ProTaper Rotary Instrument Fracture During Root Canal Preparation: A Comparison Between Rotary and Hybrid Techniques

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Abstract
Aims: This study aimed to compare the frequency of ProTaper rotary instrument fracture with rotary (conventional) and hybrid (rotary and hand files) canal preparation techniques. Secondary objectives were to determine whether there was an association of ProTaper file fracture with the canal curvature and to compare the mean time required for canal preparation in the two techniques.
Methods: An *in vitro* experiment was conducted on 216 buccal canals of extracted maxillary and mandibular first molars. After creating an access cavity and a glide path for each canal, a periapical radiograph was taken and the canal curvature was measured with Schneider's technique. The canals were then randomly divided into Group A (rotary technique) and Group B (hybrid technique). The length of ProTaper files were measured before and after each canal preparation. Time taken for each canal preparation was recorded.
Results: A total of seven ProTaper files fractured in Group A (P=0.014) in canals with a curvature $\geq$25 degrees (P<0.001). The mean time taken for preparation of the root canals was 104.04 sec (±55.7 sec) in Group A versus 122.88 sec (±41.67 sec) in Group B (P=0.007).
Conclusion: In the teeth studied, the hybrid technique of root canal preparation with ProTaper rotary files, although time consuming, was safer in canals having a curvature greater than 25 degrees.

Key Words: ProTaper Rotary System, Rotary Technique, Hybrid Technique, Root Canal Curvature

Introduction

Nickel-titanium (NiTi) rotary instruments have modernised root canal treatment by improving the operator's ability to prepare root canals effectively and efficiently, without significantly altering their centricity, curvature or length [1]. Nevertheless, unexpected instrument fracture is the major drawback associated with these instruments. Furthermore, fractured instruments may block narrow and curved canals and prevent adequate shaping and cleaning procedures [2].

Instrument fracture is a complex phenomenon. Numerous studies have addressed the mechanism of NiTi rotary instrument fracture [3,4] along with the effect of design features, speed and torque on the fracture resistance of NiTi rotary instruments [5,6]. No difference in the file distortion or breakage was found with electric or air-driven hand pieces [7]. Another study [8] examined a total of 7,159 instruments for the presence of defects and concluded that the most important influence on defect rates was the operator, which may be related to clinical skill or a conscious decision to use instruments a specified number of times or until defects were evident. A survey [9] indicated that 76% of clinicians who used LightSpeed (SybronEndo Corporation, Orange, CA, USA) instruments had experienced at least one fractured instrument. However, the exact reasons for fracture were not clear in this study. Files used at a rotational speed of 350 rpm were more likely to fracture than those used at 250 rpm or those used at 150 rpm. A decrease in the angle of curvature of the canal also significantly reduced the likelihood of fracture [10].

Studies that describe NiTi rotary instrument fracture, although comparing different preparation techniques, are limited in number [11,12]. In a study comparing root canal preparation with LightSpeed (LS) only and LS plus hand instrumen-

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tation, about 3.4% of LS only instrument fracture was found to take place in the apical portion of the root canal, whereas LS plus hand instruments did not show any fractures [11]. Similarly, ProFile instrument fracture with a pure rotary technique was 26.9%, whereas with a hybrid technique (ProFile and hand files), there was no instrument fracture [12].

To the knowledge of the authors, there has been no local or international study that has compared ProTaper NiTi rotary system (Dentsply Maillefer, Tulsa, OK, USA) instrument fracture frequency with rotary (conventional) and hybrid (rotary plus hand files) techniques.

The authors chose the ProTaper NiTi rotary system because previous work has shown that its progressively tapered design serves significantly to improve flexibility and cutting efficiency but at the same time this system has been associated with high fracture frequency in comparison with other rotary systems [8,13,14].

Aim

The aim of this study was to quantify the instrument fracture frequency using ProTaper rotary System in rotary and hybrid techniques so that a safer technique (one with less instrument fracture) could be identified and adopted in clinical practice. The objectives of this study were:

- To compare the frequency of ProTaper rotary instrument fracture between rotary and hybrid canal preparation techniques.
- To determine an association of instrument fracture with canal curvature.
- To compare the time required for canal preparation in two techniques.

Null hypotheses

- There is no difference in instrument fracture frequency between ProTaper rotary and ProTaper hybrid canal preparation techniques.
- There is no difference in time required for ProTaper rotary and ProTaper hybrid canal preparation techniques.

Methods

Two hundred and sixteen buccal canals of extracted maxillary and mandibular first molars (mesiobuccal and distobuccal canals of maxillary molars and mesiobuccal canals of mandibular molars) were included in this study. All patients whose extracted teeth were used in the study gave written consent for this to happen.

Sample size calculation

The sample size was calculated using a sample size calculator (Sample Size Determination in Health Studies, World Health Organization) as follows. The reported incidence of instrument fracture with a ProTaper alone technique is 22% [4]. Instrument fracture incidence with a manual hybrid technique is less than 1%. Data from studies on ProFile [11] and LightSpeed [12] instruments showed 0-1% instrument fracture with a hybrid technique (no data are available for instrument fracture with a ProTaper hybrid technique). Hence with a difference of 21% (P1 22% + P 21% = 21%), power at 80% and α at 5%, the sample size turned out to be 36 teeth (108 canals) in each group. Thus a total of 216 buccal canals of extracted molar teeth were required for the study.

Sample selection

Inclusion criteria:

- Extracted human maxillary and mandibular first molar teeth, with completely matured apices belonging to either gender, from the age group between 15-40 years were included in this study.

Exclusion criteria:

- Teeth with calcified or sclerosed canals.
- Teeth with internal or external root resorption and open apices.
- Previously root canal treated teeth.

After mounting into a wax block, straight-line endodontic access for each canal was made by the primary investigator (HF) using a cylindrical diamond bur. The primary investigator had two years' experience of working with the ProTaper rotary system. The canal orifice was located with DG 16 probe and the canal was negotiated with stainless steel K files (Mani, Utsunomiya Tochigi, Japan), size 8 to 15, until the tip of the file was visible at the apical foramen. The working length was established 1 mm short of the apical foramen, and adjacent cusp tip was used as a reference point. A digital periapical radiograph (VixWin™ imaging software; Gendex Corporation, Hatfield, PA, USA) with a number 15 ISO file was taken and canal curvature was measured with Schneider's method. Coronal enlargement in each canal was created with ProTaper SX files. At this stage, all canals were randomly allocated through coin-toss method into two groups:

- Group A (rotary technique).
- Group B (hybrid technique).

Group A (rotary technique)

Canals in Group A were prepared with the ProTaper conventional technique i.e., after creating the glide pathway (as explained above) with ISO stainless steel files number 15, ProTaper shaping files (S1 and S2) and finishing files (F1 and F2) were taken up to the full working length.

Group B (hybrid technique)

In Group B, after creating the glide path with ISO stainless steel files number 15, ProTaper shaping files (S1 and S2) and finishing files (F1 and F2) were used 3 mm short of the working length. The apical 3 mm in Group B was prepared with ISO hand files 20, 25 and 30.

Each canal was irrigated with 2.5% sodium hypochlorite (10 ml), using disposable syringes. Before use, each file was coated with EDTA (RC-Prep; Premier Dental, Plymouth Meeting, PA, USA). All instruments were operated in a 16:1 gear reduction handpiece with a torque- and speed-controlled electric motor (X-SMART; Dentsply-Mallifer, Tulsa, OK, USA). The speed and torque values were set as recommended by the manufacturer. After each use (one use was defined as beginning when a file was inserted into a canal and ending when it was removed from the canal), files were wiped with alcohol-soaked gauze. Instruments were measured before and after each canal preparation with a measuring scale for change in length. Any decrease in length of instrument was considered as failure (fracture). Each rotary instrument was used in nine canals after which it was discarded (irrespective of the fracture) and was replaced with a new one. Time taken for each canal preparation in both techniques was also calculated in seconds using a stopwatch.

Statistical analysis

Statistical software (IBM SPSS Statistics version 19.0; IBM Data Collection, New York, USA) was used for data analysis. Pearson's chi-square test (Fisher's exact test where required) was used to determine an association between:

- Instrument fracture and preparation techniques.
- Instrument fracture and canal curvatures.

Independent samples *t*-test was used to determine the difference in the mean time required for the canal preparation in the two techniques. The level of significance was set at 0.05.

Results

Of the 216 canals divided into two groups, each group comprised of 108 canals. *Figure 1* shows the distribution of canal curvature in the two groups. Seven instruments were fractured in seven canals while preparing 216 canals. Out of these seven, five

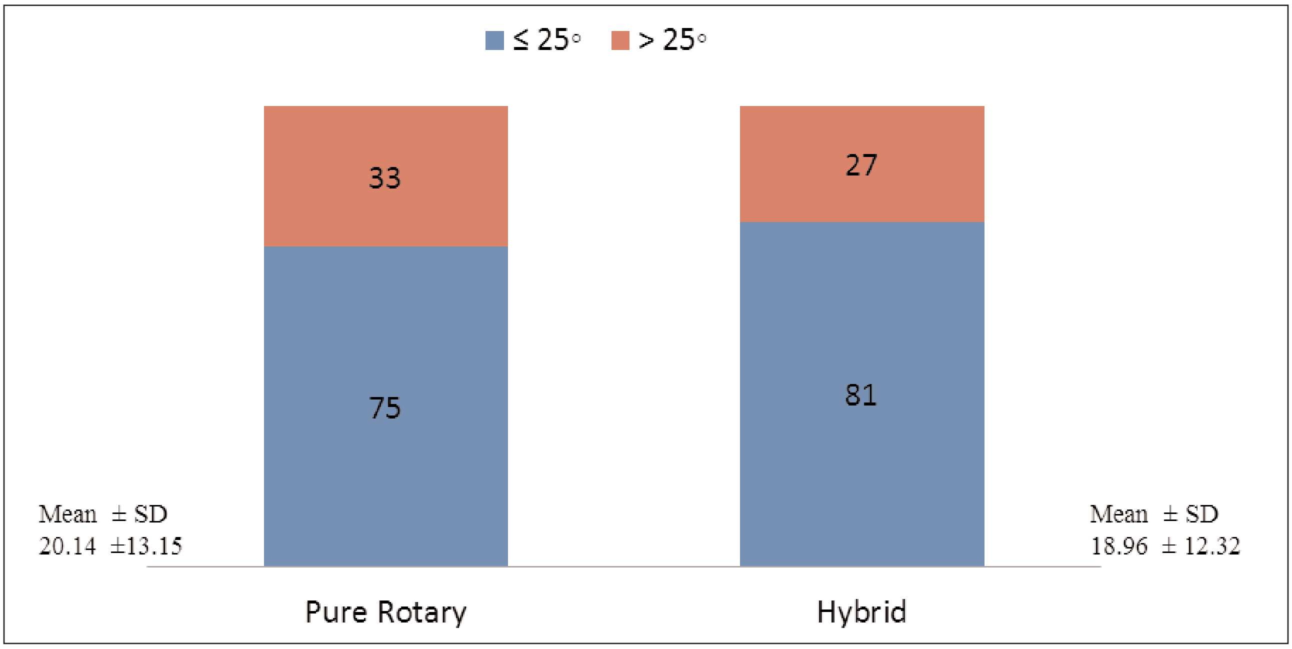

Figure 1. *Distribution of the canals according to curvature.*

instruments separated in the apical third of the canals. Almost all files fractured when used eight times or more. Fracture of one brand new instrument was also noted in one canal.

A statistically significant association was observed between instrument fracture and technique of preparation (*P*=0.014). All seven instruments fractured in Group A in canals with a curvature greater than 25 degrees (*Table 1*). This association was statistically significant (*P*≤0.001). The mean time taken for preparation of the root canals was 104.04 sec (±55.7 sec) in Group A versus 122.88 sec (±41.67 sec) in Group B (*P*=0.007) (*Table 2*).

Discussion

Several factors may play a role in the NiTi rotary instrument fracture, namely manufacturing defects, surface conditioning of the instruments, design features, speed and torque at which the instruments are operated, operator proficiency, effects of heat sterilisation, canal configuration, number of times instruments are used, and preparation techniques. This study was an attempt to find out the effect of different preparation techniques on ProTaper rotary instrument fracture frequency. To standardise the conditions, one brand of NiTi instruments (ProTaper rotary system) was used and variables such as speed, torque, operating conditions, effect of sterilisation and number of usage of instruments were kept constant. Random allocation of canals into two study groups was used to avoid these confounders.

To date, there are limited studies that have compared the instrument fracture frequency in NiTi rotary instruments using different techniques of preparation [11,12]. The results of the current study showed the fracture of seven ProTaper files in Group A whereas canal preparation in Group B was completed without any instrument fracture. This difference was also statistically significant (*P*=0.014). The apical one-third in Group B teeth was prepared with hand files instead of rotary files. This resulted in preparations without fracture. This result was in agreement with previous work [11,15], which also showed that an increase in the canal curvature in the apical third exposes the different parts of the rotary instrument to the flexure and the cyclic fatigue that might result in instrument fracture. A recent study [16] found that all ProTaper instruments fractured in the middle or apical third of the canal and 94% separation appeared in the apical third of the canals. Similarly, another study [15] showed that all rotary (ProTaper, GT, Hero 642, RaCe, Flexmaster and K3) and stainless steel hand instruments fractured when working in the apical third of the canal. This study

Table 1. *Association between instrument fracture, canal curvature and preparation technique*

		Instrument fracture		Total	*P*-value*
		Yes	No		
Preparation technique	Group A (rotary technique)	7	101	**108**	**0.014**
	Group B (hybrid technique)	0	108	**108**	
Total		**7**	**209**	**216**	
Canal curvature	Less than or equal to 25°	0	156	**156**	**≤0.001**
	More than 25°	7	53	**60**	
Total		**7**	**209**	**216**	

*Chi-square/Fisher's exact test applied. *P*<0.05 is significant

Table 2. *Mean preparation time in Group A and Group B*

Preparation technique	**Number of canals**	**Time in seconds Mean (±SD)**	***P*-value†**
Group A (rotary technique)	101	104.04 (±55.7)	0.007
Group B (hybrid technique)	108	122.88 (±41.67)	

†Independent sample *t*-test applied. *P*≤0.05 is significant

failed to find any difference between the manual and rotary instruments concerning their working safety except for ProTaper, which had the highest fracture frequency when compared to other systems. They related this high fracture frequency to the convex triangular cross-sectional design. Fractographic analysis of fractured rotary instruments also confirmed this finding, that a single overloading event causes ductile fracture of instruments more frequently as compared to fatigue accumulation process [17].

Fracture of four LS instruments was found in LS group versus no instrument fracture in LS plus hand instrument group [11]. No instrument separation was noted in a modified crown-down/step back technique (in which apical third was prepared with hand files before using rotary instruments) as opposed to a separation rate of 27% in a strict crown-down technique with rotary instruments alone [12].

A statistically significant association was seen between instrument fracture and canal curvature (P=0.001). All fractures in the current study occurred in canals having a curvature greater than 25 degrees. An abrupt increase in the canal curvature results in instrument overloading, which restrains the rotating instrument, giving rise to multidirectional loading (tension, bending and torsion) that leads to ductile fracture. A clinical practice assessment [18] found the fracture of 78% of the ProFile instruments in canals with a curvature greater than 25 degrees. Accordingly, in another study [19] all ProFile instrument fracture was recorded in canals with an angle of curvature greater than 30 degrees. In a follow-up study, the same study group observed that an increase in the angle of curvature from <30 degrees to >30 degrees led to a significant increase in the fracture incidence for ProTaper and K3 instruments.

In order to minimise instrument fracture rate in curved canals, rotary instruments must be used in curved canals for the least possible amount of time [20]. When a size 15 K-file at the working length is loose inside the root canal and a smooth glide path is confirmed, larger tapered rotary files will passively follow the canal contour to perform subsequent instrumentations. Another option [21] is to prepare the apical one-third using manual instruments in severely curved canals to minimise the instrument fracture because most of the instruments fracture in the apical one-third of the canals, where there is an abrupt increase in the curvature.

The results of the current study showed that the mean time required for a canal preparation in Group A was 104.04 sec (±55.7) and in Group B was 122.88 sec (±41.67). It is clear from the results of this study that the rotary technique is faster than the hybrid technique. Working time is highly dependent on the operator and the type of instruments used e.g., ProTaper uses fewer instruments and prepares canals faster than ProFile, LS, or any system using a larger number of instruments. This fact is also supported by previous studies [22,23], which clearly showed that the differences in the working time reflect to a high degree the operator's experience and effectiveness in root canal preparation. Various studies have compared the time required for manual and rotary canal preparation [15,24] along with the comparison of working time between different rotary systems [25], but the literature regarding comparison of working time between conventional and hybrid techniques using single rotary system is scarce.

One study [12] that compared the mean time between two techniques using ProFile showed that the time taken for preparation of the root canals was 8 min 24 sec (8.24±4.64 min) in the ProFile conventional technique (rotary) and 7 min 30 sec (7.30±3.69 min) in the hybrid group. The methodology in their study showed that they used fewer ProFile rotary instruments along with stainless steel hand instruments in the hybrid technique than in the conventional technique of root canal preparation.

Strengths of the current study were that confounding variables such as speed, torque, number of re-use of instruments and design of instrument (only one brand of instrument was used) were set constant in both groups and that there was random allocation of canals into the two groups. The fact that only one operator performed the study may be considered a weakness.

Conclusion

On the basis of results of this study, it was concluded that:

- The conventional technique of root canal preparation is quicker and can be used safely in root canals having a curvature less than 25 degrees.
- The hybrid technique of root canal preparation, although time consuming, is safer in narrow canals and those having a curvature greater than 25 degrees.
- The creation of a glide path before using rotary instruments is key to minimising instrument fracture.

Funding

The study was internally funded by the Dental Section, Department of Surgery, The Aga Khan University Hospital.

Contributions of each author

- HF performed the study and wrote the paper.
- FRK performed the statistical analysis and reviewed the manuscript.
- MR supervised the study.

Statement of conflict of interest

In the opinion of the authors, there is no conflict of interests.

References

1. Iqbal MK, Maggiore F, Suh B, Edwards KR, Kang J, Kim S. Comparison of apical transportation in four Ni-Ti rotary instrumentation techniques. *Journal of Endodontics*. 2003; **29**: 587-591.

2. Carrotte PV. A clinical guide to endodontics—update part 1. *British Dental Journal.* 2009; **206**: 79-84.

3. Patiño PV, Biedma BM, Liebana CR, Cantatore G, Bahillo JG. The influence of manual glide path on the separation rate of NiTi rotary instruments. *Journal of Endodontics*. 2005; 31: 114-116.

4. Shen Y, Cheung GS, Bian Z, Peng B. Comparison of defects in ProFile and ProTaper systems after clinical use. *Journal of Endodontics*. 2006; **32**: 61-65.

5. Lsmann MHU, Peters O, Dummer PMH. Mechanical preparation of root canals: shaping goals, techniques and means. *Endodontic Topics.* 2005; **10**: 30-76.

6. Cohen S, Burns RC. *Pathways of the Pulp.* 3rd ed. St Louis: CV Mosby; 1984. p. 181-201.

7. Bortnick KL, Steiman HR, Ruskin A. Comparison of nickel-titanium file distortion using electric and air-driven handpieces. *Journal of Endodontics*. 2001; **27**: 57-59.

8. Parashos P, Gordon I, Messer HH. Factors influencing defects of rotary nickel-titanium endodontic instruments after clinical use. *Journal of Endodontics*. 2004; **30**: 722-725.

9. Barbakow F, Lutz F. The 'Lightspeed' preparation technique evaluated by Swiss clinicians after attending continuing education courses. *International Endodontic Journal*. 1997; **30**: 46-50.

10. Martin B, Zelada G, Varela B. Factors influencing the fracture of nickel-titanium rotary instruments. *International Endodontic Journal*. 2003; **36**: 262-266.

11. Bartha T, Kalwitzki M, Lost C, Weiger R. Extended apical enlargement with hand files versus rotary NiTi files. Part I. *Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology, and Endodontics*. 2006; **102**: 692-697.

12. Khongkhunthian P, Tanmukayakul K. Nickel-titanium rotary instrument separation during root canal preparation by dental students: a comparison between a strict crown-down technique and a modified crown-down/step back technique. *Chang Mai University Journal of Natural Sciences*. 2007; **6**: 241-51.

13. Abou-Rass M, Frank AL, Glick DH. The anticurvature filing method to prepare the curved root canal. *Journal of the American Dental Association*. 1980; **101**: 792-794.

14. Shen Y, Cheung GS, Bian Z, Peng B. Comparison of defects in ProFile and ProTaper systems after clinical use. *Journal of Endodontics*. 2006; **32**: 61-65.

15. Guelzow A, Stamm O, Martus P, Kielbassa AM. Comparative study of six rotary nickel-titanium systems and hand instrumentation for root canal preparation *International Endodontic Journal*. 2005; **38**: 743-752.

16. Wu J, Lei G, Yan M, Yu Y, Yu J, Zhang G. Instrument separation analysis of multi-used ProTaper Universal rotary system during root canal therapy. *Journal of Endodontics*. 2011; **37**: 758-763.

17. Spanaki-Voreadi AP, Kerezoudis NP, Zinelis S. Failure mechanism of ProTaper Ni–Ti rotary instruments during clinical use: fractographic analysis. *International Endodontic Journal*. 2006; **39**: 171-178.

18. Di Fiore PM, Genov KA, Komaroff E, Li Y, Lin L. Nickel-titanium rotary instrument fracture: a clinical practice assessment. *International Endodontic Journal*. 2006; **39**: 700-708.

19. Zelada G, Varela P, Martin B, Bahillo JG, Magan F, Ahn S. The effect of rotational speed and the curvature of root canals on the breakage of rotary endodontic instruments. *Journal of Endodontics*. 2002; **28**: 540-542.

20. Pruett JP, Clement DJ, Carnes DL. Cyclic fatigue testing of nickel titanium endodontic instruments. *Journal of Endodontics*. 1997; **23**: 77-85.

21. Ruddle CJ. Shaping for success… everything old is new again. *Dentistry Today*. 2006; **25**: 120-127.

22. Young GR, Parashos P, Messer H. The principles of techniques for cleaning root canals. *Australian Dental Journal*. 2007; **52**(1 Suppl): S52-63

23. Rödig T, Hülsmann M, Kahlmeier C. Comparison of root canal preparation with two rotary NiTi instruments: ProFile .04 and GT Rotary. *International Endodontic Journal.* 2007; **40**: 553-562.

24. Gluskin AH, Brown DC, Buchanan LS. A reconstructed computerized tomographic comparison of Ni-Ti rotary GT files versus traditional instruments in canals shaped by novice operators. *International Endodontic Journal*. 2001; **34**: 476-484.

25. Martin B, Zelada G, Varela P, Bahillo JG, Magán F, Ahn S, *et al*. Factors influencing the fracture of nickel-titanium rotary instruments. *International Endodontic Journal*. 2003; **36**: 262-266.