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

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ABSTRACT

The objective of this study was to compare the incidence of instrument separation and distortion, and canal preparation times between a crown-down technique and a modified crown-down/step back technique in human extracted molar teeth. The operators in this study consisted of 104 undergraduate dental students with no practical experience in the use of rotary-powered root canal instrumentation. Three-hundred-and-fourteen root canals of extracted maxillary and mandibular molar teeth were used and the canals were instrumented randomly with either the crown-down or the modified crown-down/step back technique, according to the recommended sequence for each technique. The results showed the percentage of separated and distorted files in the crown-down technique group to be 26.9% and 23.1%, respectively. In the modified technique group, no files were separated or distorted. However, there was no statistical significance for separated instruments (p=0.052) and distorted instruments (p=0.083) for either technique. The modified technique took significantly less preparation time than the crown-down technique (P=0.048). It was concluded that the new hybrid technique, when used by undergraduate dental students, could be useful for preparing root canals without instrument separation or distortion and the time of canal preparation was decreased. The technique is reliable and can be used by inexperienced dental students to prepare root canals safely.

Key words: NiTi rotary instruments, Root canal preparation techniques, Crown down technique, Step back technique, Hybrid technique, Instrument separation

INTRODUCTION

The ideal shape of a root canal preparation is a taper with the smallest diameter at the apex and the widest diameter at the orifice (Schilder, 1974). This shape can be achieved either by traditional hand or contemporary mechanical preparation. Hand preparation techniques can be time-consuming, especially in narrow and curved canals, where aberrations, such as ledging and zipping, can occur because larger,

stiffer instruments tend to straighten the canal (Esposito and Cunningham, 1995; Glosson et al., 1995).

The introduction of nickel-titanium (NiTi) rotary instruments has revolutionized root canal treatment by reducing operator's fatigue and time required to complete the preparation. Their use has also minimized procedural errors associated with root canal instrumentation (Glosson et al., 1995; Bryant et al., 1999; Park, 2001). Even though the curriculum at Chiang Mai University, Thailand, includes lectures on the many advantages of NiTi instruments for endodontic use, clinical endodontic instructions still include only hand preparation with stainless steel files, using the step-back technique.

Introduction of rotary root canal preparation techniques at the undergraduate level is difficult because of the expense and the propensity for neophytes to either distort or separate (fracture) instruments with these techniques (Mandel et al., 1999; Yared et al., 2001, 2003). Instrument separation and deformation are serious concerns in root canal treatment. The fragments that remain block the root canal system and often result in inadequate cleaning, shaping and sealing of the canal. Factors such as rotational speed, torque, cyclic fatigue, instrument design, instrument technique and operator's experience can influence the incidence of deformation and separation of NiTi rotary instruments (Pruett et al., 1997; Thompson and Dummer, 1997; Blum et al., 1999; Gabel et al., 1999; Mandel et al., 1999; Yared et al., 2000; Gambarini, 2001a, 2001b; Yared and Sleiman, 2001; Yared et al., 2001, 2003). Mandel et al. (1999) identified the effects of the operator on ProFile rotary NiTi instrument fracture. The results showed that, when other factors such as geometry of the canal, instrument sequence and rotary speed were constant, the operator's ability and experience were important factors in instrument failure.

Manufacturers and clinicians have recommended discarding rotary instruments on a regular basis, e.g., after 10 canals (Yared and Sleiman, 2001) or even considering them as single-use instruments in severely curved canals to prevent instrument fracture (Kazemi et al., 1995). However, their failure is difficult to predict clinically. Unfortunately, even when they are constantly checked for defects that might occur before separation, unexpected fractures can occur during clinical use (Pruett et al., 1997; Kosa et al., 1999).

A new, modified technique which integrates traditional instruments and new NiTi rotary instruments was developed at the dental school, Chiang Mai University in Thailand. This technique was supposed to achieve ideal predefined canal shapes, using fewer NiTi rotary instruments, fewer procedural steps, providing a shorter learning curve for students, while, reducing cost and chair time and minimizing instrument separation. In this study, this modified technique will be referred to as the Chiang Mai Technique or CMT.

Aim

The principal purpose of the present study was to compare the incidence of instrument separation and distortion between the strict crown-down ProFile and

modified CMT techniques as used by undergraduate dental students in the preparation of canals in extracted molar teeth. A secondary purpose was to compare the time required in both techniques.

MATERIALS AND METHODS

One-hundred-and-four undergraduate students, with no practical experience in rotary root canal preparation, at the Faculty of Dentistry, Chiang Mai University, Chiang Mai, Thailand, were asked to prepare 314 root canals in human extracted teeth. The students were divided into two groups: the first group would use Profile technique and the second group CMT technique. Each root canal technique was explained (lectured) clearly without practical training.

Specimens and instruments

Fifty-two maxillary molar and fifty-two mandibular molar teeth were selected from a pool of extracted teeth. Teeth whose apices were not completely closed or whose roots were dilacerated or bayonet-shaped were rejected. The selected samples were then placed in 5.25% sodium hypochlorite for 15 minutes for disinfection and to remove debris. An equal number of maxillary molars and mandibular molars were randomly divided into 2 groups: ProFile and CMT, to account for possible variations in canal anatomy.

Traditional straight-line, access preparations were prepared with cylindrical diamond burs in a high-speed handpiece. The canal orifices were identified and the canals were negotiated with stainless steel K-files, sizes 8 to 15, until the tip was visible at the apical foramen. This accomplished three things; 1) the establishment of the working length; 2) canal patency; and, 3) it created a pathway or glide path for rotary instruments. The working length was established to be 1 mm short of the apical foramen, and adjacent cusp tips were used as the reference points.

The instrumentation was carried out using two techniques: ProFile and the new CMT technique. The students were assigned randomly to the ProFile group and the CMT group. A total of 314 canals (156 canals from the ProFile group and 158 canals from the CMT group) were used in this study.

The canals were prepared using the crown-down technique according to the recommended sequences for each technique, using a low torque-controlled motor (Tecnika, ATR, Dentsply, Thailand) with an auto-torque reverse function. Mesiobuccal (MB) and distobuccal (DB) canals of maxillary molars and mesiobuccal and mesiolingual (ML) canals of mandibular molars were prepared to ProFile .06/25 (D1 diameter 0.25 mm), whereas palatal (P) canals of maxillary molars and distal (D) canals of mandibular molars were shaped to ProFile .06/30 (D1 diameter 0.30 mm). The canals were prepared as follow:

ProFile group:

ProFile Orifice Shaper (O.S) #3 and #2 were used for coronal shaping until resistance was encountered (3 to 6 mm from the working length).

ProFile .06/25 and .06/20: 3 mm short of the working length.
ProFile .04/25: 3 mm short of the working length.
ProFile .04/20 and .04/25 to full working length.
ProFile .06/20 and .06/25 to full working length. For canals larger than size 25,
further enlargement using ProFile .06/30.

CMT group:

Coronal flaring using S1 ProTaper rotary instruments inserted 3 mm short of the working length.

ProFile .06/25 was used to prepare the middle third of the canal and inserted 3 mm short of the working length. If resistance was felt, ProFile .06/20 was used, followed by Profile .06/25.

The apex was prepared using a reaming or filing motion up to size 25 with stainless steel K-files at full working length, followed by a serial step-back preparation using only a filing motion in an apico-coronal direction. Every instrument beyond size 25 was inserted 1 mm short of length of the previous instrument up to average size 40. ProFile .06/25 was used to finish apical preparation at full working length. For canals larger than size 25, further enlargement was conducted using ProFile .06/30.

Rubber stops on the files were adjusted to the predetermined penetration depth before starting each preparation sequence. The root canals were irrigated after each instrument use with 2.5% sodium hypochlorite, using disposable syringes (Monoject, Ballymoney, N. Ireland) and 27-gauge irrigating tips (Endo-Tips, Ultradent Products Inc., Utah, UT, USA). Before use, each file was coated with RC-prep (Premier Dental Products Co., Philadelphia, PA, USA) to act as a lubricant.

One use was defined as beginning when a file was inserted into a canal, and ending when it was removed from the canal, even if multiple pecking motions were performed while the file was in the canal. Each file was examined before and after use for any defect and was wiped regularly on gauze to remove debris. Each file was used until it separated or deformed. In case of separation or deformation, the instrument type was recorded and the separated instruments were replaced by new ones. Distorted instruments were used until separation occurred. The students noted the time required for each canal preparation. This time was calculated from the penetration of the first instrument to the use of the final one. Files were also evaluated under 12X magnification under a light microscope by a trained and experienced endodontist.

Statistical analysis

Data were analyzed using EXCEL® (Microsoft, Redmond, WA, USA). The statistical significance between groups was analyzed using Student's t-tests performed with SPSS® 10 statistics software (SPSS, Inc., Chicago, USA). The significance was determined at the 95% confidence level ($p=0.05$).

RESULTS

Instrument separation and distortion

The percentage of separated rotary files in the ProFile group was 26.9% (7 of 26 files), including three O.S #3 files, two .06/25 files and two .06/20 files (Figs.1 and 2). In the CMT group, no file was found to have fractured. There was no significant difference between the ProFile and the CMT groups (Fisher's exact, p=0.052).

The percentage of files that distorted was 23.1% (6 of 26 files) in the ProFile group, including one .06/25 file, two .06/20 files, two .04/25 files and one .04/20 file. No distorted files were found in the CMT group (Fig. 1). There was no significant difference between the ProFile and the CMT groups (Fisher's exact, p=0.083). The type and length of separated and deformed instruments and the number of files used before separation or distortion in the ProFile group are listed in Tables 1 and 2. The number of NiTi files used in the CMT group is displayed in Table 3.

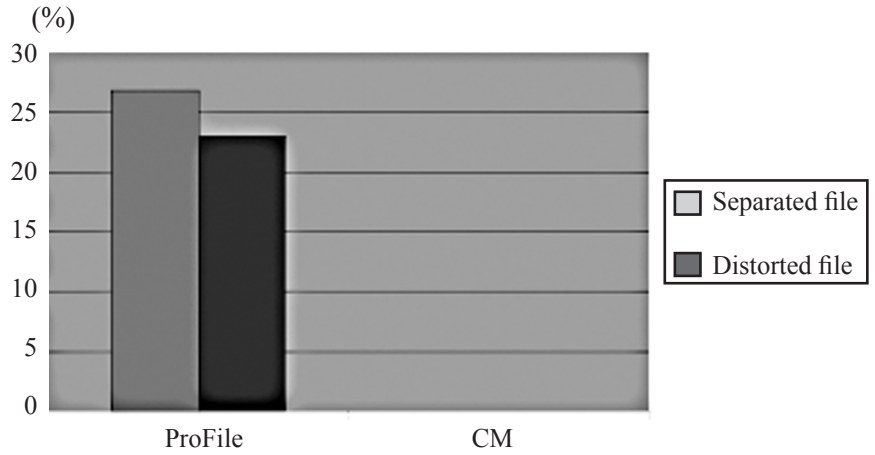

Figure 1. Percentage of NiTi files separated or distorted by preparation techniques.

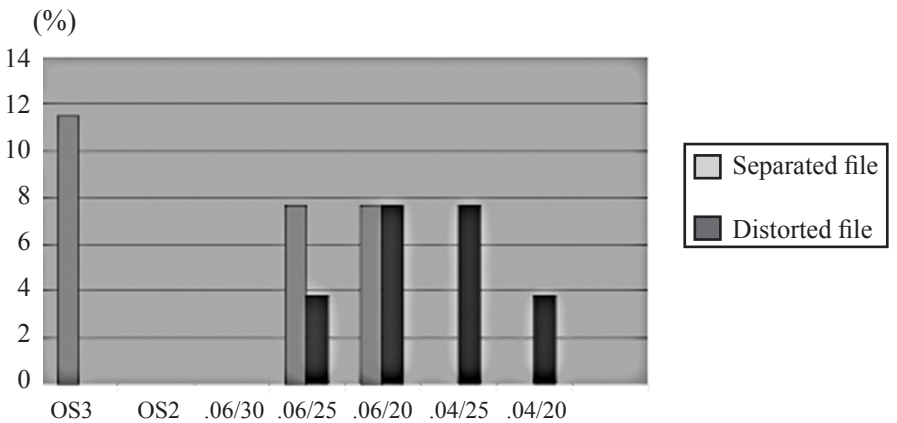

Figure 2. Percentage of NiTi files separated or distorted in the ProFile group according to type and size.

Table 1. Specifications of files separated and distorted during ProFile preparation according to type and location.

Type of file	Number of separated files	Number of distorted files	Length of separation or distortion (mm)	Number of canals filled before separation and distortion (Mean)	Total
O.S #3	3 (11.5%)	-	3, 2.5, 2.5	43.3	3 (11.5%)
O.S #2	-	-	-	-	-
.06/30	-	-	-	-	-
.06/25	2 (7.7%)	1 (3.8%)	6, 3.5, 2	15.5	3 (11.5%)
.06/20	2 (7.7%)	2 (7.7%)	6, 5, 2, 3	26.25	4 (15.4%)
.04/25	-	2 (7.7%)	2, 3	35.5	2 (7.7%)
.04/20	-	1 (3.8%)	2	-	1 (3.8%)
Total	7 (26.9%)	6 (23.1%)	-	-	13 (50%)

Table 2. Number of uses of NiTi files in canals in the ProFile group.

Number of uses (and canals) until separation (S) or distortion (D)						
Type of file	Set 1 (41 canals)		Set 2 (63 canals)		Set 3 (52 canals)	
	No.1	No.2	No.3	No.4	No.5	No.6
O.S #3	67S (41)	-	75 S (63)	-	38S (26)	28 (26)
O.S #2	54 (41)	-	65 (63)	-	52 (52)	-
.06/30	26 (17)	-	23 (19)	-	22 (19)	-
.06/25	53S (20)	45 (21)	117 (63)	-	39S (17)	57D (25)+ 28D (10)
.06/20	57S (21)	48D (20)	56D (29)+ 55D (34)	-	70S (35)	36 (17)
.04/25	93 (41)	-	93D (48)+ 21D (45)	-	48D (23)+ 53D (29)	-
.04/20	52 (41)	-	36D (36)+ 27D (27)	-	52 (52)	-

S = number of use until separation

D = number of use until distortion

Table 3. Number of uses of NiTi files in canals in the CM group.

Type of file	Number of uses (and canals)		
	Set 1 (59 canals)	Set 2 (57 canals)	Set 3 (41 canals)
S1	59 (59)	62 (57)	47 (41)
.06/30	24 (18)	27 (21)	22 (17)
.06/25	125 (59)	133 (57)	118 (41)
.06/20	19 (19)	14 (13)	14 (13)

Preparation time

The mean time taken for preparation of the root canals was 8 min 24 s (8.24 ± 4.64 min) in the ProFile group versus 7 min 30 s (7.30 ± 3.69 min) in the CMT group. This difference was significant (student t- test, p=0.048) (Table 4).

Table 4. Mean preparation time between the ProFile and the CM groups.

Preparation Technique	Number of canals	Mean time±SD	p-value
ProFile	156	8.24±4.64	0.048
CM	158	7.30±3.69	

DISCUSSION

Dental schools worldwide are facing with the challenge of providing undergraduate students with the skills to prepare root canals safely, while exposing those students to a variety of innovative instruments and techniques. Teaching new methods and instruments in dental schools is essential to improve the overall success rate of root canal treatment in each country.

Recently, nickel-titanium instruments have played an important role in root canal preparation. Although numerous authors have reported the mechanical advantages of preparation with NiTi files over preparation with stainless steel files (Esposito and Cunningham, 1995; Glosson et al., 1995; Bryant et al., 1999; Park, 2001), a major concern with the use of nickel-titanium rotary instruments is the possibility of unexpected fracture (Pruett et al., 1997; Kosa et al., 1999). Instrument distortion and separation occur in two ways: through torsional or flexural fatigue (Pruett et al., 1997; Sattapan et al., 2000). Torsional fracture results when the instrument exceeds the elastic limit of the metal, producing plastic deformation followed by fracture. This occurs when the tip or any part of the instrument binds in the canal and rotary motion still continues. Flexural fracture occurs because of frequent of using and metal fatigue. This usually occurs at the point of canal curvature when the instrument is freely rotating and the instrument flexes until fracture occurs at the point of maximum flexure. However, no study or information is available that specifies how many times rotary instruments can be used safely. Several studies on ProFile instruments have reported their canal-centering ability, but the prevalence of instrument breakage can still approach 9.4% (Baumann and Roth, 1999). Barthel et al., (1999) compared many types of rotary instruments and found that instrument separation occurred in 16.7% of 30 extracted molars, only with ProFile instruments. Gambarini (2001a) demonstrated that repeated clinical use (10 clinical cases) reduced cyclic fatigue resistance of ProFile nickel-titanium instruments significantly when compared with unused ProFile instruments of the same size. Yared et al., (2000) evaluated cyclic fatigue of used nickel-titanium rotary instruments and stated that rotary instruments could be safely used in four molar teeth.

In the present study, with regard to instrument separation and distortion, the ProFile group had more file separations and distortions, 50% (n = 13), compared to 0% (n = 0) in the CM group. Seven (26.9%) ProFile instruments in the ProFile

group fractured in the canals and none showed visible signs of plastic deformation at their tips. The results of this study support the findings of previous studies which showed that fractures occurred without any visible signs of deformation and that there was a higher incidence of such fractures in the hands of inexperienced operators (Mandel et al., 1999; Yared et al., 2001, 2003).

The incidence of instrument separation in this study was higher than that reported by others (Barthel et al., 1999; Baumann and Roth, 1999). That was most likely caused by differences in technique. This study used more samples (canals) than did the other studies and used the NiTi instruments until separation or distortion. Thus, a higher breakage incidence would be expected as a result of the increased number of uses of files. Gabel et al., (1999) found that a higher incidence of failure was observed with size .04/20 Profile and O.S #3 as compared with the other instruments. From our study, three (11.5%) O.S #3 files fractured after use in 26, 41 and 63 canals. The smaller instruments (.06/25, .06/20) demonstrated the greatest number of separations (15.4%) and deformations (more than half of the separated and deformed instruments). This was probably because of the crown-down technique where there is more engagement of the smaller instruments close to their tips. The .04 Profiles, particularily the .04/25 and .04/20, deformed after use in 23 and 48 canals, respectively, but could still survive multiple uses after their distortion without separation. While an adequate explanation for this finding is still lacking, a recent study showed that ProFile instruments are more elastic than but not so strong as ProTaper instruments (Berutti et al., 2003). The distortion of the ProFile instruments could be viewed clinically as an unwinding of the file flute and a warning sign to operators that the files are stressed and should be discarded. Gambarini et al., (2001b) evaluated clinical cyclic fatigue of .04 and .06 ProFile instruments and reported that instruments with smaller tapers were significantly more resistant to cyclic fatigue than those with larger tapers. Pruett et al., (1997) showed that the size, or diameter, of the instrument plays a role in its susceptibility to fracture. A larger instrument is more likely to undergo fracture in less time under dynamic stress than a smaller one. In the present study, when comparing the mean number of uses until failure of the O.S #3, .06/25, .06/20 and .04/25 instruments in the ProFile group, it indicated that as the tip size and taper increased, the number of revolutions until separation did not decrease proportionally. These results do not agree with those previous findings.

In the CMT technique, tapered rotary instruments were used to prepare the coronal two-third of the root canal and non-tapered instruments were used to prepare the apical one-third, using the serial step-back technique. ProTaper S1 instruments exhibited no plastic deformation or separation during many uses in up to 59 canals. Compared to O.S #3 instruments, which have constant tapers of 6%, S1 instruments are designed with 12 increasingly larger tapers, ranging from 0.02 at D (distance from tip) 1 to 0.11 at D14, allowing the instrument to prepare a specific area of the canal (Ruddle, 2001). Thus, it engages a smaller zone of dentin which reduces torsional loads, instrument fatigue and the potential for breakage. This may explain why, in the present study, the S1 instrument appeared to be resistant to cyclic fatigue with multiple uses.

In the ProFile group, to minimize torque, the following size/ taper sequence was used for apical preparation: .04/20, .04/25, .06/20 and .06/25. In the CMT group, after apical enlargement with the step-back technique, a .06/25 Profile was used subsequently to smooth the steps in the outer wall of the curvature and merge the step-back taper into the more coronally-located taper (Table 5). In the CMT group, ProFile .06/25 instruments were used up to 133 times or 59 canals without separation or deformation. A possible explanation of this finding is that once a certain amount of canal enlargement and shaping is achieved by the ProTaper S1, ProFile.06/25 and step-back preparation, the final use of the ProFile .06/25 instrument is more predictable and consistent with minimal interference, surface cutting and therefore, torque load and instrument separation.

Table 5. Diameter comparison between the ProFile .06/20, .06/25 and CM technique at apical one third of the root canal.

Distance from tip (mm)	Diameter of ProFile .06/20	Diameter of ProFile .06/25	Diameter of canal after step-back in CM technique
0	0.20	0.25	0.25
1	0.26	0.31	0.30
2	0.31	0.37	0.35
3	0.37	0.43	0.40

Operator-related factors and clinical ability are important factors relating to instrument separation (Mandel et al., 1999; Yared et al., 2001, 2003) and consequently, electric motors and handpieces have been developed to simplify the use of NiTi rotary instruments. It is clear that prolonged use of NiTi rotary instruments strongly affects instrument fatigue. In the present study, none of the NiTi rotary instruments in the CMT technique separated when used by inexperienced students. The CMT technique took significantly less preparation time than the ProFile technique even though the CMT technique incorporated traditional hand instruments with NiTi rotary instruments. More rapid preparation by this technique may be the result of its fewer instruments and procedural steps. By following the instructions for each rotary instrument strictly, including proper motion in the root canal, and maintaining adequate speed by using a low torque-controlled motor with auto-torque reverse function, it could have minimized instrument breakage.

CONCLUSION

The modified CMT technique, when used by dental students, was useful for preparing root canals in extracted human teeth in a manner that was safe and efficient as opposed to a strict crown-down technique using ProFile instruments. It resulted in no instrument separation or distortion and the time to achieve the desired goal was reduced. This indicates that the application of rotary NiTi instruments, used in

the modified manner specified in this study, can be integrated safely into the undergraduate dental curriculum.

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