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FRACTURE AND DEFORMATION RATE OF PROTAPER NEXT FILES AMONG POSTGRADUATE STUDENTS

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ABSTRACT

Aim: To evaluate the fracture and deformation rate of ProTaper Next nickel-titanium (NiTi) rotary instruments among the postgraduate students (PTN, Dentsply Maillefer, Ballaigues, Switzerland).

Materials and Methods: A total of 624 discarded PTN rotary NiTi instruments were collected over 22 months after their clinical use by residents in a graduate endodontic program. The files selected were the X1 (17/04), X2 (25/06), and X3 (30/07). The files' length was measured and all were examined under the stereomicroscope for defects, such as unwinding, fracture, and blunt tips. The fracture faces of the separated files were examined and photographed under the scanning electron microscope. The data were analyzed using the Chi-squared and Kruskal-Wallis tests.

Results: The defect rate of all files was 4.8% and consisted of 2.9% fractures and 1.9% deformation. The file that fractured most frequently was the X3 (55.6% of the total fractured files) because of cyclic fatigue. Deformation without fracture was observed largely in the X1 because of blunt tips. Cyclic fatigue was the cause of 94.4% of fractured instruments and was more frequent in larger sizes.

Conclusions: The ProTaper Next rotary files are more liable to fracture than deformity. Fractures commonly are attributable to cyclic fatigue and are more likely to occur in larger instruments. The small sizes frequently developed blunt tips.

INTRODUCTION

Nickel–titanium (NiTi) rotary instruments have been proven to perform well in root canal preparation, with short procedure times and high success rates [(1)]. However, despite their improved performance in root canal preparation, they are prone to sudden failure either because of cyclic or torsional fatigue. Many factors affect instrument fatigue, including file design and the NiTi alloy's heat treatment. The degree of root canal curvature and size also can have an effect on the file's tendency to fracture and its lifetime [(2)].

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The ProTaper Next nickel-titanium (NiTi) rotary system (PTN, Dentsply Maillefer, Ballaigues, Switzerland) was introduced as an m-wire NiTi rotary system with a file design characterized by an off-center rectangular cross section that creates a unique asymmetric rotary motion and produces a snake–like "swaggering" movement. The ProTaper Next is made of thermally treated m-wire NiTi alloy, which exhibits greater resistance to cyclic fatigue compared to files manufactured from regular NiTi alloy [(3)]. According to previous studies, PTN showed increased flexibility accompanied with less screw-in force and a variable core diameter [(4-5)].

A number of studies has evaluated different NiTi rotary instruments' incidence of deformation and fracture, but no study has investigated the development of defects and fracture in the ProTaper Next rotary system after multiple clinical uses in postgraduate clinics. Therefore, the purpose of this study was to investigate the incidence of deformation and fracture of ProTaper Next instruments discarded after clinical use, and identify the principal mode of defect.

MATERIALS AND METHODS

Sample collection

ProTaper Next NiTi rotary files (25mm length) that were discarded after clinical use by residents in a graduate endodontic program at five university clinics were collected over a 21-month period from September 2016 to June 2018. The files collected for the study were the X1 (17/04), X2 (25/06), and X3 (30/07). The protocol followed in the clinics includes using the ProTaper Next set (X1, X2, and X3) to prepare three clinical molars cases (9-12 canals). Further, any instruments that showed defects after clinical use were discarded. The set of instruments used to prepare molars with a complex anatomy, severely curved roots, or calcified canals were discarded after a single use. The instruments collected were cleaned ultrasonically in absolute alcohol and sterilized.

Deformation and fracture detection

The files' length was measured to a precision of 0.01mm using a micro-caliper. Next, each instrument was placed in a small plastic tube and their numbers, size, and length in mm were labeled. All instruments were inspected for plastic deformation using the stereomicroscope and photographed at 10X magnification (MEIJI, EMZ-13TRD, MEIJI Techno, Japan). The fractured instruments were examined later with the Scanning Electron Microscope to categorize the fracture mode and inspect tip distortion (SEM, Quanta 250 FEG, FEI, Eindhoven, Netherlands). The tip was considered blunt when there was a loss of the tip slope less than 0.1mm and there was no distortion in the machine grooves apparent in the lateral view (Fig. 1a,b). All instruments were classified as (1) intact, (2) deformed or (3) fractured [(6)]. The deformed instruments were classified as unwinding, bending, or blunted tip. The length of the deformation was determined by measuring the distance between the instrument tip and the beginning of the deformation. The fractured instruments were categorized as exhibiting torsional or cyclic (flexural) fatigue from the lateral view and fracture face.

Statistical analysis

Statistical analysis was performed using SPSS 17.0 (SPSS Inc., Chicago, IL, USA). The Chi-squared test was used to analyze whether the defect incident depended on file size. The Yates-Modification was used because the expected value was less than 5. The fracture and deformation location were analyzed using the Kruskal-Wallis test. Statistical significance was set at 0.05.

RESULTS

Deformation and fracture rate

A total of 624 ProTaper Next instruments were collected after their use to prepare 1571 molar teeth (983 mandibular and 588 maxillary). Of the 624 instruments (25mm) collected, 4.8% were defective; the defects consisted of 2.9% fractures and 1.9%

deformations. There was no significant difference in the total defect rate among the three sizes ($p>0.05$). However, the fracture rate overall was significantly higher than was the incidence of deformation ($p<0.05$), and their incidence depended significantly on the instrument's size ($p<0.05$), except in the X2 and X3, which had similar deformation rates. The highest rate of fracture was observed in the X3 (55.6% of the total fractured files), followed by the X2 (33.3%), and X1 (11.1%). In contrast, the highest rate of deformation was observed in the X1 files (50.0% of the total deformed files). The X2 and X3 exhibited the same rate of deformation (25%). The mean fracture location was 3.0633±1.579 mm from the file tip. Of the total deformed instruments, 33.3% showed unwinding and 66.6% had a blunt tip. The deformation was observed predominately 5.21±1.58 mm from the file tip, as shown in Table 1. The highest rate of unwinding was observed in the X3, while blunt tips were observed largely on the X1 files. Micro-cracks were observed with unwinding deformation most frequently with the X1. No instrument bending or curving was observed.

The modes of fracture were categorized as a result of cyclic fatigue or torsional failure. Examination of the face of the fractured instruments with the SEM revealed the fractures' causes: 94.4% of the fractures were attributable to cyclic fatigue and only 5.6% were attributable to torsional failure. Cyclic fractures were observed commonly on the X3 file, while only one X1 file with torsional failure was observed (Table 2).

TABLE (1) The Number of Discarded Instruments and Distribution of Defects and deformation in each instrument (% of Total No. of Instruments).

Size	**N**	**Intact**	**Defect**	**Deformation**			
N(%)				Unwinding N (%)	Blunt tip N (%)	Unwinding length/mm	Subtotal N (%)
X1	202	194(96.0)	8(4.0)	1	5	6.30±1.61	6(50.0)
X2	212	203(95.8)	9(4.2)	1	2	4.30±1.32	3(25.0)
X3	210	197(93.8)	13(6.2)	2	1	3.51±1.52	3(25.0)
Total	624	594(95.2)	30(4.8)	4(0.6)	8(1.3)	5.21±1.58	12(1.9)

P-value=0.05

TABLE (2) The Number of Discarded Instruments and Distribution of fracture in each instrument (% of Total No. of Instruments)

Size	**Fracture**			
	Cyclic N (%)	Torsional N (%)	Segment length/mm	Subtotal N (%)
X1	1	1	5.065±2.665	2(11.1)
X2	6	0	3.408±1.254	6(33.3)
X3	10	0	2.456±1.290	10(55.6)
Total	17(2.7)	1(0.2)	3.063±1.579	18(2.9)

***P*-value=0.05**

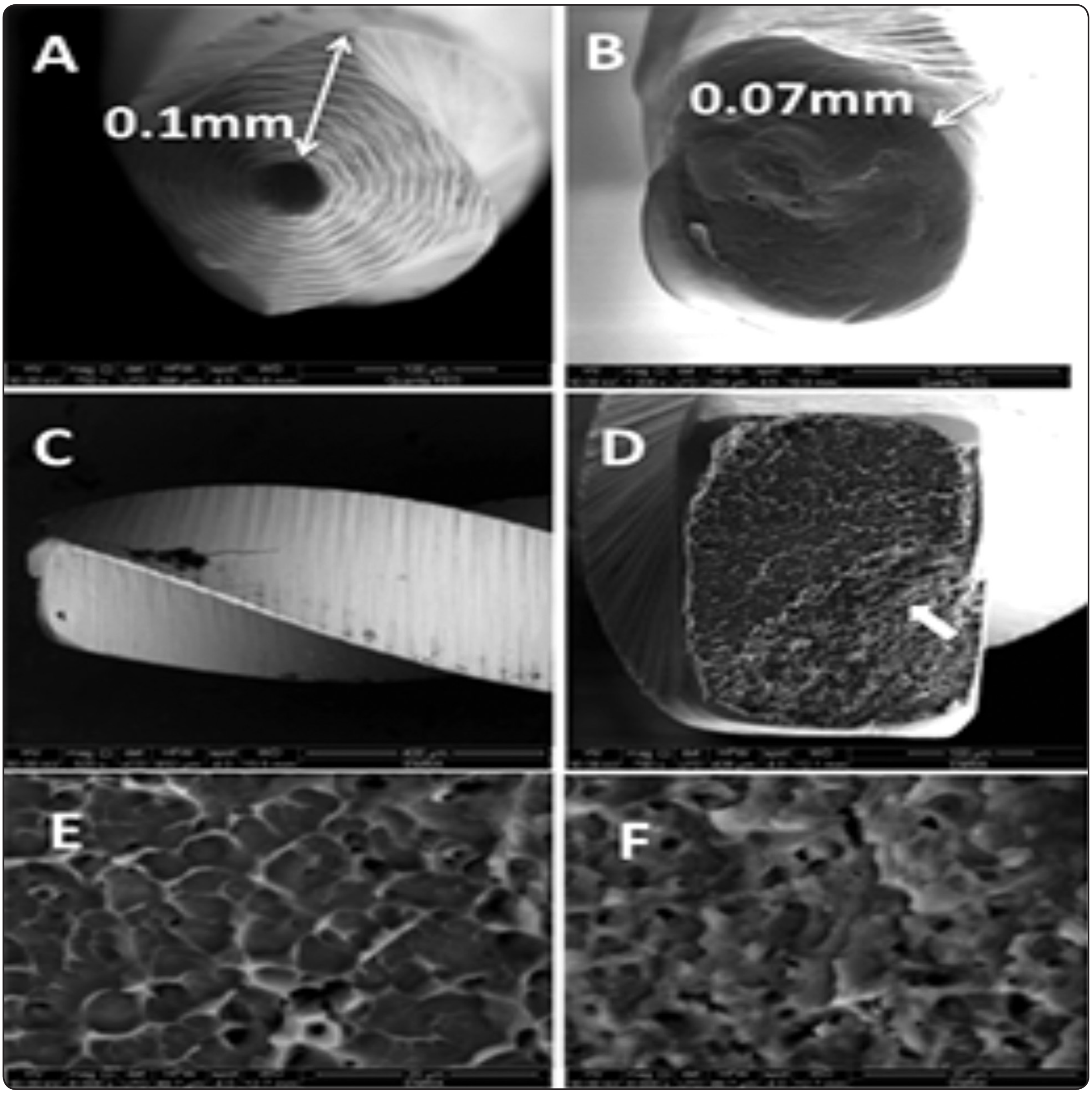

Fig. (1) Scanning back-scattered electron micrograph of the instrument tip after clinical use: (A) intact tip of X2 instrument; (B) blunt tip of X1 instrument; (C) longitudinal view of the X3 instrument showing no deformation; (D) fracto-graphic surface of the fracture face of the instrument demonstrated typical cyclic fatigue with one crack origin and propagation (arrow) and a dimpled area with micro-voids; (E) a high magnification view of the dimpled area with the absence of fatigue striations, and (F) high magnification view of the fatigue striations.

Results of scanning electron examination

In the longitudinal view, instruments with cyclic fracture and metal folding at the cutting edge were observed, but none exhibited micro-cracks. Instruments with torsional fracture showed rupture of the mechanical grooves with metal stripes at the cutting edge and surface pitting. Cyclic failure was distinguished by the presence of a crack that originated at the cutting edge, followed by typical fatigue striations and dimples (Fig.1c-f). From the fracture surfaces of instruments considered to exhibit cyclic fatigue, 47.1% had different levels of fracture where the friction between the two fractured parts occurred at the peripheries (Fig. 2a,b).

On fractographic analysis of the fracture face in the lateral view, torsional failure was characterized by the presence of concentric abrasion marks, central skewed dimples, plastic deformation, and distortion of the machine grooves in the absence of fatigue striations (Fig. 2c,d).

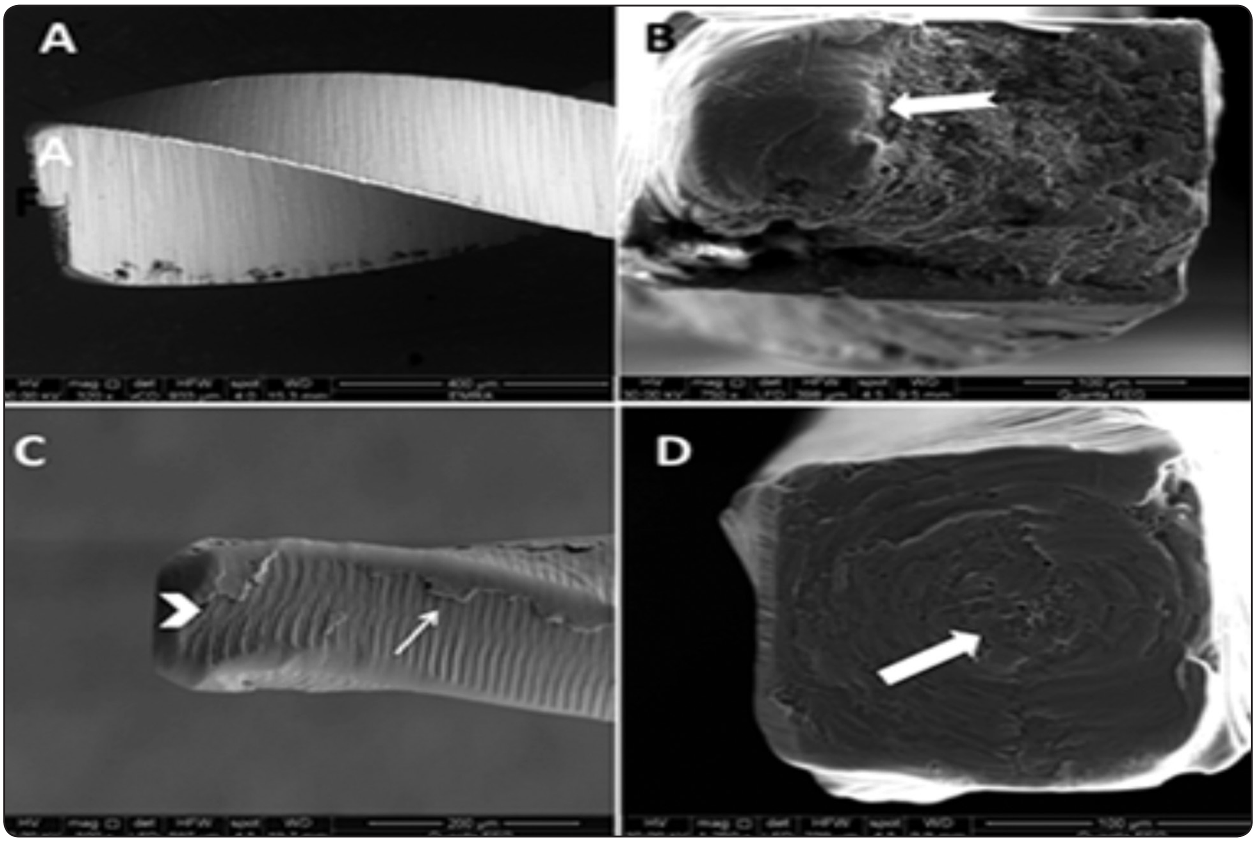

Fig. (2) (A) Longitudinal view of the X3 instrument showed no deformation and fractures at different levels; (B) fracture face of the X3 showed characteristics of cyclic fatigue with different level fractures and abrasions of the upper part attributable to friction between the separated parts (arrow); (C) longitudinal view of the X1 instrument showed distortion of the machine grooves (arrow head) and rollover of the cutting edge (arrow), and (D) fracto-graphic surface of the instrument's fracture face showed a smooth surface with circular abrasion marks and a central dimpling area (arrow) resulting from torsional failure.

DISCUSSION

Previous studies have demonstrated that the incidence of defects after NiTi instruments' clinical use ranged from 3%-22% [7-10]. The total incidence of PTN defects demonstrated in this study (4.8%) is close to the lowest values reported in these previous studies. This low defect rate could be attributed to different variables, including the files' motion, design, thermal treatment, and high flexibility that resulted in less screw-in force [4-5].

In this study, the PTN was more likely to fracture than to deform. Deformation occurs because the instrument is screwed inside the tight canal, which is less likely to happen with the PTN because of its swaggering motion that facilitates its vibration inside the canal without the screw-in within the dentin [11].

The fracture incidence in previous studies ranged from 0.5% to 16% [6,9,11] depending on the type of NiTi alloy [10], number of uses, number of canals [12-13], type of teeth [14], file size, and taper [6]. Further, it is more common with molar than premolar and anterior teeth [14]. Clinically complex molars with variable anatomy that cannot be standardized exert great stress on the instruments used in their preparation and increase the fracture rate; subsequently, these stresses are magnified with repeated clinical use [10]. This elucidates the low fracture incidence reported in some previous studies that collected instruments after preparation of both anterior teeth and premolars [6, 15], while others collected instruments after only a single use [9, 16]. In this study, the only instruments selected were used three times with molar teeth, which exerts more stress on the instruments. However, the fracture rate in the study was similar to that found in studies that included different teeth [6, 14].

The fracture rate was size-dependent, in which the X3 (size 30, taper 0.07) exhibited the highest rate of fracture. This rate could be attributable to the X3 file's dimensions, because it has the largest size and a greater taper, and thus, is subjected to more intra-canal stresses that increase the likelihood that it will fracture [6, 7, 17] .

The NiTi rotary instruments' deformation rate reported in previous studies ranged from 0.3-22%, which is similar, or commonly higher, than the deformation rate found here [6, 9, 10], which was lower than was the fracture rate. According to the previous literature, the instrument design and alloy properties are considered the major determining factors in resistance to intra-canal stresses [18, 19]. The PTN's swaggering motion inside the root canal decreases the dentin's entrapment of the flutes in the narrow canals and was responsible for the low deformation rate in this study. Repeated autoclave cycles do not affect the torsional resistance of instruments made from m-wire [20]. A major contributing factor for the low deformation rate was the fact is considered, the PTN was used by experienced endodontic practitioners who are trained well to follow the manufacturer's instructions and not and not to exert excessive apical force during instrumentation [9, 21].

According to Peter *et al.*, the torque applied during canal preparation was significantly higher for small instruments used in a single–length technique [22]. Moreover, in a narrow, curved canal, there is too much force on the tip of small sized instruments despite proper establishment of a glide path. For this reason, small instruments should be considered only for single use [23]. This could be considered a contributing factor in the X1's deformation observed, as a blunt tip represented 66.7% of the total deformations in this investigation.

In this study, most of the instruments fractured because of cyclic fatigue rather than torsion. To interpret this result, we must bear in mind that molar teeth differ in dentin hardness, internal diameter, and degree of curvature, and all of these factors are important in inducing cyclic fatigue. [20] In this literature, separation of the NiTi instruments is referred to commonly as cyclic fatigue[6,7,10,15].

With the PTN, its kinematics, variable taper, canal curvature, and multiple uses (14,21,23) are the contributing factors.

In contrast, Ertas and Cappar reported equal torsional and cyclic fatigue in the PTN when tested for its separation incidence in extracted molar teeth (13). They attributed their finding to using the PTN without the aid of a coronal flaring instrument, which could cause coronal stress. This explanation could be applied to the X1 as well, which showed a higher rate of blunt tips. In this study, approximately half of the PTN instruments fractured were observed to have different levels of fracture and the two fractured parts continued to move for some time before the operator recognized it was fractured. Because of the friction generated as the separated parts moved over each other, the fracture face was rubbed out and generated vague torsional criteria, especially on the outer part of the cross section. This could be proved, as the circular abrasion marks began at a high level of the fracture, particularly as no deformation was observed in the lateral view (Fig. 2a,b).

CONCLUSION

The incidence of defects in the ProTaper Next was 4.8% of the total discarded instruments after they were used to prepare three molar teeth. The files were more liable to fracture than deform, and the fractures were attributable commonly to cyclic fatigue and more likely with larger sized instruments, while the small files exhibited a blunt tip frequently.

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