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ORIGINAL ARTICLE

Comparative evaluation of the effectiveness of different rotary systems in removal of root canal filling materials

ABSTRACT

Aim: *The aim of this study was to compare the remaining root canal filling materials after instrumentation using ProTaper Universal Retreatment (PTUR) system alone or combined with Neoniti, One Curve, and using hand Hedstrom files and Gates Glidden drills using cone beam computed tomography (CBCT) images.*

Methodology: *Fifty-two mandibular premolars with single and straight canals were used. The canals were instrumented with ProTaper rotary instruments up to F3 and filled with gutta-percha and AH26 sealer. All the samples were placed into silicone models. Samples were scanned with CBCT and assigned into four groups (n=13): the PTUR system group, the PTUR system plus Neoniti group, the PTUR system plus One Curve group, and the hand Hedstrom files plus Gates Glidden group. The specimens were scanned once again after retreatment procedures, and the volume of the remaining filling materials was determined. Data were analyzed using Kruskal-Wallis and Dunn tests (α=0.05).*

Results: *None of the retreatment procedures provided complete removal of the filling materials. Hedstrom files plus Gates Glidden removed more residual obturation materials than the other groups. The additional use of the Neoniti or One Curve systems significantly improved the removal of filling materials when compared with the PTUR system alone (P<0.05). The differences between the PTUR plus Neoniti group and the PTUR plus One Curve group were not statistically significant (P>0.05).*

Conclusions: *Using Gates Glidden and Hedstrom files was the most effective way for retrieval of endodontic material from the root canals, while PTUR alone was the least effective method. Re-instrumenting with rotary files significantly improved the removal of root filling materials.*

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Introduction

The main reason for failure of endodontic treatment is remaining infection in the root canal (1). Nonsurgical endodontic retreatment aims to eliminate the infection from the root canal and thus resolve the inflammatory response (2). One of the crucial components of endodontic retreatment is effective removal of root filling material in order to allow access for better debridement and disinfection of the root canal system. Remnant necrotic tissues and bacteria within the gutta percha and sealer may lead to persistence of the infection and therefore may compromise the outcome of endodontic retreatments (3, 4). Success rate of appropriate endodontic retreatments is reported to be as high as 81% (5).

Several techniques are available for removal of endodontic materials, including manual or rotary nickel titanium (NiTi) instruments, endodontic solvents, and ultrasonic activation. A combination of these techniques can be used for removing the root canal filling materials (6, 7). One of the most common techniques, involve the use of Hedstrom files combined with Gates Glidden drills with or without solvents such as chloroform. This technique can be particularly difficult and time-consuming when the root filling materials are dense and compact (8). Therefore, rotary endodontic systems are preferred due to their safety and speed. Several studies have reported the effectiveness of these rotary instruments to be comparable with manual files (9-11). In addition, rotary files specifically designed for retreatment purposes have been developed. One of these systems is ProTaper Universal Retreatment (PTUR) with continuous rotation. This system contains three rotary instruments: D1(30, 0.09), D2 (25, 0.08), and D3 (20, 0.07). D1 file has a cutting tip which can penetrate the root filling material and is used to remove the material from the coronal third of the root canal. D2 and D3 files have non-cutting tips and are used to remove the endodontic materials from middle and apical thirds of the root canal, respectively (12-14).

One of the newly introduced rotary systems for root canal preparation is Neoniti which uses a continuous rotation movement. This system contains C1 (25, 0.12) and A1 (25, 0.06) files. C1 is used as an orifice shaper and A1 is used to the working length for preparation of the root canal. This system uses CM-wire alloy with heat treatment technology. Therefore, it possesses high flexibility and shape memory, allowing these files to be pre-curved. In addition, modern wire cut electrical discharge machining technique used for surface preparation increases surface roughness of these endodontic files, which can potentially increase the effectiveness of root canal shaping (15-17).

One Curve rotary system is another endodontic rotary system with a single file (25, 0.06) used to the working length. This file is made from heat-treated C-wire alloy and has a high flexibility and shape memory. Therefore, it can be pre-curved to preserve the curve and shape of the root canal (18, 19).

Removal of all endodontic materials during retreatment is virtually impossible and remnants of gutta percha and endodontic sealer remain attached to the root canal walls (20). Different methods can be used in order to measure the amount of these remnant materials. One method is sectioning the teeth and examining the samples under optical microscope (21, 22). This technique disrupts the integrity of the tooth and can distort and scatter the remnant endodontic materials (14). A more conservative approach is using imaging techniques such as cone beam computed tomography (CBCT) which allows three-dimensional (3D) observation of the root canal system and remnant endodontic material. CBCT is a reliable and non-invasive technique for detecting the configuration of the root canal system (23, 24).

No study has been previously performed to compare the effectiveness of PTUR, Neoniti, and One Curve rotary systems for endodontic retreatments. Therefore, the aim of the present study was to compare the effectiveness of these files in removal of root canal filling materials during endodontic retreatments.

Materials and Methods

This study was approved by the Ethics Committee of Isfahan University of Medical Sciences (approval date: 25.02.2020, #IR.MUI.RESEARCH.REC.1398.698). Informed consent is not applicable.
In this experimental study, fifty-two human mandibular premolar teeth which were extracted due to periodontal diseases or orthodontic reasons were selected. All teeth had a single straight root with a single canal and completely developed apex. The selected teeth were free from root caries, root fracture, root canal calcification, and external or internal resorption. Debris and attached soft tissue were removed from the teeth and the samples were kept in normal saline 0.9% solution (Samen, Mashhad, Iran) in a temperature of 4 °C. The crowns of the teeth were cut and a root with a length of 16 mm was prepared. Then, a hand K file #10 (Dentsply Maillefer, Ballaigues, Switzerland) was inserted into each root canal until the tip of the file was visible from the apical foramen using a microscope (×12.5). The working length was determined 1 mm short of this length.

Root canal treatment
Root canals were prepared using ProTaper rotary system (Dentsply Maillefer, Ballaigues, Switzerland) using the crown-down technique. At first, the cervical and middle thirds of the root canals were prepared using SX file. Thereafter, S1, S2, F1, F2, and F3 files were inserted to the working length. Apical patency was achieved using hand K file #15 (Dentsply Maillefer, Ballaigues, Switzerland) before insertion of the next rotary file. Irrigation was performed by 2 mL of sodium hypochlorite 2.0% (Cerkamed, Stalowa Wola, Poland). In order to remove the smear layer, the final irrigation was carried out by 2 mL of EDTA 17% (Cerkamed, Stalowa Wola, Poland), 2 mL sodium hypochlorite, and 5 mL sterile water. Then, the root canals were dried by paper cones (Dentsply Maillefer, Ballaigues, Switzerland) and filled by gutta percha and AH-26 sealer (Dentsply DeTrey, Konstanz, Germany) using lateral condensation technique. In order to assess the quality of root canal treatments, radiographs were obtained from the samples in buccolingual and mesiodistal directions using an intraoral size 2 film (Kodak, NY, USA). Samples which had voids in the root filling material were excluded and replaced by other teeth. Thereafter, the coronal portion of the roots was sealed using temporary restorations (Cavit, 3M ESPE, Seefeld, Germany). The samples were kept for two weeks in a temperature of 37 °C and humidity of 100% to allow complete setting of the endodontic sealer. Then, in order to create repeatable position of the samples for scanning, the roots were mounted on a putty model.

CBCT imaging
The samples were scanned using ProMax 3D Max scanner (Planmeca, Helsinki, Finland) with exposure parameters of 10 mA and 90 kVp, with a voxel size of 76 µm and 16 mm ×16 mm field of view. The imaging dataset was then exported in digital imaging and communication in medicine (DICOM) format and transferred into Mimics innovation/research software (v.21, Materialise, Leuven, Belgium) for calculating the volume of root canal filling material. Threshold gray value limits were defined between 2604-3095 which corresponds to gutta percha. A separate mask was created for each sample containing the endodontic material within the root canal using the split mask tool. Then, using the edit mask tool, each mask was meticulously edited in coronal, sagittal, and axial planes (Figure 1A). The volume of the root canal filling material was then measured.

Endodontic retreatment
The roots were removed from the putty model and were randomly assigned into four groups based on endodontic retreatment technique. Removal of gutta percha from the root canals was performed by an endodontist each lasting for 9 minutes.
PTUR group: D1, D2, and D3 files were used to remove the root filling material from the coronal, middle, and apical thirds

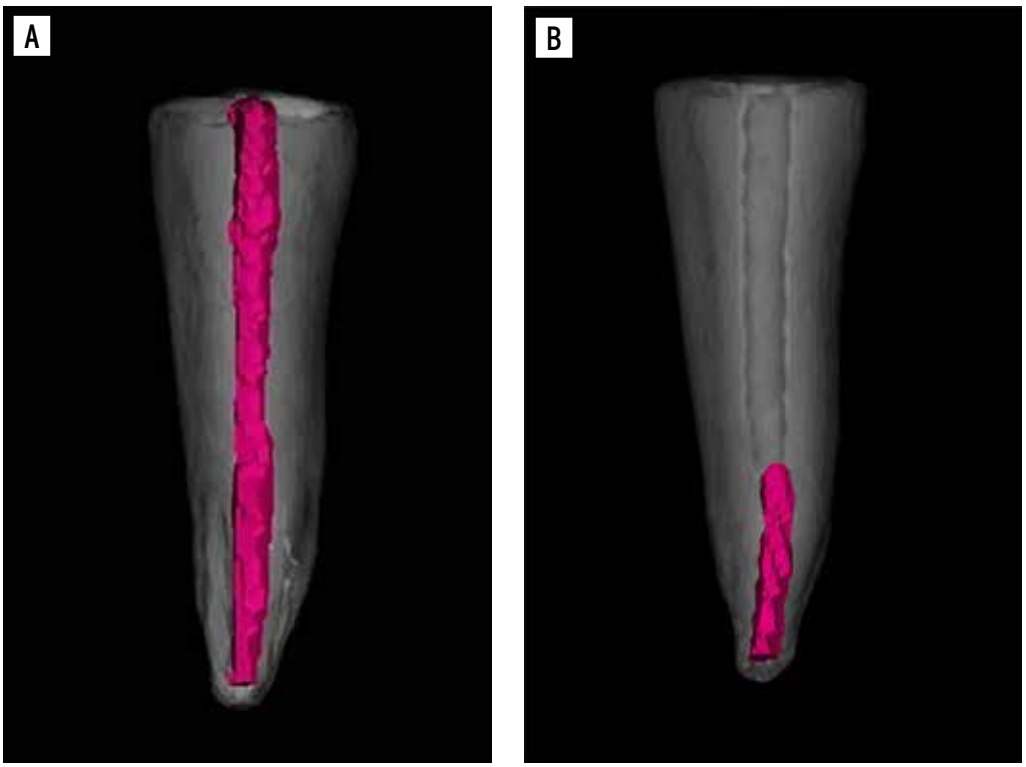

Figure 1
Three-dimensional visualization of remaining root filling material **(A)** before and **(B)** after endodontic retreatment.

of the root canal, respectively, using slight pulsed apical pressure. The files were used to the working length until no further filling material was retrieved from the canal. For all rotary files, an endo-motor (NSK, Tochigi, Japan) with 500 rpm and 3 N.cm torque was used according to the manufacturer's instructions. PTUR with Neoniti re-instrumentation group: After application of PTUR system, Neoniti A1 file was passively used to the working length with slight pulsed apical pressure with 300 rpm and 1.5 N.cm torque. PTUR with One Curve re-instrumentation group: After application of PTUR system, One Curve rotary file was used to the working length with 300 rpm and 2.5 N.cm torque.

Gates Glidden and Hedstrom hand file group: In this group, Gates Glidden size 3 and size 2 (Dentsply Maillefer, Ballaigues, Switzerland) with 2000 rpm for removal of root canal filling material from the coronal portion of the canal. Then, 0.1 mL of chloroform was used as solvent for each root canal. Hedstrom hand files #35, 30, 25 were inserted in the root canal with filing, push-pull, quarter-turn, and circumferential motion in order to reach the working length.

During the retreatment procedure, irrigation was performed by 2 mL sodium hypochlorite 2% solution. Final irrigation was carried out by 2 mL of EDTA 17% solution, 2 mL sodium hypochlorite 2% solution, and 5 mL of sterile water. The samples were mounted back on the putty model and were scanned by CBCT using the previous setting. The volume of the remaining root canal filling material after retreatment was calculated by Mimics software as described (Figure 1B). Then, the volume of remaining root canal filling material was divided by the volume of endodontic material after root canal treatment, in order to provide the percentage of remaining endodontic material in each sample.

Statistical analysis

Kruskal-Wallis nonparametric test and Dunn's test were used in order to compare the effectiveness of four systems in removal of endodontic material from the root canal. Statistical analysis was performed by Statistical Package for the Social Sciences (SPSS, v. 22, IBM, NY, USA, α=0.05). Data was presented as median due to non-normal distribution.

Table 1
Ratio of remaining material after endodontic retreatment using different file systems

	Before (mm^3)		After (mm^3)		After/Before	
	Median	Q1-Q2	Median	Q1-Q2	Median	Q1-Q2
PTUR	15.88	14.79-16.19	2.59	2.05-5.31	0.17	0.13-0.24
PTUR+ Neoniti	14.64	12.55-20.13	1.74	0.15-3.03	0.10	0.01-0.17
PTUR+ One Curve	19.12	16.27-21.77	1.72	0.40-3.47	0.11	0.02-0.19
Gates Glidden + H file	18.08	15.74-20.79	1.32	0.12-2.31	0.08	0.01-0.12

PTUR: ProTaper universal retreatment

Results

None of the tested systems were able to remove all the root canal filling material. The most effective system for removal of root canal filling material was Gates Glidden drills and Hedstrom files (table 1). Re-instrumentation with Neoniti and One Curve rotary systems were significantly more effective in retrieving endodontic material compared to PTUR file (P=0.024 and P=0.041, respectively). Re-instrumenting with Neoniti files led to better removal of root filling material from the root canal. However, this difference was not statistically significant (table 2, P=0.826).

Discussion

In the present study, the volumes of root canal filling material before retreatment were not significantly different among the experimental groups. Therefore, the comparison of root canal filling material volume after retreatment was possible. Based on our findings, using Gates Glidden drills and Hedstrom files was the most effective way for retrieval of endodontic material from the root canals, while PTUR alone was the least effective system. Re-instrumenting with rotary files significantly improved the removal of root canal filling material.

Removal of root canal filling materials from an inadequately treated root canal increases the effectiveness of instruments and irrigants on debris and microorganisms responsible for apical periodontitis (25, 26). Although, it has not been proven that remaining gutta percha causes failure of endodontic retreatments, adequate retrieval of material from the root canal system is an important factor for eliminating the necrotic tissues and bacteria from the canal (2, 27). However, none of the systems were able to completely remove the endodontic material. This finding has been shown in other studies as well (16, 24, 28-30).

In this study, PTUR was used initially

Table 2
Comparison of different retreatment techniques in removal of root canal filling material

Groups	Mean difference	SE	p-value
PTUR vs. PTUR+ Neoniti	0.129	0.046	0.024
PTUR vs. PTUR+ one curve	0.114	0.046	0.041
PTUR vs. Gates Glidden + H file	0.145	0.046	0.004
PTUR+ Neoniti vs. PTUR+ One Curve	-0.014	0.046	0.826
PTUR+ Neoniti vs. Gates Glidden + H file	0.016	0.046	0.518
PTUR+ One Curve vs. Gates Glidden + H file	0.031	0.046	0.386

PTUR: ProTaper universal retreatment

followed by Neoniti or One Curve rotary files for additional removal and shaping of the canals. Chloroform was used only in the Gates Glidden and H file group, where manual removal of the gutta percha was performed. Retrieving the endodontic material from the root canals by manual techniques alone can be time-consuming, especially when the endodontic materials are thoroughly condensed (8). Applying a small amount of solvent during endodontic retreatment can facilitate the retreatment process. Using chloroform with rotary instruments can leave a thin layer of sealer and gutta percha attached to the root canal which is difficult to remove. Therefore, chloroform was not used with rotary files (31).

In this study, PTUR was the least effective system for retrieval of endodontic material. All root canals were prepared with F3 ProTaper file with a tip size of 30, while the tip size of D3 ProTaper retreatment file is 20, meaning that the tip of D3 is not completely engaging with the canal walls in the apical portion of the root during the retreatment procedure (24).

Recently, it has been recommended that using a combination of endodontic instruments leads to more effective removal of root canal filling materials (32). Bueno et al. showed that Hedstrom files are more effective compared with PTUR in retrieving gutta percha from the root canals. The flute design and circumferential filing techniques used with Hedstrom files can facilitate removal of endodontic material. The authors recommended initiation of endodontic retreatment with rotary files followed by application of Hedstrom manual files as a complementary technique (33).

Yürüker et al. evaluated the effectiveness of different techniques in removal of endodontic materials from the root canal. They reported that combined use of PTUR and Hedstrom files or Reciproc rotary instrument significantly enhanced the retrieval of root canal filling material compared with use of PTUR alone or combined with self-adjusting files (24). These findings are consistent with our results, showing that complementing PTUR with rotary instruments improves the effectiveness of endodontic material removal.

Similarly, Aksel et al. reported that re-instrumenting with XP-Endo finisher system after PTUR enhances the removal of root canal filling material regardless of sealer type (34).

However, Ealla et al. conducted a study comparing PTUR and D-RaCe retreatment systems with hand Hedstrom files. They found that D-RaCe rotary system is more effective in removing endodontic material from the root canal (35).

n their study, for the Hedstrom file group they have only used hand H-files and K-files, while we used H-files combined with Gates Glidden drills, which performed better than the other groups in retrieving endodontic material from the root canals.

One limitation of the present study was not using micro-CT for evaluation of the samples (36). However, application of high resolution CBCT with artifact reducing algorithms and accurate thresholding techniques in third party software enabled for determination of the volume of gutta percha before and after endodontic retreatment.

Conclusions

Using Gates Glidden drills and Hedstrom files was the most effective way for retrieval of endodontic material from the root canals, while PTUR alone was the least effective method. Re-instrumenting with rotary files significantly improved the removal of root filling material.

Clinical Relevance

Based on the findings of this study, combined use of Gates Glidden and Hedstrom files is recommended as the most effective way for removal of endodontic material from the root canals for nonsurgical endodontic retreatment. However, in case of application of rotary instruments for retrieval of root filling material, re-instrumenting with a second rotary instrument improved the effectiveness of PTUR system.

Conflict of Interest

All authors declare that they have no conflict of interest.

Ethical approval

All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the Helsinki Declaration as revised in 2013.

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Informed consent

Not applicable.

References

1 Araghi S, Mirzaee SS, Soltani P, Miri S, Miri M. The effect of calcium hydroxide on the apical microleakage of canals filled with bioceramic and resin sealers. G Ital Endod. 2020;34.
2 Nair P. On the causes of persistent apical periodontitis: a review. Int Endod J. 2006;39:249-81.
3 Schirrmeister JF, Wrbas K-T, Meyer KM, Altenburger MJ, Hellwig E. Efficacy of different rotary instruments for gutta-percha removal in root canal retreatment. J Endod. 2006;32:469-72.
4 Pontoriero DIK, Grandini S, Spagnuolo G, Discepoli N, Benedicenti S, Maccagnola V, et al. Clinical Outcomes of Endodontic Treatments and Restorations with and without Posts Up to 18 Years. J Clin Med. 2021;10:908.
5 Farzaneh M, Abitbol S, Friedman S. Treatment outcome in endodontics: the Toronto study. Phases I and II: Orthograde retreatment. J Endod. 2004;30:627-33.
6 Fenoul G, Meless G, Pérez F. The efficacy of R-Endo® rotary NiTi and stainless-steel hand instruments to remove gutta-percha and Resilon. Int Endod J. 2010;43:135-41.
7 Colaco AS, Pai VA. Comparative evaluation of the efficiency of manual and rotary gutta-percha removal techniques. J Endod. 2015;41:1871-4.
8 de Oliveira DP, Barbizam JVB, Trope M, Teixeira FB. Comparison between gutta-percha and resilon removal using two different techniques in endodontic retreatment. J Endod. 2006;32:362-4.
9 Rödig T, Reicherts P, Konietschke F, Dullin C, Hahn W, Hülsmann M. Efficacy of reciprocating and rotary N i T i instruments for retreatment of curved root canals assessed by micro-CT. Int Endod J. 2014;47:942-8.
10 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;45:580-9.
11 Zuolo A, Mello Jr J, Cunha R, Zuolo M, Bueno C. Efficacy of reciprocating and rotary techniques for removing filling material during root canal retreatment. Int Endod J. 2013;46:947-53.
12 Bago I, Suk M, Katić M, Gabrić D, Anić I. Comparison of the effectiveness of various rotary and reciprocating systems with different surface treatments to remove gutta-percha and an epoxy resin-based sealer from straight root canals. Int Endod J. 2019;52:105-13.
13 Çanakçi BC, Ustun Y, Er O, Sen OG. Evaluation of apically extruded debris from curved root canal filling removal using 5 nickel-titanium systems. J Endod. 2016;42:1101-4.
14 Khedmat S, Azari A, Shamshiri AR, Fadae M, Fakhar HB. Efficacy of ProTaper and Mtwo retreatment files in removal of gutta-percha and GuttaFlow from root canals. Iran Endod J. 2016;11:184.
15 Khoshbin E, Donyavi Z, Atibeh EA, Roshanaei G, Amani F. The effect of canal preparation with four different rotary systems on formation of dentinal cracks: an in vitro evaluation. Iran Endod J. 2018;13:163.
16 Fatima K, Nair R, Khasnis S, Vallabhaneni S, Patil JD. Efficacy of rotary and reciprocating single-file systems on different access outlines for gutta-percha removal in retreatment: An in vitro study. J Conserv Dent. 2018;21:354.
17 Zinge PR, Patil J. Comparative evaluation of effect of rotary and reciprocating single-file systems on pericervical dentin: A cone-beam computed tomography study. J Conserv Dent. 2017;20:424.
18 Ertuğrul İF. Effect of sodium hypochlorite on the cyclic fatigue resistance: a scanning electron microscopy evaluation. Microsc Res Tech. 2019;82:2089-94.
19 Staffoli S, Grande NM, Plotino G, Özyürek T, Gündoğar M, Fortunato L, et al. Influence of environmental temperature, heat-treatment and design on the cyclic fatigue resistance of three generations of a single-file nickel–titanium rotary instrument. Odontology. 2019;107:301-7.
20 Eid BM, Maksoud HBA, Elsewify TM. Efficacy of XP-endo Finisher-R in enhancing removal of bioceramic sealer from oval root canal: a micro CT study. G Ital Endod. 2021;35.
21 Özyürek T, Demiryürek EÖ. Efficacy of different nickel-titanium instruments in removing gutta-percha during root canal retreatment. J Endod. 2016;42:646-9.
22 de Azevêdo Rios M, Villela AM, Cunha RS, Velasco RC, De Martin AS, Kato AS, et al. Efficacy of 2 reciprocating systems compared with a rotary retreatment system for gutta-percha removal. J Endod. 2014;40:543-6.
23 Moazzami F, Khojastepour L, Nabavizadeh M, Habashi MS. Cone-beam computed tomography assessment of root canal transportation by neoniti and reciproc single-file systems. Iran Endod J. 2016;11:96.
24 Yürüker S, Görduysus M, Küçükkaya S, Uzunoğlu

E, Ilgın C, Gülen O, et al. Efficacy of combined use of different nickel-titanium files on removing root canal filling materials. J Endod. 2016;42:487-92.
25 Silva EJNL, Orlowsky NB, Herrera DR, Machado R, Krebs RL, Coutinho-Filho TdS. Effectiveness of rotatory and reciprocating movements in root canal filling material removal. Braz Oral Res. 2015;29:01-6.
26 Gomes NN, De Carvalho GM, Sponchiado Júnior EC, Garcia LDFR, Marques AAF, De Carvalho FMA. Filling Material Removal with Reciprocating and Rotary Systems Associated with Passive Ultrasonic Irrigation. Eur Endod J. 2017;2:6-.
27 Limoeiro AG, Braitt AH, Machado AS, Bueno CE, Fontana CE, Freire LG, et al. Micro-computed tomography evaluation of filling material removal by three reciprocating systems with different thermal treatments. G Ital Endod. 2021.
28 Giuliani V, Cocchetti R, Pagavino G. Efficacy of ProTaper universal retreatment files in removing filling materials during root canal retreatment. J Endod. 2008;34:1381-4.
29 de Campos Fruchi L, Ordinola-Zapata R, Cavenago BC, Duarte MAH, da Silveira Bueno CE, De Martin AS. Efficacy of reciprocating instruments for removing filling material in curved canals obturated with a single-cone technique: a micro–computed tomographic analysis. J Endod. 2014;40:1000-4.
30 Nevares G, Diana S, Freire LG, Romeiro K, Fogel HM, Dos Santos M, et al. Efficacy of ProTaper NEXT compared with Reciproc in removing obturation material from severely curved root canals: a micro–computed tomography study. J Endod. 2016;42:803-8.
31 Mollo A, Botti G, Prinicipi Goldoni N, Randellini E, Paragliola R, Chazine M, et al. Efficacy of two Ni-Ti systems and hand files for removing gutta-percha from root canals. Int Endod J. 2012;45:1-6.
32 Hammad M, Qualtrough A, Silikas N. Three-dimensional evaluation of effectiveness of hand and rotary instrumentation for retreatment of canals filled with different materials. J Endod. 2008;34:1370-3.
33 Bueno CEdS, Delboni MG, Araújo RAd, Carrara HJ, Cunha RS. Effectiveness of rotary and hand files in gutta-percha and sealer removal using chloroform or chlorhexidine gel. Braz Dent J. 2006;17:139-43.
34 Aksel H, Küçükkaya Eren S, Askerbeyli Örs S, Serper A, Ocak M, Çelik H. Micro-CT evaluation of the removal of root fillings using the ProTaper Universal Retreatment system supplemented by the XP-Endo Finisher file. Int Endod J. 2019;52:1070-6.
35 Ealla KR, Raj PT, Mudrakola DP, Baby D, Govindankutty RK, Davis D, et al. Evaluation of effectiveness of two different endodontic retreatment systems in removal of gutta-percha: an in vitro study. J Contemp Dent Pract. 2018;19:726-31.
36 Spagnuolo G, Ametrano G, D'Antò V, Formisano A, Simeone M, Riccitiello F et al. Microcomputed tomography analysis of mesiobuccal orifices and major apical foramen in first maxillary molars. Open Dent J. 2012;6:118.