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Research Article

The Comparison of Changes and Defects between Two Common Rotary Nickel-Titanium Files, an in Vitro Study

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ABSTRACT

Introduction: Nickel-titanium instruments are of great advantage in endodontic therapy. However, there are concerns regarding defects in the instruments during root canal preparation. This study aimed at comparing defects in two types of common Nickel-Titanium files after root canal usages. **Methods:** In this study, ProTaper (n=26) and RaCe (n=26) instruments were used to prepare the mesial canals of mandibular first molars. After preparing access cavity, canals with less than 10 degrees of curvature were selected and randomly divided into two groups of ProTaper and RaCe according to instrument type. After eight times of use, the files were evaluated through 10X stereomicroscopy and SEM microscopy. The data were analyzed with SPSS 21 using Mann Whitney U tests ($p<0.05$). **Results:** The types of defects in common areas of ProTaper and RaCe groups were stretching or straightening of the twist without bending (57.7% and 61.5%; the apical one-third), peeling or tearing at instrument edges without bending or straightening of the twist (50%, 50%; the apical one-third), partial reverse twisting of instruments (57.7%, 57.7%; the middle one-third), cracking along the file axis (42.3%, 46.2%; the middle one-third), instrument fracture (50%, 38.5%; the apical one-third), and bending (23.1%, 34.6%; the apical one-third). There was no significant difference between the two groups of instruments in terms of the frequency of defects ($p<0.05$). **Conclusion:** According to the results, no difference existed between the two types of nickel titanium rotary instruments in terms of failure after application.

Keywords: Nickel titanium files, instrument defects, endodontic treatment

INTRODUCTION

Root canal therapy is known as one of the most complex dental treatments. It is performed biologically and therapeutically to prevent periodontal lesions at apical areas as well as to provide optimal conditions for the healing of periapical tissue.1 Cleaning and shaping of the root canal system constitute an important part of root canal treatment. Debridement of the root canal system and preparation of the canal with a desired shape is the main purpose of canal cleaning and shaping for preserving the basic shape of the canal.2

Various instruments are used for preparing the canal; stainless steel manual files being one of them are utilized for initial preparation of root canal, negotiation of canal, and measuring canal length. However, the use of these files is not optimal in curved canals due to hardness properties.3 Stainless steel files can lead to functional errors, including transportation, ledge, or perforation during canal shaping due to lack of flexibility.4 Nickel titanium (NiTi) made root canal instruments were introduced in 1988 to overcome rigidity or high elasticity modulus of stainless steel materials.5 Utilization of NiTi instruments has considerably resolved the problem of canal diversion in curved canals and this advantage is due to the flexibility of NiTi instruments. As another advantage, these instruments help to prepare narrow canals by providing a favorable taper, minimum transportation, and preservation of tooth structure to a greater extent (conservative function). In addition, making use of them increases work rate, and provides easier access, decreasing the therapist's fatigue through reduced preparation time.6 Despite numerous advantages of NiTi rotary instruments, these systems still have some disadvantages.7

Although the prevalence of NiTi instrument's fracture has been reported about 5% 8, dentists are still concerned about their fracture during clinical use because if the file breaks in an unclean canal, microorganisms can remain in the area and may cause injury and infection in long-term. Some clinical studies have shown that the fracture of Ni-Ti rotary instruments was classified into: torsional and flexural fatigue fracture. Torsional fracture occurs when part of the instrument binds to the dentin while the file continues to rotate. Flexural fatigue fracture occurs when the instrument rotates freely, generating tension/compression cycles in the region of maximum flexure until fracture occurs.9 Svec and Powers (2002) investigated the defects of NiTi files in curved canals of mandibular molars and showed that the surface of the instruments used were cloven and worn.10

ProTaper and RaCe are the most common NiTi rotary files usually used by dentists for preparation of root canals. The purpose of this laboratory study was to evaluate types of defects and changes of ProTaper and RaCe NiTi rotary instruments following their use in extracted human teeth.

MATERIALS AND METHODS

A total of 26 ProTaper files (Dentsply/Maillefer, Ballaigues, Switzerland) and 26 RaCe files (FKG Dentaire, La-Chaux-de-Fonds, Switzerland) were evaluated. Canals were prepared by an endodontist. Each group of files was used according to the manufacturer's instructions. All files were utilized with Xsmart contra angle reduction rotary handpiece 16:1 (DentsplyMaillefer) with the manufacturer's recommended speed.

NiTi files were used according to specific protocols in the mesial canals (Mesio Buccal and Mesio Lingual) of mandibular first molar with a slight curvature (less than 10 degrees). The severity of canal curvature was measured before starting the work through Schneider's method using periapical radiographs.11 Determination of root canal curvature by using this method is shown schematically in Fig1. The teeth curved more than 10 degrees (teeth with moderate to severe curvatures) were excluded. All canals were washed with 10 mL sodium hypochlorite 2.5% before and while working with rotary files, and Rc-Prep (Premier, Philadelphia, USA) was used during canal preparation. The files were cleaned after eight times of use and sterilized using 1% hypochlorite for 10 minutes, ultrasonic cleaning, and autoclaving at 134°C for 18 minutes prior to examination. They were evaluated by 10X stereomicroscope and Scanning Electron Microscope (JSM 5600, JEOL Ltd., Tokyo, Japan), and the defects were recorded in accordance with the study conducted by Sotokawa:12

1) Bent instrument

2) Stretching or straightening of twist contour without bending

3) Peeling or tearing off metal at edges of the instrument without bending or straightening of the twist contour
4) Partial reverse twisting of the instruments
5) Cracking along the file axis
6) Fracture of the instrument

It is noteworthy that there were several types of defects simultaneously in a number of tested files; therefore, all files were examined in terms of the presence or absence of these 6 defects.

The data were analyzed with SPSS 21 using Mann Whitney U and $p<0.05$ was considered statistically significant.

RESULTS

In this experimental study, changes and defects in two types of Nickel-Titanium rotary file systems (ProTaper and RaCe) commonly used were compared after root canal usages. Some defects of files after application are shown in Fig2. According to Table 1, no significant difference existed between the two types of ProTaper and RaCe systems in terms of the frequency of various defects respectively; stretching or straightening of the twist without bending (57.7% and 61.5%), peeling or tearing at instrument edges without bending or straightening of the twist (50%, 50%), partial reverse twisting of instruments (57.7%, 57.7%), cracking along the file axis (42.3%, 46.2%), instrument fracture (50%, 38.5%), and bending (23.1%, 34.6%). In ProTaper and RaCe, the highest degree of stretching or straightening of the twist without bending was seen in the apical 1/3. On the other hand, the most partial reverse twisting of instruments was seen in the middle 1/3, more frequently in RaCe instrument (57.7%) than ProTaper. The greatest cracking along the file axis occurred in the middle 1/3, more frequently in ProTaper (42.3%), and the highest rate of instrument fracture was observed in the apical 1/3 of ProTaper instrument (50%) (Table 2). Regarding the defects in the mentioned files, and with respect to Table 3, the greatest degree of stretching occurred in Sx files in ProTaper instrument (50%) and in RaCe instrument files of 4% 20, 4% 25, and 4% 30 with a frequency of 16.7%. Peeling defect was seen in files Sx and S1 of ProTaper instrument (50%) and the maximum number of peeling was seen in files 2% 20, 4% 20, 4%30, and 6% 25 of RaCe instrument with a total of 4 peeling files (25%). The highest reverse twisting was seen in S1 file of ProTaper instrument (50%), and 4% 20 and 4% 25 files of RaCe instrument (17.6%). Among files with bending, the highest rate of defects in ProTaper instrument occurred in file S1(50%) and in RaCe instrument occurred in 4%20,4%25 and 4%30 (18.7%). Among files with cracking, the highest defects were seen in files Sx, , S1, and F1 (28.6%) in ProTaper and in file 4% 20 (25%) of RaCe. Most fractures occurred in Sx and S1 files of ProTaper instrument (29.4%), and 4% 25 and 4% 30 files of RaCe instrument (18.7%).

DISCUSSION

According to Table 1, the present study showed no significant differences between ProTaper and RaCe systems in the frequency of defects. Wei et al. studied on 100 fractured ProTaper instruments under stereomicroscope for the presence of plastic deformation along the cutting edge near the fracture site and reported out of 100 fractured instruments, 88 bending and 12 twisting defects.

Table 1: Comparison of defect type between rotary ProTaper and RaCe file

Defect type	Rotary file	Number	Taper	Test	P value
Stretching or straightening of twist contour without bending	ProTaper	15	57.7%	Mann- Whitney U tes	0.780
	RaCe	16	61.5%		
Peeling or tearing off metal at edges of the instrument without bending or straightening of the twist contour	ProTaper	13	50%	Mann- Whitney U tes	0.998
	RaCe	13	50%		
Partial reverse twisting of the instruments	ProTaper	15	57.7%	Mann- Whitney U tes	0.642
	RaCe	15	57.7%		

Cracking along the file axis	ProTaper	11	42.3%	Mann- Whitney	0.615
	RaCe	12	46.2%	U tes	
Fracture of the instrument	ProTaper	13	50%%	Mann- Whitney	0.406
	RaCe	10	38.5%	U tes	
Bent instrument	ProTaper	6	23.1%	Mann- Whitney	0.363
	RaCe	9	34.6%	U tes	

Initiation of fatigue crack usually occurs at the surface of a working part thus some manufactures tried to remove the machining scratch marks to enhance the fracture resistance through such process as electropolishing.[17] RaCe is claimed by its manufacturers to have been electropolished to reduce the surface irregularities. In our study, the prevalence of crack in the middle third of RaCe rotary instruments were less than ProTaper, probably due to their electropolishing.

The frequency of failure of ProTaper and RaCe instruments was 50% and 38.5%, respectively (Table 2). This finding is almost similar to the results obtained by Cheung *et al*., who showed 62% torsional fractures in ProTaper instruments used manually, and almost 66% failure of instruments in rotary method due to fatigue.[18] But the frequency was much higher compared with the findings of Shen *et al*., who reported a failure rate of 14% and 7% for ProTaper and ProFile instruments, respectively.[19] The higher frequency can be attributed to the difference of studies in the number of clinical uses. In the present study, the defects were evaluated after eight times of use. In a study by Parashos *et al*., the frequency of clinical use was identified as a very important factor in the failure of instruments.[20]

Table 2: Prevalence of defects in defferent parts of ProtTaper and RaCe rotary file

Defect type	Rotary file	Apical 1/3	Middle 1/3	Coronal 1/3	None	Sum
Stretching or straightening	ProTaper	15 (57.5%)	0 (%)	0 (%)	11 (42.3%)	26 (100%)
	RaCe	16 (61.5%)	0 (%)	0 (%)	10 (38.5%)	26 (100%)
	Sum	31 (59.6%)	0 (%)	0 (%)	10 (40.4%)	52 (100%)
Peeling or tearing off metal	ProTaper	13 (50%)	0 (%)	0 (%)	13 (50%)	26 (100%)
	RaCe	13 (50%)	0 (%)	0 (%)	13 (50%)	26 (100%)
	Sum	26 (50%)	0 (%)	0 (%)	26 (50%)	52 (100%)
Partial reverse	ProTaper	3 (11.5%)	12 (462%)	0 (%)	11 (42.3%)	26 (100%)
	RaCe	0 (%)	15(57.7%)	0 (%)	11 (42.3%)	26 (100%)
	Sum	3 (5.8%)	27(51.9%)	0 (%)	22 (43.2%)	26 (100%)
Cracking	ProTaper	0 (%)	11(42.3%)	0 (%)	15 (57.7%)	26 (100%)
	RaCe	0 (%)	10(38.5%)	2 (7.7%)	14 (53.8%)	26 (100%)
	Sum	0 (%)	21(40.4%)	2(3.8%)	29 (55.9%)	52 (100%)
Fracture	ProTaper	13 (50%)	0 (%)	0 (%)	13 (50%)	26 (100%)
	RaCe	10 (38.5%)	0 (%)	0 (%)	16 (56.5%)	26 (100%)
	Sum	23 (44.3%)	0 (%)	0 (%)	29 (55.8%)	26 (100%)
Bending	ProTaper	6 (23.1%)	0 (%)	0 (%)	20 (76.9%)	26 (100%)
	RaCe	9 (34.6%)	0 (%)	0 (%)	17 (65.4%)	26 (100%)
	Sum	15 (28.8%)	0 (%)	0 (%)	37 (71.2%)	52 (100%)

Table3: Prevalence of defects based on type of rotary files

Rotary file		Stretching or straightening	Peeling or tearing	Partial reverse	Cracking	Fracture	Bending
ProTaper	Sx	7 (50%)	2 (50%)	5 (31.2%)	2 (28.6%)	5 (29.4%)	3 (37.5%)
	S1	6 (43%)	2 (50%)	8 (50%)	2 (28.6%)	5 (29.4%)	4 (50%)
	S2	1 (7%)	0 (0%)	2 (12.5%)	1 (14.2%)	3 (17.4%)	1 (12.5%)
	F1	0 (0%)	0 (0%)	1 (6.3%)	2 (28.6%)	2 (11.8%)	0 (0%)

	F2	0 (0%)	0 (0%)	0 (0%)	0 (0%)	2 (11.8%)	0 (0%)
Sum	---	14 (100%)	4 (100%)	16 (100%)	17 (100%)	17 (100%)	8 (100%)
RaCe	%152	2 (11.1%)	0 (0%)	2 (11.8%)	0 (0%)	1 (6.3%)	0 (0%)
	%202	1 (5.6%)	1 (25%)	1 (5.9%)	1 (12.5%)	1 (6.3%)	1 (6.3%)
	%252	2 (11.1%)	0 (0%)	2 (11.8%)	0 (0%)	1 (6.3%)	1 (6.3%)
	%415	1 (5.6%)	0 (0%)	1 (5.9%)	1 (12.5%)	2 (12.5%)	2 (12.5%)
	%420	3 (6.16%)	1 (25%)	3 (17.6%)	2 (25%)	2 (12.5%)	3 (18.7%)
	%425	3 (16.7%)	0 (0%)	3 (17.6%)	1 (12.5%)	3 (18.7%)	3 (18.7%)
	%430	3 (16.7%)	1 (25%)	2 (11.8%)	0 (0%)	3 (18.7%)	3 (18.7%)
	%615	1 (5.6%)	0 (0%)	1 (5.9%)	1 (12.5%)	0 (0%)	1 (6.3%)
	%620	2 (11.1%)	0 (0%)	1 (5.9%)	0 (0%)	1 (6.3%)	1 (6.3%)
	%625	0 (0%)	1 (25%)	1 (5.9%)	1 (12.5%)	1 (6.3%)	1 (6.3%)
	%835	0 (0%)	0 (0%)	0 (0%)	1 (12.5%)	1 (6.3%)	0 (0%)
Sum	---	18 (100%)	4 (100%)	17 (100%)	8 (100%)	16 (100%)	16 (100%)

In support of these findings, Subha and Sikri observed that defects in ProTaper rotary files increased considerably after the third and fourth times of use.[6] Patino *et al.* reported that rotary files used more than eight times (in canals with mean curvatures of about 40 degrees) broke more frequently than those used sparigly.[21]

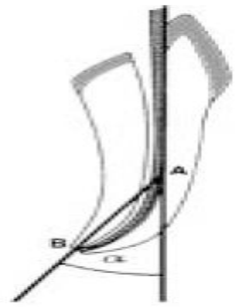
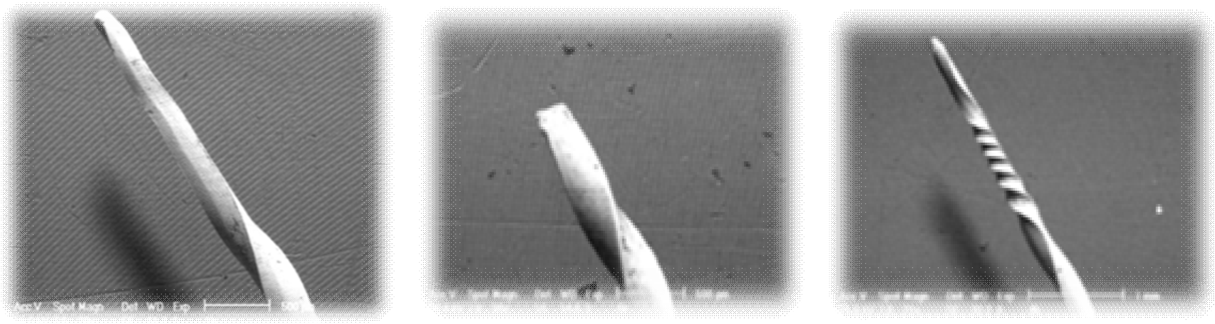


Fig. 1- Determination of root canal curvature by using Schneider's method (α = angle of root canal curvature)



A B C

Fig. 2- Scanning electron microscope showing defects on instrument surface after use (A) Stretching or straightening of twist contour, magnification ×29. (B) Fracture of instrument, magnification ×30. (C) Partial reverse twisting, magnification ×21

This study showed that among the six types of investigated defects, five defects had the highest frequency in the apical region of both ProTaper and RaCe groups. The most prevalent defect was partial reverse twisting of instruments observed in the middle one-third. Generally, there was no defect in the coronal part, or it was fewer in comparison with other regions. This difference may be due to curved canal at more apical parts (Table 2). According to the findings of Gambarini, file fracture occurs due to alternating periods of tension and pressure when instruments are placed in the area of maximum curvature.22

In this study, the rotary endodontic files were sterilized only once and at the end of usage. A number of studies have evaluated the effects of sterilization on the mechanical properties of NiTi rotary instruments. Most of these studies reported that multiple autoclaving cycles did not have any significant alterations in the cyclic fatigue resistance and surface morphology of rotary NiTi files.23 The findings of this study demonstrated that a difference existed between file types in each system in the incidence of defects in a way that the highest rate of defects was seen in S1 file of the ProTaper system and 4% 20, 4% 25, and 4% 30 files of the RaCe system (Table 3). Similarly, Arens et al. reported that defects vary among the files of a system with different sizes.24This difference may be due to the shape and structure of the files in any system. Sattapan et al. reported that instruments with different tapers are different in terms of torque.25 Difference in torque can affect the incidence of a defect.26 In the present study, instruments were not evaluated before use, while some defects in these types of files may be created during the construction phase and preexisting conditions associated with the manufacturing process. Tripi et al. showed that unused files have factory defects.27 Chianello et al. studied the unused endodontic files and observed that 100% of RaCe instruments were free of any scratches or grooves, while 100% of other studied files including K3, Hero, and ProTaper had grooves and 45% of ProFile instruments had scratches and grooves.28 It should be noted that not all RaCe and ProTaper files were used in this study. Only a number of them that could be used in the mesial canals of mandibular first molar were tested.

CONCLUSION

- Different defects are highly prevalent in nickel-titanium instruments after eight times of laboratory use.
- There was no significant difference between the two ProTaper and RaCe systems in terms of defects and structural changes.
- Different changes and defects were generally prevalent in the apical area and, in some cases, in the 1/3 middle, while the 1/3 coronal had fewer defects.

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