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ORIGINAL ARTICLE

Duration of ultrasonic activation causing secondary fractures during the removal of the separated instruments with different tapers

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Abstract

Objectives The aim of the present study was to determine the effect of taper (.08, .06, and .04) of separated K3XF instruments on duration taken for the secondary fracture formation during ultrasonic activation.

Materials and methods Ten 25/.08 K3XF (SybronEndo, Orange, CA, USA), ten 25/.06 K3XF, and ten 25/.04 K3XF instruments were used for the study. The apical 5 mm of the instruments was cut to simulate the fragments in root canals. Fragments of the instruments were sandwiched between two straight dentin blocks. An ultrasonic tip was used to cause a secondary fracture of the fragment. The time needed for the secondary fracture was recorded for each instrument. The data were statistically analyzed using the Kruskal-Wallis H test (alpha = 0.05).

Results Secondary fractures occurred in all instruments. In the .08 taper group, secondary fractures took longer than in the case of the .06 and the .04 taper groups ($P < 0.05$). There were no significant differences between the .06 and the .04 taper groups in terms of the time required for the occurrence of a secondary fracture ($P > 0.05$).

Conclusions In the .08 taper group, secondary fracture took longer time than in the case of the .06 and the .04 taper groups due to its larger cross-sectional area involved.

Clinical relevance Typically, when removing separated instruments, a much lower power setting is chosen. The purpose of this in vitro study was to determine which tapered files were more resilient to secondary fracture, thus allowing a higher power setting to be chosen. Thus, the results of the present study cannot be used in clinical practice. If the clinician knows the taper of the broken file, the clinician should be very careful with regard to secondary fractures when using ultrasonics to remove the separated smaller tapered instruments.

Keywords K3XF · Nickel titanium · Secondary fracture · Separated file · Taper · Ultrasonics

Introduction

Nickel titanium (NiTi) files offer more flexibility and better cutting efficiency than stainless steel files. However, the size and taper of NiTi files limit their bending properties. A larger tip size or taper reduces the flexibility of the instrument [1]. Instruments with larger diameter shafts fail after significantly fewer cycles than do instruments with smaller diameter shafts [2, 3]. Instruments with larger diameters also have greater internal stress accumulation [4]. On the other hand, there is a corresponding increase in the cross-sectional area due to increasing instrument diameters that may increase resistance to torsional failure [5]. Thus, to improve the physical and

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mechanical properties of NiTi instruments, new manufacturing techniques have been developed such as R-phase heat treatment (SybronEndo, Glendora, CA). R-phase is an intermediate phase between austenite and martensite [6]. Specific thermal processing of NiTi alloys, R-phase, modifies the crystalline structure to accommodate the internal stresses that are produced during the grinding process involving NiTi endodontic files. This process improves the flexibility and strength of the NiTi alloys and eliminates the disadvantages of the grinding process in such a way as to improve the mechanical properties of NiTi files [7]. The fatigue process causes crack initiation in the case of NiTi files [8, 9]. K3XF (SybronEndo, Orange, CA, USA) endodontic files are produced using R-phase technology to achieve a better flexibility and cyclic fatigue resistance compared with K3 instruments [10]. According to the results of some studies that have compared the properties of K3XF and K3 (SybronEndo), K3XF files have a greater fatigue resistance [10, 11].

Despite the recent developments in endodontics, broken instruments and the removal of instrument fragments are challenging clinicians. The incidence of instrument separation during preparation using NiTi instruments is greater than in the case of stainless steel files [12]. Also, according to the results of the study by Iqbal et al. [12], the probability of a file separating in the apical third of the root canal is six times more likely when compared with the coronal and middle thirds of the canal. The tooth type is also an important factor in instrument fractures. According to various studies, instrument fracture is more frequent in mandibular or maxillary molars due to narrow and curved root canals [12, 13]. Factors such as multiple uses of rotary instruments and the size and design of such instruments also affect the incidence of instrument fracture [13, 14]. According to the results of a study by Ward et al. [15], separated instruments would break off from the original broken file and leave a smaller fragment in the root canal. The removal of shorter fragments from root canals is more difficult than the removal of longer fragments, and the removal rates of fragments that are located apical to the canal curvature are low [16–18]. Attempts to remove a fractured instrument should be halted when the ultrasonic removal time exceeds 5 min [19, 20].

The removal of separated instruments has been achieved using the Masserann kit (Micro-Mega, Besancon, France), the loupe technique, and ultrasonic techniques [19, 21, 22]. The removal of separated instruments from root canals using the ultrasonic technique has a success rate that ranges between 76 and 100% (with experienced operators) [20, 23, 24]. The time taken for the removal of fractured instruments varies according to the separated instrument location regarding the location of canal curvature. Ward et al. [15] reported that the mean time taken for removal fractured instruments was 10, 14, and 17 min for before the curve, at the curve, and beyond the curve respectively. On the other hand, the direct contact of the tip to the separated instrument is an undesirable and unavoidable outcome that may result in secondary fractures [15, 20]. Smaller fragments associated with secondary fractures are more difficult to remove than larger fragments, and their removal rates are low for apically fractured fragments due to root canal curvature [18, 20].

Greater tapered canal preparation offers more efficient irrigant placement and fewer voids in obturation [25, 26]. The separation of instruments with different tapers may occur in the root canal. However, to date, no data are available with regard to the likely time to the secondary fracture of separated instruments with different tapers as a result of ultrasonic activation. Therefore, the aim of the present study was to determine the effect of taper (.08, .06, and .04) of separated K3XF instruments on duration taken for secondary fracture formation during ultrasonic activation. The null hypothesis tested was that there were no significant differences between the separated instruments with different tapers in terms of the duration of ultrasonic activation that led to the secondary fracture of the separated instruments.

Materials and methods

In the present study, the experimental design protocol followed the protocol as described by Terauchi et al. [20]. Straight 8-mm long, 4-mm deep, and 5-mm wide dentinal blocks were created from six mandibular molars extracted for reasons unrelated to the study purpose. Dentinal blocks were cut using cylindrical diamond burs. A total of six dentin blocks were prepared for use in three groups.

Ten 25/.08 K3XF (SybronEndo, Orange, CA, USA), ten 25/.06 K3XF, and ten 25/.04 K3XF instruments were used for the study. The apical 5 mm of the instruments was cut to simulate the fragments in the root canals. These fragments of the instruments were sandwiched between two straight dentin blocks with a torsional load of 50 Ncm. A mini aluminum vise was used to press the blocks together. A 1-mm portion of the coronal portion of the instrument was kept out of the dentin blocks to mimic separated instrument removal in a clinical setting (Fig. 1).

An ultrasonic tip (E4D; NSK Nakanishi Inc., Kanuma, Japan) was used to cause a secondary fracture of the fragment as would happen in a clinical setting. The ultrasonic tip was sharpened for each instrument using a diamond-impregnated porcelain polisher. The ultrasonic tip was activated with the help of the ultrasonic device (Varios 370, NSK Nakanishi Inc., Kanuma, Japan) at endodontic mode (power 10), and the tip was used in the form of back and forth movements between the interface of the file fragment and the dentin block until a secondary fragment was broken. The ultrasonic tip was immersed in water and cooled to reduce the heat generated during long ultrasonic applications. Each experimental procedure was conducted under an operation microscope (Zeiss Pico;

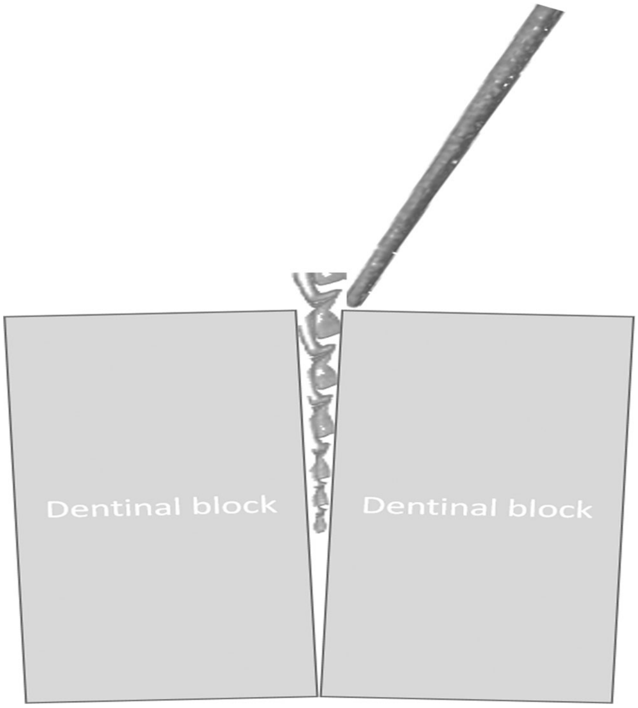


Fig. 1 Experimental model with file fragments sandwiched with dentin blocks to simulate separated files in canals

Zeiss, Oberkochen, Germany). The time needed for secondary fracture was recorded for each instrument. Normality and homogeneity tests were performed. Kruskal-Wallis H test was performed to analyze the data. The level of significance was set at 0.05 (alpha = 0.05).

Results

No instrument fragments were dislodged from the dentin blocks during the ultrasonic activation. Secondary fracture occurred in all instruments. In the .08 taper group, secondary fracture took longer time than in the case of the .06 and the .04 taper groups as shown in Fig. 2 ($P < 0.05$). The .06 and the .04 taper groups were similar in terms of the time required to secondary fracture.

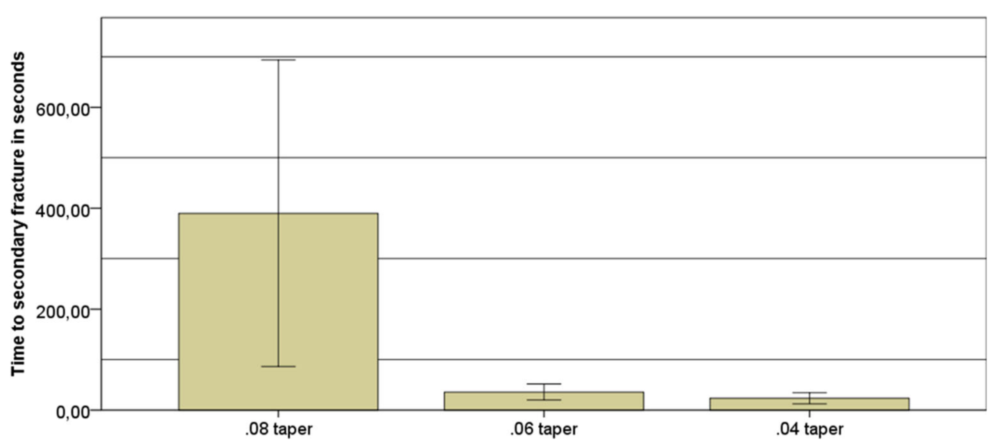
The secondary fracture occurred at 2.90 ± 0.96 mm (0.48 ± 0.07 mm in diameter), 3.25 ± 0.48 mm (0.44 ± 0.02 mm in diameter), and 3.80 ± 0.53 mm (0.40 ± 0.02 mm in diameter) from the apical terminus of the file for the .08, .06, and .04 taper groups, respectively.

Discussion

Instrument separation during root canal preparation is a common problem in routine endodontic practice. However, another problem, secondary fracture of the separated instrument can occur during the attempts to remove fragments using ultrasonics. Because more efficient irrigant placements and fewer voids in obturation can be obtained by preparation using greater tapered instruments, clinicians may prefer different instrument tapers for canal preparation [25, 26]. However, to date, no data are available on the required time to the secondary fracture of separated instruments with different tapers during ultrasonic activation. Therefore, the aim of the present study was to determine the effect of taper (.08, .06, and .04) of separated K3XF instruments on duration taken for secondary fracture formation during ultrasonic activation. Because there is a significant difference between the groups, the null hypothesis was rejected.

The results of the present study revealed that in the case of the .08 taper group, secondary fracture took longer than in the .06 and the .04 taper groups. According to the results of a previous report, a large cross-sectional area showed high torsional resistance [27]. Another study evaluated the mechanical properties of differently tapered nickel titanium endodontic rotary instruments and found that smaller tapered instruments exhibit greater resistance to cyclic fatigue [28]. In our test setup, ultrasonic activation was applied to the fragments. Thus, a direct comparison cannot be done with the results of the previous reports evaluating cyclic fatigue and torsional

Fig. 2 Diagrams presenting mean time with standard deviations in seconds for secondary fracture. .08 tapered instrument group had a longer time for secondary fracture to occur than in the other groups (Kruskal-Wallis H test, $P < .05$)



stress. The result obtained in the present study might be explained by the large cross-sectional area in the .08 taper instrument.

In our study, the protocol detailed in the study by Terauchi et al. [20] was followed. Terauchi et al. [20] used the lowest power setting in their study. The purpose of the current study was to determine which tapered files were more resilient to secondary fracture. Consequently, a higher power was chosen. A lower power setting might have been more appropriate if the purpose of the current study was to simulate a clinical situation. Since the lower power setting extends the time required for a secondary fracture, we preferred the higher power setting in this in vitro study. Thus, the results of the present study do not have clinical significance.

Perhaps the use of a small tapered file of one metallurgy might actually be more resilient than a larger tapered file of another. Thus, future studies are needed comparing different file types with different metallurgies.

In the present study, none of the instrument fragments were dislodged from the dentin blocks. However, two of the dentin blocks were fractured. Ultrasonic activation and tight fixation seem to have been the cause of this. The dentin blocks were replaced by new ones. Because the shortest time for secondary fracture to occur was observed in the case of straight dentin blocks groups, we used straight dentin blocks for both groups.

Conclusion

It can be concluded that in the case of the .08 taper group, the occurrence of secondary fracture took longer than in the case of the .06 and the .04 taper groups due to the .08 taper groups' larger cross-sectional area. If the clinician knows the taper of the broken file, the clinician should be very careful with regard to preventing secondary fractures when using ultrasonics to remove the separated smaller tapered instruments.

Compliance with ethical standards

Conflict of interest All authors declare that they have no conflict of interest.

Ethical approval The research described in this article did not involve human participants.

References

1. Melo M, Pereira E, Viana A, Fonseca A, Buono V, Bahia M (2008) Dimensional characterization and mechanical behaviour of K3 rotary instruments. Int Endod J 41:329–338
2. Haikel Y, Serfaty R, Bateman G, Senger B, Allemann C (1999) Dynamic and cyclic fatigue of engine-driven rotary nickel-titanium endodontic instruments. J Endod 25:434–440
3. Pruett JP, Clement DJ, Carnes DL (1997) Cyclic fatigue testing of nickel-titanium endodontic instruments. J Endod 23:77–85
4. Ullmann CJ, Peters OA (2005) Effect of cyclic fatigue on static fracture loads in ProTaper nickel-titanium rotary instruments. J Endod 31:183–186
5. Parashos P, Messer HH (2006) Rotary NiTi instrument fracture and its consequences. J Endod 32:1031–1043
6. Choi J, Oh S, Kim Y-C, Jee K-K, Kum K, Chang S (2016) Fracture resistance of K3 nickel-titanium files made from different thermal treatments. Bioinorg Chem Appl 2016:1–6
7. Shen Y, Zhou H, Campbell L, Wang Z, Wang R, Du T, Haapasalo M (2014) Fatigue and nanomechanical properties of K3 XF nickel-titanium instruments. Int Endod J 47:1160–1167
8. Shen Y, Cheung GS-p, Bian Z, Peng B (2006) Comparison of defects in ProFile and ProTaper systems after clinical use. J Endod 32:61–65
9. Cheung G, Peng B, Bian Z, Shen Y, Darvell B (2005) Defects in ProTaper S1 instruments after clinical use: fractographic examination. Int Endod J 38:802–809
10. Ha J-H, Kim SK, Cohenca N, Kim H-C (2013) Effect of R-phase heat treatment on torsional resistance and cyclic fatigue fracture. J Endod 39:389–393
11. Gambarini G, Plotino G, Grande N, Al-Sudani D, De Luca M, Testarelli L (2011) Mechanical properties of nickel–titanium rotary instruments produced with a new manufacturing technique. Int Endod J 44:337–341
12. Iqbal MK, Kohli MR, Kim JS (2006) A retrospective clinical study of incidence of root canal instrument separation in an endodontics graduate program: a PennEndo database study. J Endod 32:1048–1052. https://doi.org/10.1016/j.joen.2006.03.001
13. Ankrum MT, Hartwell GR, Truitt JE (2004) K3 Endo, ProTaper, and ProFile systems: breakage and distortion in severely curved roots of molars. J Endod 30:234–237. https://doi.org/10.1097/00004770-200404000-00013
14. Wu J, Lei G, Yan M, Yu Y, Yu J, Zhang G (2011) Instrument separation analysis of multi-used ProTaper Universal rotary system during root canal therapy. J Endod 37:758–763. https://doi.org/10.1016/j.joen.2011.02.021
15. Ward JR, Parashos P, Messer HH (2003) Evaluation of an ultrasonic technique to remove fractured rotary nickel-titanium endodontic instruments from root canals: an experimental study. J Endod 29:756–763. https://doi.org/10.1097/00004770-200311000-00017
16. Ruddle CJ (2002) Nonsurgical retreatment. In: Cohen S, Burns RC (eds) Pathways of the pulp, 8th edn. Mosby, St. Louis, pp 875–929
17. Hulsmann M, Schinkel I (1999) Influence of several factors on the success or failure of removal of fractured instruments from the root canal. Endod Dent Traumatol 15:252–258
18. Shen Y, Peng B, Cheung GS (2004) Factors associated with the removal of fractured NiTi instruments from root canal systems. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 98:605–610. https://doi.org/10.1016/s1079210404002884
19. Terauchi Y, O'Leary L, Kikuchi I, Asanagi M, Yoshioka T, Kobayashi C, Suda H (2007) Evaluation of the efficiency of a new file removal system in comparison with two conventional systems. J Endod 33:585–588. https://doi.org/10.1016/j.joen.2006.12.018
20. Terauchi Y, O'Leary L, Yoshioka T, Suda H (2013) Comparison of the time required to create secondary fracture of separated file fragments by using ultrasonic vibration under various canal conditions. J Endod 39:1300–1305. https://doi.org/10.1016/j.joen.2013.06.021
21. Gencoglu N, Helvacioglu D (2009) Comparison of the different techniques to remove fractured endodontic instruments from root canal systems. Eur J Dent 3:90–95
22. Yoldas O, Oztunc H, Tinaz C, Alparslan N (2004) Perforation risks associated with the use of Masserann endodontic kit drills in mandibular molars. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 97:513–517. https://doi.org/10.1016/s1079210403005675

23. Ward JR, Parashos P, Messer HH (2003) Evaluation of an ultrasonic technique to remove fractured rotary nickel-titanium endodontic instruments from root canals: clinical cases. J Endod 29:764–767. https://doi.org/10.1097/00004770-200311000-00018
24. Shahabinejad H, Ghassemi A, Pishbin L, Shahravan A (2013) Success of ultrasonic technique in removing fractured rotary nickel-titanium endodontic instruments from root canals and its effect on the required force for root fracture. J Endod 39:824–828. https://doi.org/10.1016/j.joen.2013.02.008
25. Boutsioukis C, Gogos C, Verhaagen B, Versluis M, Kastrinakis E, Van der Sluis LW (2010) The effect of root canal taper on the irrigant flow: evaluation using an unsteady computational fluid dynamics model. Int Endod J 43:909–916. https://doi.org/10.1111/j.1365-2591.2010.01767.x
26. Zogheib C, Naaman A, Medioni E, Arbab-Chirani R (2012) Influence of apical taper on the quality of thermoplasticized root fillings assessed by micro-computed tomography. Clin Oral Investig 16:1493–1498. https://doi.org/10.1007/s00784-011-0638-4
27. Goo HJ, Kwak SW, Ha JH, Pedulla E, Kim HC (2017) Mechanical properties of various heat-treated nickel-titanium rotary instruments. J Endod 43:1872–1877. https://doi.org/10.1016/j.joen.2017.05.025
28. Fukumori Y, Nishijyo M, Tokita D, Miyara K, Ebihara A, Okiji T (2018) Comparative analysis of mechanical properties of differently tapered nickeltitanium endodontic rotary instruments. Dent Mater J 37:667–674. https://doi.org/10.4012/dmj.2017-312