Journal of Dentistry Indonesia

Volume 29 | Number 1 Article 9

4-30-2022

The Effects of Two Instrumentation Techniques for VDW.Rotate Instruments on the Apical Extrusion of Debris and Irrigants: An In Vitro Study

Seda Falakaloğlu
Department of Endodontics, Faculty of Dentistry, Afyonkarahisar Health Sciences University, Afyonkarahisar, Turkey, sedafalakaloglu@gmail.com

Merve Yeniçeri Özata
Department of Endodontics, Faculty of Dentistry , Dicle University, Diyarbakır, Turkey, merveyeniceri05@hotmail.com

Emre İriboz
Department of Endodontics, Faculty of Dentistry, Marmara University, Istanbul, Turkey, eriboz@yahoo.com

The Effects of Two Instrumentation Techniques for VDW.Rotate Instruments on the Apical Extrusion of Debris and Irrigants: An In Vitro Study

Cover Page Footnote

ACKNOWLDGEMENTS The authors thanks to Dr. Ömer Yavuz for technical support.

Journal of Dentistry Indonesia 2022, Vol. 29, No. 1, 61-66
doi: 10.14693/jdi.v29i1.1299

ORIGINAL ARTICLE

The Effects of Two Instrumentation Techniques for VDW.Rotate Instruments on the Apical Extrusion of Debris and Irrigants: An In Vitro Study

Seda Falakaloğlu[1], Merve Yeniçeri Özata[*2], Emre İriboz[3]

[1]Department of Endodontics, Faculty of Dentistry, Afyonkarahisar Health Sciences University, Afyonkarahisar, Turkey
[2]Department of Endodontics, Faculty of Dentistry, Dicle University, Diyarbakır, Turkey
[3]Department of Endodontics, Faculty of Dentistry, Marmara University, Istanbul, Turkey
[*]Correspondence e-mail to: merveyeniceri05@hotmail.com

ABSTRACT

Objectives: This study compared the amount of apically extruded debris and irrigant using VDW.ROTATE instruments with different kinematics (continuous rotation and reciprocation motion) and the ProTaper Gold system. **Methods**: Sixty extracted mandibular premolar teeth were selected. The teeth were prepared for the agar gel model. The roots were randomly divided into three groups (n=20). In two groups, the root canals were instrumented using the following movement kinematics: VDW.ROTATE reciprocation motion and continuous rotation. In the other group, root canals were prepared with ProTaper Gold. Apically extruded debris and irrigant during instrumentation were collected into preweighed Eppendorf tubes and were assessed with an electronic balance. All procedures were performed in a 35°C hot water bath. The data were analyzed using the Shapiro–Wilk and Kruskal–Wallis tests at a 5% significance level. **Results**: ROTATE-Reciprocation extruded the least amount of debris, but this finding was not significant when compared with the amount of debris and irrigant extruded by the ProTaper Gold and ROTATE-Rotation (p>.05). **Conclusion**: All instrumentation kinematics were associated with apical debris and irrigant extrusion. Movement kinematics did not affect the amount of apically extruded debris and irrigants when using VDW.ROTATE instruments.

Key words: agar gel model, apical extrusion, kinematics, ProTaper Gold, VDW.ROTATE

How to cite this article: Falakaloğlu S, Özata MY İriboz E. The effects of two instrumentation techniques for vdw.rotate instruments on the apical extrusion of debris and irrigants: An in vitro study. J Dent Indones. 2022;29(1): 61-66

INTRODUCTION

The apical extrusion of debris (AED) during chemomechanical preparation has been reported in the literature; however, many factors affect the amount of AED, including the preparation technique, kinematics, and the number, design, and size of the instruments used in each system.[1] A reduction in AED is desirable to help reduce postoperative pain after root canal treatment.[2] The AED is the main cause of periodontal ligament inflammation.[3] The existing literature is divided on whether reciprocating movement produces more AED than continuous rotation.[4] Some studies showed no significant differences between the two motions.[5–7] However, there are studies indicating that continuous rotating motion causes more AED than reciprocating movement.[8,9]

The ProTaper Gold (Dentsply Maillefer, Ballaigues, Switzerland) is made of "Gold Wire" and has some characteristics similar to those of Controlled Memory wire (CM wire).[10] This rotary system has a unique instrument design with a triangular cross-section and a variable progressive taper.[11] The ProTaper Gold system was compared with many file systems with different kinematics in terms of AED.[12–14] The VDW.ROTATE (VDW GmbH, Munich, Germany) is made of a special heat-treated "Blue Wire" NiTi alloy. According to the manufacturer, this rotary system has a double-bladed, adapted-S cross-sectional design and a constant taper. The instruments' designs and increased flexibility reduce canal transportation and preserve root canal anatomy.[15] NiTi file systems with S-shapes and different

names are produced by the same manufacturers in the market. Burklein and Schafer found that the Reciproc (VDW GmbH, Munich, Germany) file system extruded significantly more debris than the Mtwo (VDW GmbH, Munich, Germany) file system, both of which have an identical S-shaped, cross-sectional design.[16] However, Arslan et al. reported that reciprocating motions of 150° counterclockwise (CCW)/30° clockwise (CW) and 270° CCW/30° CW produced fewer debris extrusions compared with continuous rotation when using Reciproc instruments as root canal instrumentation.[17] In contrast to the view that conventional rotary file systems were associated with more debris extrusions than single file systems that used reciprocating motion,[1,18] some researchers have observed similar amounts of AED when using both rotary and reciprocating systems.[19,20]

To the best of our knowledge, no published studies have investigated the effects of different kinematics on the apical extrusion of debris and irrigants (AEDI) during canal preparation using the VDW.ROTATE system. Therefore, the purpose of the present study was to compare the amount of AEDI after instrumentation of root canals using the VDW.ROTATE system with both reciprocation and continuous rotation and also using the ProTaper Gold system.

The null hypotheses of the present study were there would be no significant difference in the mean weights of AEDI by a VDW.ROTATE used in either a continuous rotation or a reciprocating motion and there would be no significant differences between the VDW.ROTATE and ProTaper Gold systems regarding AEDI.

METHODS

This study was approved by the local ethics committee (Research Ethics Committee of Afyonkarahisar Health Sciences University, Afyonkarahisar, Turkey; No: 2011-KAEK-2/2020/13). Based on a previous study,[21] a power calculation was performed using G*Power 3.1 software (Heinrich Heine University, Dusseldorf, Germany) with α=0.05 and ß=0.80. The calculation indicated that the sample size for each group must be a minimum of 19 teeth. Therefore, 60 mandibular premolar teeth that had been extracted for periodontal reasons were included in the study. The inclusion criteria were that all the selected teeth must have mature apices with a single apical foramen without resorption/calcification or previous root canal treatment and that the root must have less than a 5° curvature.[22] Soft- and hard-tissue debris on the external surfaces of all the teeth was mechanically removed. To increase standardization, only teeth with lengths between 19 and 21 mm, as measured using a millimeter ruler, were included in the study.

All teeth were decoronated, and a #15 K-file (VDW GmbH, Munich, Germany) was advanced within the canal until the tip was seen through the major apical foramen. Then, the working length was determined by subtracting 1 mm from this length. No tooth had an apical foramen greater than 0.15mm.

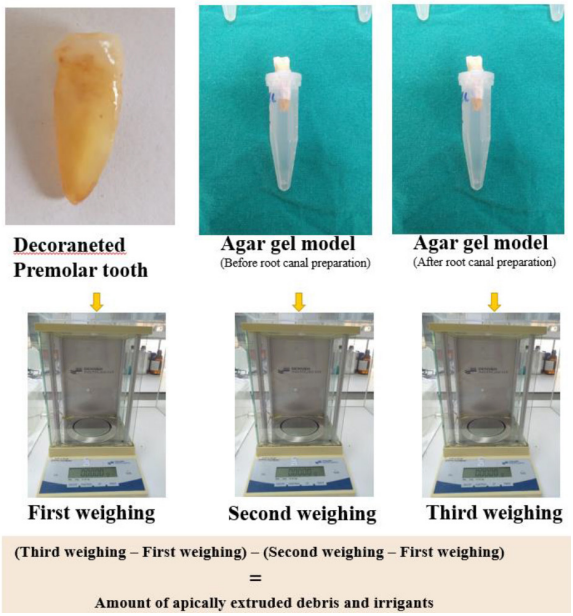

Figure 1. Description and visualization of AEDI calculation

The selected roots were randomly divided into three groups of 20 each and numbered. The root surfaces of each tooth were covered with a Teflon band, except for 1 mm of the apical part. The weight of the samples was measured three times using an electronic scale of 10^{-4} g (Denver Instrument, New York, USA), and the mean value was calculated. Then, as Lu et al. described in their study, 1.5 grams of agar was dissolved in 100 ml of sterile distilled water with the help of a microwave and a homogeneous mixture was prepared.[23] Agar gel (3 mL, 1.5%) was injected into Eppendorf tubes, and the samples were fixed into the tubes at the cementoenamel junction using cyanoacrylate adhesive (UHU Patafix; UHU GmbH & Co. KG, Baden, Germany) to prevent leakage of the irrigating solution through the hole. After gelation of the agar, the weights of the tubes, including the agar solution, were measured three times. The weight of each tooth-free apparatus was calculated by subtracting the value of the first weight measurement of each sample from the value of the second weight measurement[23,24] (Figure 1). The Eppendorf tubes were positioned in a glass bottle filled with water, and the equipment was placed in a 35°C hot water bath (JSR Research Inc., Republic of Korea).[25]

Each instrument used was used on four specimens to simulate a molar having four canals. The root canal preparation was complete when the final instrument of each system reached the working length. Using a 30-G IrriFlex needle (Produits Dentaires SA, Switzerland),

the canals were irrigated with 5 mL 2.5% NaOCl solution. To standardize the irrigation protocol, the needle was attached to a device (Mindray BeneFusion SP1, Shenzhen, China) and inserted into the canal within 2 mm of the working length without binding and moved in an up-and-down motion. In all groups, the flow rate of the irrigating solution was constant and equal to 2.5 ml/min. After completion of the preparation, final irrigation was applied using 5 mL of 17% EDTA followed by 5 mL of 2.5% NaOCl. All endodontic procedures were completed by a single operator.

1. ROTATE-Rotation (VDW.ROTATE in continuous rotation motion): The root canals were prepared using the ROTATE 20.05 and 25.06 files at 300 rpm and 2.0 Ncm of torque produced by an endomotor (VDW Gold; VDW, Munich, Germany).
2. ROTATE-Reciprocation (VDW.ROTATE in reciprocation motion): The root canals were prepared using the ROTATE 20.05 and 25.06 files at 300 rpm and CCW = 150°/CW = 30° using a torque-controlled endomotor (Genius; Ultradent Products Inc., South Jordan, UT, USA).
3. ProTaper Gold (in continuous rotation motion): The root canals were prepared using ProTaper Gold S2 (20.04), F1 (20.07), and F2 (25.08) files at 300 rpm and 2.0 Ncm of torque using an endomotor (VDW Gold; VDW, Munich, Germany).

When the root canal preparation was completed, the Eppendorf tubes were removed from the glass bottles, and the teeth were removed from the tubes. After the Teflon bands were removed from the teeth, each apparatus was weighed three times consecutively. The amount of AEDI was calculated by subtracting the weight of the tooth-free apparatus from the post-preparation weight. The mean weight of each tube containing debris and irrigant was recorded. All the measurements of AEDI were performed by a second independent operator.

Statistical Analysis

The Shapiro–Wilk test indicated that the data showed non–normal distribution ($p<.05$). The amounts of AEDI for the three groups were analyzed using the Kruskal–Wallis H test and SPSS 20.0 software (IBM Corp., Armonk, NY, USA). The level of significance was set at $p<.05$.

RESULTS

Table 1 shows the descriptive statistics regarding the AEDI in each group. All groups and kinematics caused AEDI, and the amount of AEDI in milligrams has shown in Figure 2. There were no statistically significant differences among the ROTATE-Rotation, ROTATE-Reciprocation, and ProTaper Gold groups ($p<.05$). The ROTATE-Reciprocation extruded the least amount of debris, but this finding was not significant when compared with the amounts of AEDI by the ROTATE-Rotation and the ProTaper Gold ($p<.05$).

Table 1. The mean, standard deviation (SD), median, minimum, and maximum values of AEDI for all instruments, in milligrams.

Group (n=20)	Mean ± SD	Median (Minimum-Maximum)	H	p
VDW ROTATE-Rotation	32.0 ± 38.7	13.3 (4.0 – 143.4)		
VDW ROTATE-Reciprocation	17.8 ± 31.8	11.4 (0.9 – 147.6)	4.754	0.093*
Protaper Gold	28.7 ± 32.3	19.5 (1.0 – 120.6)		

*Kruskal Wallis H test

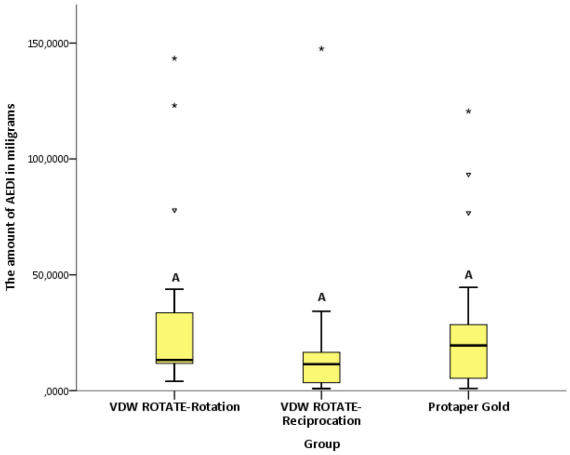

Figure 2. The amount of AEDI for all groups, in milligrams

DISCUSSION

Extrusion of tissue residues, root canal filling materials, and irrigation solution outside the apical foramen has been associated with flare-up, which is an unpleasant post-treatment condition.[3] The amount of AED may be one determining factor in the severity of inflammatory response.[26] Previous studies have reported that all file systems used in the preparation resulted in AED.[27,28] In addition, the length of the irrigation needle, the penetration of the tip of the needle into the apical, and the speed of irrigant administration can cause irrigant extrusion.[29] Accordingly, as in other studies, we used a 30-G IrriFlex irrigation needle integrated into a syringe pump for the irrigation procedure, set at a speed of 2.5

ml/min.[30,31] Moreover, NaOCl and EDTA were used in the present investigation as irrigating solutions.

The present study was designed to evaluate the amount of AEDI by chemomechanically preparing root canals using the VDW.ROTATE in both reciprocation and continuous rotation and using the ProTaper Gold system in continuous rotation. According to our literature research, only one study had determined the amount of AED produced when the VDW.ROTATE instrument was used during root canal preparation. Düzgün et al. reported no statistical difference between the AED resulting from using the VDW.ROTATE, EdgeFile, OneCurve, and K3XF systems.[32] In the current study, the ProTaper Gold and VDW.ROTATE, which are wires with different heat treatments, did not show a statistically significant difference. The "Gold Wire" heat-treated process of the ProTaper Gold and "Blue Wire" heat-treated process of the VDW.ROTATE instruments were evaluated with debris and irrigant extrusion. Also, the evaluated rotary file systems are characterized by different tapers; the ProTaper Gold has a variable progressive taper, and VDW.ROTATE has a constant taper. Although the instrument taper of the tested rotary file system was different, it did not result in statistical differences between the systems.

Uygun reported that when VDW.ROTATE instruments were used in a reciprocation motion, the fracture resistance increased compared to when it was used in a continuous rotation motion.[33] Considering the results of this study, we wanted to examine the effect of VDW.ROTATE on AEDI when used with different kinematics. In the present study, all experimental groups caused AEDI. However, there were no statistically significant differences among the ROTATE-Rotation, ROTATE-Reciprocation, and ProTaper Gold systems. Therefore, the null hypotheses were accepted. Other studies compared rotary and reciprocating systems using another methodology and detected no statistical difference, although minor numeric differences were identified.[19,20] In the present study, we compared different kinematics using the same NiTi system and found no statistically significant differences among them. We observed less debris and irrigants in the ROTATE-Reciprocation group, although this difference was not statistically significant. Similarly, De-Deus et al.[34] used the ProTaper F2 instrument in a conventional sequence and in reciprocal movement; although the reciprocal movement of the F2 extruded less apical debris than the conventional sequence, the difference was not significant.

The results of in vivo studies determined that instrument design was the most effective factor causing inflammation after root canal preparation, regardless of the number of files or the type of movement.[35,36] Therefore, in the present study, each instrument used had a different cross-sectional design: the VDW. ROTATE has an S-shaped cross-sectional design for higher cutting efficiency, and the ProTaper Gold has a triangular cross-section design. Another study found that instrument designs can provide space that improves the cutting, loading, and transportation of debris in the coronal direction.[37] The results of that study may explain why the present study found similar amounts of AEDI in all groups.

Yet another study found that the presence of periapical tissues around the apical foramen and the resistance of this tissue may impede the extrusion of debris and irrigation solution from the apical foramen, thereby affecting the results.[38] That study used the agar gel method to simulate periapical tissues. Lu et al. reported that a 1.5% agar gel model had a similar density and provided resistance similar to that of periapical tissues.[23] However, the agar gel model has some limitations, as the thickness of agar gel around the apex is standard, a circumstance that does not represent all periapical conditions. In addition, it has been thought that the use of real teeth might affect study results due to differences in the microhardness of the dentine.[2] Hemptinne et al. reported that 35°C is the average temperature inside a root canal.[39] This temperature affects the physical characteristics of the rotary file.[40] Using a hot water bath might affect the instruments' topographic properties. Therefore, in the present study, an agar gel model with real teeth was placed into a 35°C hot water bath to replicate the clinical conditions in the method used by Uslu et al.[25]

CONCLUSION

Within the limitations of this in vitro study of extracted teeth, all the kinematics and instruments used caused AEDI. Although Ni-Ti instruments used with reciprocating motion are more resistant to cyclic fatigue, there are no statistical differences in the effect of different kinematics on debris and irrigant extrusion. Further investigations are needed to confirm the present findings of different kinematic effects on AEDI.

CONFLICT OF INTERESTS

None declared.

ACKNOWLDGEMENT

The authors thanks to Dr. Ömer Yavuz for technical support.

REFERENCES

1. Üstün Y, Çanakçi BC, Dinçer AN, Er O, Düzgün S. Evaluation of apically extruded debris associated with several Ni-Ti systems. Int Endod J. 2015; 48(7):701-4.
2. Tanalp J, Güngör T. Apical extrusion of debris: A literature review of an inherent occurrence during root canal treatment. Int Endod J. 2014; 47(3):211-21.
3. Siqueira JF. Microbial causes of endodontic flare-ups. Int Endod J. 2003; 36(7):453-63.
4. Caviedes-Bucheli J, Castellanos F, Vasquez N, Ulate E, Munoz H.R. The influence of two reciprocating single-file and two rotary-file systems on the apical extrusion of debris and its biological relationship with symptomatic apical periodontitis. A systematic review and meta-analysis. Int Endod J. 2016; 49(3):255-70.
5. Ozsu D, Karataş E, Arslan H, Topcu MC. Quantitative evaluation of apically extruded debris during root canal instrumentation with ProTaper Universal, ProTaper Next, WaveOne, and self-adjusting file systems. Eur J Dent. 2014; 8(4):504-8.
6. Silva EJ, Carapiá MF, Lopes RM, Belladonna FG, Senna PM, Souza EM, De-Deus G. Comparison of apically extruded debris after large apical preparations by full-sequence rotary and single-file reciprocating systems. Int Endod J. 2016; 49(7):700-5.
7. Küçükyilmaz E, Savas S, Saygili G, Uysal B. Assessment of apically extruded debris and irrigant produced by different nickel-titanium instrument systems. Braz Oral Res. 2015; 29:1-6.
8. Karataş E, Arslan H, Kırıcı DÖ, Alsancak M, Çapar ID. Quantitative evaluation of apically extruded debris with Twisted File Adaptive instruments in straight root canals: Reciprocation with different angles, adaptive motion and continuous rotation. Int Endod J. 2016; 49(4):382-5.
9. Nayak G, Singh I, Shetty S, Dahiya S. Evaluation of apical extrusion of debris and irrigant using two new reciprocating and one continuous rotation single file systems. J Dent. 2014; 11(3):302-9.
10. Kwak SW, Lee CJ, Kim SK, Kim HC, Ha JH. Comparison of screw-in forces during movement of endodontic files with different geometries, alloys, and kinetics. Materials (Basel). 2019; 12(9):1506:1-7.
11. 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(10):1718-24.
12. Falakaloglu S, Özata MY, İriboz E. Apically extruded debris and irrigants during root canal instrumentation with TruNatomy and ProTaper Gold rotary file systems. G Ital Endod. 2021; 35(2):38-43.
13. Karataş E, Ersoy İ, Gündüz HA, Uygun AD, Kol E, Çakıcı F. Influence of instruments used in root canal preparation on amount of apically extruded debris. Artif Organs. 2016; 40(8):774-7.
14. Cakici F, Cakici EB, Küçükekenci FF, Uygun AD, Arslan H. Apically extruded debris during root canal preparation using ProTaper Gold, ProTaper Universal, ProTaper Next, and Reciproc instruments. Int J Artif Organs. 2016; 39(3):128-31.
15. VDW.ROTATE. Available at: https://www.vdw-dental.com/en/products/detail/vdwrotate/
16. Bürklein S, Schäfer E. Apically extruded debris with reciprocating single-file and full-sequence rotary instrumentation systems. J Endod. 2012; 38(6):850-2.
17. Arslan H, Doğanay E, Alsancak M, Çapar ID, Karataş E, Gündüz HA. Comparison of apically extruded debris after root canal instrumentation using Reciproc® instruments with various kinematics. Int Endod J. 2016; 49(3):307-10.
18. De-Deus G, Neves A, Silva EJ, Mendonça TA, Lourenço C, Calixto C, Lima EJ. Apically extruded dentin debris by reciprocating single-file and multi-file rotary system. Clin Oral Investig. 2015; 19(2):357-61.
19. Koçak S, Koçak MM, Sağlam BC, Türker SA, Sağsen B, Er Ö. Apical extrusion of debris using self-adjusting file, reciprocating single-file, and 2 rotary instrumentation systems. J Endod. 2013; 39(10):1278-80.
20. Kirchhoff AL, Fariniuk LF, Mello I. Apical extrusion of debris in flat-oval root canals after using different instrumentation systems. J Endod. 2015; 41(2):237-41.
21. Boijink D, Costa DD, Hoppe CB, Kopper PMP, Grecca FS. Apically extruded debris in curved root canals using the waveone gold reciprocating and twisted file adaptive systems. J Endod. 2018; 44(8):1289-92.
22. Schneider SW. A comparison of canal preparations in straight and curved root canals. Oral Surg Oral Med Oral Pathol. 1971; 32(2):271-5.
23. Lu Y, Wang R, Zhang L, Li HL, Zheng QH, Zhou XD, Huang DM. Apically extruded debris and irrigant with two Ni-Ti systems and hand files when removing root fillings: A laboratory study. Int Endod J. 2013; 46(12):1125-30.
24. Keskin C, Sariyilmaz E, Sariyilmaz O. Effect of solvents on apically extruded debris and irrigant during root canal retreatment using reciprocating instruments. Int Endod J. 2017; 50(11):1084-8.
25. Uslu G, Özyürek T, Yılmaz K, Gündoğar M, Plotino G. Apically extruded debris during root canal ınstrumentation with Reciproc Blue, HyFlex EDM, and XP-endo Shaper Nickel-titanium Files. J Endod. 2018; 44(5):856-9.

26. Sjögren U, Sundqvist G, Nair PN. Tissue reaction to gutta-percha particles of various sizes when implanted subcutaneously in guinea pigs. Eur J Oral Sci. 1995; 103(5):313-21.
27. Azar NG, Ebrahimi G. Apically-extruded debris using the ProTaper system. Aust Endod J. 2005; 31(1):21-3.
28. Reddy SA, Hicks ML. Apical extrusion of debris using two hand and two rotary instrumentation techniques. J Endod. 1998; 24(3):180-3.
29. van der Sluis LW, Gambarini G, Wu MK, Wesselink PR. The influence of volume, type of irrigant and flushing method on removing artificially placed dentine debris from the apical root canal during passive ultrasonic irrigation. Int Endod J. 2006; 39(6):472-6.
30. Toyoğlu M, Altunbaş D. Influence of different kinematics on apical extrusion of ırrigant and debris during canal preparation using K3XF instruments. J Endod. 2017; 43(9):1565-8.
31. Capar ID, Arslan H, Akcay M, Ertas H. An in vitro comparison of apically extruded debris and instrumentation times with ProTaper Universal, ProTaper Next, Twisted File Adaptive, and HyFlex instruments. J Endod. 2014; 40(10):1638-41.
32. Düzgün S, Topçuoğlu HS, Kahraman Ö. Evaluation of apically extruded debris during the canal preparation using new heat-treated nickel-titanium files in curved canals. Aust Endod J. 2021; 47(1):54-8.
33. Uygun AD. Cyclic fatigue resistance of VDW. ROTATE and Reciproc Blue nickel-titanium files at root canal temperature. J Dent Res Dent Clin Dent Prospects. 2020; 14(3):177-80.
34. De-Deus G, Brandão MC, Barino B, Di Giorgi K, Fidel RA, Luna AS. Assessment of apically extruded debris produced by the single-file ProTaper F2 technique under reciprocating movement. Oral Surg Oral Med Oral Pathol Oral Radiol Endod. 2010; 110(3):390-4.
35. Caviedes-Bucheli J, Azuero-Holguin MM, Gutierrez-Sanchez L, Higuerey-Bermudez F, Pereira-Nava V, Lombana N, Munoz HR. The effect of three different rotary instrumentation systems on substance P and calcitonin gene-related peptide expression in human periodontal ligament. J Endod. 2010; 36(12):1938-42.
36. Caviedes-Bucheli J, Moreno JO, Carreño CP, Delgado R, Garcia DJ, Solano J, Diaz E, Munoz HR. The effect of single-file reciprocating systems on Substance P and Calcitonin gene-related peptide expression in human periodontal ligament. Int Endod J. 2013; 46(5):419-26.
37. Ruddle CJ, Machtou P, West JD. The shaping movement: Fifth-generation technology. Dent Today. 2013; 32(4):94, 96-9.
38. Salzgeber RM, Brilliant JD. An in vivo evaluation of the penetration of an irrigating solution in root canals. J Endod. 1977; 3(10):394-8.
39. de Hemptinne F, Slaus G, Vandendael M, Jacquet W, De Moor RJ, Bottenberg P. In vivo ıntracanal temperature evolution during endodontic treatment after the ınjection of room temperature or preheated sodium hypochlorite. J Endod. 2015; 41(7):1112-5.
40. Goo HJ, Kwak SW, Ha JH, Pedullà E, Kim HC. Mechanical properties of various heat-treated nickel-titanium rotary ınstruments. J Endod. 2017; 43(11):1872-7.

(Received September 13, 2021 ; Accepted April 12, 2022)