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A Comparison of Flexural Fracture of Three Different Nickel-Titanium Rotary File Systems

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A COMPARISON OF FLEXURAL FRACTURE OF THREE DIFFERENT NICKEL-TITANIUM ROTARY FILE SYSTEMS

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

by

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Abstract

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The purpose of this study was to compare the number of rotations to failure of three different rotary file systems. ProFile, Sequence, and Liberator files in sizes 25 and 40 with 0.04 taper were divided into groups of five and rotated against a grooved metal block mounted to a Universal testing machine at 31 and 34 degrees. Each file was rotated at 300 rpm until fracture occurred. The number of rotations to fracture were calculated. Use of a three-way ANOVA and Tukey's HSD multiple comparison tests revealed significant differences for the angle of deflection, size, and type of file. An increased angle of

deflection resulted in a decreased number of rotations to failure for all three file types. An increased size of file also resulted in a decreased number of rotations to failure in all the groups. Liberator and Sequence files required fewer rotations to failure than ProFiles in all groups tested except the size 25 files rotated at the less severe angle. ProFiles appear to be more resistant to flexural fracture than Liberator and Sequence files unless the files are of smaller size with a less severe curvature. Care should be taken to limit the number of uses when using larger size files, especially Liberator and Sequence files, around severe curvatures.

INTRODUCTION

Nickel-titanium alloy was developed in the 1960's by W. F. Buehler at the Naval Ordinance Laboratory (1). Nickel-titanium for use in endodontic instrumentation was introduced by Walia and associates as a more flexible alternative to stainless steel (2). Since then, rotary nickel-titanium files have become very common in endodontic treatment. Nickel-titanium files have several advantages over stainless steel files, including increased flexibility (2-5) and a decreased tendency to produce canal transportation (6-8). Despite these advantages, they are still prone to fracture in very small or tortuous canals (9-11). Nickel-titanium instruments may be more prone to fracture depending on the file design or size (12,13). The type of fracture that occurs can be torsional, due to binding of the file tip during rotation (12), or rotational, due to repeated flexure around canal curvatures leading to work-hardening and failure (13-15).

Various research techniques have been used to test file performance, most of which were designed to simulate clinical conditions. These techniques range from binding the tips of files with clamps and rotating the files until fracture (12), to rotating the files with a lathe in a curved steel groove (15).

Recently, several new file systems have been introduced. One is the Liberator® (Miltex, York PA), a file system incorporating a non-helical flute shape designed to maximize cutting efficiency and minimize binding and fracture (16). A second new system is the Sequence files by Brasseler® (Savannah, GA). These files have been designed with a more traditional flute shape but incorporate a unique “Alternate Contact Point” geometry with an emphasis on cutting efficiency while maintaining flexibility (17).

A review of the literature failed to disclose any previous studies comparing resistance to flexural fracture using these file systems. A comparison of these two file systems to the ProFile® system (Dentsply, Tulsa OK), which has been extensively tested (10,12,18,19), would give in-vitro information as to the comparative resistance to fracture of these files. The purpose of this study was to compare the flexural fracture of the Liberator and Sequence with the ProFile systems.

MATERIALS AND METHODS

Size 25 and Size 40 files were chosen for testing. All files tested were 0.04 taper and 25mm long. Each file was removed from the manufacture's packaging and placed in an 8:1 contra-angle handpiece (Anthogyr, Aseptico Inc.) attached to a slowspeed electric motor (Aseptico Endo ITR, Aseptico Inc., Woodinville, WA). The contra-angle handpiece was mounted to a universal testing machine (Instron) by a custom fabricated jig in such a manner as to allow vertical positioning of each file. An adjustable apparatus consisting of an aluminum baseplate and stainless steel metal block was fabricated that attached to the base of the universal testing machine. The 65mm x 25mm x 3mm block was constructed from hardened 316 stainless steel with polished chrome plating; a 2mm-wide groove was machined into the surface to keep the file tip in place during testing. The block was attached to a 15 cm diameter aluminum baseplate that was fixed to the Instron machine with screws. The block holder was designed to allow the operator to set the angle of the file deflection as desired by moving the block in a sliding mount and fixing it with two hex screws. After placement of each file to the specified angle of deflection against the metal block, the Schneider method was used to determine the angle of curvature (21). A photograph of each file on the apparatus was taken and traced to determine the degree of curvature. Thirty-one degree and thirty-four degree angles of curvature were simulated with the ramp. To insure consistency, all files were tested at a given angle before changing the angle of the apparatus.

Each file was rotated at 300 RPM with an electric motor at the specified angle until failure occurred. Testing of the files was performed by one operator. Testing protocol was similar to that used by Kitchens and associates (20). The time to fracture was measured with a stopwatch and recorded. Five files of each brand and size were tested at each angle until failure occurred. The time to fracture and the rotational speed were used to calculate the number of rotations to fracture. A three-way ANOVA and Tukey's HSD were used to determine statistical significance. Significance was declared at $p<0.05$.

RESULTS

The geometric mean rotations to failure for each experimental group are shown in Table 1. File size, minimum and maximum number of rotations to failure are included in the table. Rotation of the files at the more acute angle caused a significant decrease in the number of rotations to failure with the exception of the ProFile size 25 files.. The size of the file also significantly affected the failure within brands, with larger files failing sooner, with exception of the ProFiles at the less severe angle.

The Tukey's HSD results are shown in Table 2. The geometric mean rotations to failure are displayed in descending order along with the statistical significance. Liberator and Sequence files size 40 at the 34 degree angle failed with the lowest mean number of rotations to fracture of 82.65 and 79.91 respectively. These results were statistically significant compared to all other files tested. The size 25 Liberator and Sequence files rotated at the 31 degree angle required the most rotations to fracture (mean rotations of 766.07 for the Liberator and 704.49 for the Sequence files) but not significantly more than the corresponding ProFile (mean rotations to failure of 548.45).

Figure 1 illustrates that the Liberator and Sequence failure times were more adversely affected by the angle and size variables than the ProFiles. This difference was especially pronounced at the less acute angle of curvature.

Table 1

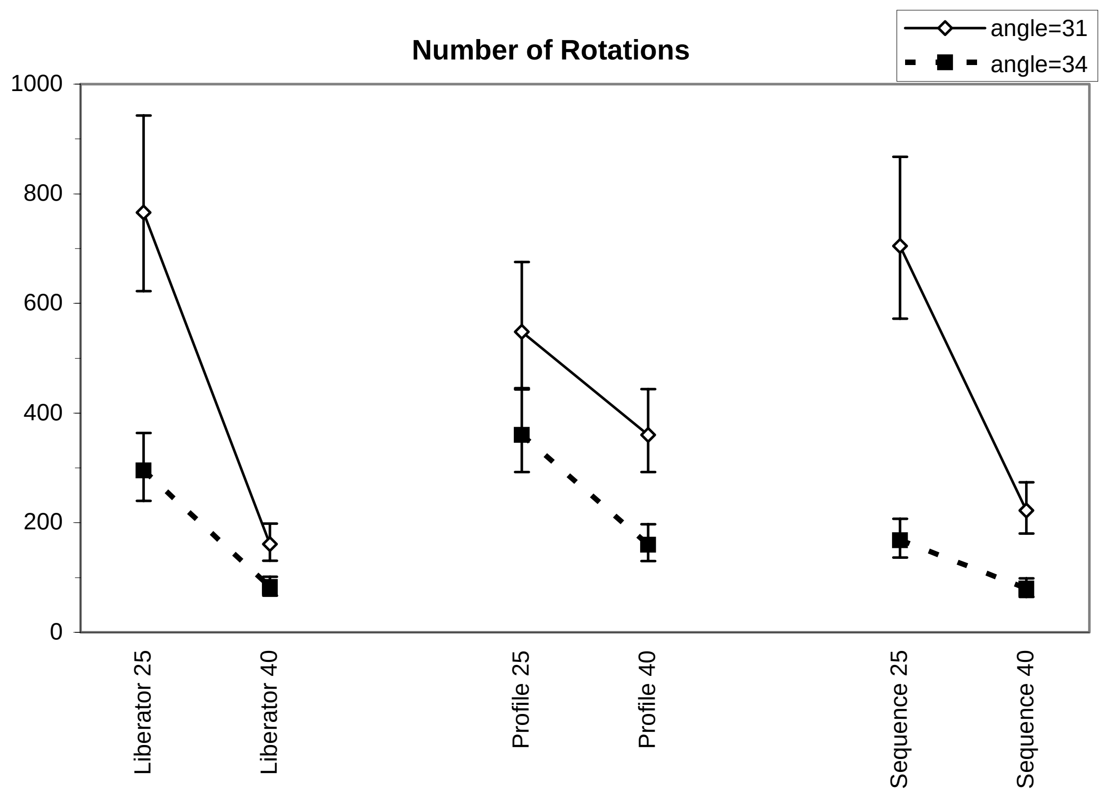
Rotations to Failure in the Twelve Experimental Conditions

			Number of Rotations				
angle	brand	size	Min.	Max.	Geometric Mean	95% CI	
31	Liberator	25	610	975	766.07	622.31	943.05
31	Liberator	40	110	200	161.30	131.03	198.56
34	Liberator	25	260	345	295.24	239.83	363.45
34	Liberator	40	55	150	82.65	67.14	101.74
31	Profile	25	440	700	548.45	445.52	675.15
31	Profile	40	270	405	360.33	292.71	443.57
34	Profile	25	320	395	360.02	292.46	443.19
34	Profile	40	135	210	160.22	130.15	197.23
31	Sequence	25	550	815	704.49	572.28	867.24
31	Sequence	40	185	265	222.33	180.60	273.69
34	Sequence	25	130	220	168.33	136.74	207.21
34	Sequence	40	55	135	79.91	64.91	98.37

Table 2
Tukey's HSD results

angle, brand, size						Geometric Mean
31,liberator,25	A					766.07
31,sequence,25	A					704.49
31,profile,25	A	B				548.45
31,profile,40		B	C			360.33
34,profile,25		B	C			360.02
34,liberator,25			C			295.24
31,sequence,40			C	D		222.33
34,sequence,25				D		168.33
31,liberator,40				D		161.30
34,profile,40				D		160.22
34,liberator,40					E	82.65
34,sequence,40					E	79.91

Figure 1
Average Rotations to Failure in the Twelve Experimental Groups



DISCUSSION

The apparatus used to test the files was fabricated to allow rotation of the files at a repeatable angle. The ramp against which the files were rotated was highly polished to reduce the amount of friction generated during testing. It is possible, however, that the different blade geometries of the files could allow for variable friction generation and thus different heat production. Whether or not this occurred or if the increased friction and heat could cause a significant difference in file fracture times was not examined in this study.

All files were tested at 300 rpm. It has been shown that it is not the speed at which a file is rotated, but the number of rotations that leads to fracture (20). To reduce the possible difference in friction generated during the testing, it was decided to rotate all files at one consistent rate.

It has also been shown in previous studies that larger files tend to fracture more quickly than smaller files when testing for fatigue resistance (13, 15, 20). Our results are in agreement with those studies. All size 40 files failed with significantly less rotations than the size 25 files of the same brand with the exception of the ProFiles rotated at the less severe curvature. This appears to be due to the decreased flexibility of the larger files that leads to more distortion and fracture propagation than with smaller files. There is more force required to maintain the larger files in the specific angle of curvature. This force is transferred to the rotating file.

Pruett and associates claimed that several parameters including radius of curvature, angle of curvature, instrument size, and the point of maximal instrument flexure all have a significant effect on rotational failure (13). There is more stress generated with a smaller radius of curvature. The angle of curvature and instrument size were tested in this study. By placing the files against the sloped metal block at a fixed, repeatable angle of deflection, it was assumed that the radius of curvature was identical between the files. This assumption, however, cannot be verified. Due to the different flexibilities of the various instruments, the radius of curvature may have been altered enough to affect the results. The point of maximal instrument flexure was also assumed to be consistent between instruments. The location of fracture and lengths of remaining fragments appeared to be similar among all files tested, but no actual measurement of fragments was conducted to verify any significant differences.

The Schneider method was used to determine the angle of deflection (21). Originally, this method involved measuring the angle formed between the long axis of a tooth and the apex radiographically. This method is arbitrary and subject to interpretation, however, all files in this study were rotated at the same angles of deflection irrespective of the actual Schneider angle derived afterward. All files were tested at 31 degrees prior to testing any files at 34 degrees. This was done to minimize discrepancy between angles.

Our results also show that a more acute angle of rotation led to failure more quickly than a less acute angle. This is in agreement with several previous studies (13, 15). By subjecting the file to angular rotation, the file undergoes tension on the outside of the curvature and compression forces on the inside of the curvature. These bending forces cause the propagation of small stress fractures on the surface of the file until failure occurs. A more acute angle allows more flexure of the file and greater stress production which leads to more rapid failure of the file.

The Liberator and Sequence size 25 files rotated at the 31 degree angle required the most rotations to fail. They did not, however, perform significantly better than the matching ProFile. These smaller instruments required significantly fewer rotations to fail at the more acute angle of curvature. We may conclude that in less severe curvatures, the use of a small file is relatively safe and the type of file is not important. When rotated at 34 degrees, the Liberator and Sequence size 40 files failed after significantly fewer rotations than the matching ProFile. The ProFiles appear to be less affected by the variables when applied individually than the other two file systems. The ProFiles were, however, significantly affected by the combination of size and angle.

CONCLUSION

The geometric mean rotations to failure for each experimental group are shown in Table 1. File size, minimum and maximum number of rotations to failure are included in the table. Rotation of the files at the more acute angle caused a significant decrease in the number of rotations to failure with the exception of the ProFile size 25 files.. The size of the file also significantly affected the failure within brands, with larger files failing sooner, with exception of the ProFiles at the less severe angle.

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Literature Cited

Literature Cited

1. Thompson S. An overview of nickel-titanium alloy used in dentistry. International Endodontic Journal 2000; 33:297-310.

2. Walia H, Brantley WA, Gerstein H. An initial investigation of the bending and torsional properties of nitinol root canal files. JOE 1988; 14: 346-351.

3. Canalda-Sahli C, Brau-Aguade E, Berastegui-Jimeno E. Torsional and bending properties of stainless steel and nickel-titanium Canal Master U and Flexogate instruments. Endodontic Dental Traumatology. 1996 June; 12:141-145.

4. Haikel Y, Serfaty R, Wilson P, Speisser JM, Allemann C. Mechanical properties of nickel-titanium endodontic instruments and the effect of sodium hypochlorite treatment. JOE 1998; 24: 731-735.

5. Kazemi RB, Stenman E, Spangberg LS. A comparison of stainless steel and nickel-titanium H-type instruments of identical design: torsional and bending tests. OOO 2000; 4:500-506.

6. Tasdemir T, Aydemir H, Inan U, Unal O. Canal preparation with Hero 642 rotary Ni-Ti instruments compared with stainless steel hand K-file assessed using computed tomography. International Endodontic Journal; 2005:38(6):402-8.

7. Perez F, Schoumacher M, Peli JF. Shaping ability of two rotary instruments in simulated canals: stainless steel ENDOflash and nickel-titanium HERO shaper. International Endodontic Journal 2005;38(9):637-44.

8. Schafer E, Florek H. Efficiency of rotary nickel-titanium K3 instruments compared with stainless steel hand K-Flexofile. Part I. Shaping ability in simulated curved canals. International Endodontic Journal 2003;36(3):199-207.

9. Hubscher W, Barbakow F, Peters OA. Root canal preparation with FlexMaster: assessment of torque and force in relation to canal anatomy. International Endodontic Journal 2003;36(12):883-90.

10. Bahia MG, Buono VT. Decrease in the fatigue of nickel-titanium rotary instruments after clinical use in curved root canals. OOO 2005; 100(2):249-55.

11. Martin B, Zelada G, Varela P, Bahillo JG, Magan F, Ahn S, Rodriguez C. Factors influencing the fracture of nickel-titanium rotary instruments. International Endodontic Journal 2003;36(4):262-6.

12. Booth JR, Scheetz JP, Lemons JE, Eleazer PD. A comparison of torque required to fracture different nickel-titanium rotary instruments around curves of the same angle but of different radius when bound at the tip. JOE 2003; 29: 55-57.

13. Pruett JP, Clement DJ, Carnes DL. Cyclic fatigue testing of nickel-titanium endodontic instruments. JOE 1997;23(2):77-85.

14. Sattapan B, Nervo G, Palamara J, Messer H. Defects in rotary nickel-titanium files after clinical use. JOE 2000; 26:161-165.

15. Haikel Y, Serfaty R, Bateman G, Senger B, Allemann C. Dynamic and cyclic fatigue of engine driven rotary nickel-titanium endodontic instruments. JOE 1999; 25(6):434-40.

16. Miltex information from manufacturer.

17. Brasseler information from manufacturer.

18. Gambarini. Cyclic fatigue of ProFile rotary instruments after prolonged clinical use. International Endodontic Journal 2001;34(5):386-9.

19. Li UM, Lee BS, Shih CT, Lan WH, Lin CP. Cyclic fatigue of endodontic nickel-titanium rotary instruments: static and dynamic tests. JOE 2002;28(6):448-51.

20. Kitchens GG, Liewehr FR, Moon PC. The effect of operational speed on the fracture of nickel-titanium rotary instruments. JOE 2007; 33(1):52-54.

21. Schneider SW. A comparison of canal preparation in straight and curved root canals. Oral Surgery 1971;32:271-5.

VITA

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