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Torsional Testing of Race, K3 and Profile Nickel Titanium Endodontic Files

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TORSIONAL TESTING OF RACE, K3 AND PROFILE NICKEL TITANIUM

ENDODONTIC FILES.

A Thesis submitted in partial fulfillment of the requirements for the degree of Master of Science at Virginia Commonwealth University.

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Table of Contents

List of Tables

Page

List of Figures

Abstract

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Rotary endodontic instruments have different cross sectional designs that may affect their resistance to torsional stress. The purpose of this study is to evaluate the static torsional properties of two nickel titanium files that have recently been introduced for use in endodontics and compare them to the same size Profile instruments. Ten new files of each brand and size were tested. The files tested were: RaCe 25 tip 0.02, 0.04, 0.06 taper, K3 and Profile 25 and 40 tip in 0.02, 0.04 and 0.06 taper. The diameter of each file was measured at 3 mm from tip. The last three millimeters of the working area of the file was

grasped with a non-rotating stainless steel chuck and the handle was held in freely rotating chuck. Torque was applied with the Instron Universal Tester in a direction that simulated the direction of torque encountered clinically. The crosshead speed was set to produce 2 rotations per minute until fracture occurred. The maximum torque achieved and the rotations to fracture were recorded. A multi-way ANOVA and Tukey's HSD of rotations to fracture revealed that RaCe 25-0.02 exhibited significantly fewer rotations to fracture than Profile and K3 of the same size ($p<0.0001$). RaCe 25 tip exhibited lower maximum torque in all tapers than corresponding K3 and Profile instruments. The mean diameter was significantly smaller for the RaCe files. In this study the RaCe file series exhibited lower values for maximum torque and rotations to fracture. Files with greater rotations to fracture, clinically, could demonstrate more deformation prior to fracture. This deformation could warn the practitioner of impending separation of the file. These results should be taken into account while using these files clinically, however further testing is indicated.

Introduction

Chemomechanical instrumentation is a very important step in endodontic therapy, one of the goals being a continuous taper from coronal access to the apex (1). In the past the instruments used to accomplish this were made of carbon and stainless steel. These instruments had inherent weakness of causing root canal aberrations such as ledging, zipping and transporting (2). The introduction of rotary nickel-titanium (NiTi) files to endodontics has helped to reduce these errors by allowing more flexibility. Walia, et al. (3) reported that size 15 NiTi files have two to three times more elastic flexibility and superior resistance to fracture than size 15 stainless steel file.

These files have also made instrumentation faster with the use of a motor driven handpiece. One danger with motor driven rotary instruments is threading or locking into the canal, which can lead to high levels of torque. This high torque can cause NiTi files to separate and compromise the endodontic treatment, especially if the file cannot be removed or bypassed.

There are new NiTi files being marketed with different cross-sectional shapes, designs and fabrication processes. Schafer and Tepel (4) determined that file cross sectional design had an effect on resistance of stainless steel files to fracture, both in angular deflection and maximum torque. It is reasonable to assume then, that cross sectional designs of NiTi files could alter a files resistance to fracture. These differences in design could lead to a file with different physical properties, perhaps even a file that is more prone to fracture in a situation of high torque.

Profile (PF) nickel-titanium rotary instruments (Tulsa Dental Products, Tulsa, OK) are a widely used and accepted rotary instrumentation system. The PF 0.02, 0.04 and 0.06 taper files all have the radial land design. A radial land is the surface between the cutting edges that projects axially from the center of the file. This design is claimed to lift debris out of the canal (5).

K3 Endo (K3) nickel-titanium rotary instruments (Sybron Endo, Orange, CA) are relatively new to the market. K3 has three modified land areas. One blade has a radial land area while the other two have a relieved land area. This design is intended to impart peripheral strength to resist torsional stress. The relieved areas reduce friction on the canal walls to reduce torsional stress (6).

RaCe Rotary Endodontic System (RaCe) (Brasseler USA, Savannah, Ga) is also a relatively new instrumentation system. This file uses a triangular cross section as well as alternating contact points. The claim is that because of the sharper cutting edges and no radial land area the file is more flexible and the torque is minimized, therefore, reducing the risk of fracture (7). Cross sectional designs of the PF, K3 and RaCe files studied can be seen in Figure 1.

The initial test to evaluate torsional limits for these instruments is the static torque test. The American National Standards Institute / American Dental Association (ANSI/ADA) Specification #28 (8) lists certain torsional property requirements for stainless steel endodontic files, as well as the procedures for testing these instruments.

Rowan, et al. (9) determined that there was no difference in the torque required to fracture stainless steel and nickel titanium files. Marsicovetere, et al. (10) demonstrated that a NiTi file far exceeded the specification for revolutions to fracture, but certain file sizes were deficient when measuring the torque at failure.

Berruti, et al (11) used mathematical models to compare convex (triangular) and concave (radial land) cross sectional file designs. They found that there was a difference in elasticity and stress distribution. There is little literature available comparing different cross sectional designs of NiTi files and their resistance to torsional stress. Results of this type of test are important in determining when or even if a file should be used in a clinical situation. The purpose of this study was to evaluate the static torsional properties of three NiTi files that have been introduced for use in endodontics. The maximum torque and number of revolutions needed to separate the instruments were compared.

Material and Methods

Torsional testing was conducted on ten new files of each brand, taper and size for a total of 150 files. The files tested were 25-mm length, 25 tip, 0.02, 0.04 and 0.06 taper in RaCe, K3 and PF. Size 40 tip, 0.02, 0.04 and 0.06 taper in K3 and PF were also tested. The RaCe system did not have a 40 size tip with comparable taper so it could not be compared at this size. The diameter of each file was measured 3 mm from the tip with calipers to within 0.01 mm.

Each instrument was tested for rotations to fracture and maximum torque on the Instron tester. A lathe was mounted on the top surface of the crosshead with the 50 pound load cell on the upper member. A metal ball and clasp chain was used to connect the axle of the lathe to the load cell. The chain was wound around the axle of the lathe in a single layer so when the crosshead was activated it turned the axle in a clockwise direction. On one side of the lathe there was a stainless steel Jacob's chuck that was held stationary with a set screw. This chuck held the last three millimeter of the working end of the files. On the other side of the lathe was chuck attached to the axle of the lathe. This chuck held the handle of the file. The working end of each tested file was grasped first and then the handle was grasped in the chuck attached to the axle. This allowed the investigator that was loading the files to accurately load 3 mm of working end into the chuck.

Prior to securing the handle of the files into the chuck, the crosshead was placed at the starting position and it was verified that the chain was attached and wound around the free end of the axle. The handle was secured in the chuck, the graph was activated, the starting point marked on the graph, and finally the crosshead was activated.

The Instron was recalibrated after every tenth file was tested and the crosshead speed was set to achieve 2 rotations per minute. One investigator placed the files into the lathe, observed and recorded when the file fractured. The other investigator that did not know which file was being tested set the crosshead to the starting position, activated the crosshead, observed the graph and recorded the maximum torque and revolutions to fracture in a blind manner.

The friction of the lathe and the weight of the chain were accounted for by running the system 20 times without a file engaged and a constant graph was created. This graph was then subtracted from the graphs created when the files were engaged. Means and standard deviations were calculated for the 3 mm measurement, maximum torque and rotations to fracture for each set of files.

The experimental design used a three-way classification: Files were from one of three brands (K3, PF, RaCe), one of two tip-sizes (25 or 40), and one of three tapers (0.02, 0.04, 0.06). However, note that for tip size 40, only two brands were used (K3, PF). A multi-way ANOVA was used to determine the difference between the groups of files. If groups were different, the pattern of differences was determined using a Tukey's HSD multiple comparison procedure. The Browne-Forsythe test was used to compare the variability of the groups. Analyses of the data were performed using JMP software (ref:

Version 5.0.1, SAS Institute Inc., Cary, NC USA). Significance was determined at alpha = 0.05.

Results

Results of the diameter study can be seen in Table 1. In the 25 size group the K3 and PF groups were not significantly different from each other, but both were significantly wider than the corresponding RaCe. In the 40 size group the K3 and the PF were not significantly different from each other.

Results of the fracture study can be seen in Table 2. Regarding rotations to failure, in the size 25 group, there was a significant difference in the 0.02 taper group. The K3 and PF brands were not significantly different from one another but they each had a significantly higher rotation to failure than the RaCe brand (p-value < .0001). There was no significant difference between the brands in the 0.04 taper group (p-value = 0.1463) and in the 0.06 taper group (p-value = 0.2902). See Figure 2.

In the size 40 group there were significant differences in the 0.02 and 0.04 taper groups, but not in the 0.06 taper group. The K3 had significantly higher rotations to failure than the PF group. See Figure 3.

The results for maximum torque can also be seen in Table 2. The brand-taper interaction was ignorable (p-value = 0.2940) so all the tapers for each brand (size 25) were considered together. The brands were significantly different (p-value = 0.0012). Tukey's HSD indicated that K3 (mean = 23.27, SE = 0.93) and PF (mean = 23.00, SE = 0.93) were not different, but both were significantly higher than RaCe (mean = 18.78, SE =0.93). See Figure 4.

The three tapers were significantly different as well (p-value < .0001). The 0.04 taper group mean (21.96, SE = 0.93) was not significantly different than the 0.06 taper mean (25.31, SE = 0.93) but the 0.02 taper mean (17.78, SE = 0.93) was significantly weaker than both of the other tapers. See Figure 5.

Table1. Diameter measurement at 3mm.

Tip Size	Taper	Brand	Mean	SD
		Specified Diameter = 0.31		
25	0.02	K3	0.33	0.00
25	0.02	PF	0.33	0.00
25	0.02	RaCe	0.31	0.01
		Specified Diameter = 0.37		
25	0.04	K3	0.40	0.01
25	0.04	PF	0.40	0.01
25	0.04	RaCe	0.39	0.01
		Specified Diameter = 0.44		
25	0.06	K3	0.47	0.01
25	0.06	PF	0.46	0.00
25	0.06	RaCe	0.44	0.02
		Specified Diameter = 0.46		
40	0.02	K3	0.49	0.01
40	0.02	PF	0.48	0.00
		Specified Diameter = 0.52		
40	0.04	K3	0.56	0.01
40	0.04	PF	0.55	0.01
		Specified Diameter = 0.58		
40	0.06	K3	0.61	0.01
40	0.06	PF	0.61	0.01

Table 2. Calculated means and standard deviations of collected data

				Rotations to Fracture		Max. Torgue (gm*cm)	
TipSize	**Taper**	**Brand**	**n**	**Mean**	**SD**	**Mean**	**SD**
25	0.02	k	10	3.95	0.82	20.53	4.89
25	0.02	p	10	3.63	0.67	16.86	3.25
25	0.02	r	10	2.80	0.40	15.95	6.10
25	0.04	k	10	1.79	0.21	23.64	5.02
25	0.04	p	10	1.74	0.86	23.69	5.59
25	0.04	r	10	1.39	0.20	18.55	4.69
25	0.06	k	10	1.29	0.20	25.63	6.78
25	0.06	p	10	0.94	0.08	28.43	4.50
25	0.06	r	10	1.08	0.12	21.86	4.26
40	0.02	k	10	2.93	0.38	24.10	3.92
40	0.02	p	10	2.64	0.22	22.77	4.66
40	0.04	k	10	1.98	0.12	32.35	5.87
40	0.04	p	10	1.76	0.12	31.33	3.03
40	0.06	k	10	0.97	0.15	38.77	4.61
40	0.06	p	10	0.91	0.10	37.55	5.03

Table 3. Tukey's HSD for rotations to failure. Means not connected by the same letter are significantly different. k=K3, p=PF, r=RaCe

Group					Mean
25,k,.02	D				3.95
25,p,.02	D				3.63
40,k,.02		E			2.93
25,r,.02		E			2.80
40,p,.02		E			2.64
40,k,.04			F			1.98
25,k,.04			F	G		1.79
40,p,.04			F	G		1.76
25,p,.04			F	G		1.74
25,r,.04			F	G	H	1.39
25,k,.06				G	H	1.29
25,r,.06					H	1.08
40,k,.06					H	0.97
25,p,.06					H	0.93
40,p,.06					H	0.91

Table 4. Tukey's HSD Results for Maximum Torque. Means not connected by the same letter are significantly different. k=K3, p=PF, r=RaCe

Group							LS Mean
40,k,.06	D						35.42
40,p,.06	D						33.70
40,k,.04	D	E					29.75
40,p,.04	D	E	F				28.89
25,p,.06		E	F	G			24.19
25,k,.06		E	F	G	H		21.87
25,k,.04			F	G	H	I	20.20
25,p,.04			F	G	H	I	20.14
40,k,.02				G	H	I	19.93
40,p,.02				G	H	I	19.17
25,r,.06				G	H	I	17.77
25,k,.02				G	H	I	15.82
25,r,.04					H	I	14.96
25,p,.02						I	12.64
25,r,.02						I	11.39

FIG 1. Cross sectional design of PF, K3 and RaCe respectively.

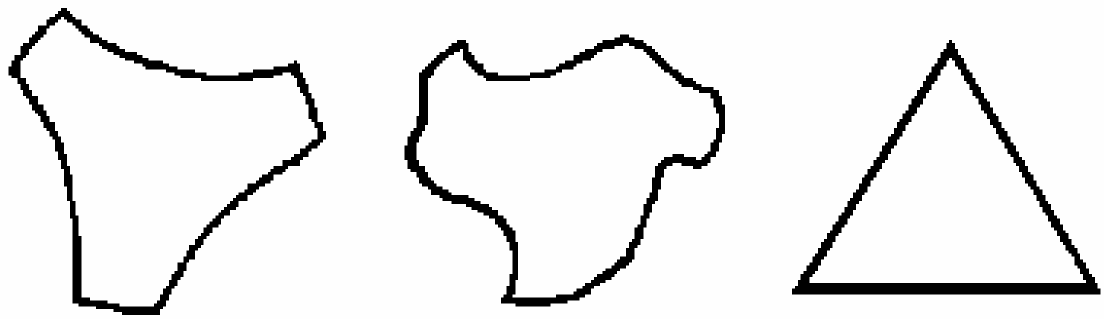


FIG 2. Rotations to fracture by taper and File System (size 25). k=K3, r=RaCe, p=PF

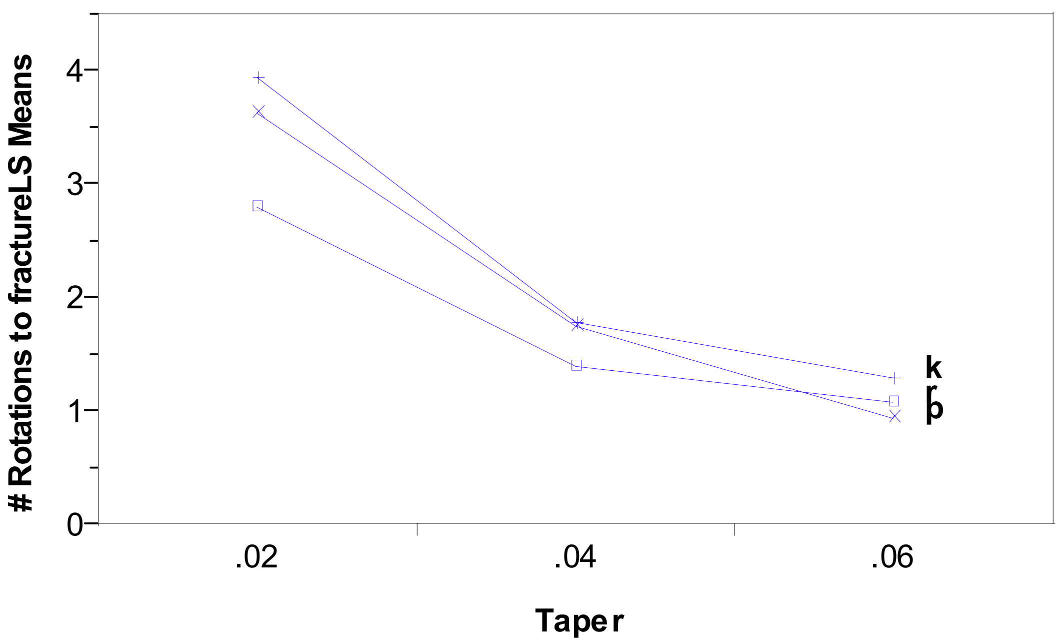


FIG 3. Rotations to fracture by taper and File System (size 40). k=K3, p=PF

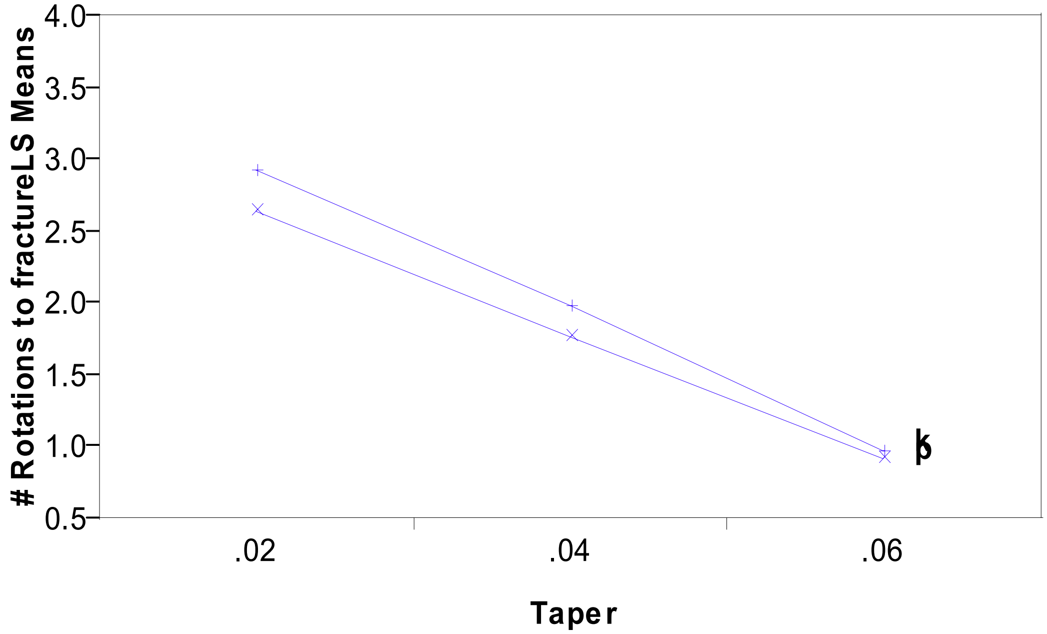


FIG 4. Maximum torque by brand (size 25). k=K3, p=PF, r=RaCe

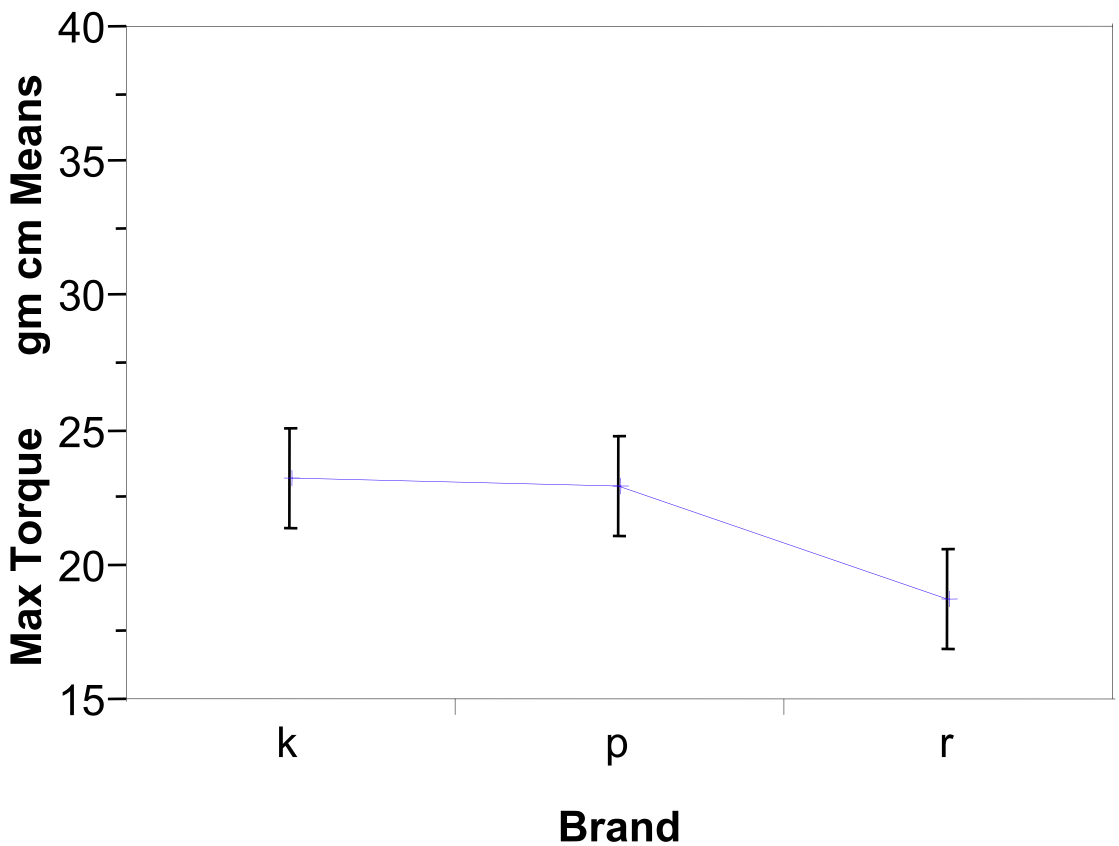


FIG 5. Maximum torque by taper (size 25).

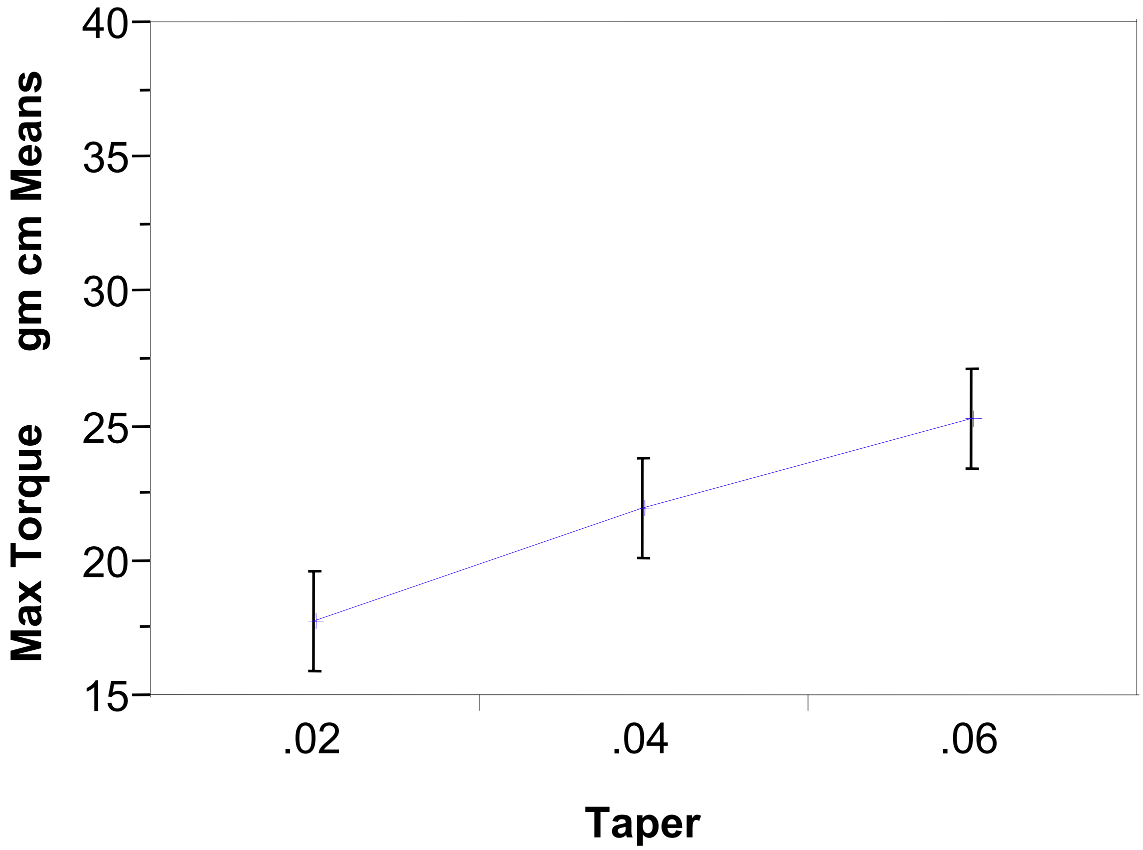
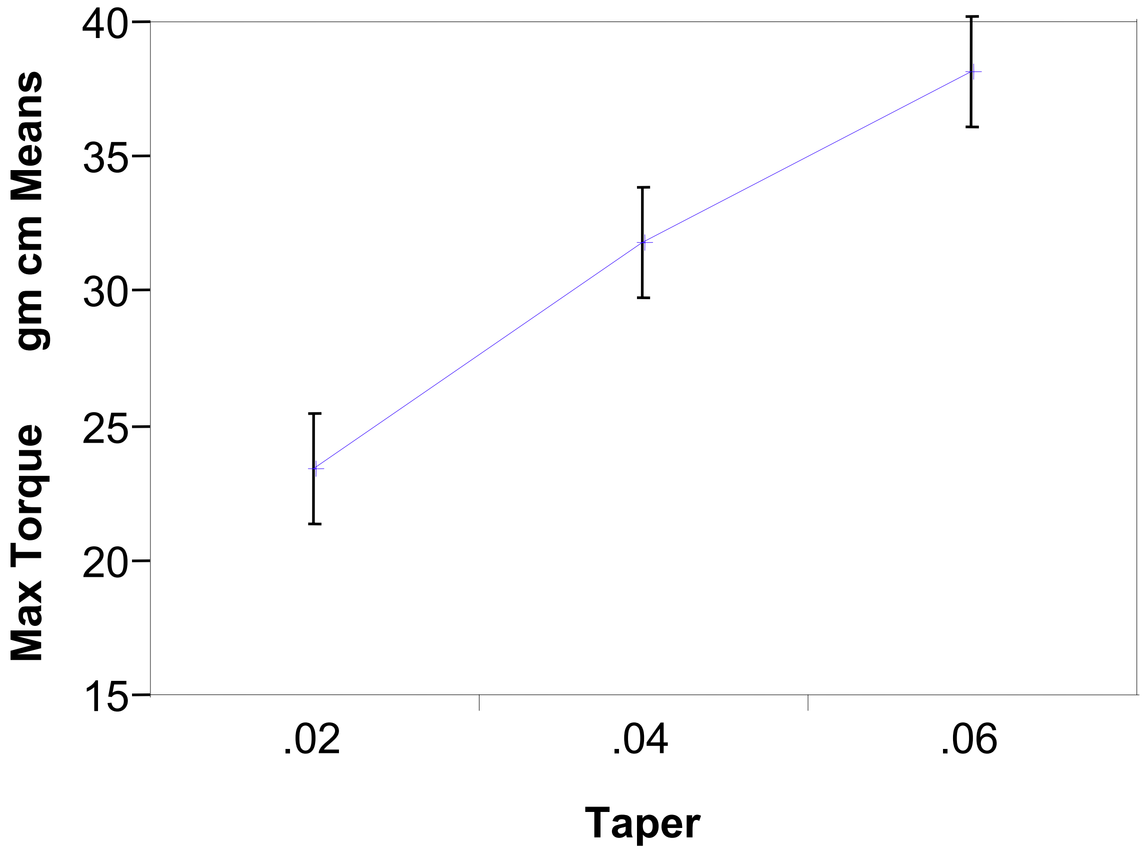


FIG 6. Maximum torque by taper (size 40).



Discussion

The purpose of this research was to investigate torsional properties of three file systems with different cross sectional designs. The research design was based on the ANSI/ADA Specification #28 for files and reamers, type K. Some deviations were necessary, for example, Specification #28 calls for a brass chuck to hold 3 millimeters of the working end of the file. Using this system the file would rotate in the chuck, so a stainless steel Jacob's chuck to hold the files stationary was used instead. It was also decided that the handles would remain on the files because this is how they would be used clinically. If angular deflection was noted at the handle shank interface this would be clinically relevant and could influence file separation. This was not noted, however, as one investigator observed the file at all times during activation of the Instron crosshead.

The size 25 files were chosen to compare the RaCe system's apical preparation files. At the time of the study the RaCe system's apical preparation files were the size 25 in the 0.02, 0.04 and 0.06 taper. The size 40 files were chosen because that is a common master apical file when using the K3 and PF systems. It seemed appropriate to compare the K3 and PF in this file size. The RaCe system tested does not have a 40 size with the same taper so it could not be included in this comparison.

Regarding file diameter it was noted that the RaCe system was consistently narrower than the corresponding PF and K3 files. This could be a result of manufacture' tolerance or the method of measurement. The diameter at 3 mm was measured with calipers sensitive to 0.01 mm. The stopper was fixed on the files with cyanoacrylate cement so 3 mm of the working area was exposed. The jaws of the calipers were placed flush with the stopper and the narrowest diameter recorded. Due to the triangular cross section of the RaCe file, the measurement would actually be the height of a triangle whereas the PF and K3 would be closer to the diameter of the circle formed by the radial lands.

The last 3 mm of the working end of the files were grasped by the stainless steel Jacob's chuck. After the Instron was activated instrument fracture was determined both visually and audibly and verified by a drop in torque as measured by the Instron. At this point the Jacob's chuck was inspected as well as the file to determine if the separation occurred at the 3 mm level. All of the files that separated did so at the 3 mm level as observed by one of the investigators.

Two size 25, 0.02 taper, K3 files and on size 25, 0.02 taper PF file did not separate within the maximum angular deflection allowed by the system. The results for angular deflection of these two files were included in the mean as the maximum angular deflection of the files that did fracture. It was felt that simply throwing this data out would skew the results for that file size and type, so it was decided to assign the highest angular deflection achieved by this file size, taper and brand.

It was noted that the triangular cross section file had the lowest deformation in the 0.02 taper group. Clinically this could mean that files with a triangular cross section would show less sign of fatigue than files with a radial land such as K3 and PF. A file showing signs of fatigue may be replaced prior to fracture provided the deformation is noticed by the clinician, thus reducing the risk of fracturing a file in a canal.

In a recent publication Schäfer, et al, (12) determined the cross sectional area of the files tested in this study at 3 mm. They found that the K3 file had the highest area followed by the PF and then the RaCe file. They also found that the composition of these three files was all 55-Nitinol and the differences in composition were all within the precision of the instrument. Knowing that the alloy is the same, the difference in maximum torque would have to be explained by the cross sectional area and design of each file.

There are other factors to consider when evaluating file strength. The torque required to use a file could be reduced due to its cross section and cutting efficiency. A file with greater cutting efficiency could require significantly less torque to instrument a canal, therefore reducing the chances of fracture. Cyclic fatigue is also a very important factor in file separation. The cross section of a file could influence its ability to tolerate cyclic fatigue. Further study is necessary to determine the safety of these different cross sectional designs.

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Appendix A

Raw Data Table

File	Brand	Rotation	Max Torque
1	r2502	39.0	2.2
2	k2502	44.0	3.6
3	p4002	32.0	3.7
4	k2502	57.5	3.7
5	p2502	62.0	3.4
6	r2502	38.5	2.2
7	p4002	40.0	3.3
8	k4002	44.5	5.0
9	r2502	49.0	4.1
10	p4002	36.5	4.2
11	p4002	34.0	3.5
12	k2502	DNF	5.4
13	k2502	DNF	4.6
14	k2502	41.0	2.5
15	p4002	37.0	5.9
16	k4002	41.0	6.3
17	r2502	35.0	4.8
18	p2502	43.0	4.7
19	p4002	38.5	5.8
20	k2502	53.0	4.7
21	p4002	41.0	5.2
22	r2502	46.0	4.3
23	k4002	37.0	5.7
24	p2502	DNF	3.0
25	r2502	31.0	4.8
26	k2502	53.0	4.8
27	k2502	69.0	4.8
28	r2502	36.0	2.1
29	p2502	47.0	2.9
30	p2502	38.0	2.2
31	k4002	38.0	3.8
32	k2502	54.0	3.3
33	r2502	43.0	2.3
34	r2502	41.0	2.2
35	k4002	36.0	4.3
36	p4002	37.0	4.1
37	p2502	49.0	3.6
38	r2502	34.0	2.3
39	k4002	44.0	4.3
40	p4002	33.0	4.3
41	p2502	50.0	3.2
42	k4002	37.0	4.0
43	p2502	56.0	3.6
44	k4002	43.0	4.5
45	k4002	53.0	4.8
46	p2502	47.0	3.4
47	k4002	37.0	4.6
48	p4002	40.0	4.7
49	k2502	41.0	2.9
50	p2502	46.0	3.1
51	p4006	11.0	5.8
52	k4006	28.0	6.7
53	r2504	28.0	3.0
54	k4004	54.0	5.9
55	k2504	52.0	4.0
56	r2504	37.0	3.4
57	r2506	27.0	4.8
58	k2504	47.0	5.7
59	p4006	22.0	9.1
60	p2506	27.0	7.0
61	p2506	27.0	6.3
62	r2506	30.0	6.1
63	k2506	29.0	6.8
64	p2504	43.0	5.1
65	p4006	27.0	8.9
66	r2504	47.0	2.1

67	p4006	25.0	6.7
68	k2506	41.0	3.2
69	k2506	35.0	3.9
70	k4006	26.0	6.8
71	k2506	30.0	4.0
72	k4004	55.0	4.6
73	k2506	27.0	4.5
74	k2504	47.0	3.5
75	r2504	47.0	3.6
76	p2504	34.0	3.7
77	p4006	25.0	7.0
78	p2504	32.0	3.5
79	r2504	40.0	3.0
80	p4004	50.0	5.7
81	p2504	36.0	3.5
82	k4004	60.0	4.7
83	k2506	38.0	3.9
84	p2504	34.0	3.7
85	k4004	53.0	5.4
86	r2506	28.0	3.2
87	k2504	65.0	3.3
88	k2504	50.0	3.5
89	r2504	37.0	2.9
90	p4004	50.0	5.9
91	k4006	27.0	6.8
92	k4006	38.0	7.9
93	k4004	55.0	6.3
94	r2504	38.0	4.3
95	r2506	29.0	3.7
96	r2506	31.0	4.2
97	p4004	48.0	5.7
98	p2506	23.0	5.0
99	k2504	53.0	4.7
100	r2506	37.0	4.2
101	p4004	49.0	5.8
102	r2506	36.0	3.4
103	p4006	29.0	6.8
104	k4006	24.0	7.9
105	r2506	28.0	4.3
106	k2506	39.0	4.9
107	p4004	53.0	6.8
108	p2506	23.0	4.3
109	p4006	27.0	7.5
110	k2506	42.0	6.1
111	p4006	26.0	7.2
112	r2506	29.0	4.1
113	r2504	42.0	4.7
114	p4006	30.0	7.4
115	k4006	27.0	8.2
116	r2504	39.0	4.8
117	r2504	35.0	4.6
118	k4004	61.0	6.9
119	k4006	24.0	7.2
120	p2504	87.0	4.4
121	p4004	45.0	5.3
122	r2506	28.0	4.9
123	p2506	24.0	5.2
124	p4006	23.0	7.3
125	p4004	50.0	6.2
126	k2504	47.0	5.5
127	p4004	53.0	7.0
128	p2504	45.0	5.4
129	k2504	48.0	5.4
130	k4004	50.0	7.5
131	p2506	30.0	4.7
132	p2506	26.0	5.3
133	k2504	44.0	5.8
134	k2504	49.0	5.0
135	p2504	100.0	5.2
136	p4004	43.0	7.0
137	k4004	53.0	7.6
138	k4004	58.0	7.1
139	k2506	37.0	6.3
140	p4004	52.0	6.1
141	k2506	42.0	6.7
142	k4006	26.0	6.7
143	k4006	29.0	8.7
144	p2506	27.0	5.2
145	k4006	23.0	9.2
146	p2506	29.0	6.3
147	p2504	34.0	6.9
148	k4004	56.0	7.5
149	p2504	43.0	5.1
150	p2506	27.0	6.5

Appendix B

Equation 1. Conversion for Rotations to Fracture

For graph speed 1 inch per minute. Files 1-52:

$$\frac{(1 \text{ revolution})}{(14 \text{ chart divisions})}$$

For graph speed 2 inches per minute. Files 53-150

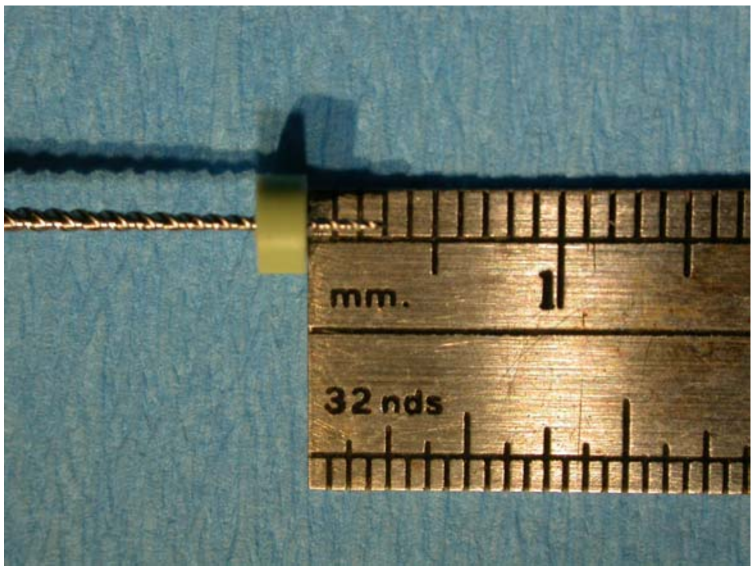
$$\frac{(1 \text{ revolution})}{(28 \text{ chart divisions})}$$

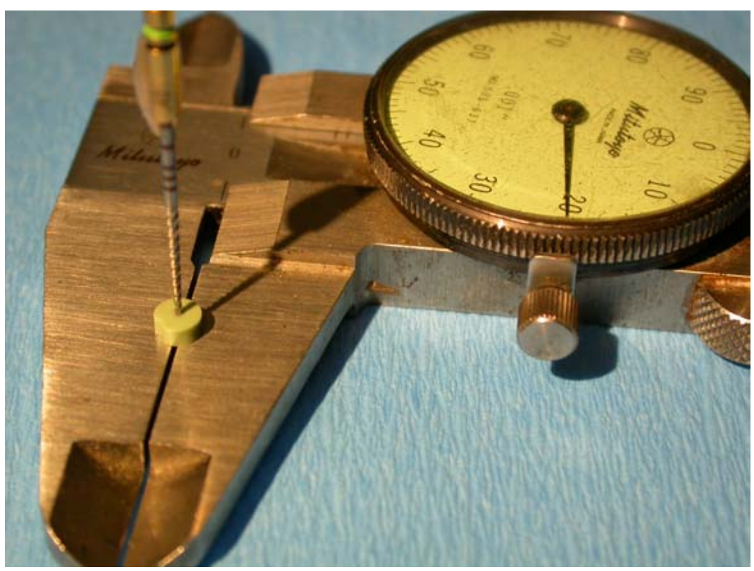
Equation 2. Conversion for Maximum Torque

For Sensitivity set on HIGH, range ABC

$$\frac{(5.50 \text{ gm}\cdot\text{cm})}{(\text{Chart Division})} \quad \text{When FSL} = 5$$

Appendix C



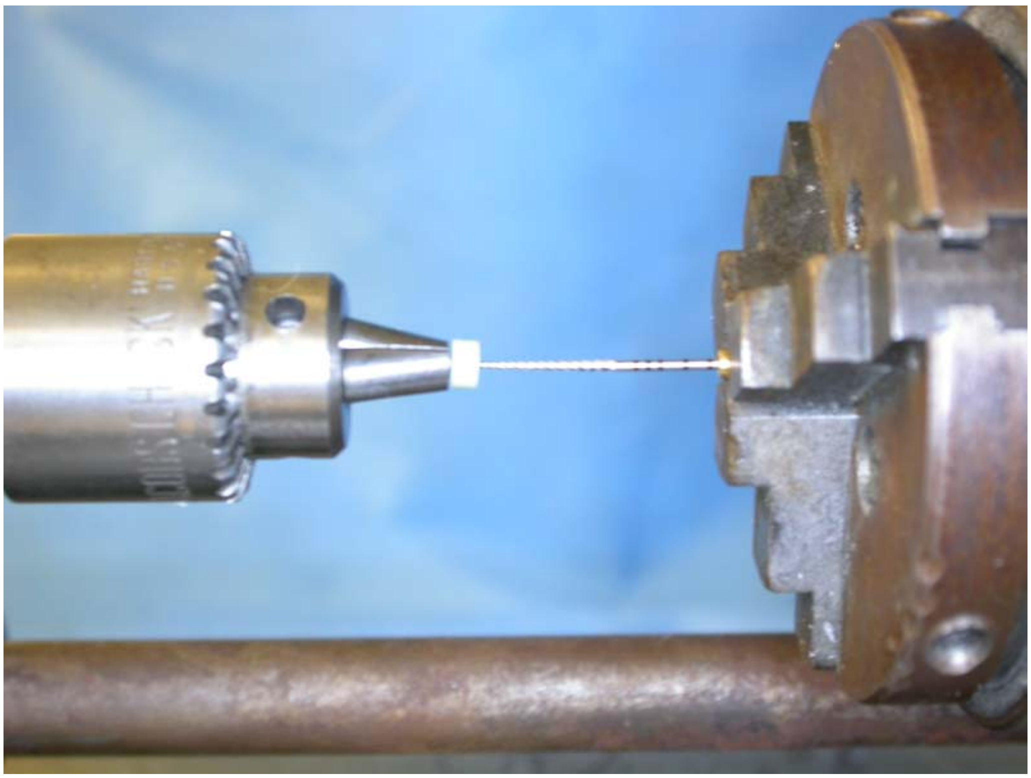


Diameter measurement 3 mm. Stopper fixed with cyanoacrylate cement at 3 mm. File then measured with calipers to the nearest 0.01 mm

Appendix D

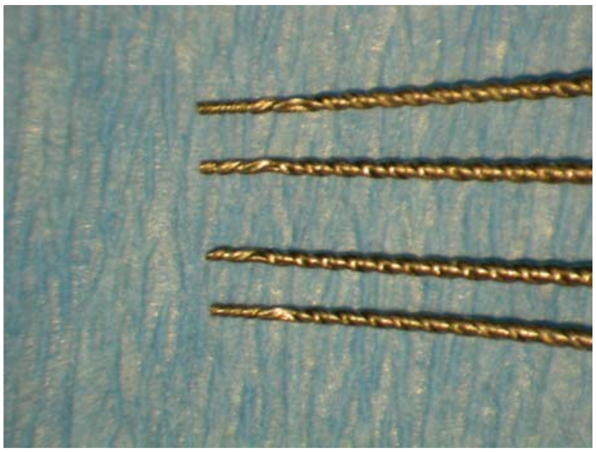
Instron Set Up. Lathe with axle attached ball and clasp chain. File handle can be seen in chuck on left. Chain attaches to 50 pound load cell superiorly.

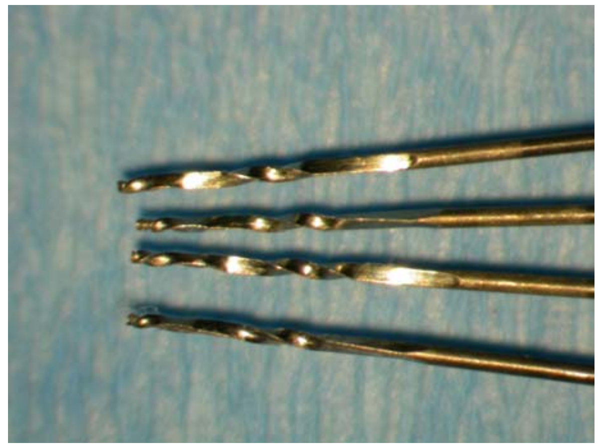
Appendix E

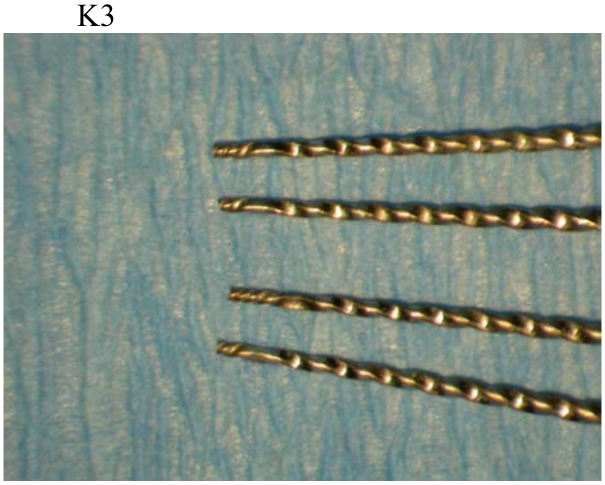


Close up view of file inserted in both chucks. Jacob's chuck on left is stationary and the handle is inserted in chuck on right which is attached to axle of lathe.

Appendix F

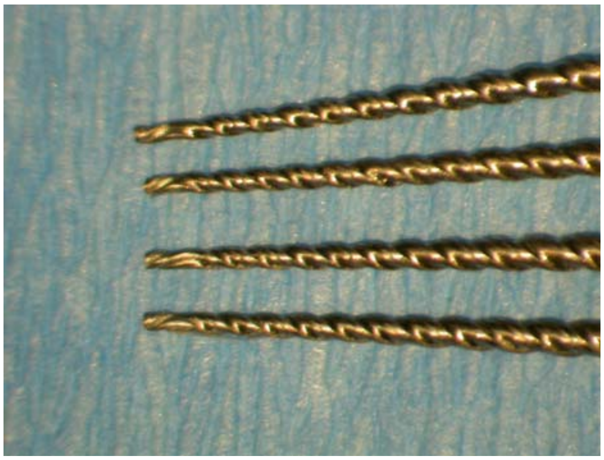

K3

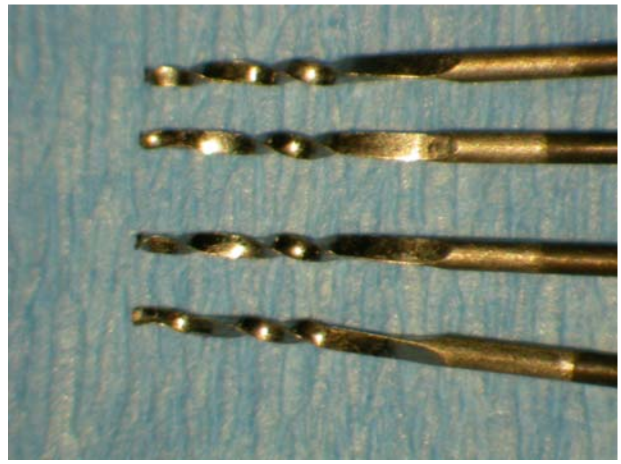

RaCe

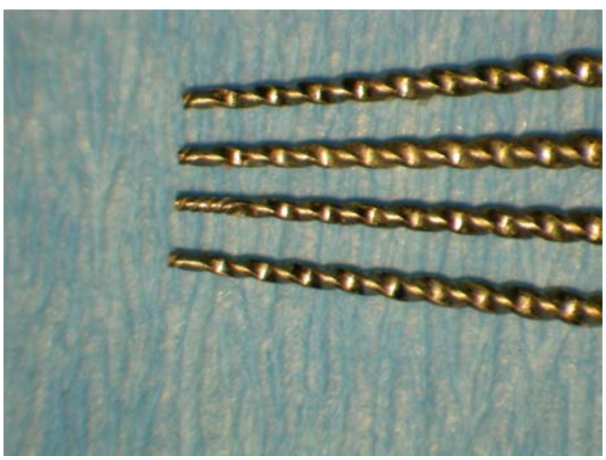

PF

Fractured files size 25, 0.02 taper.

Appendix G

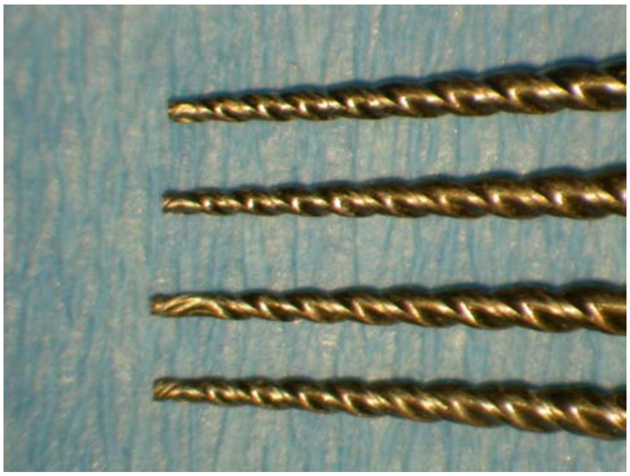

K3


RaCe

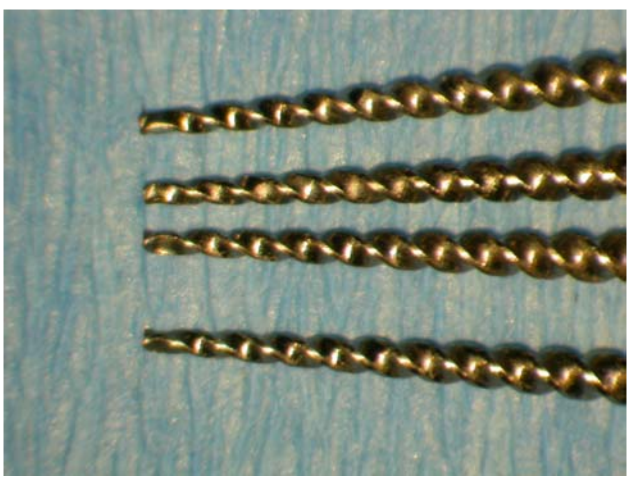

PF

Fractured files size 25, 0.04 taper.

Appendix H

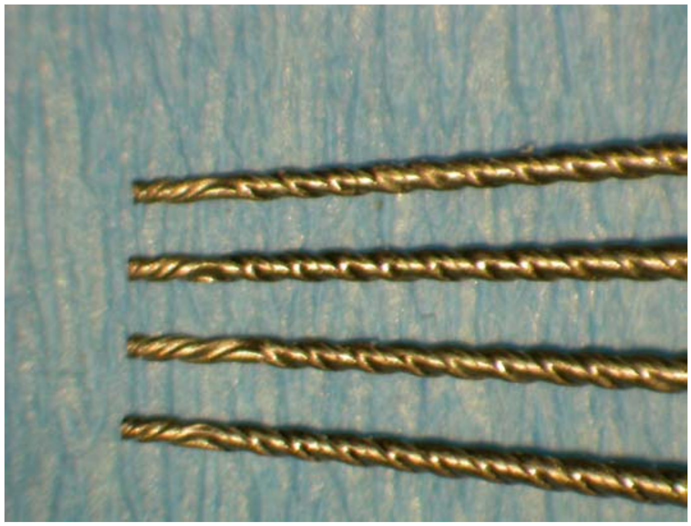

K3


RaCe

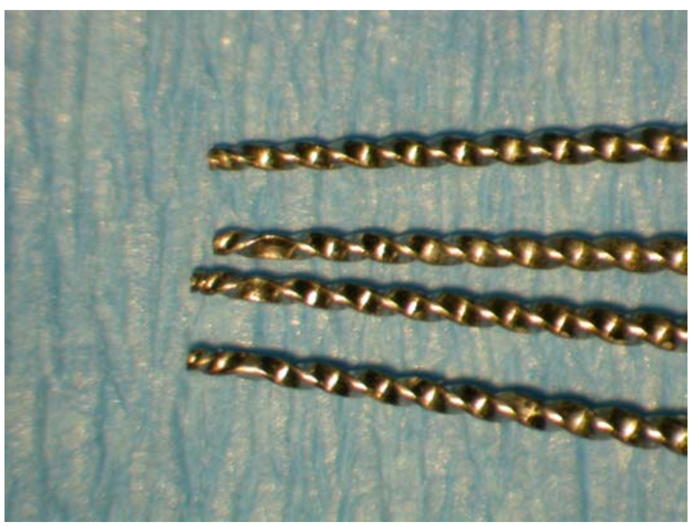

PF

Fractured files size 25, 0.06 taper.

Appendix I



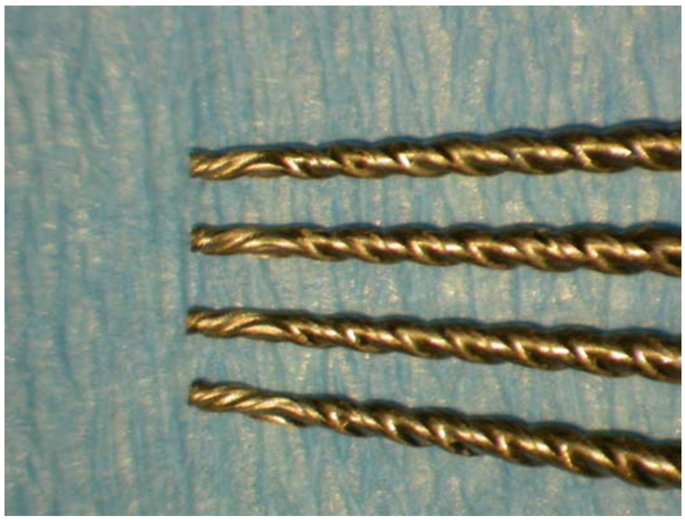
K3



PF

Fractured files size 40, 0.02 taper.

Appendix J



K3

PF

Fractured files size 40, 0.04 taper.

Appendix K

K3

PF

Fractured files size 40, 0.06 taper.

VITA

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July 2002 to July 2004:	Medical College of Virginia Virginia Commonwealth University School of Dentistry, Richmond, VA Certificate in Endodontics Masters in Dentistry
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August 1982 to May 1986:	Brighton High School Sandy, Utah

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