

Research Article



OPEN ACCESS

Received: Jul 1, 2020

Revised: Aug 8, 2020

Accepted: Sep 13, 2020

Dhaimy S, Kim HC, Bedida L, Benkiran I

*Correspondence to

Hyeon-Cheol Kim, DDS, MS, PhD

Professor, Department of Conservative Dentistry, Dental Research Institute, School of Dentistry, Pusan National University, 20 Geumo-ro, Mulgeum-eup, Yangsan 50612, Korea.

E-mail: golddent@pusan.ac.kr

Copyright © 2021. The Korean Academy of Conservative Dentistry

This is an Open Access article distributed under the terms of the Creative Commons Attribution Non-Commercial License (<https://creativecommons.org/licenses/by-nc/4.0/>) which permits unrestricted non-commercial use, distribution, and reproduction in any medium, provided the original work is properly cited.

Conflict of Interest

No potential conflict of interest relevant to this article was reported.

Author Contribution

Conceptualization: Dhaimy S; Data curation: Dhaimy S, Bedida L; Formal analysis: Dhaimy S, Kim HC; Investigation: Dhaimy S, Bedida L, Benkiran I; Methodology: Dhaimy S, Kim HC; Project administration: Dhaimy S; Software: Dhaimy S; Supervision: Dhaimy S, Kim HC; Validation: Dhaimy S, Kim HC; Visualization: Dhaimy S, Bedida L, Benkiran I; Writing - original draft: Dhaimy S, Bedida L, Benkiran I; Writing - review & editing: Kim HC.

Efficacy of reciprocating and rotary retreatment nickel-titanium file systems for removing filling materials with a complementary cleaning method in oval canals

Said Dhaimy ,¹ Hyeon-Cheol Kim ,^{2*} Lamyae Bedida ,¹ Imane Benkiran ¹

¹Department of Conservative Dentistry and Endodontics, School of Dentistry, Hassan II University, Casablanca, Morocco

²Department of Conservative Dentistry, Dental Research Institute, School of Dentistry, Pusan National University, Yangsan, Korea

ABSTRACT

Objectives: This study aimed to evaluate and compare the efficacy of the S1 reciprocating system and the D-Race retreatment rotary system for filling material removal and the apical extrusion of debris.

Materials and Methods: Sixty-four freshly extracted maxillary canines were shaped with size 10 and size 15 K-files, instrumented using ProTaper Gold under irrigation with 2.5% sodium hypochlorite (NaOCl), obturated according to the principle of thermo-mechanical condensation with gutta-percha and zinc oxide eugenol sealer, and allowed to set for 3 weeks at 37°C. Subsequently, the teeth were divided into a control group ($n = 4$), the D-Race rotary instrument group ($n = 30$), and the S1 reciprocating instrument group ($n = 30$). After classical retreatment, the canals were subjected to a complementary approach with the XP-Endo Shaper. Desocclusol was used as a solvent, and irrigation with 2.5% NaOCl was performed. Each group was divided into subgroups according to the timing of radiographic readings. The images were imported into a software program to measure the remaining filling material, the apical extrusion, and the root canal space. The data were statistically analyzed using the Z-test and JASP graphics software.


Results: No significant differences were found between the D-Race and S1 groups for primary retreatment; however, using a complementary cleaning method increased the removal of remnant filling ($p < 0.05$).

Conclusions: Classical removal of canal filling material may not be sufficient for root canal disinfection, although a complementary finishing approach improved the results. Nevertheless, all systems left some debris and caused apical extrusion.

Keywords: Retreatment; S1; D-Race; Debris; Extrusion; Filling material

INTRODUCTION

Endodontic therapy may not always lead to desirable healing results. In particular, periapical bone destruction, sometimes accompanied by clinical symptoms, may persist or appear following endodontic treatment [1].

ORCID iDsSaid Dhaimy <https://orcid.org/0000-0002-7846-6228>Hyeon-Cheol Kim <https://orcid.org/0000-0001-8032-1194>Lamyae Bedida <https://orcid.org/0000-0002-9513-9237>Imane Benkiran <https://orcid.org/0000-0003-3068-1516>

The mechanical removal of infected root filling material can be accomplished by different instruments that provide access to the dentin; consequently, instrumentation and irrigation should preferably disrupt the biofilm to the greatest extent possible in order to make the microbes more susceptible to the antiseptic effects of the irrigant [2]. Furthermore, some studies have quantified the apical extrusion of materials during endodontic retreatment [3,4].

During the past few decades, several techniques for root-filling material removal have been proposed, using manual instruments, chemical solvents, and ultrasonic tips [5-7]. Different techniques have been proposed for nonsurgical retreatment using nickel-titanium (NiTi) rotary retreatment systems. Recently, D-Race retreatment files (FKG, La Chaux-de-Fonds, Switzerland) have been introduced to complete the Race NiTi system. These 2 retreatment instruments, DR1 and DR2, are designed with alternating cutting edges and a triangular cross-section. Several authors have evaluated the efficacy of D-Race retreatment instruments in straight or curved root canals [4,8-10].

While reciprocating systems were originally designed for root canal preparation, they have also been recommended for the removal of filling materials [11]. S1 (Sendoline AB, Taby, Sweden) is a newly introduced single-file reciprocating system that also has the purpose of canal shaping. All S1 instruments are designed with a unique S cross-section, and they have a non-cutting ISO size 25 tip with a constant taper of 6%. The substantial flexibility of the S1 instrument provided by its progressive pitch and rounded tip makes it easy to negotiate the canal. Unlike WaveOne and Reciproc, this system has not been extensively evaluated in terms of cleaning, shaping, or retreatment. The difficulty of retreatment procedures relates to the root canal anatomy. Removing debris from the inner dentin of previously filled root canals from an oval cross-section, such as in flattened canals, may require complementary removal procedures [12].

A novel NiTi system, called XP-Shaper (FKG), was recently introduced. It is a single-file system used with a continuous rotary movement. According to the manufacturer, it is made with the MaxWire alloy and its “snake” shape gives the instrument the capacity to expand from its original size when exposed to body temperature, enabling the preparation of areas of the canal space that would be unreachable with conventional NiTi systems [13]. In retreatment procedures, it may also improve the cleanliness of the root canal.

The aim of this study was to evaluate and compare the efficacy of the S1 reciprocating system and the D-Race retreatment rotary system for removing the filling material and the apical extrusion of debris, followed by a complementary cleaning method with the XP-Endo Shaper shaping instrument in extracted maxillary canines.

MATERIALS AND METHODS

Selection of teeth

Sixty-four freshly extracted maxillary canines were preserved upon extraction in physiological solution, and assessed radiographically in the buccal and proximal directions. All teeth had a single, straight, completely formed root and no calcification or internal resorption.

Teeth with immature apices, previous treatments, fractures, or severe curvature were excluded. To eliminate interoperator variability, a single operator performed all the procedures.

Root-canal treatment

For the access opening, a 016 diamond bur was used, and the working length (WL) was determined by introducing a size 10 K-file until its tip was visible in the apical foramen under a magnifying glass. Individual plinths were filled with condensation silicone, where the samples were sunk.

ProTaper Gold rotary files (Dentsply Sirona, Ballaigues, Switzerland) were used to clean and shape root canals in the sequence of S1, S2, F1, and F2 at the WL in a crown-down manner. After each motion, the file was removed from the canal and cleaned. The irrigation protocol employed 2.5% sodium hypochlorite (NaOCl) between each file, and irrigation was performed using a 5 mL plastic syringe with a 30-gauge needle placed passively into the canal up to 2 mm from the apical foramen. The canals were dried with absorbent paper points and filled with sealer based on zinc oxide eugenol (Endoseal, Prevest Denpro Limited, Jammu, India) and ProTaper F2 gutta-percha cones (Dentsply Sirona) using thermomechanical compaction. The master cone was lightly covered with sealer and slowly inserted into the root canal until it reached the WL. A size 25 gutta-percha condenser (Dentsply Sirona) was applied for 5 seconds until 6 mm from the WL; then, the excess material was removed with a heated instrument and vertically condensed with a plugger.

Mesio-distal and bucco-lingual radiographs were obtained to check the quality of the root canal filling. The teeth were stored at 37°C for 3 weeks to allow the sealer to set.

Retreatment techniques

The teeth were randomly divided into 2 main groups: the D-Race group ($n = 30$) and the S1 group ($n = 30$). A control group ($n = 4$) was also created. Afterwards, the teeth were decoronated to obtain a standardized root length of 25 mm. Cotton balls dipped in a drop of Desocclusol (ACTEON Group, Produits dentaires Pierre Rolland, Mérignac, France) with an endodontic syringe were placed at the entry of each canal 24 hours before filling removal.

D-Race retreatment instruments were used with the X-Smart Plus endodontic motor according to the manufacturer's instructions. The coronal third of the root filling was removed using the DR1 instrument (size 30/0.10 taper) at a speed of 1,000 rpm, and the DR2 (size 25/0.04 taper) instrument was used at a speed of 600 rpm was used with light apical pressure until the WL was reached. Copious irrigation with 5 mL of 2.5% NaOCl was performed throughout the procedures at each instrument change.

The S1 (25/0.06) file (Sendoline AB) was used with the Sendoline S1 handpiece (Sendoline AB) at a speed of 40,000 rpm with passive penetration, brushing against the walls until the WL was reached. During retreatment, the root canals were irrigated with 5 mL of 2.5% NaOCl at each instrument change, and the retreatment procedure was declared to be complete after no debris from the filling material was observed.

Subsequently, a complementary cleaning method with XP-Shaper was performed in the root canals. The XP-Shaper instrument (30/0.01) was used with the X-Smart Plus endodontic motor at a speed of 800 rpm. The instrument was activated and placed up to 0.5 mm short of the WL, and 3 cycles of in-and-out movement were performed. Irrigation with 0.5 mL of 2.5% NaOCl was delivered to the WL by an endodontic syringe, and the instrument was cleaned after each cycle.

Radiographic evaluation of gutta-percha removal

For this purpose, the 2 groups were divided into 3 subgroups in order to analyze radiographic images, as follows: radiographs of the initial filling material ($n = 10$), radiographs after filling removal ($n = 10$), and radiographs after complementary cleaning with XP-Shaper ($n = 10$). The control group ($n = 4$) was used to calibrate the method of the analysis.

A wooden device system was developed and divided into 2 parts: the first part was used to fix the intraoral digital sensor and to place the sample in the proximal direction, while the second was used to fix the mobile X-ray unit. The distance between the X-ray source and the location where the digital image was captured was constant. Radiography was carried out with an irradiation time of 0.05 seconds at 90 kVp. The images were processed using dedicated software (KODAK Dental Imaging 6.12.10.0, KODAK, Rochester, NY, USA).

The obtained images were analyzed with AutoCAD 2010 software (Autodesk, San Rafael, CA, USA), to measure the area of the filling material, the filling material remaining on the root canal walls in each portion, and the extracted debris in millimeters squared based on radiopacity differences (**Figures 1 and 2**).

The percentage of residual filling material in the root canal walls was calculated using the following equation: $(\text{area of the remnant} \times 100) / \text{area of the root canal}$. The percentage of the apically extruded debris was calculated as follows: $(\text{area of the extruded debris} \times 100) / \text{area of the total root canal}$.

Statistical analysis

The data were found to be normally distributed. Consequently, 1-way analysis of variance was used to analyze the differences between the groups. The cleanliness of the root canal walls and extruded materials were analyzed with the JASP statistical program (University of Amsterdam, Amsterdam, The Netherlands), using the Z-test with a significance level of $p < 0.05$.

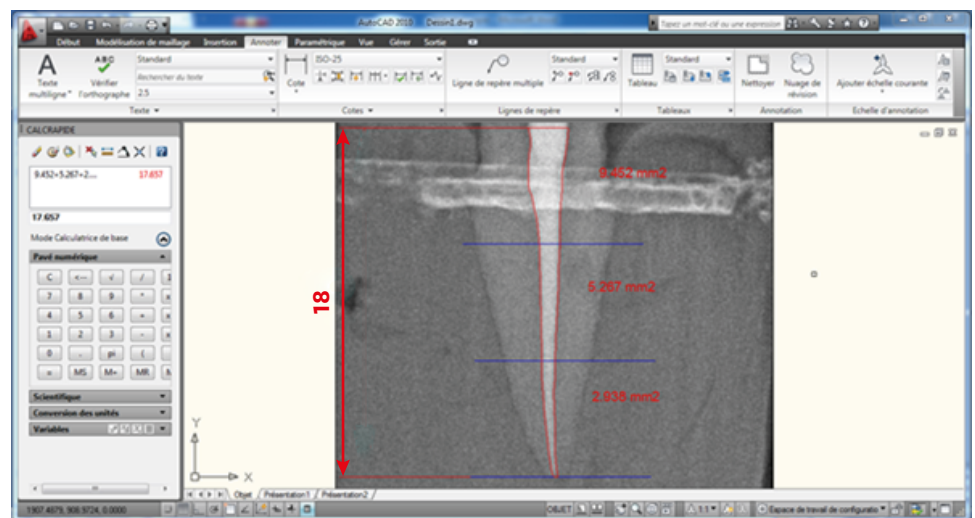


Figure 1. AutoCAD software analysis: measurement of the obturation area = the total area (mm^2).

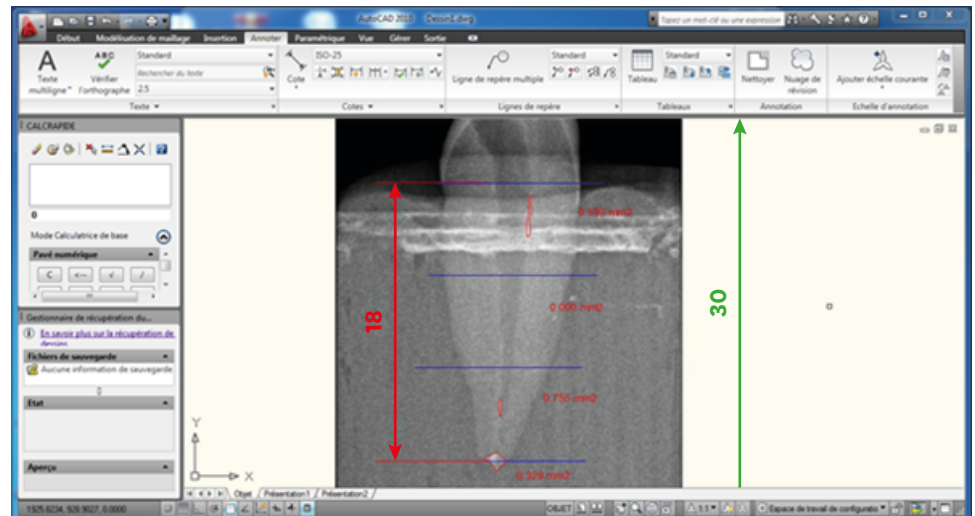


Figure 2. AutoCAD software analysis: measurement of residual gutta-percha and sealer on the root canal wall and the extrusion debris (mm²).

RESULTS

Table 1 shows the values of the area (mm²) and the percentage (%) of residual filling material in the entire roots and the apical, middle, and cervical thirds, as well as extruded debris, in the D-Race and S1 groups after filling removal, and the values of the area (mm²) and the percentage of remaining filling material and of extrusion after complementary cleaning using the XP-Shaper.

Complete removal of filling material only occurred in 3 specimens retreated with D-Race instruments and 4 specimens retreated with S1 instruments when evaluated radiographically.

Considering the whole canal, no statistically significant differences were found between the D-Race and S1 groups after filling removal ($p = 0.18$). When evaluating the remaining filling material between the D-Race and S1 groups after filling removal, there were no significant differences in the coronal ($p = 0.129$), middle ($p = 0.209$), and apical thirds ($p = 0.389$). No significant difference was found in the extruded debris in both groups ($p = 0.617$) (**Table 1**). XP-Shaper significantly reduced the amount of filling material in the apical ($p = 0.019$; $p = 0.003$), middle ($p = 0.017$; $p = 0.024$), and the cervical thirds ($p = 0.001$; $p = 0.001$) after

Table 1. Area and percentages of residual filling material and extrusion

Residual filling material		D-Race	S1	D-Race + XP-Shaper	S1 + XP-Shaper
Area or Percentage	Location and Extrusion				
Area (mm ²)	Cervical	2.11 ± 2.54 ^a	1.21 ± 1.41 ^a	1.86 ± 2.37 ^b	0.98 ± 1.31 ^b
	Middle	1.54 ± 2.66 ^a	0.75 ± 0.90 ^a	1.23 ± 2.29 ^b	0.58 ± 1.05 ^b
	Apical	1.14 ± 2.09 ^a	0.80 ± 1.24 ^a	0.91 ± 1.85 ^b	0.54 ± 0.78 ^b
	Total	4.81 ± 6.31 ^a	2.82 ± 3.10 ^a	3.99 ± 5.71 ^a	2.13 ± 2.66 ^a
	Extruded debris	0.21 ± 0.43 ^a	0.26 ± 0.32 ^a	0.08 ± 0.25 ^a	0.19 ± 0.29 ^a
	Percentage (%)	Cervical	16.64	9.91	16.17
Middle		21.19	12.58	15.63	9.16
Apical		32.70	21.60	25.97	15.44
Total		21.44	17.03	12.50	9.56
Extruded debris		0.88	1.21	0.34	0.89

Values are presented as mean ± standard deviation or percentages.

^{a,b}Different superscript letters indicate a statistically significant difference among the groups in the same rows ($p < 0.05$).

retreatment procedures with S1 and D-Race, respectively. No significant differences were found between the groups in terms of the apically extruded material ($p = 0.072$; $p = 0.065$).

DISCUSSION

Gutta-percha is a filling material commonly used for the obturation of root canals. It is relatively difficult to remove it from the oval-shaped canals, as residues of gutta-percha and sealer are bonded in the lingual and vestibular extensions. In the literature, retreatment studies mostly focused on teeth with an oval cross-section [3,7,14].

Root canals were instrumented using ProTaper Gold rotary instruments, which have been found to generate less apical transportation and a slight decrease in dentin thickness [15]. Root canals were filled with the thermomechanical compaction technique using gutta-percha and sealer due to its simplicity and speed, as documented in a similar study, compared to the cold lateral condensation technique, which has been widely used in the literature [8,16,17].

Filling material removal was preceded by the introduction of a solvent based on Desocclusol orange oil. Colombo *et al.* [18] pointed that a solvent facilitates the penetration of the instrument, and may be responsible for improving the cleanliness of the canal system, while Takahashi *et al.* [19] acknowledged that its use could increase the time required for filling material removal because of the formation of a layer that adheres to the walls of the canal, making it difficult to remove.

Previous studies standardized the length of teeth through the section of the crowns [3,8,9]. In the current study, the crowns were partially sectioned in order to create an accurate simulation of daily practice, and to eliminate the constraints of the access cavity.

According to the current literature, several methods, including cone-beam computed tomography, micro-computed tomography, scanning electron microscopy, tooth clearing, 2-dimensional (2D) analysis of split teeth images, and decalcification have been used to evaluate root canal materials [3,4,7,11,12,14,16,20,21].

In the present study, the residual gutta-percha and sealer were analyzed using digital radiography, which has been used extensively in previous research [2,5,22,23]. Although radiographs provide only 2D information about 3D structures, cannot distinguish sealer from gutta-percha, and may be subject to magnification and distortion, the radiological method is more conservative. In total, 188 images were assessed radiographically according to their differences in radiopacity, and were evaluated using the AutoCAD software.

In this study, the D-Race retreatment rotary system and the S1 reciprocating system were used to remove root canal filling material, along with a supplementary instrument (XP-Shaper) to complete the retreatment. Both of the systems were efficient; in terms of percentage, S1 left less debris (17.03%) in the canal than the D-Race (21.44%), but S1 caused more extruded debris (1.21%) than D-Race (0.88%). However, this difference was not statistically significant. D-Race was effective for removing filling material, as it allowed a reduction of 78.56% of the material; this finding is in agreement with the results of Rödiger *et al.* [9], who compared the D-Race with the ProTaper Universal retreatment instrument and hand files, and found that the D-Race instrument was significantly more effective than both

other groups regarding cleanliness. In contrast to the present study, Marques da Silva *et al.* [8] demonstrated poor effectiveness of the D-Race instrument in comparison with the ProTaper Universal retreatment and Mtwo retreatment instruments. Akhavan *et al.* [6] reported that the Mtwo system and D-Race were equally effective for gutta-percha removal. Topçuoğlu *et al.* [4,10] showed in 2 studies that D-Race caused more apical extrusion of debris and dentinal defects after retreatment.

In the current study, the effectiveness of the S1 reciprocating system was investigated for retreatment, and it was found to be as efficient as the D-Race instrument, with a rate of filling material reduction of 82.97%. This agrees with the recent findings reported by Madarati *et al.* [24] that the S1 system showed an equal efficacy in root filling removal as the Reciproc and the WaveOne reciprocating systems. According to the literature, reciprocating systems can be more efficient than retreatment or conventional rotary systems for removing gutta-percha and sealers [11,17].

With the intention to complete the previous removal, a complementary cleaning strategy with the use of the XP-Shaper instrument was tested. The results of the present study could be corroborated by 2 previous studies. Borges *et al.* [21] observed greater efficacy of the XP-Shaper in removing the rest of the filling material when used as a complementary method compared with passive ultrasonic irrigation and an oscillatory device with H-files. Machado *et al.* [25], who used the XP-Shaper for complementary treatment after initial disobturation with the D-Race instrument, noted its effectiveness over the self-adjusting file and the TRUShape.

Further studies using other instruments in various conditions would be helpful for improving retreatment procedures and achieving cleanliness of the root canal wall.

CONCLUSIONS

Under the conditions of the present study, the D-Race and S1 showed a similar efficacy of filling material removal, yet they both generated apical extrusion. A complementary cleaning method with the XP-Shaper significantly improved the removal of filling materials.

REFERENCES

1. Bergenholtz G, Lekholm U, Milthorpe R, Heden G, Odesjö B, Engström B. Retreatment of endodontic fillings. *Scand J Dent Res* 1979;87:217-224.
[PUBMED](#)
2. Ulin C. Non-surgical retreatment. In: Kvist T, editor. *Apical periodontitis in root-filled teeth*. Cham: Springer International Publishing; 2018. p89-102.
3. Pawar AM, Pawar M, Metzger Z, Thakur B. Apical extrusion of debris by supplementary files used for retreatment: an *ex vivo* comparative study. *J Conserv Dent* 2016;19:125-129.
[PUBMED](#) | [CROSSREF](#)
4. Topçuoğlu HS, Aktı A, Tuncay Ö, Dinçer AN, Düzgün S, Topçuoğlu 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;40:2066-2069.
[PUBMED](#) | [CROSSREF](#)
5. Unal GC, Kaya BU, Taç AG, Keçeci AD. A comparison of the efficacy of conventional and new retreatment instruments to remove gutta-percha in curved root canals: an *ex vivo* study. *Int Endod J* 2009;42:344-350.
[PUBMED](#) | [CROSSREF](#)

6. Akhavan H, Azdadi YK, Azimi S, Dadresanfar B, Ahmadi A. Comparing the efficacy of Mtwo and D-Race retreatment systems in removing residual gutta-percha and sealer in the root canal. *Iran Endod J* 2012;7:122-126.
[PUBMED](#)
7. Bernardes RA, Duarte MA, Vivan RR, Alcalde MP, Vasconcelos BC, Bramante CM. Comparison of three retreatment techniques with ultrasonic activation in flattened canals using micro-computed tomography and scanning electron microscopy. *Int Endod J* 2016;49:890-897.
[PUBMED](#) | [CROSSREF](#)
8. Marques da Silva B, Baratto-Filho F, Leonardi DP, 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;45:927-932.
[PUBMED](#) | [CROSSREF](#)
9. Rödiger 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;45:580-589.
[PUBMED](#) | [CROSSREF](#)
10. Topçuoğlu HS, Demirbuga S, Tuncay Ö, Pala K, Arslan H, Karataş E. The effects of Mtwo, R-Endo, and D-Race retreatment instruments on the incidence of dentinal defects during the removal of root canal filling material. *J Endod* 2014;40:266-270.
[PUBMED](#) | [CROSSREF](#)
11. Rios MA, Villela AM, Cunha RS, Velasco RC, De Martin AS, Kato AS, Bueno CE. Efficacy of 2 reciprocating systems compared with a rotary retreatment system for gutta-percha removal. *J Endod* 2014;40:543-546.
[PUBMED](#) | [CROSSREF](#)
12. Rechenberg DK, Paqué F. Impact of cross-sectional root canal shape on filled canal volume and remaining root filling material after retreatment. *Int Endod J* 2013;46:547-555.
[PUBMED](#) | [CROSSREF](#)
13. De-Deus G, Belladonna FG, Simões-Carvalho M, Cavalcante DM, Ramalho CN, Souza EM, Lopes RT, Silva EJ. Shaping efficiency as a function of time of a new heat-treated instrument. *Int Endod J* 2019;52:337-342.
[PUBMED](#) | [CROSSREF](#)
14. Niemi TK, Marchesan MA, Lloyd A, Seltzer RJ. Effect of instrument design and access outlines on the removal of root canal obturation materials in oval-shaped canals. *J Endod* 2016;42:1550-1554.
[PUBMED](#) | [CROSSREF](#)
15. Gagliardi J, Versiani MA, de Sousa-Neto MD, Plazas-Garzon A, Basrani B. Evaluation of the shaping characteristics of ProTaper Gold, ProTaper NEXT, and ProTaper Universal in curved canals. *J Endod* 2015;41:1718-1724.
[PUBMED](#) | [CROSSREF](#)
16. Taşdemir T, Er K, Yildirim T, Çelik D. Efficacy of three rotary NiTi instruments in removing gutta-percha from root canals. *Int Endod J* 2008;41:191-196.
[PUBMED](#) | [CROSSREF](#)
17. Zuolo AS, Mello JE Jr, Cunha RS, Zuolo ML, Bueno CE. Efficacy of reciprocating and rotary techniques for removing filling material during root canal retreatment. *Int Endod J* 2013;46:947-953.
[PUBMED](#) | [CROSSREF](#)
18. Colombo AP, Fontana CE, Godoy A, De Martin AS, Kato AS, Rocha DG, Pelegrine RA, Bueno CE. Effectiveness of the waveone and ProTaper D systems for removing gutta-percha with or without a solvent. *Acta Odontol Latinoam* 2016;29:262-267.
[PUBMED](#)
19. Takahashi CM, Cunha RS, de Martin AS, Fontana CE, Silveira CF, da Silveira Bueno CE. *In vitro* evaluation of the effectiveness of ProTaper Universal rotary retreatment system for gutta-percha removal with or without a solvent. *J Endod* 2009;35:1580-1583.
[PUBMED](#) | [CROSSREF](#)
20. Pawar AM, Thakur B, Metzger Z, Kfir A, Pawar M. The efficacy of the Self-Adjusting File versus WaveOne in removal of root filling residue that remains in oval canals after the use of ProTaper retreatment files: a cone-beam computed tomography study. *J Conserv Dent* 2016;19:72-76.
[PUBMED](#) | [CROSSREF](#)
21. Borges MM, Duque JA, Zancan RF, Vivan RR, Bernardes RA, Duarte MA. Efficacy of reciprocating systems for removing root filling material plus complementary cleaning methods in flattened canals: microtomography and scanning electron microscopy study. *Microsc Res Tech* 2019;82:1057-1064.
[PUBMED](#) | [CROSSREF](#)

22. Özyürek T, Özsezer-Demiryürek E. Efficacy of ProTaper next and ProTaper Universal retreatment systems in removing gutta-percha in curved root canals during root canal retreatment. *J Istanbul Univ Fac Dent* 2017;51:7-13.
[PUBMED](#) | [CROSSREF](#)
23. Schropp L, Kirkevang LL. Accuracy and reliability of intraoral radiographs in determining the cleanliness of root canals after endodontic retreatment. *Eur Endod J* 2020;2:1-5.
[PUBMED](#)
24. Madarati AA, Al-Nazzawi AA, Sammani AM, Alkayyal MA. The efficacy of retreatment and new reciprocating systems in removing a gutta-percha-based filling material. *J Taibah Univ Med Sci* 2018;13:452-458.
[PUBMED](#) | [CROSSREF](#)
25. Machado AG, Guilherme BP, Provenzano JC, Marceliano-Alves MF, Gonçalves LS, Siqueira JF Jr, Neves MA. Effects of preparation with the Self-Adjusting File, TRUShape and XP-endo Shaper systems, and a supplementary step with XP-endo Finisher R on filling material removal during retreatment of mandibular molar canals. *Int Endod J* 2019;52:709-715.
[PUBMED](#) | [CROSSREF](#)