Evaluation of the incidence of microcracks caused by Mtwo and ProTaper Next rotary file systems versus the self-adjusting file: A scanning electron microscopic study

Suparna Ganguly Saha, Neelam Vijaywargiya, Divya Saxena, Mainak Kanti Saha, Anuj Bharadwaj, Sandeep Dubey
Departments of Conservative Dentistry and Endodontics and Prosthodontics, College of Dental Science and Hospital, Indore, Madhya Pradesh, India

Abstract

Introduction: To evaluate the incidence of microcrack formation canal preparation with two rotary nickel–titanium systems Mtwo and ProTaper Next along with the self-adjusting file system.

Materials and Methods: One hundred and twenty mandibular premolar teeth were selected. Standardized access cavities were prepared and the canals were manually prepared up to size 20 after coronal preflaring. The teeth were divided into three experimental groups and one control group (n = 30). Group 1: The canals were prepared using Mtwo rotary files. Group 2: The canals were prepared with ProTaper Next files. Group 3: The canals were prepared with self-adjusting files. Group 4: The canals were unprepared and used as a control. The roots were sectioned horizontally 3, 6, and 9 mm from the apex and examined under a scanning electron microscope to check for the presence of microcracks. The Pearson’s Chi-square test was applied.

Results: The highest incidence of microcracks were associated with the ProTaper Next group, 80% (P = 0.00), followed by the Mtwo group, 70% (P = 0.000), and the least number of microcracks was noted in the self-adjusting file group, 10% (P = 0.068). No significant difference was found between the ProTaper Next and Mtwo groups (P = 0.368) while a significant difference was observed between the ProTaper Next and self-adjusting file groups (P = 0.000) as well as the Mtwo and self-adjusting file groups (P = 0.000).

Conclusion: All nickel–titanium rotary instrument systems were associated with microcracks. However, the self-adjusting file system had significantly fewer microcracks when compared with the Mtwo and ProTaper Next.

Keywords: Microcracks; Mtwo; ProTaper Next; self-adjusting file

INTRODUCTION

Various rotary nickel–titanium systems with different configurations and designs have markedly improved the cleaning and shaping procedures of root canal preparation.

Address for correspondence:
Dr. Divya Saxena, College of Dental Science and Hospital, F-12, Jhoomer Ghat, Rau, Indore, Madhya Pradesh - 453 331, India.
E-mail: saxena.divya26@gmail.com

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Mtwo is a rotary file system (VDW, Munich, Germany) which has been reported to maintain canal curvatures\[^6\] and has been shown to have a favorable behavior in cyclic fatigue studies.\[^5\] According to the manufacturer, these instruments have an s-shaped cross-section and two efficient cutting edges with a core that is designed for maximum flexibility without compromising the strength of the dentin or the instrument.

ProTaper Next (Dentsply Maillefer, Ballaigues, Switzerland) is a fifth-generation file system designed such that the center of mass is offset,\[^6\] which generates a mechanical wave of motion analogous to the oscillation noted along a sinusoidal wave, as a result of which it is associated with a bigger envelope of motion.\[^7\]

The self-adjusting file (ReDent Nova, Ra’anana, Israel) is an innovative file system that adjusts to the anatomy of the root canal because of its compressive nature and is designed to efficiently prepare root canals that do not have a round cross-section.\[^8,9\] This adaptive feature lowers the risk of overpreparation and also weakening of the canal walls.\[^10\]

The purpose of the present study was to evaluate the incidence of microcrack formation in root dentin after root canal shaping with two rotary nickel–titanium file systems Mtwo and ProTaper Next along with the self-adjusting file system. The null hypothesis was that there would be no significant difference in dentinal microcracks produced among the groups.

**MATERIALS AND METHODS**

One hundred and twenty mandibular premolar teeth having straight roots extracted for orthodontic purposes from patients of the mean age group of 17–25 years were selected and stored in distilled water. Radiographs were taken with buccolingual as well as mesiodistal angulations to confirm the presence of single canals. Teeth with open apices, fractures, internal resorption, or complex canal anatomy were excluded from the study. The external root surface of all the samples was inspected under a stereomicroscope (Zeiss Stemi SV6; Carl Zeiss, Göttingen, Germany) to ensure intact teeth without any preexisting external defects or microcracks.

Each tooth was wrapped with a single layer of aluminum foil and embedded in autopolymerizing acrylic resin (Probase, Ivoclar Vivadent Ltd, Seoul, Korea), which was allowed to set in a plastic tube. The tooth was then removed from the tube, and the aluminum foil removed. A hydrophilic polyvinyl siloxane impression material (Aquasil, Dentsply, Konstanz, Germany) was poured into the space within the acrylic mold created by the foil to represent a simulated periodontal ligament, and the tooth was immediately repositioned.\[^11\]

Standardized access cavity was prepared in each of the samples, and the coronal part of each canal was sequentially flared up to size 2 Gates-Glidden drills (Dentsply Maillefer). The working length was estimated using a size 10/15 K-file (Dentsply Maillefer) using radiographs. Hand files were used for establishing the initial glide path, and the canals were then manually enlarged up to a size 20 K-file (Dentsply Maillefer).

A minimum sample size of 24 in each group was required considering a difference of 40% in nonmicrocrack proportion between the two groups at an alpha of 0.05, with a power of 80%. Hence, 30 teeth were used in each group. All the canals were instrumented by a single operator and each canal was instrumented by a fresh set of files.

**Group 1 – Mtwo (n = 30)**

The canals were prepared using Mtwo rotary files sequentially according to the manufacturer’s recommendations up to size 40, 0.04 taper using an X-Smart endomotor (Dentsply Tulsa Dental Specialties, Tulsa, OK, USA).

**Group 2 – ProTaper Next (n = 30)**

The canals were prepared with ProTaper Next files sequentially according to the manufacturer’s recommendations up to X4 which corresponds to the tip diameter of 0.40 mm and has a maximum apical taper of 6.5% using an X-Smart endomotor (Dentsply Tulsa Dental Specialties).

**Group 3 – Self-adjusting file (n = 30)**

The canals were prepared with self-adjusting files (1.5 mm) which are recommended for narrow canals of size 20–40. The instrumentation was done according to the manufacturer’s instructions. The file was used with an in-and-out vibrating motion using a RDT3 handpiece (ReDent Nova, Ra’anana, Israel) at an amplitude of 0.40 mm and at 5000 vibrations/min.\[^6\] The self-adjusting file was used in a pecking motion to the working length for 4 min in each tooth.

**Group 4 – Control (n = 30)**

The samples in this group were left unprepared and were used as the control.

For Mtwo and ProTaper Next file systems, 2.5% sodium hypochlorite was used sequentially between each instrumentation using a syringe with side-vented 29-gauge needle (NaviTip; Ultradent, South Jordan, UT, USA), which was placed 1 mm from working length. For self-adjusting file system, continuous irrigation was
performed with 2.5% sodium hypochlorite using a VATEA motor pump.

The samples were then decoronated and sectioned horizontally 3, 6, and 9 mm from the apex with a low-speed saw (Isomet; Buehler Ltd, Lake Bluff, IL, USA) under water cooling. To prevent defect formation due to dehydration of the samples, the teeth were kept moist throughout the procedure. The samples were prepared for evaluation by gold sputtering and then observed under a scanning electron microscope (JEOL JSM 7500F, JEOL Ltd, Peabody, MA, USA). The evaluation was done at 30.0 kV and ×35 magnification. Results were expressed as the number of roots with defects in each group. To avoid confusing descriptions of root fractures, two distinct categories were made: “no defect” and “defect” [Figure 1].

No defect: Root dentin was devoid of any lines or cracks where both the external surface of the root and the internal root canal wall did not have any evident defects.

Defect: The samples were classified as “with defect” if at least one of the three sections had a craze line, a partial crack, or a fracture.

Craze line: A line extending from the outer surface of the root into the dentin without reaching the canal lumen.

Partial crack: A line extending from the root canal walls into the dentin without reaching the outer surface.

Fracture: A line extending from the root canal space all the way to the outer surface of the root.

Statistical analysis
The results obtained were expressed as the number and percentage of microcracked roots in each group. The difference between the experimental groups and control was analyzed using the Pearson’s Chi-square test. Two-sample proportion test was applied for intergroup comparison of microcrack propagation between two experimental groups.

RESULTS
Defects were found in all the groups except the control. The highest incidence of microcracks was associated with the ProTaper Next group, 80% ($P = 0.00$), followed by the Mtwo group, 70% ($P = 0.000$); the least number of microcracks were seen in the self-adjusting file group, 10% ($P = 0.068$) [Table 1]. No significant difference in the incidence of microcrack formation was observed between the ProTaper Next and the Mtwo group ($P = 0.368$) while a significant difference was observed between the ProTaper Next and the self-adjusting file groups ($P = 0.000$) as well as the Mtwo and self-adjusting file groups ($P = 0.000$).

DISCUSSION
Resistance to root fracture is an important prognostic factor in root canal treatment as root defects caused by instrumentation may decrease the survival rate and ultimately lead to failure.

During canal instrumentation, when nickel–titanium rotary instruments are used, a variable degree of rotational force is applied to root canal walls which can lead to the creation of microcracks or craze lines in root dentin. The extent of a defect may be related to various contributing factors such as the tip design, cross-sectional geometry, taper, pitch, and flute form.

The complexity of root canal anatomy, remaining dentinal wall thickness and canal diameter after preparation may also influence the stress concentration. In addition, the age-related change in microstructure of dentin leading to progressive dentinal sclerosis may correspond to lower resistance to damage initiation and propagation.

In the present study, dentinal microcracks were observed in all groups except the control group which implies that access cavity preparation, coronal preflaring with Gates-Glidden drills, hand filing up to size 20, and sectioning did not induce dentinal microcracks, which is in accordance with previous studies.

In this study, both ProTaper Next and Mtwo were associated with significantly more microcracks than the self-adjusting file system. ProTaper Next and Mtwo have an active rotating movement which leads to higher levels of stress concentrations in root canal walls that may result in microcrack formation.

The taper of the instrument could also be a contributing factor in the generation of dentinal defects. All tapered nickel–titanium file systems tested so far create microcracks in a substantial percentage of treated roots, ranging from 18% to 60% of the roots. Kim et al. found that the stress created by some tapered instruments in the outer surface of dentin may reach values that are higher
than the tensile strength of the dentin, i.e., 106 MPa.\[19\] The X4 instrument of ProTaper Next series is a variable taper instrument with a maximum taper of 6.5% in the apical portion which could be responsible for the greater incidence of defects as compared to Mtwo which has a constant smaller taper of 4% and self-adjusting file which is tapered toward the tip. Tip diameter of X4 of ProTaper Next system and size 40, 0.04 taper instrument of Mtwo was identical, i.e., 0.40 mm. Hence, the higher incidence of microcrack formation with ProTaper Next when compared to the Mtwo system cannot be attributed to a larger tip diameter. Moreover, the cross-section of Mtwo is “s-shaped” making it more flexible in contrast to ProTaper Next which has a rectangular cross-section and hence is comparatively less flexible.\[7\]

The self-adjusting file system unlike the other rotary systems does not rotate within the confines of the root canal. Instead, it works with a back and forth motion that removes dentin from the canal walls in a scraping action due to a nickel–titanium abrasive coating. In addition, it neither has a cutting edge nor does it have flutes. The self-adjusting file comes in intimate contact with the inner canal wall as a result of compressible and expansive structure of the lattice.\[8,9\] As opposed to continuous rotary cutting action, the self-adjusting file works like sandpaper which scrapes the dentin, thus effectively enlarging the canal. Furthermore, this system is used with continuous irrigation delivered through the hollow file, which minimizes the generation of frictional stresses.\[8,9\] The results obtained in the present study were similar to previous studies in which minimal microcracks were found in teeth prepared with the self-adjusting file.\[10,14,20\] Metzger reported that the stress created by this file system is minimal, i.e., 10 MPa, which is considerably lower than the tensile strength of dentin.\[21\]

The result of the current study is also in accordance with the study conducted by Ustun et al.,\[12\] who compared the incidence of dentinal microcracks caused by hand files, ProTaper F2 (both in rotation and reciprocation), Reciproc R25, and ProTaper Next and concluded that ProTaper Next was associated with more microcrack formation than other systems.

The root canal systems vary greatly in their cross-sectional anatomy, and root fracture susceptibility may be influenced by the canal morphology. Mandibular premolars with single wide canals without any canal complexities were used in the present study to minimize the effect of complex canal anatomical variations. A study conducted by Adorno et al. reported the incidence of apical microcracks in 50% of mandibular premolars after canal preparation to the apical foramen, which is in accordance with the present study.\[22\]

Unlike the majority of the previously conducted studies, in which stereomicroscope was used for the evaluation of microcrack propagation, a scanning electron microscope was used in this study.

It has been observed that the scanning electron microscope provides high definition images with much greater magnification and resolution, thus making it easier to distinguish between craze lines and partial and full microcracks due to the provision of three-dimensional image interpretation. The absence of microcracks in the control group, which was treated with the same cutting, drying, spray-coating, and secondary electron microscope (SEM) observations as the experimental groups, confirmed that the preparation procedures for the sectioning and SEM examination did not induce microcrack formation themselves.\[23\]

**CONCLUSION**

Damage to root dentin during canal preparation may be caused by the use of nickel–titanium rotary instrument systems. The self-adjusting file system caused fewer microcracks when compared to Mtwo and ProTaper Next systems. However, further clinical evidence is necessary to corroborate these findings.

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**Conflicts of interest**

There are no conflicts of interest.

**REFERENCES**

1. Blum JY, Machtou P, Ruddle C, Micallef JP. Analysis of mechanical preparations in extracted teeth using ProTaper rotary instruments: Value
of the safety quotient. J Endod 2003;29:567-75.

2. 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.

3. Tsesis I, Rosen E, Tamse A, Taschieri S, Kfir A. Diagnosis of vertical root fractures in endodontically treated teeth based on clinical and radiographic indices: A systematic review. J Endod 2010;36:1455-8.

4. Schäfer E, Erler M, Dammaschke T. Comparative study on the shaping ability and cleaning efficiency of rotary Mtwo instruments. Part 2. Clearing effectiveness and shaping ability in severely curved root canals of extracted teeth. Int Endod J 2006;39:203-12.

5. Plotino G, Grande NM, Melo MC, Bahia MG, Testarelli L, Gambarini G. et al. Cyclic fatigue of NiTi rotary instruments in a simulated apical abrupt curvature. Int Endod J 2010;43:226-30.

6. Hashem AA, Ghoneim AG, Lutfy RA, Foda MY, Omar GA. Geometric analysis of root canals prepared by four rotary NiTi shaping systems. J Endod 2012;38:996-1000.

7. Rahman H, Chandra A, Singh S. In vitro evaluation of dentinal microcrack formation during root canal preparations by different NiTi systems. Indian J Restor Dent 2014;3:43-7.

8. Metzger Z, Teperovich E, Zary R, Cohen R, Hof R. The self-adjusting file (SAF). Part 1: Respecting the root canal anatomy – A new concept of endodontic files and its implementation. J Endod 2010;36:679-90.

9. Hof R, Perevalov V, Eltanani M, Zary R, Metzger Z. The self-adjusting file (SAF). Part 2: Mechanical analysis. J Endod 2010;36:691-6.

10. Hin ES, Wu MK, Wesselink PR, Shemesh H. Effects of self-adjusting file, Mtwo, and ProTaper on the root canal wall. J Endod 2013;39:262-4.

11. Adorno CG, Yoshioka T, Suda H. Microcrack initiation of the apical root surface caused by three different nickel-titanium rotary files at different working length. J Endod 2011;37:522-5.

12. 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.

13. 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.

14. Yoldas O, Yilmaz S, Atakan G, Kudan 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.

15. Rundquist BD, Versluis A. How does canal taper affect root stresses? Int Endod J 2006;39:226-37.

16. Mireku AS, Romberg E, Fouad AF, Arola D. Vertical fracture of root filled teeth restored with posts: The effects of patient age and dentine thickness. Int Endod J 2010;43:218-25.

17. Shemesh H, Bier CA, Wu MK, Tanomaru-Filho M, Wesselink PR. The effects of canal preparation and filling on the incidence of dentinal defects. Int Endod J 2009;42:208-13.

18. West JD. Introduction of a new rotary endodontic system: Progressively tapering files. Dent Today 2001;20:50-2, 54-7.

19. Kim HC, Lee MH, Yum J, Versluis A, Lee CJ, Kim BM, et al. Potential relationship between design of nickel-titanium rotary instruments and vertical root fracture. J Endod 2010;36:1199-9.

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. J Endod 2013;39:1054-6.

21. Metzger Z. The self-adjusting file (SAF) system: An evidence-based update. J Conserv Dent 2014;17:401-19.

22. Zhou X, Jiang S, Wang X, Wang S, Zhu X, Zhang C, et al. Comparison of dentinal and apical crack formation caused by four different nickel-titanium rotary and reciprocating systems in large and small canals. Dent Mater J 2015;34:903-9.