Mustansiria Dental Journal
DOI: 10.32828/mdj.v19i2.890

E- ISSN: 2618-0944
P- ISSN: 1813-8500

Research Article | **Open Access** | **Volume: 19, Issue: 2, 2023**

Effect of Using Race Evo, EdgeFile X7, and Protaper Gold Rotary File Systems on the Fracture Resistance of Obturated Root Canal (A comparative study)

Israa Kh. A. Alzaidy [1] and Biland M. S. Shukri [1]

[1] *College of Dentistry, Mustansiriyah University, Department of Conservative Dentistry, Bagdad, Iraq*

Correspondence: *Biland M. S. Shukri*
Email: *blandms@uomustansiriyah.edu.iq*
Received: 9 August 2023; Accepted: 29 December 2023; Published: 30 December 2023

Abstract

Aim of the study: The purpose of this research was to compare the fracture resistance of obturated roots prepared by using the Race Evo, Edge File X7, and Protaper Gold file systems.

Material and method: 60 extracted maxillary first molars were selected, their coronal portions were removed and their working length was calculated. The samples were separated into three experimental groups according to the used NiTi rotary systems and one control group; each group contains 15 samples. Group one remained uninstrumented (control), Groups 2-4 were instrumented by the Race Evo (FKG Dentaire SA, La Chaux-de-Fonds, Switzerland), Edge File X7(Edge Endo; Albuquerque, New Mexico, United States), and Protaper Gold file systems (Dentsply, Maillefer, Switzerland) respectively. After instrumentation, the experimental groups were filled using a single-cone technique. The sealer was mixed according to manufacturing instructions with master Gutta-Percha cones of size 40 (0.04 taper, (Diadent Group International, Korea) for Race Evo and Edge file X7, and size 40 taper 0.06 for the Protaper Gold file system (Dentsply, Maillefer, Switzerland). To set the sealer, the specimens were kept at 37 °C and 100% humidity for two weeks. The root fracture stress was measured in Newtons using Instron universal testing equipment.

Results: One Way ANOVA test showed there was a significant difference in the mean value of the fracture resistance between the four groups ($P < 0.05$). The LSD test was used for the comparison of the multiple groups so the control group showed the highest fracture resistance among groups ($p < 0.05$). among the experimental groups, the roots prepared by Race Evo showed the highest fracture resistance ($p < 0.05$), while roots prepared by Protaper Gold and Edge file x7 showed the lowest fracture resistance with a statistically significant difference ($p > 0.05$).

Conclusion: Root canal instrumentation with NiTi rotary files damages roots and promotes root fractures. NiTi file-cutting efficiency may reduce root canal dentinal wall fractures.

Keywords: fracture resistance, rotary instruments, Race Evo, Protaper Gold, and Edge File X7.

Introduction

Mechanical root preparation is one of the most important factors affecting the outcome of root canal treatment and creating sufficient space for chemical irrigation and obturation materials (Hülsmann et al., 2005).

Because of their flexibility and shape memory, rotary Ni-Ti instruments simplify root canal treatment; however, dentinal cracks may develop as a result, weakening the tooth structure and leading to fractures (Liu et al., 2013; Pawar et al., 2018)

Tooth structure loss from cavities or trauma, dentin dehydration, access cavity preparation, instrumentation with rotary files, the negative effects of irrigation solutions, and too much pressure during filling procedures are all factors that can weaken the integrity of an endodontically treated tooth

DOI: 10.32828/mdj.v19i2.890

and lower its chances of survival (Karapinar et al., 2009; Tang et al., 2010)

When the frequency of microcracks increases, so does the danger of vertical root fractures (VRF) in teeth (Bier et al, 2009). VRF associated with endodontically treated teeth is one of the most problematic clinical problems that might occur as a result of instrument design, kinematics, and mechanical behavior after root canal therapy operations (Testori et al., 1993; Capar et al., 2014).

ProTaper Gold (PTG) has advanced metallurgy but the same geometrical characteristics similar to ProTaper Universal (PTU; Dentsply Maillefer): triangular convex cross-section, modified non-cutting tip, and varied tapers across each file's cutting blades (Shi et al., 2022).

The EdgeEndo X7 rotary system: An annealed heat-treated (AHT) nickel-titanium alloy is used in the construction of the EdgeEndo X7 rotary system, and FireWire technology is used (EdgeEndo; Albuquerque, New Mexico, USA). The files in its system are all constantly tapered with varying pitches. The manufacturer claims that the technology is reliable and adaptable (Gambarini et al., 2019)

Race Evo file systems (FKG Dentaire SA, La Chaux-de-Fonds, Switzerland) have a non-cutting tip, a triangular cross-section, a constant taper, and a patented alternative cutting edge that reduces the screwing effect. They are heat-treated to improve the shape memory of the NiTi alloy and reduce its sensitivity to cyclic fatigue and fracture, and their blue hue indicates the existence of a titanium oxide layer that improves their resistance (FKG Dentaire, 2020).

Several studies have been done to find out how different NiTi rotary files, either full rotation or reciprocating files, have an impact on the fracture resistance of teeth that have had endodontic treatment. The Race Evo and Edge file X7 file systems were utilized in this investigation since there was no evidence available in the literature concerning their impact on the fracture resistance of obturated roots.

The goal of this study was to compare the performance of the Race Evo, the EdgeEndo X7, and the Protaper Gold endodontic rotary systems in terms of reducing root fractures.

Materials and methods

The local ethics committee of Mustansiriyah University's School of Dentistry authorized the present study (code: 9412257396). The research used 60 extracted maxillary first molars. The teeth exhibited no cavities, open apices, or cracks. A digital caliper was used to measure buccolingual and mesiodistal widths at 3 mm, 6 mm, and 9 mm to standardize root measurements. Palatal roots were cut 11 mm from the apex. Subtracting 1 mm from root length gives working length. The samples were divided into four groups according to the instrument used.

Group 1: control group (n = 15)

Group 2: Race Evo endodontic files (n = 15)

DOI: 10.32828/mdj.v19i2.890

Group 3: Edge file x 7 endodontic files (n = 15)

Group 4: Protaper Gold endodontic file (n = 15)

Root canal preparation

Each instrument was utilized in no more than three canals per tooth while using a torque-controlled endodontic motor (X-Smart; Dentsply Maillefer) with all NiTi rotary files, as recommended by the manufacturer. All files are used in a rotation motion.

The patency of the canal was confirmed by size #10 k file and the initial size file of the canal was #20 K file.

Group 1: The roots were left un instrumented, and just the pulp was extirpated. Irrigants included 2% NaOCl and distilled water.

Group 2 (Race Evo): fifteen samples were instrumented with the Race Evo system. This was done by first using an ISO No 10 stainless steel hand file to create a smooth glide path then using a size 15 glide path RE1 (15.04), then start the preparation with a RE2 (25.04) initial shaping file, then a RE3 (30.04), and finally RE4 40 with a taper of 0.04 that was used in a rotation motion using an electric speed and torque-controlled endodontic micromotor X Smart Plus, which has a pre-programmed setting with speeds of (800–1000 rpm) and (1–1.5 Ncm) as recommended by manufacturing instruction.

Group 3 (EdgeEndo X7 system): the fifteen samples were prepared by using a 15K file to the working length that was operated at 300 rpm (3 Ncm) in the following order: file (17/04), file (20/04), file (25/04), file (30/04), file (35/04), and file (40/04) until the entire working length was attained (AbdelWahed, 2021).

Group 4 (Protaper Gold System): the fifteen samples were prepared with a rotational file in this sequence SX: 0.19/.04, S1: 0.18/.02, S2: 0.20/.04, F1: 0.20/.07, F2: 0.25/.08, F3: 0.30/.09, and F4: 0.40/.06 according to the manufacturing instructions (Protaper Gold Brochure,2014.)

Every time a new file size was introduced, the canals were irrigated with 5 mL of a 2.5% NaOCl solution and after instrumentation, we flushed the root canals with 5 milliliters of a solution containing 17% EDTA for one minute, Finally, 10 mL of normal saline was used to flush the canals before being dried with paper points (Mohammed & Al-Zaka,2020)

root canal obturation

The samples in groups 2, 3, and 4 were obturated using a single cone obturation method utilizing Guttaflow 2 Rokeo sealer (COLTENE, Switzerland) that was mixed according to the manufacturing instructions, a master gutta-percha cone of Diadent taper 0.04 for race Evo, and edge file, and a gutta-percha cone of Protaper Gold taper 0.06 for protaper gold file were used. The specimens were maintained at 37°C and 100% humidity for two weeks. (Omran & Alhashimi, 2019; Mohammed & Al-Zaka, 2020)

Fracture test

DOI: 10.32828/mdj.v19i2.890

The roots were marked at the 9 mm point of the root length and the root surfaces were dipped into molten wax (dipping wax) (Shanghai New Century Material Co. Shanghai) to get a wax layer of 0.2 to 0.3 mm thickness, then self-cure acrylic (Shanghai New Century Material Co., Shanghai) mixed and placed into a mold and the samples were placed vertically with the aid of surveyor (Hassan & Gholam,2020; Omran & Alhashimi,2019). A universal testing device was used to evaluate the resistance to root fracture (Instron). The upper plate of the testing apparatus consisted of a tapered metal rod with a tip diameter of 0.8 mm and a 6% taper. After positioning the tip of the instrument above the canal opening, a gradually increasing vertical force was applied. (0.5 mm/min) until fracture occurred. (AbdelWahed, 2021)

statistical analysis

The Statistical Package for the Social Sciences (SPSS) version 20 program was used to analyze the data (SPSS Inc., Chicago, IL, USA). Data normality was tested using the Shapiro-Wilk test (P value > 0.05), and the degree of significance was tested using the "One Way ANOVA test" (for multiple comparisons). To examine the differences in force values between groups LSD tests were used at a $P < 0.05$.

Results

The result of the Shapiro-Wilk test showed that the samples were normally distributed, $P > 0.05$. The One Way ANOVA test showed a statistically significant difference among groups (Tables 1 and 2). The fracture resistance of roots prepared by Race evo, Edge File X7, and Protaper Gold was significantly lower than the control (unprepared root) ($p < 0.05$). Race Evo had significantly higher fracture resistance compared to Edge File and Protaper Gold file systems ($p < 0.05$), while Protaper Gold and Edge File X7 were not statistically significant differences ($p > 0.05$).

Table 1: One way Anova test for comparsion of root fracture resistance prepared by different file systems

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	372094.067	3	124031.356	15.914	.000
Within Groups	436445.867	56	7793.676		
Total	808539.933	59			

Table 2: LSD test for comparison across the group

Groups		Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Control	Race Evo	97.6000(*)	32.23596	.004	33.0236	162.1764

DOI: 10.32828/mdj.v19i2.890

	Edge filex7	183.4667(*)	32.23596	.000	118.8903	248.0430
	Protaper Gold	196.6667(*)	32.23596	.000	132.0903	261.2430
Race Evo	Edge filex7	85.8667(*)	32.23596	.010	21.2903	150.4430
	protaper	99.0667(*)	32.23596	.003	34.4903	163.6430
Edge filex7	Protaper Gold	13.2000	32.23596	.684	-51.3764	77.7764

* The mean difference is significant at the .05 level.

Discussion

Dentin microcracks from root canal preparation are still controversial. Numerous investigations have found that root dentin prepared using rotational NiTi tools develops structural defects such as microcracks and craze lines. Nevertheless, multiple micro-computed tomography investigations found no dentinal microcracks after root canal instrumentation (De-Deus et al.,2015; Pradeep Kumar et al., 2019).

Effective chemo-mechanical root canal preparation is thought to have an impact on successful endodontic results. Because of the constant contact that is maintained between the endodontic cutting tool and the dentin walls during preparation, there is a potential increase in the risk of root fractures. (Rundquist et al, 2006; Adorno et al, 2009). When the root canal system is mechanically instrumented using a NiTi instrument, tiny cracks in the canal dentinal walls are possible (Bürklein et al., 2013).

The cross-section, taper, flute form, alloy type, and rotational motion of NiTi instruments used for root canal preparation might impact VRF resistance (Mohan et al.,2018).

Mechanical testing requires specimen uniformity to determine fracture resistance [Nur et al., 2015]. After decoronation, similar roots were selected and root lengths equalized. This research used upper permanent first molar palatal roots because they had more circular channels, distributing stress more evenly (Khdairah and Al-Gharrawi, 2020)

The results of this investigation demonstrated that Group 1 (the control) has the greatest statistically significant fracture resistance value, which clearly explains and validates the deleterious influence of NiTi file instrumentation on root canal fracture resistance as compared to, unprepared roots. There was a significant difference between the experimental groups as well.

Comparatively, Group RaceEvo has high fracture resistance. The triangular cross section's smaller area may explain this. Compared to smaller cross-sectional areas, the stress buildup during bending increased as the cross-sectional area increased. The contact between the instrument and root canal walls generates internal stresses in the instrument and on the root canal wall. The convex triangular cross-section design in this study displayed the highest von Mises stress during bending and torsion; this is because

DOI: 10.32828/mdj.v19i2.890

the cross-section's surface area and perimeter were increased in addition to the three points of contact with the canal walls, which increased torsional fatigue. Conversely, a decrease in cross-sectional area may be related to the file's increased flexibility (Kim et al., 2009a; Galal and Hamdy, 2020).

Adjusting the transition temperature and alloy microstructure during the thermal treatment of NiTi alloys improves their mechanical performance. The heat-treated NiTi alloy is mostly R-phase and martensite, which is more flexible than austenite (Pereira et al., 2015; Zupanc et al., 2018) Heat treatment makes all of the rotational systems employed in this study more flexible.

We employ four files sequentially in Race Evo, six files in Edge File X7, and seven files in Protaper Gold Systems during instrumentation. So this agrees with Liu et al. (2013), who conducted research comparing the fracture resistance of the three single-file systems (Reciproc, OneShape, SAF), and ProTaper systems (multiple files) and discovered that the Reciproc, OneShape, and SAF—caused less damage than the ProTaper system. This is consistent with other studies that have suggested that additional canal modifications may result in the accumulation of harm (Shemesh et al., 2011; Liu et al., 2013).

the fracture resistance of the root canal by using Protaper Gold which has a greater taperness of 6% while other groups have 4% (according to the manufacturer). this decrease in fracture resistance was attributed to that greater taper weakening the treated tooth and lowering the fracture resistance (Aidasani et al, 2020; Nassar et al., 2022)

Taking into account the limitations of this in vitro study, when the ProTaper Universal instrument was used to clean out root canals with high torque settings, more cracks appeared in the root canal dentin than when the instrument was used with low torque settings. The high-torque settings may have more cracks because the dentinal surface was under more stress (Dane et al., 2016). This may support the results of this study as The torque values used in Race Evo, Edge File X7, and Pro Taper Gold were 1.5, 3, and 4 Ncm, respectively.

According to Peter et al.,2014 and Capar et al.,2015, the increased rotational speed is related to increased cutting efficiency and lesser crack formation so this may indirectly affect the result of the current study in that group Race Evo had the greatest fracture resistance as it was used at high speed (800) rpm according to the manufacturing instruction.

The ProTaper Next and HyFlex instruments cause fewer dentinal cracks than the ProTaper Universal instrument, which may be related to the fact that the ProTaper Next and HyFlex systems require fewer instruments to shape than the ProTaper Universal system and that the HyFlex instrument's suggested speed (500 rpm) is greater than the other devices examined in this study. the low incidence of cracks in root dentin after root Due to their superior cutting effectiveness, the HyFlex, and ProTaper Next groups had fewer fractures than the ProTaper

DOI: 10.32828/mdj.v19i2.890

Universal group (Peters et al., 2014; Capar et al., 2014).

An in-and-out motion of NiTi rotary instrumentation, commonly known as the pecking motion, has been proposed to lessen the risk of fracture by distributing the instrument's flexural stress. The pecking action is supposed to be a regulated movement against the rotating instruments' screw-in forces this may coincide with the current study result in that the Race Evo group had the highest fracture resistance compared to the other experimental groups as the pecking motion used with Race Evo files (Li et al.,2002; Ha et al., 2017)

The results of this research reject the null hypothesis that there is no difference in the fracture resistance of root canals prepared using different rotary file systems (Race Evo, Edge File X7, and Protaper GOLD file systems).

Conclusion:

Root canal instrumentation with NiTi rotary files has a negative impact on roots and increases the risk of root fractures in comparison to intact, unprepared roots. Roots prepared by the Race Evo file system have better fracture resistance than other experimental groups.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

Funding

This research received no external funding.

Data Availability Statement

Data are available from the authors upon reasonable request.

Acknowledgments

The authors would like to thank Mustansiriyah University (www.uomustansiriyah.edu.iq), Baghdad, Iraq, for its support in the present work.

References

1. AbdelWahed A. Comparative assessment of apically extruded debris using Protaper Next, Hyflex CM and EdgeFile X7 nickel titanium instruments (An in vitro Study). Egyptian Dental Journal. 2021 Oct 1;67(4):3751-7. https://doi.org/10.21608/edj.2021.90728.1751
2. Adorno CG, Yoshioka T, Suda H. The effect of root preparation technique and instrumentation length on the development of apical root cracks. Journal of endodontics. 2009 Mar 1;35(3):389-92. https://doi.org/10.1016/j.joen.2008.12.008
3. Aidasani GL, Mulay S, Borkar A. Comparative evaluation of flexural fracture resistance of mandibular premolars after instrumentation with four different endodontic file systems: An In Vitro study. Indian Journal of Dental Research. 2020 Sep 1;31(5):701. https://doi.org/10.4103/ijdr.IJDR_102_18

DOI: 10.32828/mdj.v19i2.890

4. Bier CA, Shemesh H, Tanomaru-Filho M, et al. The ability of different nickel-titanium rotary instruments to induce dentinal damage during canal preparation. J Endod 2009;35:236-8 https://doi.org/10.1016/j.joen.2008.10.021
5. Bürklein S, Tsotsis P and Schafer E. Incidence of dentinal defects after root canal preparation: reciprocating versus rotary instrumentation. J Endod. 2013; 39(4):501-04. https://doi.org/10.1016/j.joen.2012.11.045
6. Capar ID, Arslan H, Akcay M, Uysal B. Effects of ProTaper Universal, ProTaper Next, and HyFlex instruments on crack formation in dentin. Journal of endodontics. 2014 Sep 1;40(9):1482-4. https://doi.org/10.1016/j.joen.2014.02.026
7. Capar ID, Kaval ME, Ertas H, Sen BH. Comparison of the cyclic fatigue resistance of 5 different rotary pathfinding instruments made of conventional nickel-titanium wire, M-wire, and controlled memory wire J Endod. 2015;41:535-8 https://doi.org/10.1016/j.joen.2014.11.008
8. De-Deus G, Belladonna FG, Souza EM, Silva EJ, de Almeida Neves A, Alves H, Lopes RT, Versiani MA. Micro-computed tomographic assessment on the effect of ProTaper Next and Twisted File Adaptive systems on dentinal cracks. Journal of endodontics. 2015 Jul 1;41(7):1116-9. https://doi.org/10.1016/j.joen.2015.02.012
9. Dentsply Tulsa Dental Specialties. ProTaper Gold Brochure. 2014.
10. EdgeEndo. EdgeFile X7 directions for use. Available at: https://edgeendo.com/wp
11. FKG Dentaire. The XP-endo Shaper Brochure. Available at: http://www.fkg.ch/sites/default/files/201612_fkg_XPS_brochure_v3_en_web .pdf.
12. Galal M, Hamdy TM. Evaluation of stress distribution in nickel-titanium rotary instruments with different geometrical designs subjected to bending and torsional load: A finite element study. Bulletin of the National Research Centre. 2020 Dec;44(1):1-1. https://doi.org/10.1186/s42269-020-00377-x
13. Gambarini G, Galli M, Seracchiani M, Di Nardo D, Versiani MA, Piasecki L, Testarelli L. In vivo evaluation of operative torque generated by two nickel-titanium rotary instruments during root canal preparation. European Journal of Dentistry. 2019 Oct;13(04):556-62. https://doi.org/10.1055/s-0039-1698369
14. Ha JH, Kwak SW, Sigurdsson A, Chang SW, Kim SK, Kim HC. Stress generation during pecking motion of rotary nickel-titanium instruments with different pecking depth. Journal of endodontics. 2017 Oct 1;43(10):1688-91. https://doi.org/10.1016/j.joen.2017.04.013
15. Hassan SA, Gholam MK. Fracture resistance of posterior occlusal veneers fabricated from different types of computer-aided design/computer-aided

DOI: 10.32828/mdj.v19i2.890

manufacturing materials (an in vitro study). International Medical Journal. 2020;25(1).
16. Hülsmann M, Peters O, Dummer PMH. Mechanical preparation of root canals. shaping goals, techniques and means. Endod Topics 2005;10:30-76. https://doi.org/10.1111/j.1601-1546.2005.00152.x
17. Khdairah HR, Al-Gharrawi HA. The effect of canal preparation using 2shape, protaper gold and protaper next file systems on the fracture resistance of obturated roots. Journal of International Dental and Medical Research. 2020;13(1):42-5.
18. Kim TO, Cheung GSP, Lee JM, Kim BM, Hur B, Kim HC. Stress distribution of three NiTi rotary files under bending and torsional conditions using a mathematic analysis. Int Endod J 2009;42:14-21 https://doi.org/10.1111/j.1365-2591.2008.01481.x
19. Kwak SW, Shen Y, Liu H, Kim HC, Haapasalo M. Torque generation of the endodontic instruments: A narrative review. Materials. 2022 Jan 17;15(2):664. https://doi.org/10.3390/ma15020664
20. Liu R, Hou BX, Wesselink PR, Wu MK, Shemesh H. The incidence of root microcracks caused by 3 different single-file systems versus the ProTaper system. Journal of endodontics. 2013 Aug 1;39(8):1054-6. https://doi.org/10.1016/j.joen.2013.04.013
21. Li UM, Lee BS, Shih CT, Lan WH, Lin CP. Cyclic fatigue of endodontic nickel titanium rotary instruments: static and dynamic tests. Journal of endodontics. 2002 Jun 1;28(6):448-51. https://doi.org/10.1097/00004770-200206000-00007
22. Mohammed YT, Al-Zaka IM. Fracture resistance of endodontically treated teeth obturated with different root canal sealers (a comparative study). J Contemp Dent Pract. 2020 May 1;21(5):490-3. https://doi.org/10.5005/jp-journals-10024-2841
23. Mohan GM, Basheer SA. Assessment of fracture resistance of teeth instrumented by different file system. Inter J Appl Dent Sci. 2018;4(2):233-6.
24. Nur BG, Ok E, Altunsoy M, Tanriver M, Capar ID. Fracture strength of roots instrumented with three different single file systems in curved root canals. European journal of dentistry. 2015 Apr;9(02):189-93. https://doi.org/10.4103/1305-7456.156804
25. Omran AN, Alhashimi RA. The effect of ah plus and guttaflow bioseal sealers on the fracture resistance of endodontically treated roots instrumented with reciprocal rotary systems. International Journal of Medical Research & Health Sciences. 2019;8(2):102-8.
26. Pawar AM, Pawar MG, Thakur B, Banga K S, Luke AM. Resistance to fracture of teeth instrumented using novel EndoStar E5 rotary versus ProTaper Next and WaveOne file systems. Conserv Dent. 2018; (21):52-6.
27. Pereira ÉSJ, Viana ACD, Buono VTL, Peters OA, de Azevedo Bahia MG. Behavior of nickel-titanium instruments manufactured with different thermal

DOI: 10.32828/mdj.v19i2.890

treatments. J Endod. 2015;41(1):67-71 https://doi.org/10.1016/j.joen.2014.06.005

28. Peters OA, Morgental RD, Schulze KA, Paqué F, Kopper PM, Vier-Pelisser FV. Determining cutting efficiency of nickel-titanium coronal flaring instruments used in lateral action. International endodontic journal. 2014 Jun;47(6):505-13. https://doi.org/10.1111/iej.12177
29. PradeepKumar A.R., Shemesh H., Archana D., Versiani M.A., Sousa-Neto M.D., Leoni G.B., Silva-Sousa Y.T.C., Kishen A. Root canal preparation does not induce dentinal microcracks in vivo. J. Endod. 2019;45:1258-1264. https://doi.org/10.1016/j.joen.2019.06.010
30. Rundquist BD, Versluis A. How does canal taper affect root stresses? Int Endod J. 2006; 39: 226-237. https://doi.org/10.1111/j.1365-2591.2006.01078.x
31. Shemesh H, Roeleveld AC, Wesselink PR, Wu MK. Damage to root dentin during retreatment procedures. Journal of endodontics. 2011 Jan 1;37(1):63-6. https://doi.org/10.1016/j.joen.2010.10.002
32. Shi L, Zhou J, Wan J, Yang Y. Shaping ability of ProTaper Gold and WaveOne Gold nickel-titanium rotary instruments in simulated S-shaped root canals. Journal of Dental Sciences. 2022 Jan 1;17(1):430-7. https://doi.org/10.1016/j.jds.2021.08.008
33. Tang W, Wu Y, Smales RJ. Identifying and reducing risks for potential fractures in endodontically treated teeth. J Endod 2010;36:609-17. https://doi.org/10.1016/j.joen.2009.12.002
34. Zupanc J, Vahdat-Pajouh N, Schäfer E. New thermomechanically treated NiTi alloys-a review. Int Endod J. 2018;51(10):1088-103 https://doi.org/10.1111/iej.12924