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Effect of Repeated use on Topographical Features of ProTaper Next Endodontic Rotary File

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Abstract:
Background: The purpose of this study was to evaluate the morphological alterations of the ProTaper next rotary file (PTN) under scanning electron microscopy (SEM).
Materials and Methods: A total of 18 simulated root canals were allocated to three groups. Six new sets of PTN instruments were used 3 times. A #10 K-file was inserted into the working length, followed by ProGlider to create a glide path. Ensuring the manufacturer's instructions with 99% ethyl alcohol for irrigation, all canals were prepared. Files were photographed in the same position before and after three canals preparations using a high-resolution SEM.
Result: A metal strip appeared on one X1 instrument surface preoperatively. Microcrack defects were observed on two X2 files postoperatively, and the blunt cutting edge was observed on three X1 files before and after use and one file fractured.
Conclusion: Small number of changes appeared on PTN surfaces, yet same PTN file can be used safely 3 times to prepare multi-rooted teeth within the same patient.

Key Words: ProTaper next, rotary endodontics files, scanning electron microscopy, surface changes

Introduction

NiTi files are prone to fracture without any visible defects. Their fatigability occurs as a result of stress during instrumentation of the root canal.[1] In practice, the potential difficulty in removing fractured pieces of the broken files may compromise the outcome of endodontic treatment. This difficulty makes it imperative to know the in-service use of these instruments and identify the fracture mechanisms.

Fatigability that leads to failure of NiTi endodontic instruments can be caused by flexural fatigue or torsional fatigue. Flexural fatigue, also called cyclic fatigue,[2] occurs when the file is used in a curved canal,[3] which is the most destructive form of stress.[4] On the other hand, torsional fatigue occurs in two forms: Dynamic fatigue, which result from frictional forces that are caused by resistance of dentin to the file's cutting;[5] and static fatigue, which occurs during root canal preparation when the tip or any other part of the file is locked in, but the shaft continues to rotate.[5] Torsional fatigue normally shows plastic deformation followed by fracture[6] and can be evaluated microscopically. Therefore, examining the surface of endodontic files would have an important impact on the identification of fracture initiation and file failure.[7]

New endodontic instruments have been subjected to new strategies to improve flexibility, resistance to fracture, fatigability, and cross-sectional designs compared to conventional NiTi instruments. Manufacturers have also proposed different thermomechanical treatments. The ProTaper next (PTN) file system was produced from an M-wire alloy that has greater flexibility and fatigue resistance than conventional NiTi instruments.[8]

Previous studies have reported that PTN instruments have superior cyclic fatigue resistance compared with other NiTi rotary instruments.[9-14] However, to date, no evaluation of the surface characteristics of PTN files have been performed. In addition, no studies have assessed the impact of the repeated use of PTN files to simulate multi-rooted teeth. The link between fatigability of the metal surface changes and file failure with repetitive usage could possibly lead to more understanding about the characteristics of PTN files. Thus, the purpose of this study was to observe the morphological alterations of PTN files before and after continuous use by scanning electron microscopy (SEM).

Materials and Methods

Sample preparation

A total of 18 simulated root canals (16 mm in length and 60°C in curvature) in clear resin blokes (Dentsply-Maillefer Ballaigues, Switzerland) were selected for this study. The blocks were given numbers from 1 to 18 and then assembled into three groups consisting six blocks each. Six kits of a PTN (Dentsply-Maillefer Ballaigues, Switzerland) file system were also given numbers from 1 to 6; each kit was used to prepare the corresponding block group. The blocks and the file groups are detailed in Table 1.

Canal instrumentation

All canals were treated by a single operator. For each canal, the working length (WL) was estimated at the level of the apical foramen using a #10 hand K-file (Dentsply-Maillefer, Ballaigues, Switzerland), and a glide path was established using ProGlider (Dentsply-Maillefer, Ballaigues, Switzerland). PTN files were used in the canals with the crown-down technique, driven by the Wave One Endodontic Motor (Dentsply-Maillefer, Ballaigues, and Switzerland) in rotational motion. The rotational speed was set as recommended, at 350 rpm with a torque of 2.5 N/cm. The preparation was performed using two files (X1 and X2) through a gentle in-and-out motion until the full WL was reached. The instrumentation sequence was as follows: X1 file (size 17, 0.04 taper) followed by the X2 file (size 26, 0.06 taper). All canals were frequently irrigated with 99% ethyl alcohol using a 30-G side-vented needle and repeatedly recapitulated with a K-file ISO 10 to keep the glide path open.

Topographic evaluation

Before the canal preparation started, all files were examined by SEM. A high-resolution FEI QUANTA 400 FEG SEM (FEI, Hillsboro, Oregon 97124, USA) was used for this purpose. All instruments were photographed in the same position before and after each of three uses to observe any surface changes. Three views were chosen: Apical, middle, and critical point area, the latter of which is 3-5 mm away from the apical point of the file. The files were cleaned after use by ultrasonic sterilization (Biosonic UC125 Coltene Whaledent, Langenau/Germany) for 30 min and then reexamined.

Table 1: Sample distribution.

File system no.	Group 1	Group 2	Group 3
F.S.1=1 PTNX1-X2	B1	B7	B13
F.S.2=2 PTNX1-X2	B2	B8	B14
F.S.3=3 PTNX1-X2	B3	B9	B15
F.S.4=4 PTNX1-X2	B4	B10	B16
F.S.5=5 PTNX1-X2	B5	B11	B17
F.S.6=6 PTNX1-X2	B6	B12	B18

F.S.1: File system No. 1-6, B: Endodontic block No. 1-18, PTN: ProTaper next

Examination criteria

The criteria used for checking the instruments' surface defects were adopted by Eggert *et al.*,[15] and were as follows: No visible defects, pitting, corrosion, fretting, microcracks, fractures, metal strips, spiral distortion, blunt cutting edges, disruption of cutting edges or fatigue cracks (Table 2).

Results

PTNX1 and PTNX2 of each of the six systems were examined two times; before (B) and after use (A) (a total of 24 files). The files showed no pitting, corrosion, fretting, spiral distortion, disruption of cutting edges or fatigue cracks. However, other changes were observed, which listed in Table 2 and shown in Figures 1-7.

Among these, 15 files showed no visible defects, and 9 files showed some topographic surface defects. One X2 file had a metal strip on the apical portion (from the top view) before its use (1 PTNX2) (Figure 1). Three X1 files had blunt cutting edges of their apical and middle surfaces before use (4 PTNX1, 5 PTNX1, and 6 PTNX1) (Figures 2 and 3); such defects persisted after usage (Figures 4-5). Small microcracks were observed on the critical point area under ×1000 magnification in two X2 files after use (1 PTNX2 and 6 PTNX2) (Figures 6a-b). Moreover, only one file had fractures after its third use (5 PTNX1) (Figure 7a and b).

Discussion

The quality of both the cutting surfaces and head surfaces of rotary NiTi files after repeated use is of clinical interest.[16] Therefore, examining the file surfaces before and after instrumentation becomes essential to understand the changes that occur before the instruments fail. This will help in the selection and application of NiTi rotary instruments during root canal treatment[17] and can provide insights for clinical use in an attempt to reduce the risk of instrument breakage within root canals.[18]

Our qualitative evaluation was done by SEM observation. Endodontic literature shows that SEM offers high-resolution

Table 2: Criteria selection and topographic changes results for files.

Criteria	1PTN X1		1PTNX2		2PTNX1		2PTNX2		3PTNX1		3PTNX2		4PTNX1		4PTNX2		5PTNX1		5PTNX2		6PTNX1		6PTNX2	
	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A
No visible defect	X	X			X	X	X	X	X	X	X	X			X	X			X	X			X	
Corrosion																								
Fretting																								
Microcracks				X																				X
Fracture																		X						
Metal flash																								
Metal strips			X																					
Spiral distortion																								
Blunt cutting edges													X	X			X	X			X	X		
Disruption of cutting edge																								
Fatigue cracks																								

Before (B) and after (A) use. PTN: ProTaper next

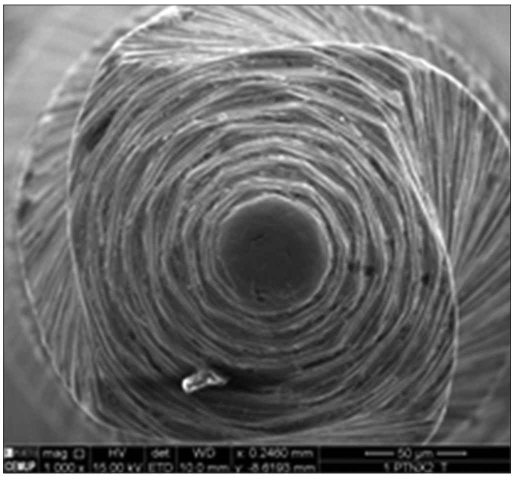

Figure 1: Metal strip - observed on the tip of 1 ProTaper next X2 file.

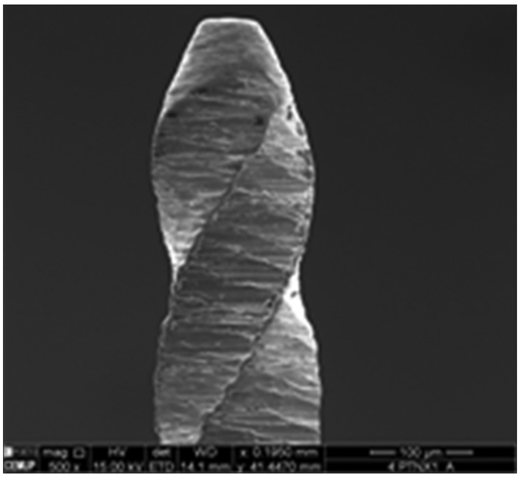

Figure 2: Apical view of 4 ProTaper next X1 files before usage.

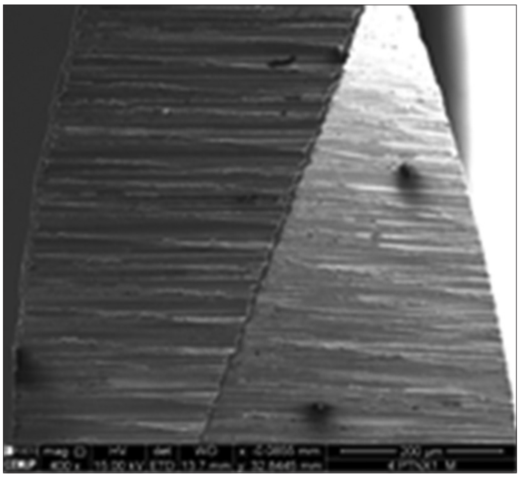

Figure 3: Middle view of 4 ProTaper next X1 files before usage.

images and allows characterization of the topographic features that appear on the file surfaces and the fractured surfaces of broken instruments.[10,15,19] SEM has also been used to observe the dentinal debris and explore patent dentinal tubules.[20] In addition, SEM was proven to be useful in repeatedly evaluating

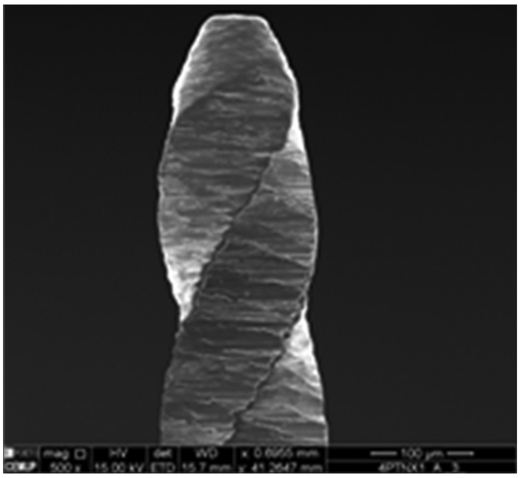

Figure 4: Apical view of 4 ProTaper next X1 files after usage.

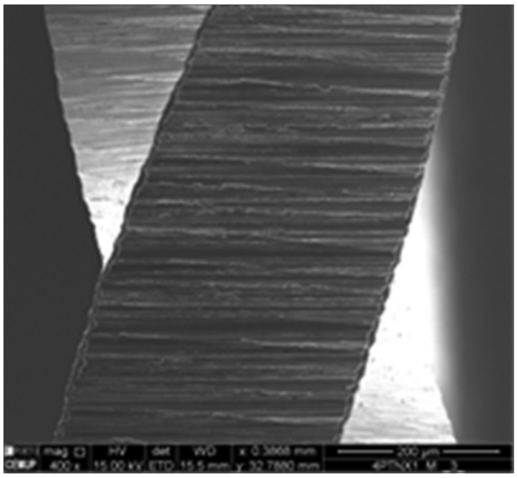

Figure 5: Middle view of 4 ProTaper next X1 files after usage.

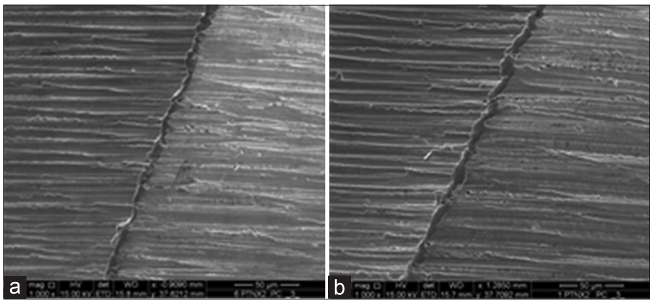

Figure 6: Small microcracks observed on the critical point area in 1 ProTaper next (PTN)X2 file (a) and 6 PTNX2 files (b).

surface defects without affecting the physical properties of endodontic files.[21]

Three areas were selected for evaluating the surface changes: The middle, apical third, and critical area of the file. Those locations were in accordance with Sattapan *et al.*,[22] who indicated that these three areas are the most critical because the files tend to fracture close to their tip. Moreover, the tapering of the file increased toward the handle, making the bulk of the file much stronger than its tip.[18]

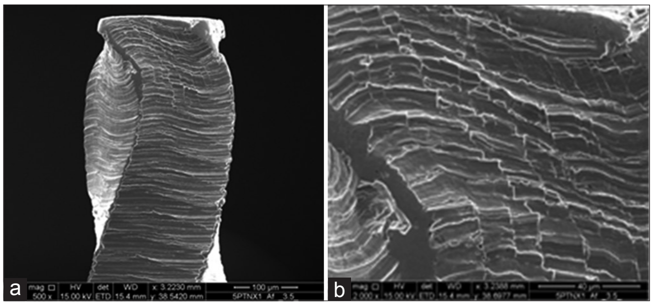

Figure 7: Fracture view - of 5 ProTaper next X1 files (critical area) (a), magnification of showing the plastic deformation (b).

Before use, the files had a highly smooth surface except for one metal strip observed on the tip of one PTNX2 file (Figure 1). This finding was mentioned in previous reports[15,23] as a result of the manufacturing process. However, most defects in these reports were in the form of milling grooves, multiple cracks, and pits.

In the current study, blunt cutting edges were observed in three files before use and stayed unchanged after the third use. Similarly, in testing the light speed file, Eggert *et al*.,z[15] described a remaining blunt cutting edge after use and explained that it meant that the sharp cutting edges were not overused. Kumar analyzed the ProTaper Universal file (PTU) and found the same defects but only after use. The authors explained these defects as a result of the safe cutting tip and the anti-screwing design, which require less pressure to avoid such defects.[23]

Microcracks were also detected in this study, similarly to other work that showed that the ProTaper rotary files also exhibited microfractures after the third and fourth use compared with K3, PTU hand files.[24] Microcracks or micro fractures are the results of a rotational bending of the file within the canal due to shear forces on the blades, which later combine to become the fatigue cracks.[25]

Our result also revealed a fracture on one file, X1 (number five) that happened immediately after the third use. Similarly, in a study that examined the separation incidence of the PTN, the author revealed that most fractured PTN files were X1 files. Those instruments were the first used to penetrate and shape the full WL of the canal, and thus, they were more likely to suffer from fatigue.[26] We used ProGlider to create glide paths before using the PTNX1 files, which could have made our X1 files less subject to fatigue, thus reducing the number of fractures.[27]

SEM at larger magnifications revealed a strong plastic deformation near the fracture zone, resembling a previous study on PTN that presented typical dimpling near the center of the fracture surface.[28] Such a defect indicates that the fracture occurred by torsional stress rather than by cyclic fatigue.[14,18] The same files that broke (5 PTNX1 file) had shown few changes before use (blunted cutting edge), and such changes could act as a stress concentration area and lead to fracture; the elastic limit of the material was exceeded, which led to plastic deformation followed by fracture.[29,30] The fracture occurred 4 mm from the apical point. This is comparable to previous works.[2,31] that indicated that instruments did not fracture at the tip of the file but rather at the point of supreme flexure of the shaft or the midpoint.[10,32]

The repeated use of NiTi files may cause the plastic deformation of the material.[33] That if happened, could result in inadequate preparation, insufficient cleansing, and shaping of the root canal system and lead ultimately to the fracture of the files.[34] The present *in vitro* study evaluated the surface changes of PTN rotary instruments before and after the third use under an SEM.

The results showed the low occurrence of topographic changes, low fracture incidence, and high resistance to cyclic fatigue compared to previous studies. This difference could be due to many factors; alloys such as NiTi have been proven to increase the cyclic fatigue resistance of the instruments.[35] The M-wire technology, which provides greater flexibility for the files along with the off-centered rectangular cross-sectional design, also improves the file's strength and gives the system high resistance to cyclic fatigue.[36,37] The unequal contact between the PTN instrument and the root canal wall could also be a feature that enhanced the fracture resistance of the PTN file.[10]

Although PTN is able to resist high torsional stress, the incidence of fracture occurred was a result of torsional failure. Therefore, clinicians should consider these findings, especially when preparing curved root canals with the same file that have already been used to shape narrow root canals. It is recommended that the clinician use light insertion and avoid forcing the instrument apically during instrumentation.

Conclusion

In this study, the morphological alterations of PTN rotary files after preparation of three simulated root canals were examined by SEM. The changes in file surfaces were few and had no influence on the file's stability. Thus, PTN rotary instruments were used multiple times and safely in curved simulated root canals that mimicked the clinical situation of multi-rooted canals without fear of fracture when avoiding incorrect file use.

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