So, round preparations will be formed in oval shaped canals. Thus, the polar recesses found in the middle thirds of oval canals are prone to be out of reach of rotary files.

In this study apical one third evaluation was neglected, due to small apical diameter of D3 (20/.07) retreatment file which doesn't permit full cleaning action, so apical one third will remain untouched by the file. This was explained by Somma et al.[24], Giuliani et al.[22], Marfisi et. al.[29], Kfir et. al.[30]. Accordingly, they suggested that hand files would help in completing the cleaning of the canals from obturating materials after the use of the D3 file[30]. But our study aimed to evaluate the effect of the rotary files only without the help of any additional instruments.[30].

Regarding the amount of apically extruded debris, our results showed that the lowest value was found in group (IV) M3 pro gold retreatment system with non-significant difference with group (I) Protaper universal retreatment system.

Despite PTUR files having three points of contact with the root canal wall, there is enough space between the file and the walls for collection of the debris. Our results in agreement with Topc¸uoglu et al.[12], S.Gkampesi et. al.[31], Mannu Vikram[32]. But this was disagreed with by Silva et al.[33], Amit jena et al.[34], who found that PTUR system group extruded more debris than tested groups with significant difference.

M3 progold retreatment file system has a parallelogram cross section with flat side according to manufacturer's information to allow more space for collection of debris and pushing them in coronal direction. The root canal is shaped asymmetrically by the file, as it allows only two points of contact with the canal walls. Thus, file has a large area for escaping of debris and directing it in coronal direction. Our results agree with Machado M E de L. et al.[35].

Ünal et al.[36], Dincer et al.[37], found less extrusion of debris with parallelogram cross section files. They explained that the file attaches less to the canal wall and allows for more space to extrude debris coronally during root canal treatment.

Regarding time to reach working length, Group (I) Protaper universal retreatment system was the fastest with significant difference to other groups. This is due to the easy penetration of D1 file in the root filling because of its active tip, and because of its efficient cutting angles, removal of obturating materials can be done easily and rapidly. Also, the higher speed recommended by manufacturer instructions minimizes the time needed to achieve the apex. The speed operated by Protaper files was 500 RPM with torque 2.5N. Our results agree with Bramante et al.[38], S. Gkampesi et al.[31], Özlek and Gündüz[39].

Regarding the number of fractured files, Group (I) Protaper universal retreatment system showed three D3 fractured. This agrees with Jorgensen et al.[40], Beasley et al.[41], who found that the D3 file was the only deformed or fractured PTUR file during use.

Group II (Rogin) showed 6 fractured files, 3 D2 files and 3 D3 files. Group III (Soco pro) showed 13 fractured files 2 D1, 3 D2 and 5 D3 files. Group IV (M3 pro gold) showed 10 fractured files 1 D1, 3 D2 and 3 D3 files.

CONCLUSION

Protaper retreatment file system has higher efficiency in removal of root canal filling material than Rogin, Soco pro and M3 pro gold retreatment file systems. M3 pro gold and Protaper retreatment file systems extruded less amount of debris than Rogin and Soco pro retreatment file systems. Protaper retreatment system was the fastest to reach working length than other 3 systems. Protaper retreatment system had the least number of broken files than other 3 group.

REFERENCES

1. Torabinejad M, Corr R, Handysides R, Shabahang S. Outcomes of Nonsurgical Retreatment and Endodontic Surgery: A Systematic Review. Vol. 35, J Endod. 2009 ;35(7):930-7.
2. Giuliani V, Cocchetti R, Pagavino G. Efficacy of ProTaper Universal Retreatment Files in Removing Filling Materials during Root Canal Retreatment. J Endod. 2008;34(11):1381–4.
3. Galal S, Kamel W, nour el din M. The Efficacy of Reciprocating Instruments Versus Continuous Rotary Nickel-Titanium Instruments in Root Canal Retreatment with Different Filling Materials. Al-Azhar Dental Journal for Girls. 2019;6(2):223-9.
4. Friedman S, Stabholz A, Tamse A. Endodontic retreatment caseselection and technique. Part 3. Retreatment techniques. J Endod. 1990;16(11):543-9.
5. Jagtap A, Aher G, Gulve M, Kolhe SJ. Comparative evaluation of effectiveness of manual and various rotary retreatment techniques for removal of root canal filling material: An in-vitro study. Endodontology. 2022;34(3):184–8.
6. Olcay K, Eyüboglu T, Özcan M. Clinical outcomes of nonsurgical multiple-visit root canal retreatment: a retrospective cohort study. Odontology. 2019;107(4):536–45.
7. Tomar A, Kumar Pyasi S, Dubey S, Sahani S, Anil Tomar CK, Sthapak U. To compare the efficacy of different file systems to remove filling material during root canal retreatment utilizing stereomicroscope: An in vitro study. IJADS. 2018;4(2):154–7.
8. Schirrmeister J, Wrbas K, Schneider F, Altenburger M, Hellwig E. Effectiveness of a hand file and three nickel-titanium rotary instruments for removing gutta-percha in curved root canals during retreatment. Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology and Endodontology. 2006;101(4):542–7.
9. Obeid M, Elgendy A. Efficacy of three Ni–Ti rotary systems for removal of filling materials from root canal system of extracted teeth. Tanta Dental Journal. 2015;12(4):259–64.
10. Keleş A, Arslan H, Kamalak A, Akçay M, Sousa-Neto MD, Versiani MA. Removal of filling materials from oval-shaped canals using laser irradiation: A micro-computed tomographic study. J Endod. 2015;41(2):219–24.
11. Martins M, Duarte M, Cavenago B, Kato A, da Silveira B. Effectiveness of the ProTaper Next and Reciproc Systems in Removing Root Canal Filling Material with Sonic or Ultrasonic Irrigation: A Micro–computed Tomographic Study. J Endod. 2017;43(3):467–71.
12. Topçuoɔlu H, Akti A, Tuncay Ö, Dinçer A, Düzgün S, Topçuoɔlu G. Evaluation of debris extruded apically during the removal of root canal filling material using ProTaper, D-RaCe, and R-Endo rotary nickel-titanium retreatment instruments and hand files. J Endod. 2014;40(12):2066–9.
13. Preetam C, Chandrashekhar M, Gunaranjan T, Kumar S, Miskeen Sahib S, Kumar M. A comparative evaluation of two rotary Ni-Ti instruments in the removal of gutta percha during retreatment. J Int Soc Prev Community Dent. 2016;6(8): S131–6.
14. Raj P, Mudrakola D, Baby D, Govindankutty R, Davis D, Sasikumar T, et al. Evaluation of effectiveness of two different endodontic retreatment systems in removal of Gutta-percha: An in vitro study. Journal of Contemporary Dental Practice. 2018;19(6):726–31.
15. Wahane K, Kulkarni S, Daokar S, Patil K, Patel K, Thorat T. An assessment of the efficacy of a rotary and a reciprocating retreatment file system for removal of guttapercha from root canals: An in vitro cone-beam computed tomography study. Endodontology. 2021;33(1):20–4.
16. Rödig T, Hausdörfer T, Konietschke F, Dullin C, Hahn W, Hülsmann M. Efficacy of D-RaCe and ProTaper Universal Retreatment NiTi instruments and hand files in removing gutta-percha from curved root canals - a micro-computed tomography study. Int Endod J. 2012;45(6):580–9.
17. Yılmaz F, Koç C, Kamburoğlu K, Ocak M, Geneci F, Uzuner M, et al. Evaluation of 3
18. Different Retreatment Techniques in Maxillary Molar Teeth by Using Micro–computed Tomography. J Endod. 2018;44(3):480–4.
19. Sameh R, Omaia M. The Efficacy of Two Novel Retreatment Systems in the Removal Root Canal Obturating Materials (An In vitro Study). Open Access Maced J Med Sci. 2022; 10:76–82.
20. Takahashi C, Cunha R, De Martin A, Fontana C, M. Silveira C, Bueno C, In Vitro Evaluation of the Effectiveness of ProTaper Universal Rotary Retreatment System for Gutta-Percha Removal with or without a Solvent. J Endod. 2009, 35(11) 1580-1583.
21. Azim A, Wang H, Tarrosh M, Azim K, Piasecki L. Comparison between Single file Rotary Systems: Part 1—Ef-

ficiency, Effectiveness, and Adverse Effects in Endodontic Retreatment. J Endod. 2018;44(11):1720–4.

22. Rahde. In Vitro Comparative Analysis of 2 Mechanical Techniques for Removing Gutta-Percha during Retreatment. JCDA.2007.
23. Giuliani V, Cocchetti R, Pagavino G. Efficacy of ProTaper Universal Retreatment Files in Removing Filling Materials during Root Canal Retreatment. J Endod. 2008;34(11):1381–4.
24. Gu L, Ling J, Wei X, Huang X. Efficacy of ProTaper Universal rotary retreatment system for gutta-percha removal from root canals. Int Endod J 2008; 41:288-295.
25. Somma F, Cammarota G, Plotino G, Grande N, Pameijer C. The Effectiveness of Manual and Mechanical Instrumentation for the Retreatment of Three Different Root Canal Filling Materials. J Endod. 2008;34(4):466–9.
26. Topcuoglu H, Sener I, Demirbuga S, Çakir N, Topcuoglu G. Efficacy of Endodontic Files with Different Metallurgical Characterization in Removing Root Canal Filling Material. Vol. 5, Journal of Dental Biomaterials. 2018;5(2):551-8.
27. Patil A, Aggarwal S, Pol T, Bhor S, Shenoy V, Mv S. Retreatment Efficacy of Hand vs Rotary Instrumentation in Oval-shaped Root Canals: An In Vitro Study. World Journal of Dentistry. 2022;13(5):454–9.
28. Marques da Silva B, Baratto-Filho F, Leonardi D, Henrique Borges A, Volpato L, Branco Barletta F. Effectiveness of ProTaper, D-RaCe, and Mtwo retreatment files with and without supplementary instruments in the removal of root canal filling material. Int Endod J. 2012;45(10):927–32.
29. Zmener O, Pameijer CH, Banegas G. Retreatment efficacy of hand versus automated instrumentation in oval-shaped root canals: An ex vivo study. Int Endod J. 2006;39(7):521–6.
30. Marfisi K, Mercade M, Plotino G, Duran-Sindreu F, Bueno R, Roig M. Efficacy of three different rotary files to remove gutta-percha and Resilon from root canals. Int endod J. 2010, 43(11): 1022-1028.
31. Kfir A, Tsesis I, Yakirevich E, Matalon S, Abramovitz I. The efficacy of five techniques for removing root filling material: Microscopic versus radiographic evaluation. Int Endod J. 2012;45(1):35–41.
32. Gkampesi S, Mylona Z, Zarra T, Lambrianidis T. Assessment of apical extrusion of debris during endodontic retreatment with 3 rotary nickel-titanium retreatment systems and hand files. Balkan Journal of Dental Medicine. 2016;20(3):22–8.
33. Vikram M. Comparison of Apically Extruded Debris during Retreatment Procedure by Two Types of Endodontic Instruments. International Journal of Recent Surgical and Medical Sciences. 2017 ;03(01):007–9.
34. Silva E, Sá L, Belladonna F, Neves A, Accorsi-Mendonça T, Vieira V, et al. Reciprocating versus rotary systems for root filling removal: Assessment of the apically extruded material. J Endod. 2014;40(12):2077–80.
35. Jena A, Shashirekha G, Barai S, Mahaprasad A. Comparison of apically extruded debris after retreatment procedure with protaper and endostar retreatment file systems. Journal of Clinical and Diagnostic Research. 2018;12(7): ZC31–4.
36. Machado ME de L, Nabeshima C, Caballero-Flores H, Elmadjian-Filho M, Duarte M, Odinola-Zapata R, et al. Instrument design may influence bacterial reduction during root canal preparation. Braz Dent J. 2017;28(5):587–91.
37. Ünal B, Zan R. Cumhuriyet Dental Journal Comparative Evaluation of the Effect of Different Rotary Instrument Systems on the Amount of Apically Extruded Debris. Cumhuriyet Dental Journal. 2022;25(2):172–8.
38. Dincer A, Guneser M, Arslan D. Apical extrusion of debris during root canal preparation using a novel nickel-titanium file system: WaveOne gold. J Conserv Dent. 2017;20(5):322-325.
39. Bramante C, Fidelis N, Assumpção T, et al. Heat Release, Time Required, and Cleaning Ability of MtwoR and ProTaper Universal Retreatment Systems in the Removal of Filling Material. J Endod. 2010;36(11):1870-1873.
40. Özlek E, Gündüz H. Effectiveness of different rotary file systems in removing the root canal filling material: A micro-computed tomography study. J Dent Res Dent Clin Dent Prospects. 2021;15(4):273–8.
41. Jorgensen B, Williamson A, Chu R, Qian F. The Efficacy of the WaveOneReciprocating File System versus the ProTaper Retreatment System in Endodontic Retreatment of Two Different Obturating Techniques. J Endod. 2017;43(6):1011–3.
42. Beasley R, Williamson A, Justman B, Qian F. Time required to remove guttacore, Thermafil plus, and thermoplasticized gutta-percha from moderately curved root canals with protaper files. J Endod 2013; 39:125–8.