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Impact of different kinematics on the efficiency of canal cleanliness

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Abstract

Introduction: A properly formed and cleansed root canal is crucial to effective treatment. There have been several breakthroughs in this particular subspecialty of endodontics in recent years.

Aim of the study: This research examines three rotational root canal instruments, the TF Adaptive, Reciproc, and ProTaper Next file systems, comparing them regarding cleaning efficiency.

Subjects and Methods: Twenty-four freshly removed mandibular premolars were divided into three groups, each with eight samples. Three file systems were utilized, TF Adaptive, Reciproc, and ProTaper NEXT. When the three files were prepared, they were scored based on how well they removed debris, and SEM images were captured to determine how well they had been cleaned.

Results: The coronal areas of canals treated with ProTaper NEXT showed much less debris and a smear layer. All employed file systems did not effectively remove debris in the middle and apical thirds.

Conclusions: ProTaper Next files were the most effective in canal cleanliness in the coronal, middle, and apical thirds, followed by Reciproc and then TF Adaptive.

Keywords: Kinematics; Cleaning efficiency; TF Adaptive file system; Reciproc file system; ProTaper Next file system.

1. Introduction

Treatment for a root canal is performed to ensure the canals are properly shaped and cleaned. Only thorough root canal preparation and cleaning can guarantee success in root canal treatment. Even though endodontics has made great strides in the scope of science and technology, the fundamental principles of root-canal preparation—namely, the removal of all organic debris and germs from the root-canal system and the sculpting of the root-canal walls to aid in cleaning and obturation remain the same [1]. Introducing nickel-titanium (NiTi) rotary devices into dental treatment has radically altered the procedure for root canal preparation. They were produced to reinforce the effectiveness of root canal equipment. Compared to stainless steel, NiTi alloys have a lower elongation modulus [2]. They have better

strength and are more robust and durable. They possess the exceptional characteristics of shape memory and superelasticity. Preparing a root canal manually is time-consuming and more prone to iatrogenic errors than rotary systems [3–6]. After instrumentation, certain sections of the root canal wall remain extinct [7–10]. These regions may harbor germs that hinder the effectiveness of endodontic therapy [11]. In addition, root canal instrumentation produces a smear layer (12) and a 1–2 m thick amorphous surface layer [12]. However, this layer does not exist on the walls of uninstrumented canals. When the material from the cutting process is forced into the dentin tubules, smear plugs develop [12]. This layer, which frequently includes bacteria and obstructs dentinal tubules, considerably affects irrigant activity, obturation quality, and, ultimately, endodontic treatment efficiency [13, 14]. The capacity of root canal instruments to properly clean canals is dependent on their design and the dynamics of the equipment utilized. The Twisted File is a ground-breaking rotary nickel-titanium (RNT) system with three novel design techniques: R-phase heat treatment, metal twisting during manufacturing, and specific surface conditioning. Furthermore, it has been demonstrated that a unique kinematic (reciprocating motion) boosts the durability and fatigue resistance of a NiTi instrument when compared to continuous rotational movement [4]. Reciprocation-driven instruments cover a smaller angular distance than rotary instruments, resulting in reduced stress and a longer fatigue life [15, 16]. The most common commercially available method for root canal preparation with reciprocating motion is Reciproc (VDW, Munich, Germany) [17]. The ProTaper System is a popular choice since it is both safe and effective [6, 18, 19].

The current study aimed to compare the performance of the TF Adaptive, Reciproc, and ProTaper Next file systems in eliminating debris from lower premolar canal walls during kinematic preparation by using the scanning electron microscopy (SEM).

2. Subjects and methods

2.1. Subjects

Twenty-four recently extracted, mostly straight human mandibular premolars were chosen. There were three sets of eight samples each, which were randomized. All patients were informed of the study's purpose and methods and gave their written consent for using their extracted teeth, per the requirements of the Research Ethics Committee of the Faculty of Dentistry at Ain Shams University. The collected specimens were stored in sterile saline until the time of the experiment. An ultrasonic scaler removed tartar, calculus, and infected bone and soft tissue from every tooth. To remove biofilms from the tooth roots, we soaked them in a solution of 5.25% sodium hypochlorite (NaOCl) (Clorox Co., 10th Ramadan, Egypt) for five minutes. The pulp chambers of the teeth were de-roofed entirely using a carbide round bur (Komet; Brasseler, Lemgo, Germany) to get access. The WL was determined to be 1 mm shorter than the apical foramen (size 10) at the primary apical foramen. Teeth with apical minor constriction measurements greater than #20 K-file were omitted from the analysis. The bulk of the measured working lengths for teeth ranged from 22 to 23 mm; hence, this range was used to select the samples for analysis.

Inclusion criteria

Human mandibular premolars sound like they have a single straight root and a single root canal, and the radiographs showed a patent root canal.

Exclusion criteria

Teeth with exterior and internal resorption, cracks or fracture lines, and obvious root caries were excluded (SEILER MEDICAL VISION, USA). The removal of teeth with numerous root canals, apical foramina, immature root apices, or root canal curvatures greater than 10° (20)

2.2. Study design

File systems

The cleaning efficiency of three kinematic file systems was evaluated: the TF Adaptive system (SybronEndo, Orange, CA, USA), the Reciproc file (VDW, Munich, Germany), and the ProTaper NEXT (Dentsply Tulsa Dental, Tulsa, OK).

Study groups

A total of 24 samples were collected, and they were divided equally among three groups of eight.

- Group I: TF Adaptive instruments were utilized in the sequences ML1 (25/.08), ML2 (35/.06), and ML3 (50/.04). The files were used in concurrence with an Elements motor (SybronEndo, Glendora, CA) at full WL with a reasonable in-and-out motion.
- Group II: For root canal preparation using the RC system, the R50 (50/0.05) instrument was used in all root canal thirds, with little pecking motions of 3 mm amplitude until the necessary length was reached. The tool was removed and cleaned with sterile gauze between each root third to prevent contamination. Using the manufacturer-recommended RECIPROC ALL setting on an electric motor (X-Smart, Dentsply, Maillefer), the instrument was fastened to a 6:1 contra-angle.
- Group III: The following sequence of PTN files was employed with an endodontic motor set to 300 rpm and 2 Ncm torque: PTN X1 (17/.04), PTN X2 (25/.06), PTN X3 (30/.07), PTN X4 (40/.06), and PTN X5 (50/.06). It was a Dentsply-Maillefer X Smart motor in ProTaper Next mode. The PTN data was brushed on circularly from the center outward. The process was performed many times until the X5 file finally made it to the WL.

Sample preparation

The teeth were divided in half longitudinally using a precision linear saw (Isomet 4000, BUEHLER, Malaysia) (Figure 1). Using High resolution Scanning Electron Microscopy (SEM), the surface and structural morphology of the manufactured samples were studied, with analytical studies done on an FEI Quanta FEG 250 system (Massachusetts, USA).

Figure 1: Sectioning of teeth into halves using Isomet 4000, BUEHLER, Malaysia precision linear saw

Scanning electron microscope inspection

Coronal, middle, and apical root canal thirds were imaged at x500 and x2500 for debris removal assessment. The debris included dentine shards, pulp remnants, and objects that were weakly adhering to the root canal wall. Using the following scoring criteria, created by Hülsmann et al. (1997) [21]:

- Score 1: Tubules open; no smear.
- Score 2: minimal smear; most tubules are open.
- Score 3: The root surface features closed tubules and a consistent smear layer.
- Score 4: Smeared, closed tubules cover the whole root surface.
- Score 5: A thick smear layer covers all root surfaces.

Statistics were used to compare debris and smear layer scores at the three canal locations within and between groups.

2.3. Statistical Analysis

The Kruskal-Walli's test, Dunn's post hoc test for comparisons between groups, Friedman's test, and Nemenyi post hoc test for comparisons within groups were used to evaluate non-parametric cleaning efficiency score data. The statistical study was performed using R statistical analysis program for Windows, version 4.1.3 [22].

3. Results

Table 1 displays the results of using the TF Adaptive System, the Reciproc, and the Protaper NEXT to clean up debris. Utilizing the TF adaptive system for debris removal, no statistically significant changes were seen between the coronal, middle, and apical thirds ($P = 0.180$). Also, there was no statistically significant change across the root canal's coronal, middle, and apical thirds when employing Reciproc. Removing debris from the root canal with the ProTaper NEXT instrument varied considerably ($P = 0.018$) in the coronal, middle, and apical thirds. Furthermore, compared to the TF Adaptive and Reciproc file systems, the ProTaper NEXT instrument was much more effective in clearing away trash and smearing smear layers. Using the ProTaper NEXT rotating file system, the canal's coronal one-third was rigorously cleaned ($P = 0.005$). Concerning cleaning debris, there were no statistically significant differences between the three groups in the middle ($P = 0.053$) and apical ($P = 0.074$) thirds. It could not tell how much of the canal was instrumented due to the possibility of debris in canal sections that weren't entirely instrumented across all three approaches. Figures 2, 3, and 4 are example images obtained using SEM.

Table 1: Efficiency of debris removal at various stages of the root canal following the application of the TF Adaptive system, the Reciproc file, and the ProTaper NEXT.

Root section	Cleaning efficiency score (Mean ± S. D.)			*P*-value
	TF Adaptive	Reciproc	ProTaper NEXT	
Coronal	3.75 ± 0.71^{Aa}	3.00 ± 0.53^{Aba}	2.50 ± 0.35^{Bb}	0.005^{*}
Middle	3.75 ± 0.89^{Aa}	3.25 ± 0.71^{Aa}	2.75 ± 0.46^{Aab}	0.053
Apical	4.38 ± 0.52^{Aa}	3.88 ± 0.99^{Aa}	3.50 ± 0.35^{Aa}	0.074
***P*-value**	0.180	0.161	0.018*	

*Means with different upper and lowercase superscript letters within the same horizontal row and vertical column are significantly different. *; significant (P ≤ 0.05).*

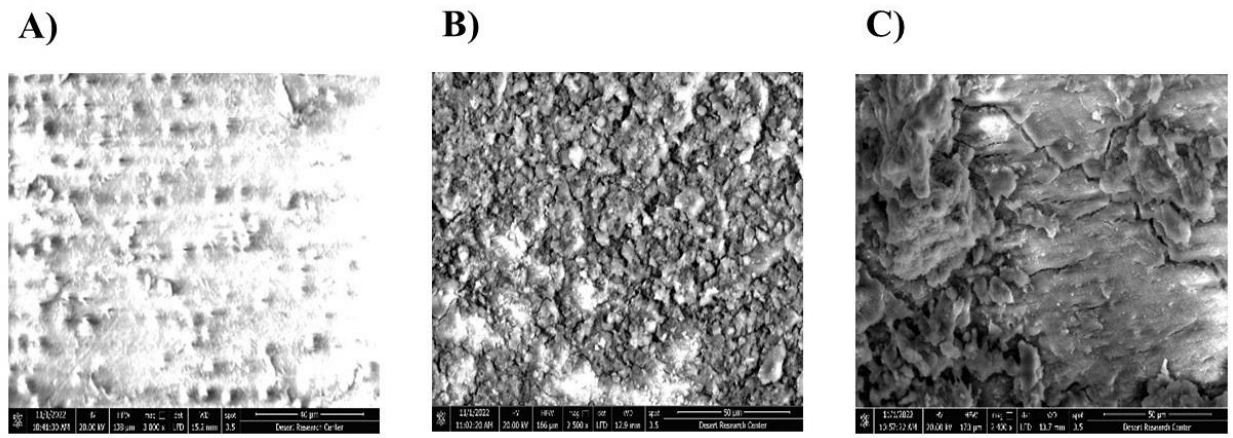

Figure 2: SEM photo illustrating the ProTaper NEXT preparation segment. A. middle third, score 2, B. coronal third, score 3; and C. apical third, score 4 (x2500).

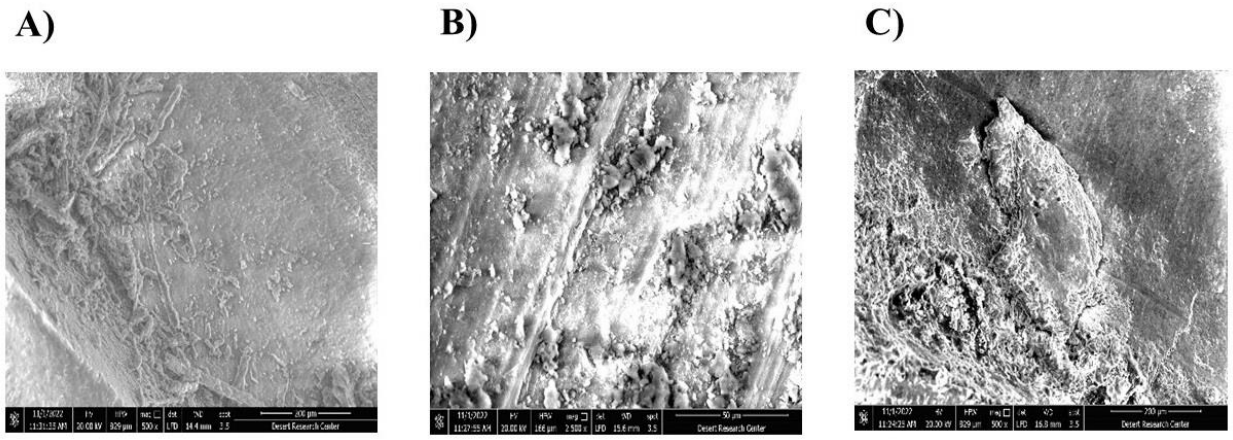

Figure 3: SEM photo illustrating the Reciproc preparation segment. A. apical third, score 3 (x500); B. coronal third, score 4 (x2500); and C. apical third, score 5 (x2500).

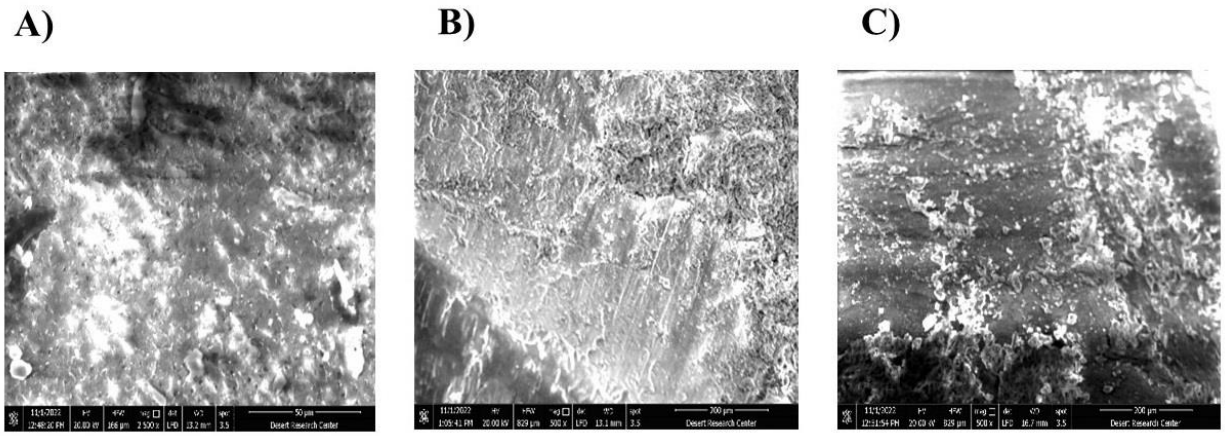

Figure 4: SEM photo illustrating the TF Adaptive preparation segment. A. coronal third, score 3 (x2500); B. coronal third, score 4 (x500); and C. apical third, score 5 (x500).

4. Discussion

Root canal instrumentation creates the smear layer, a 1-2 m thick amorphous layer [23]. On the other hand, in uninstrumented canals, this layer is absent. Cutting debris forced into dentin tubules at various depths results in smear plugs [24]. This layer has a detrimental effect on the effectiveness of obturation and, eventually, endodontic treatment because of the presence of bacteria and the blockage of dentinal tubules. The smear layer must be eliminated to thoroughly sanitize and clean the root canals in all three dimensions [13, 25]. The same length was used to analyze all root segments (22–23 mm).

As a consequence, the outcomes of the different file systems were similar. Only bidistilled water was used to avoid causing any changes to the smear layer of the irrigation material. As the selected file systems all had the same apical size preparation (#50), they were mechanically prepared. Thus, the current study compared the efficiency of three rotary file systems (TF Adaptive, Reciproc, and ProTaper NEXT) in cleaning the root canal of mandibular premolars. The cleaning capacity was assessed using a numeric grading system for debris using SEM to examine the canal's coronal, middle, and apical thirds. Needle irrigation with NaOCl, according to previous studies, did not dissolve the smear layer [26, 27]. Dentine chips and residual live or necrotic pulp tissue, which is weakly attached to the root canal walls and is frequently regarded as unhealthy, were added as additional assessment criteria in this study to assess the cleaning performance of various devices [27]. The scanning electron microscope, which offers high resolution, magnification, and measurements at coronal, intermediate, and apical levels, has been used to assess the cleanliness of canal walls after instrumentation. As it provided a broader view and allowed identifying significant bits of leftover debris at low magnification, a magnification of x500 was used in this investigation to score debris. In addition, a magnification of around x2500 was used because higher magnification covers the too-small surface area and provides more accurate data for the determination of the patency of the dentinal tubule apertures [28].

The apical third of the root canal is more difficult to clean than the rest of the canal due to anatomical differences (constrictions, ramifications, additional canals) [29], the small diameter of the apical preparation that complicates canal debridement, and the difficulties in achieving proper irrigation in the

apical portion of the root canal. This conclusion was consistent with another research showing that the root canal became cleaner from the apical to the coronal portion [30–34]. ProTaper Next's superior outcomes could be attributed to its distinctive swaggering action, in which the file always makes two encounters with the canal walls. The constant motion of rotary files encourages material removal upward along the flutes.

With a reciprocating file, on the other hand, the debris is crushed along the dentinal walls and forced into the lateral canals due to the file's backward movement [28]. Both symmetrical and asymmetrical rotational motions have been used in developing rotary instruments [35]. As their name implies, asymmetrical rotary instruments have asymmetrical centers concerning the instrument's primary axis of rotation. To lessen the amount of time the file is in touch with the dentin, the working part of the instrument rotates while a mechanical wave of motion travels down its length [36]. In this situation, rotating systems rather than reciprocating instruments could provide cleaner canals with less debris collection [28]. Both Reciproc and adaptive TF go through reciprocation. However, Reciproc may have a lower propensity to retain debris because a larger chip area allows for more coronal debris transit. Also, using a single-file approach, canal preparation was often finished after around three repetitions.

More debris will be created as file insertion rates rise for the two reciprocating files (Reciproc and TF Adaptive), becoming packed more firmly along dentin walls and more challenging to drain out of the canal. Thus, the single-file method could be the primary factor in the cleaner canal walls.

All research groups demonstrated a rise in smear presence from coronal to apical [37], which was consistent with the current investigation. In addition, while comparing the cleaning efficiency of the rotary devices at the coronal third, ProTaper Next showed a lower average mean smear layer than WaveOne Gold and Xp-endo Shaper in a previous comparable study to the current investigation. This may be explained by its distinctive swaggering action, in which the file always makes two impacts with the canal walls. This creates greater room for clearing debris [38, 39]. Consistent with prior studies, debris is more prevalent in the apical third, where the apical canals are located. Also, when one approaches the coronal regions, the efficacy of the canals in cleansing them rises [1, 4, 7, 15].

Conclusion

In this study, the cleaning effectiveness of the ProTaper NEXT instrument was much higher than that of either the TF adaptive or Reciproc instruments. All rotary file methods left more debris and smears in the root canal's apical three-quarters. Comparing the three file instruments of debris and smears, we find significant differences in the central and terminal thirds but no differences in the remaining residue. Better root canal treatment results from thorough cleaning and shaping performed by an endodontist, efficiently removing debris and stains from the canals.

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Conflicts of Interest: All authors declare no conflict of interest.

References

1. Gu YP, Lu CH. Cleaning efficacy of two kinds of mechanical nickel-titanium instruments in preparation of severely curved root canals: a scanning electron microscopic study. Chin J Tissue Eng Res. 2021;25(10):1566. doi: 10.3969/j.issn.2095-4344.3021.
2. Elnagar MH, Ghoname NA, Ghoneim WM. Cleaning efficacy of rotary versus manual system for root canal preparation in primary teeth. Tanta Dental Journal. 2018;15(1):14. doi: 10.4103/tdj.tdj_43_17.
3. Kishore A, Gurtu A, Bansal R, Singhal A, Mohan S, Mehrotra A. Comparison of canal transportation and centering ability of Twisted Files, HyFlex controlled memory, and Wave One using computed tomography scan: An in vitro study. J Conserv Dent. 2017;20(3):161. doi: 10.4103/JCD.JCD_110_16.
4. Agrawal S, Bichpuriya A, Maria R. Comparison of Cleaning Efficiency of Root Canal Using Different Rotary NiTi Instrumentation System: A Scanning Electron Microscopic Study. Cureus. 2022;14(4):e24200. doi: 10.7759/cureus.24200.
5. Li H, Zhang C, Li Q, Wang C, Song Y. Comparison of cleaning efficiency and deformation characteristics of Twisted File and ProTaper rotary instruments. Eur J Dent. 2014;8(2):191-196. doi: 10.4103/1305-7456.130598.
6. Aydin C, Inan U, Gultekin M. Comparison of the shaping ability of Twisted Files with ProTaper and RevoS nickel-titanium instruments in simulated canals. J Dent Sci. 2012;7(3):283–288. doi: 10.1016/j.jds.2012.06.003.
7. Li KZ, Gao Y, Zhang R, Hu T, Guo B. The effect of a manual instrumentation technique on five types of premolar root canal geometry assessed by microcomputed tomography and three-dimensional reconstruction. BMC Med Imaging. 2011;11:14. doi: 10.1186/1471-2342-11-14.
8. Markvart M, Darvann TA, Larsen P, Dalstra M, Kreiborg S, Bjørndal L. Micro-CT analyses of apical enlargement and molar root canal complexity. Int Endod J. 2012;45(3):273-281. doi: 10.1111/j.1365-2591.2011.01972.x.
9. Elsherief SM, Zayet MK, Hamouda IM. Cone-beam computed tomography analysis of curved root canals after mechanical preparation with three nickel-titanium rotary instruments. J Biomed Res. 2013;27(4):326-335. doi: 10.7555/JBR.27.20130008.
10. Zhao D, Shen Y, Peng B, Haapasalo M. Root canal preparation of mandibular molars with 3 nickel-titanium rotary instruments: a micro-computed tomographic study. J Endod. 2014;40(11):1860-1864. doi: 10.1016/j.joen.2014.06.023.
11. Haapasalo M, Shen Y, Wang Z, Gao Y. Irrigation in endodontics. Br Dent J. 2014;216(6):299-303. doi: 10.1038/sj.bdj.2014.204.
12. Shaheen N. The efficacy of different single file systems in cleaning oval shaped root canal. Tanta Dental Journal. 2019;16(2):73. doi: 10.4103/tdj.tdj_46_18.
13. Torabinejad M, Handysides R, Khademi AA, Bakland LK. Clinical implications of the smear layer in endodontics: a review. Oral Surg Oral Med Oral Pathol Oral Radiol Endod. 2002;94(6):658-666. doi: 10.1067/moe.2002.128962.
14. Silva PV, Guedes DF, Nakadi FV, Pécora JD, Cruz-Filho AM. Chitosan: a new solution for removal of smear layer after root canal instrumentation. Int Endod J. 2013;46(4):332-338. doi: 10.1111/j.1365-2591.2012.02119.x.
15. Singh I, Goyal P, Bansal M, Gupta R, Garg S, Arora B. Comparative evaluation of twisted and protaper files in pediatric endodontics – In-vitro study. Indian J Dent Sci.

2020;12(3):117. Doi: 10.4103/IJDS.IJDS_33_19.

16. Rathi N, Jain SA, Thosar N, Baliga S, Ahmed F, Mehta J. Comparative Evaluation of Cleaning Efficiency and Apical Extrusion of Debris Using Two Pediatric Rotary Endodontic Files: An In Vitro Study. Int J Clin Pediatr Dent. 2021;14(2):196-200. doi: 10.5005/jp-journals-10005-1918.
17. De-Deus G, Silva EJ, Vieira VT, Belladonna FG, Elias CN, Plotino G, Grande NM. Blue Thermomechanical Treatment Optimizes Fatigue Resistance and Flexibility of the Reciproc Files. J Endod. 2017;43(3):462-466. doi: 10.1016/j.joen.2016.10.039.
18. Al-Dulaimi LA, Al-Gharrawi HA. Evaluation of the cleaning efficiency of Oneshape, Waveone, Reciproc and Protaper Systems using digital image morphometric analysis (An in vitro study). JODR. 2017;4(2):169–183.
19. Otero D, Selvaraju SB, Kathpalia A, Elmallah W, Elbatouty K, Nagy MM. Evaluation of bacterial reduction after root canal shaping using ProTaper gold and waveone gold rotary systems. European J Gen Dent. 2021;10(2):73–77. doi: 10.1055/s-0041-1732953.
20. Schneider SW. A comparison of canal preparations in straight and curved root canals. Oral Surg Oral Med Oral Pathol. 1971;32(2):271-275. doi: 10.1016/0030-4220(71)90230-1.
21. Hülsmann M, Rümmelin C, Schäfers F. Root canal cleanliness after preparation with different endodontic handpieces and hand instruments: a comparative SEM investigation. J Endod. 1997;23(5):301-306. doi: 10.1016/S0099-2399(97)80410-4.
22. Bunn AG. A dendrochronology program library in R (dplR). Dendrochronologia (Verona). 2008;26(2):115–124. doi: 10.1016/j.dendro.2008.01.002.
23. Goldman M, Goldman LB, Cavaleri R, Bogis J, Lin PS. The efficacy of several endodontic irrigating solutions: a scanning electron microscopic study: Part 2. J Endod. 1982;8(11):487-492. doi: 10.1016/s0099-2399(82)80073-3.
24. Mader CL, Baumgartner JC, Peters DD. Scanning electron microscopic investigation of the smeared layer on root canal walls. J Endod. 1984;10(10):477-483. doi: 10.1016/S0099-2399(84)80204-6.
25. Violich DR, Chandler NP. The smear layer in endodontics - a review. Int Endod J. 2010;43(1):2-15. doi: 10.1111/j.1365-2591.2009.01627.x.
26. Ahlquist M, Henningsson O, Hultenby K, Ohlin J. The effectiveness of manual and rotary techniques in the cleaning of root canals: a scanning electron microscopy study. Int Endod J. 2001;34(7):533-537. doi: 10.1046/j.1365-2591.2001.00429.x.
27. Bürklein S, Hinschitza K, Dammaschke T, Schäfer E. Shaping ability and cleaning effectiveness of two single-file systems in severely curved root canals of extracted teeth: Reciproc and WaveOne versus Mtwo and ProTaper. Int Endod J. 2012;45(5):449-461. doi: 10.1111/j.1365-2591.2011.01996.x.
28. Robinson JP, Lumley PJ, Cooper PR, Grover LM, Walmsley AD. Reciprocating root canal technique induces greater debris accumulation than a continuous rotary technique as assessed by 3-dimensional micro-computed tomography. J Endod. 2013;39(8):1067-1070. doi: 10.1016/j.joen.2013.04.003.
29. Gulabivala K, Patel B, Evans G, Ng YL. Effects of mechanical and chemical procedures on root canal surfaces. Endod Topics. 2005;10(1):103–122. doi: 10.1111/j.1601-1546.2005.00133.x.
30. Hülsmann M, Gressmann G, Schäfers F. A comparative study of root canal preparation using FlexMaster and HERO 642 rotary Ni-Ti

instruments. Int Endod J. 2003;36(5):358-366. doi: 10.1046/j.1365-2591.2003.00664.x.

31. Paqué F, Musch U, Hülsmann M. Comparison of root canal preparation using RaCe and ProTaper rotary Ni-Ti instruments. Int Endod J. 2005;38(1):8-16. doi: 10.1111/j.1365-2591.2004.00889.x.
32. Haapasalo M, Endal U, Zandi H, Coil JM. Eradication of endodontic infection by instrumentation and irrigation solutions. Endod Topics. 2005;10(1):77–102. doi: 10.1111/j.1601-1546.2005.00135.x
33. Arvaniti IS, Khabbaz MG. Influence of root canal taper on its cleanliness: a scanning electron microscopic study. J Endod. 2011;37(6):871-874. doi: 10.1016/j.joen.2011.02.025.
34. Fornari VJ, Silva-Sousa YT, Vanni JR, Pécora JD, Versiani MA, Sousa-Neto MD. Histological evaluation of the effectiveness of increased apical enlargement for cleaning the apical third of curved canals. Int Endod J. 2010;43(11):988-994. doi: 10.1111/j.1365-2591.2010.01724.x.
35. Çapar ID, Arslan H. A review of instrumentation kinematics of engine-driven nickel-titanium instruments. Int Endod J. 2016;49(2):119-135. doi: 10.1111/iej.12432.
36. Kherlakian D, Cunha RS, Ehrhardt IC, Zuolo ML, Kishen A, da Silveira Bueno CE. Comparison of the Incidence of Postoperative Pain after Using 2 Reciprocating Systems and a Continuous Rotary System: A Prospective Randomized Clinical Trial. J Endod. 2016;42(2):171-176. doi: 10.1016/j.joen.2015.10.011.
37. Aksoy F, Aydin U, Alacam T. Smear layer removal efficiency of Er,Cr;YSGG and Er:YAG lasers in root canals prepared with different NiTi File systems. Ann Med Res. 2021;26(8):1545–1550.
38. Rao A, Pandya D, Roy S, Upadhyay K, Pal A. Comparison of instrumentation time and cleaning efficacy of manual k-file, rotary protaper universal and rotary protaper next in primary anterior teeth: an in-vitro study. Int J Sci Res. 2018;7(1):27-30. doi: 10.36106/ijsr.
39. Krishna V, Sujatha I, Jayalakshmi KB, Nadig PL, Chandra SSM, Mayur GN, Sivaji K, Singh GP. Comparison of the cleaning effectiveness of Mtwo & protaper next rotary systems in permanent molar root canals: An in vitro study. Int J Appl Dent Sci. 2016;2(2):19–23.