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Original Article

Evaluation of dentinal defects during root canal preparation using thermomechanically processed nickel-titanium files

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ABSTRACT

Objective: The aim of this study was to compare the incidence of root cracks after root canal instrumentation with thermomechanically processed nickel-titanium (Ni-Ti) files with different instrumentation kinematics. **Materials and Methods:** A total of 150 extracted mandibular premolars with mature apices and straight root canals were divided into five groups and used in this study. In Group 1, 30 teeth were prepared using hand K-files and assigned to control group, Group 2 was instrumented using K3XF Rotary files (SybronEndo, Glendora, CA, USA) with continuous rotary motion. The teeth in Group 3 were instrumented by ProTaper Next (Dentsply Maillefer, Ballaigues, Switzerland) rotary files which make asymmetric rotary motion, In Group 4, teeth were instrumented by RECIPROC (VDW, Munich, Germany) with reciprocation motion and in Group 5, teeth were instrumented by Twisted File (TF) Adaptive (SybronEndo, Orange, CA, USA) files that use combination of continuous rotation and reciprocation motion (n = 30/per group). All the roots were horizontally sectioned 3, 6, and 9 mm from the apex with a low speed saw under water cooling. Then, the slices were examined through a stereomicroscope to determine the presence of dentinal microcracks. **Results:** For the apical (3-mm) and coronal (9-mm) sections, the ProTaper Next and TF Adaptive produced significantly more cracks than the hand files, RECIPROC, and K3XF ($P < 0.05$). There was no significant difference between the experimental groups and control group at the 6-mm level ($P > 0.05$). **Conclusions:** Within the limitations of this *in vitro* study, all thermal-treated Ni-Ti instruments and hand files caused microcracks in root canal dentin.

Key words: Kinematic, M-wire, microcracks, nickel-titanium instruments, R-phase, thermal treatment

INTRODUCTION

Optimum cleaning and shaping principles are positively related to prognosis in endodontic treatment.[1] For efficient disinfection, root canal shaping instruments should provide maximum contact with the root canal walls,[2] whereas the remaining root structure should be solid and stable.[3] Since 1998, nickel-titanium (Ni-Ti) alloys have been used in endodontics,[4] also new techniques, design concepts, and instrumentation kinematics are being developed and marketed continuously. Despite these technological advances, vertical root fracture and crack formation still remain as significant problems during root canal shaping procedures using Ni-Ti instruments.[5]

Vertical root fracture is an undesirable clinical state that can lead to extraction of the tooth.[6] During

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and after root canal-shaping procedures, the tooth structure can be harmed with the development of microcracks or craze lines that can propagate with repeated stress due to occlusal forces and may result in vertical root fracture.[5] Variation in the physical properties of Ni-Ti alloys and different instrumentation kinematics may result in different degrees of crack formation.[7] M-wire and R-phase Ni-Ti alloys are produced using a special heat treatment process to improve the resistance and flexibility of endodontic files.[8,9]

K3XF (SybronEndo, Orange, CA, USA) files under continuous rotary motion, and the Twisted File (TF) Adaptive system (SybronEndo, Orange, CA, USA) under combination of continuous rotation and reciprocal motion. Both of these instruments are made of R-phase Ni-Ti alloys. ProTaper Next (DentsplyMaillefer, Ballaigues, Switzerland), makes an asymmetrical rotary motion. Also, RECIPROC (VDW, Munich, Germany) under reciprocal motion and manufactured from M-wire Ni-Ti alloys.

To authors' knowledge, no reports have examined the influence of different instrumentation kinematics of these heat-treated Ni-Ti endodontic files on the occurrence of root canal wall cracks. Therefore, this study compared the frequencies of dentinal microcrack and craze line formation using the K3XF, ProTaper Next, RECIPROC, and TF Adaptive systems. The null hypothesis was that there would be no significant difference in dentinal microcracks among these systems.

MATERIALS AND METHODS

The study design was approved by the Erciyes University Ethics Committee (Protocol No. 148). Freshly extracted mandibular premolars with mature apices and a root canal curvature <5° were selected and kept in distilled water. The presence of only one straight canal was confirmed with radiographs taken from the mesiodistal and buccolingual directions. One-hundred and fifty mandibular premolars with similar width were selected for the study. The roots were randomly distributed to five experimental groups, prepared with thermomechanically treated Ni-Ti files and stainless steel hand files (n = 30). The coronal portions of all of the teeth were removed using a diamond-coated bur with water-cooling, leaving roots approximately 12 mm in length. All roots were inspected with a stereomicroscope (BX60; Olympus, Tokyo, Japan) at ×12 magnification to detect any preexisting external defects or cracks. Teeth with such defects were excluded from the study and replaced by similar teeth. All roots were embedded in autopolymerizing acrylic resin, and hydrophilic vinyl polysiloxane impression material (Elite HD, Zhermack, Italy) was used to simulate periodontal ligament.[10] In all groups, a size of 15 K-type file was inserted into the canal until it was visible from the apical foramen, and the length of the canal was recorded. The working length (WL) was established by subtracting 1 mm from the initial length. After preparing the glide path with a size 15 K-type file, apical preparations were performed up to a size of #25 instrument in all experimental groups. The K3XF (SybronEndo, Orange, CA, USA) ProTaper Next (Dentsply Maillefer, Ballaigues, Switzerland), RECIPROC (VDW, Munich, Germany), and TF Adaptive (SybronEndo, Orange, CA, USA) were used in the experimental groups.

Group hand file (control)
Specimens were prepared with stainless steel K-type files (G-Star; Golden Star Medical, Guangdong, China) up to a #25 size of K-type file using a step-back technique with the balanced force concept.[11] Two taper files were advanced into the canal with the clockwise movement of 90° without causing apical pressure. Then, the apical-directed pressure was used to cut the dentin with a clockwise movement of 120°. Size #15, #20, and #25 K-type files were used, respectively.

Group K3XF
In this group, specimens were prepared with K3XF instruments at 350 rpm with 2 Ncm torque (Endo-Mate DT; NSK). Root canals were prepared with 20/0.06 and 25/0.06 K3XF files in sequence with a gentle in- and out motion. Both of these instruments were used at the full WL.

Group ProTaper next
In this group, specimens were prepared with ProTaper Next with a gentle in and out motion at 300 rpm and with 2 Ncm torque (Endo-Mate DT; NSK). X1 (17/0.04) and X2 (25/0.06) were used sequentially. Both the X1 and X2 files were used at full WL.

Group RECIPROC
Roots were instrumented with a RECIPROC reciprocating single file (25/0.08 in first apical 3 mm) with a gentle in- and out-pecking motion. The RECIPROC files were used with a VDW Silver endodontic motor (VDW, Munich, Germany).

Group twisted file adaptive

Roots were instrumented using TF Adaptive instruments with an Elements motor (SybronEndo, Glendora, CA, USA). SM1 (20/0.04), SM2 (25/0.06), and ML1 (25/0.08) were used sequentially with a gentle in- and out-motion. SM1 was used at two-thirds of the WL, and SM2 and ML1 were used at the full WL.

All root canal preparations were performed by the same operator. Each instrument was discarded after being used for four canals. Between the use of each instrument, the teeth were irrigated with 2 mL of 1% NaOCl solution via a syringe using a 27-Gauge needle (Hayat, Istanbul, Turkey) placed 1 mm from the WL. In the control group, all canals were irrigated with 1% NaOCl solution, followed by recapitulation with a size #15 file following use of each file. In all groups, a total of 15 mL of NaOCl was used for each canal. After the preparation process, all canals were flushed with 2 mL of saline. All roots were kept in a humid environment throughout the procedure.

Sectioning and microscopic evaluation

All roots were sectioned horizontally at a distance of 3, 6, and 9 mm from the apex with a low-speed saw (Minitom; Struers, Denmark) under water-cooling. Two operators who were blinded to the technique examined sections by a stereomicroscope at ×25 magnification, and the images were captured with a digital camera (DP-70; Olympus, Tokyo, Japan) attached to the stereomicroscope. Images were classified as follows: "crack" or "no crack." "Crack" was defined as any lines, microcracks, or fractures in the root dentin [Figure 1]. "No crack" was used if the root dentin was devoid of craze lines, microcracks on the external surface of the root, and microcracks on the internal surface of the root canal wall [Figure 2]. In each group, the number and percentage of cracks were recorded. Data were analyzed with the Chi-square test using SPSS (SPSS, Chicago, IL, USA). The level of significance was set at $P < 0.05$.

RESULTS

Table 1 shows the percentage and frequency of cracks in each group. For the apical (3-mm) and coronal (9-mm) sections, the ProTaper Next and TF Adaptive produced significantly more cracks than the hand files (RECIPROC, or K3XF) ($P < 0.05$). In terms of total cracks in the three sections, the ProTaper Next and TF Adaptive systems produced significantly more cracks than the hand files (RECIPROC and K3XF) ($P < 0.05$). There was no significant difference among the experimental groups and control group at the 6-mm level ($P > 0.05$).

DISCUSSION

All root canal-shaping files, including hand K-files (control group), produced microcracks in root dentin. These findings are in accordance with previous reports,[5,10,12] except for the hand K-files group. Examination with an operating microscope is not fully sufficient for detecting craze lines or cracks on the inner surface of the root, which helps to explain the contradictory result in the control group. The cracks seen in 1% of all sections in the hand file group (control group) may be internal preexisting cracks that became visible after sectioning the roots.

Wilcox *et al*.[3] claimed that the amount of tooth structure removed was associated with vertical root fractures. A previous study[13] reported that the ProTaper Next X2 instrument removed similar amounts of dentin compared with other instruments with larger taper sizes. The design features of the ProTaper Next might be related with the greater crack formation at the 3- and 9-mm levels than with the K3XF and RECIPROC. Furthermore, Bier *et al*.[14]

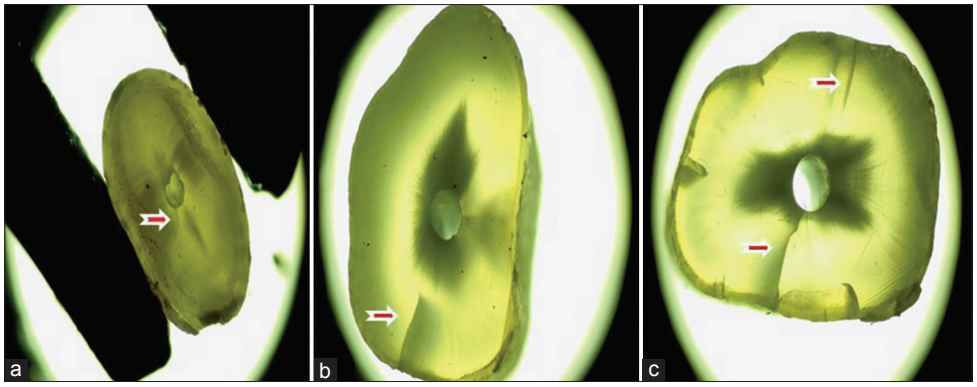

Figure 1: Representative images of (a) 3-mm, (b) 6-mm, and (c) 9-mm level horizontal root sections. Arrows indicate the cracks

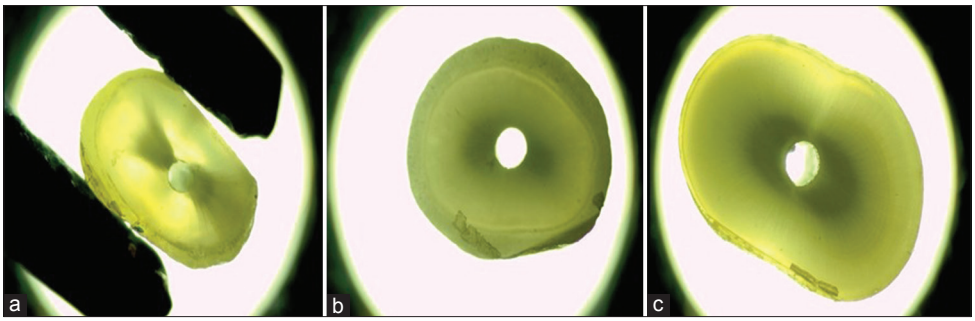

Figure 2: Representative images 9-mm level of (a) 3-mm, (b) 6-mm, and (c) horizontal root sections (without any cracks)

Table 1: Number and percentage of cracks in the different cross-section

Group	Absolute number of cracks (%)			Total cracked roots per group
	3 mm	6 mm	9 mm	
Control	1 (3)[b]	0	0[b]	1 (1)[b]
K3XF	0[b]	1 (3)	2 (6)[b]	3 (3)[b]
ProTaper Next	7 (23)[a]	4 (13)	2 (6)[a]	13 (14)[a]
Twisted File Adaptive	6 (20)[a]	4 (13)	6 (20)[a]	16 (17)[a]
RECİPROC	0[b]	1 (3)	2 (6)[b]	3 (3)[b]
P	0.002	0.074	0.041	0.000

Values with same superscripts letters were not statistically different at $P>0.05$

stated that the instrument taper affected the incidence of microcracks in root dentine. In this study, the apical preparation size was standardized to the size of #25 instrument. Nevertheless, for the final apical taper there were two different sets: 0.06 for K3XF and ProTaper Next and 0.08 for RECIPROC and TF Adaptive system. The larger apical taper in the TF Adaptive group may have contributed to the greater crack formation at the 3-mm level.

Abou El Nasr and Abd El Kader[15] stated that the alloy of the instrument affects the number and percentage of dentinal cracks. Root canal instruments with greater flexibility were associated with fewer microcracks in the root structure.[16] The total frequency (percentage) of microcracks in the groups were 3 (3%) for K3XF, 13 (14%) for ProTaper Next, 3 (3%) for RECIPROC, and 16 (17%) for TF Adaptive. In the present study, the results revealed a significant difference in the incidence of microcracks among the experimental groups at the 3- and 9-mm levels. Hence, the null hypothesis is rejected.

Aydın *et al*.[17] emphasized the importance of the motion style of preparation systems in crack formation. In previous studies, continuous rotary motion was associated with greater crack formation than was asymmetrical rotary,[16,18] reciprocating,[10,19,20] or adaptive motions.[18] In the current study, the K3XF files were used with continuous rotary motion and caused less microcrack formation at the 3- and 9-mm levels, as did the RECIPROC system. This result may be related to the special file design and cross-sectional geometry of the K3XF system, which is exactly the same as that of K3. The manufacturer of K3XF claims that the special design features of the instruments prevent over-engagement and friction on the canal walls.[21]

The adaptive motion was developed to provide the advantages of both rotary and reciprocating motions.[22] According to Karatas *et al*.,[18] the TF Adaptive system with adaptive motion, induces fewer cracks at the 3-mm level than the WaveOne system, with a reciprocating motion. In the present study, reciprocating motion was represented by the RECIPROC system (both the RECIPROC and WaveOne systems prepare the root canal using only a single file). In addition, in RECIPROC group; one file was used for canal preparation, in K3XF group and ProTaper next group; two files were used, and in the TF Adaptive group three files were used. Finishing the root canal preparation with more files might explain why TF Adaptive caused more cracks at the 3- and 9-mm levels than the K3XF and RECIPROC systems.

Regarding 6-mm level, there was no significant difference between the experimental groups and control group. The number of cracks increased with K3XF and RECIPROC systems that associated less cracks in other sections and decreased with PNEXT and TF Adaptive systems that induced more cracks totally. A variable amount of pressure can be transmitted to different parts of the canal wall. Using an initial instrument with greater taper and size in K3XF group than other groups may explain why more cracks occurred at 6-mm level. Likewise, preparing root canals without performing an open and wide pathway with the smaller size of the instrument in RECIPROC group may result as more cracks at 6-mm level.

This study examined new-generation Ni-Ti instruments with similar tapers and manufacturing methods to isolate the effects of motion kinematics on dentinal microcrack formation. Unfortunately, the most commercial preparation systems have unique designs, variable tapers, and different kinematics, and endodontic motors. Therefore, the standardization of preparation systems is limited. Hence, further studies should examine the same number and brands of instruments.

Vertical root fracture is an infrequent complication of root canal treatment.[23] There is no consensus on whether all microcracks lead to vertical root fracture. In addition, the impact of the detected dentinal defects on the long-term prognosis of the tooth needs to be investigated further.

Although acrylic blocks and silicone-based material were used to simulate bone and periodontal ligament in this study, there is no way to imitate the viscoelastic properties of periodontal ligament exactly.[24] We used a proven sectioning method[5,10,25] to evaluate the presence of microcracks in different segments of the root canal. Nonetheless, the sectioning method is destructive, this could be a limitation of the present study.

CONCLUSIONS

Within the limitations of this *in vitro* study, all thermal-treated Ni-Ti instruments caused microcracks in root canal dentin. The TF Adaptive and ProTaper Next systems induced significantly more dentinal damage at the 3- and 9-mm levels than did the K3XF and RECIPROC systems.

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Conflicts of interest
There are no conflicts of interest.

REFERENCES

1. Peters OA. Current challenges and concepts in the preparation of root canal systems: A review. J Endod 2004;30:559-67.
2. Paranjpe A, de Gregorio C, Gonzalez AM, Gomez A, Silva Herzog D, Piña AA, *et al.* Efficacy of the self-adjusting file system on cleaning and shaping oval canals: A microbiological and microscopic evaluation. J Endod 2012;38:226-31.
3. Wilcox LR, Roskelley C, Sutton T. The relationship of root canal enlargement to finger-spreader induced vertical root fracture. J Endod 1997;23:533-4.
4. Walia HM, Brantley WA, Gerstein H. An initial investigation of the bending and torsional properties of Nitinol root canal files. J Endod 1988;14:346-51.
5. Yoldas O, Yilmaz S, Atakan G, Kuden C, Kasan Z. Dentinal microcrack formation during root canal preparations by different NiTi rotary instruments and the self-adjusting file. J Endod 2012;38:232-5.
6. Tamse A, Fuss Z, Lustig J, Kaplavi J. An evaluation of endodontically treated vertically fractured teeth. J Endod 1999;25:506-8.
7. Adorno CG, Yoshioka T, Suda H. Crack initiation on the apical root surface caused by three different nickel-titanium rotary files at different working lengths. J Endod 2011;37:522-5.
8. Al-Hadlaq SM, Aljarbou FA, AlThumairy RI. Evaluation of cyclic flexural fatigue of M-wire nickel-titanium rotary instruments. J Endod 2010;36:305-7.
9. Gambarini G, Testarelli L, De Luca M, Milana V, Plotino G, Grande NM, *et al.* The influence of three different instrumentation techniques on the incidence of postoperative pain after endodontic treatment. Ann Stomatol (Roma) 2013;4:152-5.
10. 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. J Endod 2013;39:1054-6.
11. Roane JB, Sabala CL, Duncanson MG Jr. The "balanced force" concept for instrumentation of curved canals. J Endod 1985;11:203-11.
12. Bürklein S, Tsotsis P, Schäfer E. Incidence of dentinal defects after root canal preparation: Reciprocating versus rotary instrumentation. J Endod 2013;39:501-4.
13. Capar ID, Ertas H, Ok E, Arslan H, Ertas ET. Comparative study of different novel nickel-titanium rotary systems for root canal preparation in severely curved root canals. J Endod 2014;40:852-6.
14. Bier CA, Shemesh H, Tanomaru-Filho M, Wesselink PR, Wu MK. The ability of different nickel-titanium rotary instruments to induce dentinal damage during canal preparation. J Endod 2009;35:236-8.
15. Abou El Nasr HM, Abd El Kader KG. Dentinal damage and fracture resistance of oval roots prepared with single-file systems using different kinematics. J Endod 2014;40:849-51.
16. Capar ID, Arslan H, Akcay M, Uysal B. Effects of ProTaper Universal, ProTaper Next, and HyFlex instruments on crack formation in dentin. J Endod 2014;40:1482-4.
17. Aydin U, Aksoy F, Karatasliogl E, Yildirim C. Effect of ethylenediaminetetraacetic acid gel on the incidence of dentinal cracks caused by three novel nickel-titanium systems. Aust Endod J 2015;41:104-10.
18. Karatas E, Gündüz HA, Kirici DÖ, Arslan H, Topçu MÇ, Yeter KY. Dentinal crack formation during root canal preparations by the twisted file adaptive, ProTaper Next, ProTaper Universal, and WaveOne instruments. J Endod 2015;41:261-4.
19. Ashwinkumar V, Krithikadatta J, Surendran S, Velmurugan N. Effect of reciprocating file motion on microcrack formation in root canals: An SEM study. Int Endod J 2014;47:622-7.
20. Kansal R, Rajput A, Talwar S, Roongta R, Verma M. Assessment of dentinal damage during canal preparation using reciprocating and rotary files. J Endod 2014;40:1443-6.
21. K3XF Guidelines and Pack Details. Available from: https://www.kerrdental.com/kerr-endodontics/k3-nickel-titanium-files-shape. [Last accessed on 2016 Mar 15].
22. Çapar ID, Arslan H. A review of instrumentation kinematics of engine-driven nickel-titanium instruments. Int Endod J 2016;49:119-35.
23. Friedman S, Abitbol S, Lawrence HP. Treatment outcome in endodontics: The Toronto Study. Phase 1: Initial treatment. J Endod 2003;29:787-93.
24. Arias A, Lee YH, Peters CI, Gluskin AH, Peters OA. Comparison of 2 canal preparation techniques in the induction of microcracks: A pilot study with cadaver mandibles. J Endod 2014;40:982-5.
25. Ustun Y, Aslan T, Sagsen B, Kesim B. The effects of different nickel-titanium instruments on dentinal microcrack formations during root canal preparation. Eur J Dent 2015;9:41-6.