A Retrospective Clinical Study of Incidence of Root Canal Instrument Separation in an Endodontics Graduate Program: A PennEndo Database Study

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Abstract

This study investigated the incidence of hand and rotary instrument separation (IS) in the endodontics graduate program at the University of Pennsylvania between 2000 and 2004. In 4,865 endodontic resident cases the incidence of hand and rotary IS was 0.25% and 1.68%, respectively. The odds for rotary IS were seven times more than for hand IS. The probability of separating a file in apical third was 33, and 6 times more likely when compared to coronal and middle thirds of the canals. The highest percentage of IS occurred in mandibular (55.5%) and maxillary (33.3%) molars. Furthermore, the odds of separating a file in molars were 2.9 times greater than premolars. Among the ProFile series 29 rotary instruments, the .06 taper # 5 and # 6 files separated the most. There was no significant difference in IS between the use of torque controlled versus nontorque controlled handpieces, nor between first and second year residency. *(J Endod 2006;32:1048–1052)*

Key Words

Graduate endodontic program, hand instrument, instrument separation, root canal, NiTi rotary instrument

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Louis Grossman once reported that a dentist who has not separated a tip of a file, reamer, or broach has not done enough root canals (1). Review of the literature shows that the incidence of separated stainless steel hand instruments ranges between 2% and 6% (2, 3). Nickel titanium (NiTi) instruments were introduced in the 1980s to facilitate instrumentation while reducing procedural errors. They were found to have 2 to 3 times more elastic flexibility and superior resistance to torsional fracture than their stainless steel counterparts (4). However, with the advent of rotary NiTi files, there has been also an unfortunate increase in the occurrence of broken instruments (5). In vitro studies determining the incidence and possible causes of instrument separation (IS) between various engine driven NiTi rotary systems are extensively reported. However, clinical studies that report in vivo incidence of rotary IS after repeated clinical use are few.

The purpose of this study was to investigate the incidence of hand and rotary IS in an endodontic graduate program between 2000 to 2004 and to determine if any common denominators exist. This information would be useful in identifying variables that affect IS.

Materials and Methods

This was a historical retrospective cohort study. The study population was comprised of patients treated between 2000 and 2004 by endodontic postgraduate students at the University of Pennsylvania School of Dental Medicine. Patients in this population were either outside referrals or patients registered at the School of Dental Medicine and represented cases with a higher level of difficulty. A total of 4,865 endodontic cases (2,828 molars, 1,014 premolars, and 1,023 anterior teeth) were entered into a database known as PennEndo database, developed with FileMaker Pro 7.0 (FileMaker, Inc., Santa Clara, CA). Data regarding tooth number, canal, and the level (apical, middle, coronal) at which the instrument separated was extracted. Additional information regarding the type, size, and brand of instrument, and whether the resident used a torque or a nontorque controlled motor at the time of IS was also included. The student's year of residency (first versus second year) was considered operator experience. Clinical records and radiographs of all the cases with separated instruments were retrieved to ensure accuracy of the data.

The following data analysis was conducted to determine which variables were associated with IS during a root canal procedure. The dependent variable used was a dichotomous measure of IS; yes or no. Eight independent variables were analyzed separately:

1. File type (either rotary and hand or hand only)
2. Tooth location (mandibular or maxillary)
3. Molar (mandibular or maxillary)
4. Premolar (mandibular or maxillary)
5. Tooth type (molar or premolar)
6. Mandibular molar canal

(MB/ML canal)

(MB/Distal canal)

(ML/Distal canal)

TABLE 1. Percentage of IS in Hand and Rotary Instrumentation Groups

	Hand Instrumentation						Rotary Instrumentation	
	Hand Instrumentation Before Rotary Instrumentation		Hand Instrumentation Only		Total of Hand Instrumentation Cases			
No. of Separated instruments	9		3		12		69	
n	Cases 4,116	Canals 10,237	Cases 749	Canals 1,801	Cases 4,865	Canals 12,038	Cases 4,116	Canals 10,237
Separated instruments (%)	0.22	0.09	0.40	0.17	0.25	0.10	1.68	0.67

7. Maxillary molar canal

   (MB/DB canal)

   (MB/Palatal canal)

   (DB/Palatal canal)

8. Separated instrument location (apical one-third or middle one-third or coronal one-third)

For the first five variables single logistic regression analyses were conducted in SAS Version 8.0. Odds ratios, 95% confidence intervals, and p-values were all computed. Probabilities were calculated for the last three variables. Odds ratios, confidence intervals, and p-values were not calculated because of the overlapping nature of the data. Such statistics can only be computed on variables with mutually exclusive values. ANOVA was used to find any statistical significance between the use of torque versus nontorque controlled motors and paired *t*-test was used to compare IS between first and second year of residency. Comparison between different brands of rotary system was not possible because of the smaller number of teeth instrumented by brands other than ProFile.

Results

Incidence

There were a total of 81 separated instruments; 12 were hand stainless steel files and 69 were rotary NiTi files. The IS incidence of hand and rotary files was 0.25% and 1.68%, respectively, with an overall average of 1.66% (Table 1). Furthermore, the incidence of IS between hand and rotary instruments was statistically significant, with an odds ratio of 6.898: almost seven times greater than hand IS.

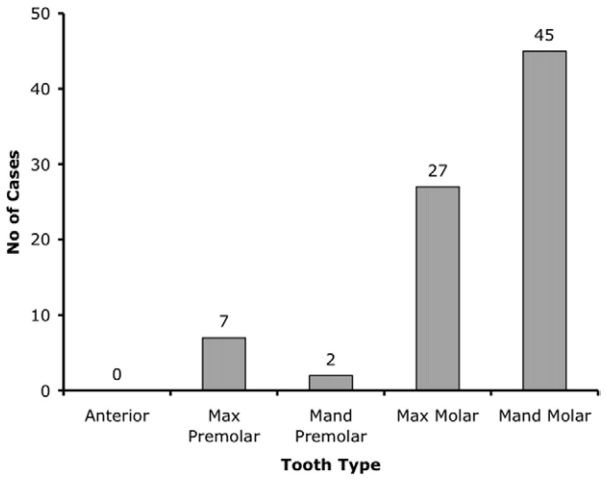

Figure 1. Number of hand and rotary IS according to tooth type.

Tooth Type

When hand and rotary instruments were combined, mandibular molars accounted for 45 (55.5%) of the separated files, followed by maxillary molars with 27 (33.3%); 7 files separated in maxillary and 2 in mandibular premolars. No ISs were encountered in anterior teeth (Fig. 1). The percentage of IS according to tooth type is given in Table 2. The likelihood of IS was almost three times greater (odds ratio = 2.918) in molars than premolars, and was statistically significant. There was no statistical difference between IS in maxillary teeth compared to mandibular ($p = > 0.05$) (Table 3).

Level of Separation

Of the 81 files, 67 (82.7%) separated in the apical third, 12 (14.8%) in the middle third, and 2 (2.5%) in the coronal third of the canals (Fig. 2). Instrument separation was 33.5 times more likely to occur in the apical one-third versus the coronal one-third of the tooth (Table 4).

Hand Files

There were 12 separated hand files: 5 H and 5 K files ranging from ISO sizes 15 to 25, and 2 size 8 C files. The distribution of separated hand files in different root canals is shown in Fig. 3.

Rotary Files

A higher frequency of separation of ProFiles series 29 (49 files) and GTs (10 files) noted during this study represented a greater proportion of teeth instrumented with these systems. The highest incidence of separations among the 49 ProFile series 29 files was shown by .06 taper #5 and #6 instruments (13 each); #6 .04 taper was next with eight file separations (Fig. 4). In the less frequently used rotary systems, the separated instruments included three LightSpeed (LightSpeed Technology Inc., San Antonio, TX), five ProTaper (Dentsply Tulsa Dental, Tulsa, OK) and two K3 files (SybronEndo Orange, CA). The percentage of rotary instruments separated was highest in the mesiobuccal canals of mandibular and maxillary molars (Fig. 5). The likelihood of IS in MB canal was three times greater when compared to ML canal. Similarly, in maxillary molars the likelihood of IS in MB canal was almost three times greater compared to DB canal (Table 4).

TABLE 2. Percentage of IS According to Tooth Type

Tooth Type	No. of Teeth	No of Separated Instruments	% of Separated Instruments
Maxillary molars	1,235	27	2.2
Mandibular molars	1,593	45	2.8
Total molars	2,828	72	2.5
Maxillary premolars	619	7	1.1
Mandibular premolars	395	2	0.5
Total premolars	1,014	9	0.9

TABLE 3. Odds Ratios and Confidence Intervals for Independent Variables

Explanatory Variables (test category/reference category)	Single Logistic Regression Analyses		
	OR	95% CI For OR	p-value
File type (rotary/hand)	6.898	3.731–12.752	<0.0001*
Tooth location (mand/max)	1.297	0.830–2.026	0.2532
Molar (mand/max)	1.301	0.802–2.108	0.2863
Premolar (mand/max)	0.668	0.172–2.600	0.5612
Tooth type (molar/premolar)	2.918	1.454–5.856	0.0026*

Odds Ratio = odds of IS with test category/odds of IS with reference category.

*Significant at $p < 0.05$.

Other Variables

No statistically significant differences in IS incidence were found in IS between the use of torque (2.3%) versus nontorque controlled handpieces (1.2%). The incidence of separations among first year (1.5%) and second year (1.8%) residency was not statistically significant.

Discussion

Cleaning and shaping of the root canal system is an important phase of endodontic therapy. Procedural errors such as transportation, zipping, ledging, and perforations can be minimized with NiTi rotary instruments compared with stainless steel ones (6, 7). However, NiTi rotary instruments have an inherent disadvantage leading to unexpected intracanal breakage (8). The results of this study have shown that the odds of separating a NiTi rotary instrument are almost seven times greater when compared to hand instruments. Nevertheless, the incidence of separation in both instrument groups is quite low.

The results of this study show that the overall incidence of NiTi rotary file separation is 1.67%. However, the incidence jumps to 2.5% if only molars are considered and 2.8% when only mandibular molars are analyzed (Table 2). Yared et al. (9) have reported a 0% incidence of ProFile 29 series .06 taper separation. This could be attributed to a small sample size (52 molars), exclusion of teeth with complex canal anatomy, use of low 150 rpm, and using each set of files on only four teeth. In addition, the instrumentation was considered complete when size 20 ProFile .06 taper reached the working length. A slightly higher incidence of 4.6% was reported by Al-Fouzan (10) who looked at ProFile series 29 IS in 419 molars. The canals were instrumented to a minimum size of 30 and each set of ProFiles was used five times.

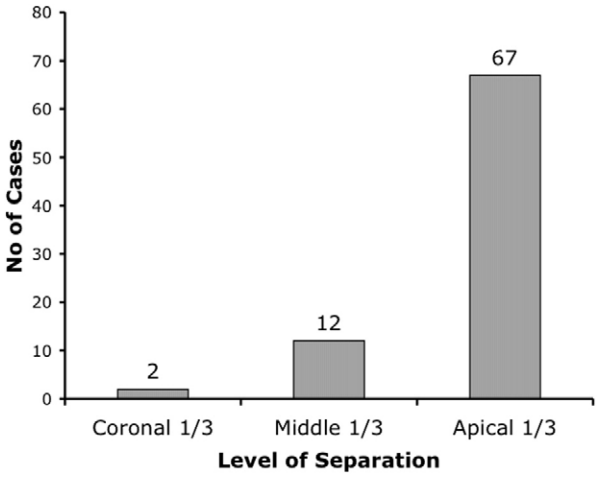

Figure 2. Number of hand and rotary IS according to coronal, middle, and apical level of the canal.

Our study consisted of 4,865 cases carrying a higher level of difficulty that entailed treatment by postgraduate endodontic residents. The minimal size of apical preparation performed in our cases was #35, irrespective of the file system used. At Penn, the files are generally discarded after an average of eight clinical cases or when there is evidence of permanent file deformation under magnification. The files are regularly operated in a high torque handpiece at 300 rpm.

NiTi rotary endodontic files are known to undergo some metal fatigue because of repeated usage. The torque necessary for failure of a previously used instrument was significantly lower compared with the new instruments (11). Therefore, it is recommended to discard the NiTi files after a certain number of clinical uses (12, 13). However, there is no agreement on specifically how many times a file should be used before being discarded. In our study the files were used on the average of eight times before being discarded. Safe clinical usage of NiTi instruments requires an understanding of basic fracture mechanisms and their correlation to canal anatomy (14).

The primary cause of NiTi separation has been attributed to torsional and fatigue failure of NiTi alloy (13, 14). In the torsional failure mode the tip of the instrument is locked in the root canal while the remaining instrument continues to rotate. This type of failure is associated with unwinding of the instrument flutes. In the flexural failure the instrument fractures because of cyclic fatigue usually at the midpoint of the greatest curvature of the root canal (15, 16). The file separates at the fracture line without unwinding of flutes. The mode of failure of instruments could not be determined in our study as only nine instruments were available for analysis. Two of these instruments separated by torsional and seven by flexure failure.

Torsional failure of instruments decreases and flexure failure increases as the size of the instrument increases (17, 18). Instrument separations in our study may have occurred because of flexure failures because the majority of separated instruments belonged to higher sizes. This assumption is supported by the fact that separations occurred more in the mesiobuccal canals of mandibular and maxillary molars, which are known for their greater curvatures. The higher incidence of separation in .06 taper ProFiles compared to .04 tapered ProFiles also lends credence to our assumption (Fig. 4). However, Sattapan et al. (13) noted a slightly higher incidence of torsional failure compared to flexure failure in Quantec files collected from an endodontic practice. Similar observations were also made by Alapati et al. (18), who observed many clinically fractured ProFiles, ProFile GT, and ProTaper instruments. Unfortunately, the preparation techniques used in these studies were not detailed. It has been shown that rotary NiTi instruments tend to fracture at the midpoint of their curvature within simulated root canals (15). Therefore, it was not surprising to find that most of the instruments in our study separated in the apical third of canals where canals typically curve and have their smallest diameters. The probability of separating a file in the apical area is 33 times greater compared to the

TABLE 4. Probability of IS According to Tooth Type and Location

Explanatory Variables (test category/reference category)	Probability
Mandibular molar	
[Mesiobuccal (MB/Mesio lingual (ML) canal)]	2.600
[MB canal/Distal canal (D)] (ML/D)	2.889
Maxillary molar	1.111
[MB/Distobuccal (DB) canal]	2.714
[MB/Palatal canal (P)]	19.00
(D/P Canal)	7.000
Tooth location	
(Apical/Coronal)	33.50
(Middle/Coronal)	6.000
(Apical/Middle)	5.583

Probability = probability of IS with test category/probability of IS with reference category.

coronal third of the canal and almost six times greater when compared to the middle third of the root canal. The higher incidence of IS in the apical third of canals in this study is in agreement with other studies (9, 19).

The probability of separating an instrument in the MB canal of a maxillary molar was almost three times greater when compared to the DB canal. A similar probability was found for mandibular molars when comparing MB and ML canals. The MB canal of the mandibular molar is known for its greater curvature (20). In addition, the mesial canals of mandibular molars coalesce to form one major foramen in 49% of the cases (21). The canals join one another in the apical third with the main canal gradually curving to its terminus and the other joining it at an abrupt angle. The latter type of canal should be instrumented to the point where it joins the main canal because instrumenting it to full working length will force the file to navigate the abrupt curvature possibly leading to IS.

In our study the lower separation rate of smaller size NiTi files may be attributed to the instrumentation technique. Preparation of a manual glide path before rotary instrumentation has been shown to decrease IS (22). In our study a manual glide path to at least a size 20 K-file was prepared before initiating rotary instrumentation. This could further explain why all the separated hand instruments ranged in size from size 8 to 25, whereas only few rotary instruments belonged to smaller sizes. Creation of a glide path followed by a combination of GT and ProFiles or ProFiles alone were commonly used for completing the root canal preparation. This explains the higher number of separated ProFiles and GT files in our database.

Residents in the postdoctoral clinic use both torque controlled and nontorque controlled motors. In vitro studies have shown that torque controlled motors, which perform below the elastic limit of the file, reduce IS because of torsional overload (23). However, incidence of separation in the two groups in this study was not found to be statistically

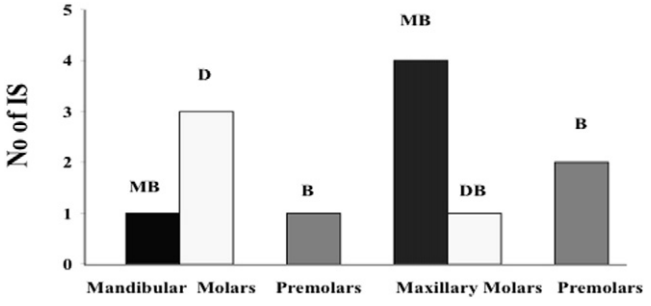

Figure 3. Number of hand IS according to root canals of the mandibular and maxillary teeth.

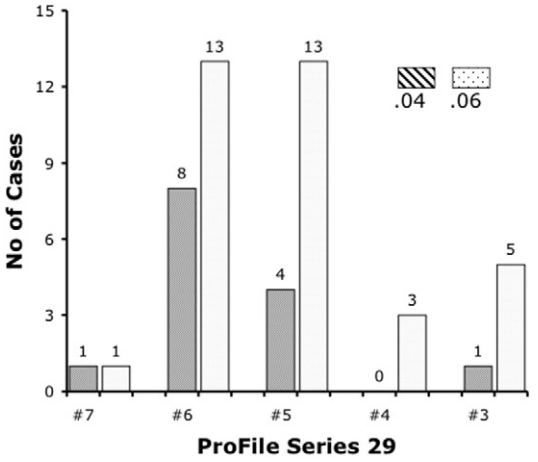

Figure 4. Number of ProFile IS according to size of the instrument. The figure also compares number of IS between .04 and .06 taper ProFiles.

significant. Graduate students at Penn are required to complete rotary instrumentation on 30 extracted molars before being allowed to work on patients. This may have provided enough experience for residents to adjust to nontorque controlled motors. Our results agree with Yared et al. (24) who did not find any difference in failure of ProFile instruments used with high or low torque motors.

Mandel et al. (25) suggested that when other factors such as geometry of the canal, instrument speed, and sequence were kept constant, the ability of the operator seems to be an important factor of instrument failure. These findings are supported by Parashos et al. (26) who report that the most important influence on defect rates of the NiTi instruments was the operator. We rejected our hypothesis that the number of IS in the second year of residency would be much lower compared to the first year as the operator gains experience. This may indicate a longer learning curve for mastering instrumentation strategies. It could also be because of the fact that the second year residents are routinely assigned cases involving a higher level of difficulty.

The limitation of the retrospective evaluation of charts from our database was that only completed cases were analyzed. Incomplete cases either because of patient's noncompliance or extraction before obturation are not entered in the database. However, the number of such cases would be considerably low, as most cases, especially those with procedural errors are followed closely not just for completion but also for subsequent surgical intervention if necessary.

It should be realized that no definite conclusions could be drawn regarding incidence of separation of instruments for a particular rotary system. There are a number of variables that affect the separation rate. These variables include: how many times an instrument is used, the techniques used to instrument the canals, whether a manual glide path

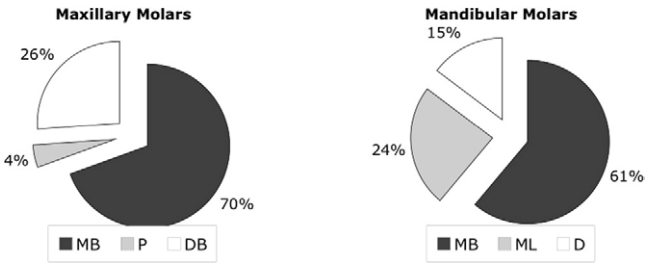

Figure 5. Percentage distribution of rotary IS in different canals of maxillary and mandibular molars.

is prepared before using these instruments, the size to which the canals are enlarged, the rate of rotation of these instruments, the combination of instruments used, the extent of preclinical experience before using these instruments in a clinical setting, the depth of knowledge regarding configuration of the root canals, and the physically properties of NiTi instruments.

The results of the present study show that NiTi rotary instruments have a greater tendency to separate in root canals than stainless steel hand instruments. However, under the conditions of this study the failure rate of NiTi instruments is still quite low, even in the hands of endodontic residents with limited experience. The instruments are more likely to separate in the mesiobuccal canals of maxillary and mandibular molars and also in the apical third of the root canals.

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