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Comparing Cyclic Fatigue of the new GT® Series XTM Files to the Original ProFile® GT® Rotary Instruments

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Comparing Cyclic Fatigue of the new GT® Series X^{TM} Files to the Original ProFile® GT® Rotary Instruments

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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Table of Contents

List of Tables

Page

List of Figures

Abstract

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The purpose of this study was to test the number of rotations to fracture of the M-Wire GT**®** Series X^{TM} rotary files compared to the original ProFile**®** GT**®** rotary files in a simulated curved canal. Eighty GT**®** Series X^{TM} files of 25mm length were divided into eight groups of ten, one for each of the new GT**®** Series X^{TM} files. Eighty original ProFile**®** GT**®** files of 25mm length were divided into eight groups of the same tip and taper sizes consistent with the GT**®** Series X^{TM} file groups. Files were rotated at 300 rpm. While the angle may have slightly changed due to the flexure property of the file, the angle

was the same for each file with the same tip and taper. The time to fracture was recorded and rotations to fracture were calculated. The data collected was analyzed using a two-way ANOVA, followed by specific post-hoc contrasts comparing the two brands for each tip and taper combination. The results show the M-Wire GT® Series X ™ files were significantly more resistant to fracture by cyclic fatigue than the ProFile® GT® rotary instruments for the following tip and taper sizes: 20/.04, 30/.04, 30/.06, 30/.08, and 40/.08. The following tip and taper sizes: 20/.06, 40/.04, and 40/.06 were not statistically significant.

INTRODUCTION

In 1988, Walia et al. introduced nickel-titanium (NiTi) material to be used for rotary instrumentation in endodontics. This material became the alloy of choice for rotary instruments over stainless steel because NiTi alloy had better properties of superelasticity and high resistance to cyclic fatigue (1). Nickel-titanium has been shown to be stronger and more flexible than stainless steel (2), allowing the instrument to better negotiate the root canal system without ledging or transporting (3).

Nickel-titanium withstands the forces of cyclic fatigue and torsional fracture to a greater degree than other materials historically used. Torsional fracture of an endodontic file occurs when the tip of the file binds in a canal and the shank continues to rotate (4). Cyclic fatigue occurs from repeated bending of a file which will eventually lead the metal to fatigue and fracture (5).

Instrumenting the root canal system is essential in cleaning bacterial debris from the canal. Equally important is the simultaneous movement of antibacterial irrigants disinfecting the canal space of microorganisms and infected dentin and pulp tissue (6, 7, 8, 9). Instrumentation of the canal system can be very difficult in teeth with dilacerated roots or curved canals because of torsional and cyclic fatigue stresses (10). Nickel-titanium, while exhibiting the ability to resist forces of cyclic fatigue and torsional fracture, still experience stresses, especially in these curved canal systems. There are limits to the amount of stress an instrument can withstand and if these stresses exceed the elastic limit of the NiTi material producing plastic deformation, then the instrument separates (11, 12). A separated instrument can decrease the success rate of root canal therapy depending on the preoperative diagnosis of the tooth (13, 14). New techniques and materials are constantly being developed to decrease the incidence of instrument separation.

Haikel et al. stated that the leading cause of file separation is cyclic fatigue (15). The M-Wire NiTi alloy, developed by Ben Johnson, is a new NiTi alloy created by "a series of heat treatment and annealing cycles applied during the drawing of the wire" (16). Dentsply Tulsa Dental Specialties Company® introduced this technology in October 2007, claiming that the M-Wire technology will significantly increase a file's resistance to cyclic fatigue and at the same time decrease the incidence of instrument separation. The increased flexibility of the M-Wire alloy and new design features of the GT® Series X™ file is purported to decrease the incidence of ledging, minimize transportation, and increase efficiency in instrumentation of curved canals (16).

The purpose of this study is to test the number of rotations to fracture of the M-Wire GT® Series X™ files compared to the original ProFile® GT® rotary instruments using a benchtop apparatus simulating a curved canal.

MATERIALS AND METHODS

A total of eighty GT® Series X™ files of 25mm length were divided into eight groups. Each group represents one of the eight new GT® Series X™ files. These eight groups will be compared to eighty original ProFile® GT® files of 25mm length divided into eight groups of tip and taper sizes consistent to the GT® Series X™ file groups.
The method used to test time to fracture is similar to that used by Kitchens et al. (17). An apparatus was fabricated to simulate a consistent curvature inside a canal. A 2.5 in. x 1 in. x 3 mm block was made from hardened steel and polished chrome, with a 2mm wide groove machined into the face to keep the file in position during testing. A 6 in. aluminum baseplate and adjustable block holder was attached to the baseplate of an Instron machine (Instron Corp., Canton, MA) and set to replicate an endodontic file at the same angle for each of the groups compared. The files were measured using the Schneider method which defines the angle of curvature as the angle between a line parallel to the long axis of the canal, and another line from the apical foramen to the intersect point with the first line at the point where the canal begins to leave the long axis of the canal (18). Lubrication of RC-Prep (Premier Products Co, Plymouth Meeting, PA) was used before each file tested.

An electric motor (Aseptico Endo ITR, Aseptico Inc., Woodinville, WA) with an 8:1 contra-angle handpiece (Anthogyr, Aseptico Inc., Woodinville, WA) was placed in a custom jig fabricated to attach to the Instron testing machine. Each file was rotated in the handpiece at 300 rpm until the file separated. The time of separation of the instrument was measured with a stopwatch. The number of instrument rotations completed before separation was equated [time to fracture x speed] and compared.

The significance of each brand of file with corresponding tip and taper combination was analyzed using a two-way ANOVA followed by specific post-hoc contrasts comparing the two brands for each tip and taper combination.

RESULTS

The number of rotations until failure was skewed and so the log-transformed values were analyzed. This satisfied the assumptions of ANOVA, equal variability and normality. A two-way ANOVA was used with the following effects in the model: brand, tip and taper combination and the brand, tip and taper interaction. The interaction test determined whether the brand differences were consistent across all tip and taper combinations. After the establishment of group differences by ANOVA, at alpha = 0.05, specific post-hoc contrasts compared the two brands for each tip and taper combination. The back transformed values yield the geometric mean rotation, and are shown in the summary tables.

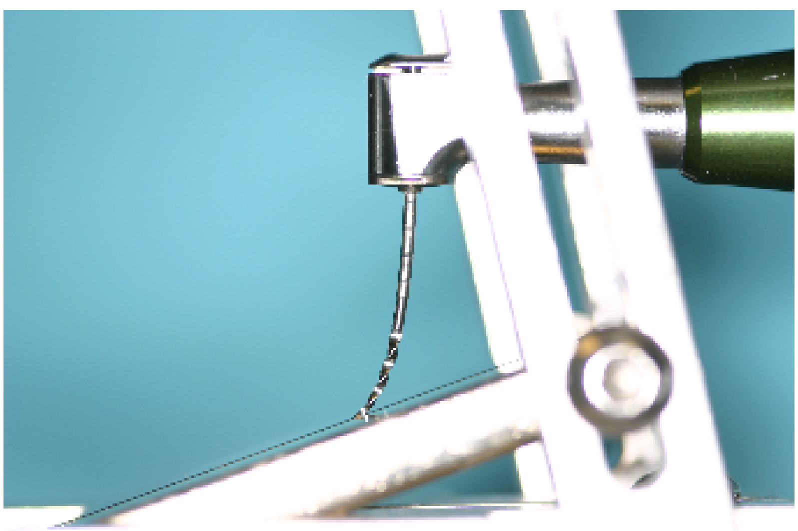
The number of rotations for each of the ten replicates is shown in

Figure 1. The median and range for these values are shown in

Table 1. A two-way ANOVA indicated that the sixteen groups were significantly different ($F(15, 144) = 18.6$, $p < .0001$). The brand, tip and taper interaction indicated that the differences between the brands varied by tip and taper combination ($F(7, 144) = 11.7$, $p < .0001$).

The estimated geometric means for each condition are shown in Table 2. In this table, for each brand, tip and taper the estimated geometric mean rotation to failure is shown with 95% confidence interval. For each tip and taper combination the two brands are compared and the result of this comparison is shown with the p-value in the right column. Differences between the brands vary by tip and taper as indicated by the fact that some of the comparisons are significant (e.g., tip = 20, taper = .04) and others are not (e.g., tip = 20, taper = .06). This is shown in Figure 2 by the vertical separation between the two lines. The top-most line is the estimated number of rotations to failure for each of the GT® Series X™ files. For the tip and taper combination 20/.04, the GT® Series X™ file rotated 2.06 times as long, and this was significantly longer than the ProFile® GT® file (p = <.0001). For the tip and taper combination 20/.06, the GT® Series X™ file rotated 1.01 times as long, but this was not significantly different than the ProFile® GT® (p = 0.9306). For the tip and taper combination 30/.04, the GT® Series X™ file rotated 1.49 times as long, and this was significantly longer than the ProFile® GT® (p = 0.0008). For the tip and taper combination 30/.06, the GT® Series X™ file rotated 1.7 times as long, and this was significantly longer than the ProFile® GT® (p = <.0001). For the tip and taper combination 30/.08, the GT® Series X™ file rotated 1.51 times as long, and this was significantly longer than the ProFile® GT® ($p = 0.0005$). For the tip and taper combination 40/.04, the GT® Series X™ file rotated 1.11 times as long, but this was not significantly different than the ProFile® GT® ($p = 0.3877$). For the tip and taper combination 40/.06, the GT® Series X™ file rotated 0.99 times as long, but this was not significantly longer than the ProFile® GT® ($p = 0.9584$). For the tip and taper combination 40/.08, the GT® Series X™ file rotated 3.08 times as long, and this was significantly longer than the ProFile® GT® ($p = <.0001$).

Picture 1: GT® Series X™ 20/ .06 file



Picture 2: ProFile® GT® 20/ .06 file

Figure 1: Rotations for Each of the Test Conditions

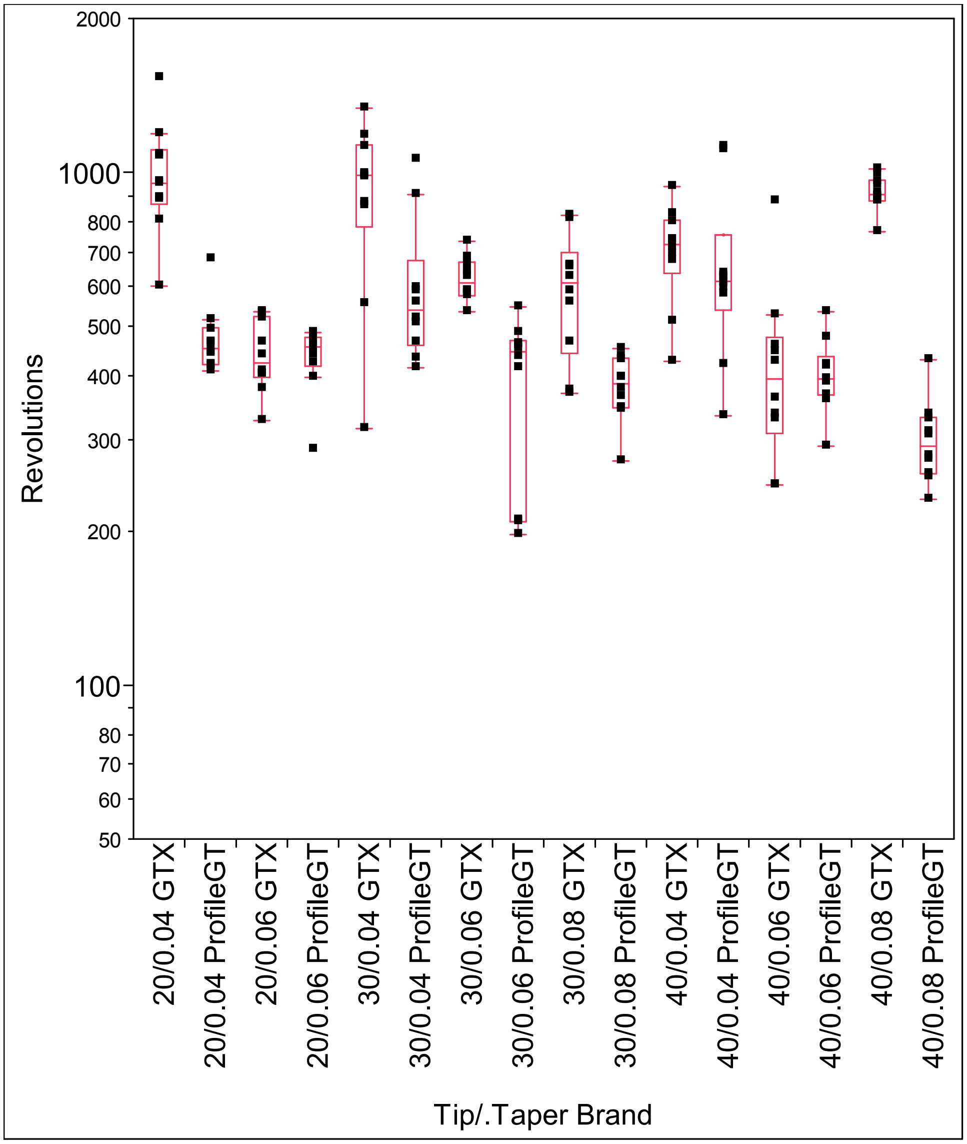

Revolutions
2000
1000
800
700
600
500
400
300
200
100
80
70
60
50
20/0.04 GTX
20/0.04 ProfileGT
20/0.06 GTX
20/0.06 ProfileGT
30/0.04 GTX
30/0.04 ProfileGT
30/0.06 GTX
30/0.06 ProfileGT
30/0.08 GTX
30/0.08 ProfileGT
40/0.04 GTX
40/0.04 ProfileGT
40/0.06 GTX
40/0.06 ProfileGT
40/0.08 GTX
40/0.08 ProfileGT
Tip/.Taper Brand

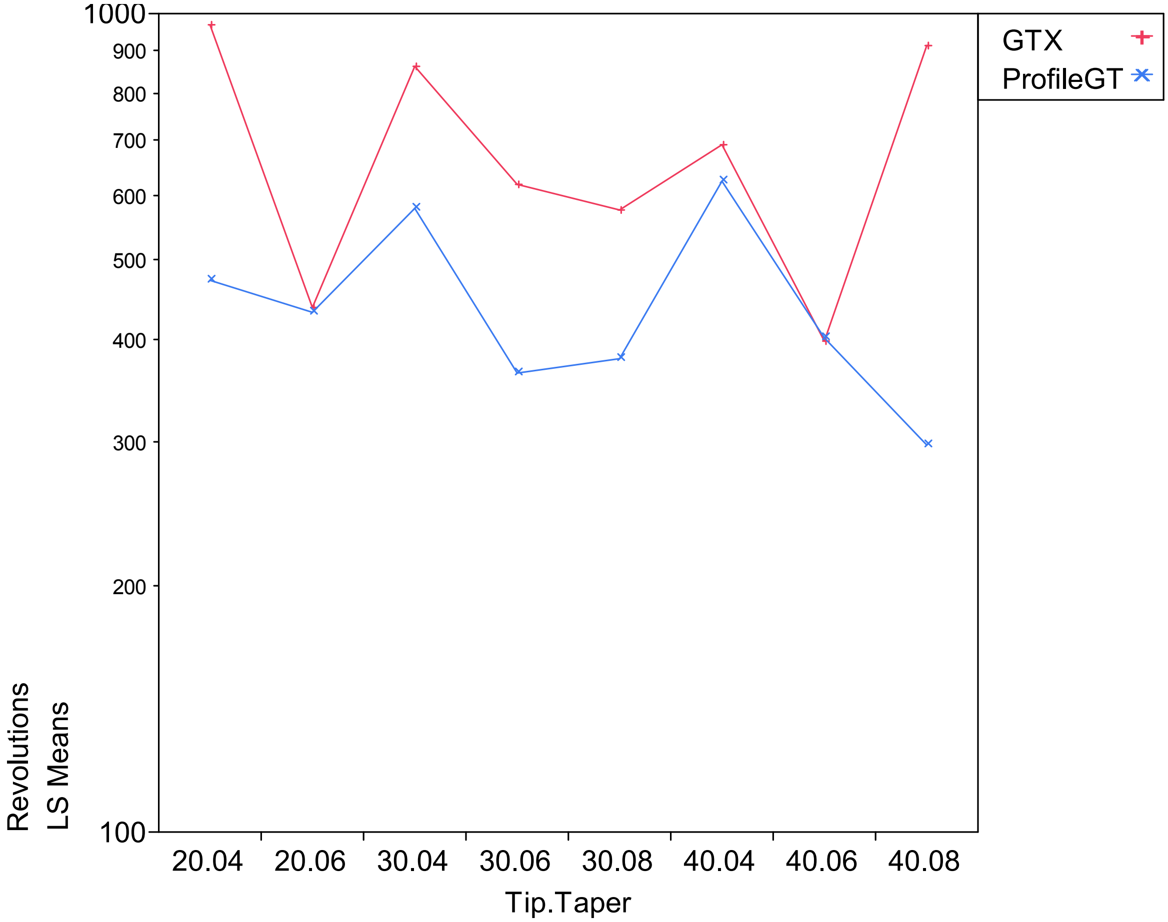
Table 1: Description of the Number of Rotations for Each of the Test Conditions

		Rotations to Failure		
Tip/Taper	Brand	Minimum	Median	Maximum
20/.04	GTX	599.00	954.25	1531.50
	ProfileGT	411.00	454.50	678.50
20/0.06	GTX	327.00	424.75	533.50
	ProfileGT	287.50	455.25	486.50
30/0.04	GTX	317.00	983.75	1338.50
	ProfileGT	414.50	539.75	1062.00
30/0.06	GTX	533.50	607.50	736.00
	ProfileGT	197.00	446.00	547.50
30/0.08	GTX	371.00	608.00	825.50
	ProfileGT	273.50	388.25	453.00
40/0.04	GTX	428.50	725.00	938.00
	ProfileGT	334.50	615.00	1122.00
40/0.06	GTX	245.00	395.25	882.50
	ProfileGT	291.50	395.25	536.00
40/0.08	GTX	766.00	906.50	1019.00
	ProfileGT	229.50	292.75	430.00

Table 2: Estimated Rotations to Failure

			Rotations			
Tip	Taper	Brand	Mean	95% CI		p-value
20	.04	GTX	969.94	824.76	1140.67	
		ProfileGT	471.19	400.67	554.13	
		Ratio	2.06	1.64	2.58	<.0001
	.06	GTX	436.63	371.28	513.49	
		ProfileGT	432.24	367.54	508.32	
		Ratio	1.01	0.80	1.27	0.9306
30	.04	GTX	861.44	732.51	1013.08	
		ProfileGT	578.42	491.85	680.24	
		Ratio	1.49	1.19	1.87	0.0008
	.06	GTX	618.65	526.05	727.54	
		ProfileGT	363.65	309.22	427.66	
		Ratio	1.70	1.35	2.13	<.0001
	.08	GTX	573.87	487.98	674.89	
		ProfileGT	379.03	322.30	445.75	
		Ratio	1.51	1.21	1.90	0.0005
40	.04	GTX	691.07	587.63	812.71	
		ProfileGT	624.98	531.44	734.99	
		Ratio	1.11	0.88	1.39	0.3877
	.06	GTX	398.13	338.54	468.21	
		ProfileGT	400.55	340.59	471.05	
		Ratio	0.99	0.79	1.25	0.9584
	.08	GTX	912.94	776.29	1073.64	
		ProfileGT	296.81	252.38	349.05	
		Ratio	3.08	2.45	3.86	<.0001

Figure 2: Geometric Mean Rotations to Failure



DISCUSSION

The purpose of this study was to test the number of rotations to fracture of the M-Wire GT® Series X™ files compared to the original ProFile® GT® rotary instruments using a benchtop apparatus simulating a curved canal.

To test the number of rotations to fracture, an apparatus which had been designed and fabricated to create a low-friction surface against which files could be rotated at 300 rpm and reproduce the same angle for comparable tip size and taper was used. The apparatus was polished and lubricated so the torsional stress would be negligible. This allowed testing of file separation of the NiTi instrument due only to cyclic metal fatigue. This mechanism replicated a curved canal where the file is bent back-and-forth repeatedly as the file is rotated. Using the Schneider method, each file with the same tip and taper was rotated at the same angle of curvature as shown in Pictures 1 and 2.

The hypothesis that the M-Wire GT® Series X ™ files would have a greater resistance to cyclic fatigue than the original ProFile® GT® rotary instrument was tested. Results showed that the M-Wire GT® Series X ™ files were more resistant to fracture than the ProFile® GT® rotary instruments in selected files only. The M-Wire GT® Series X ™ files were statistically significant to resistant to fracture for the following tip and taper sizes: 20/.04, 30/.04, 30/.06, 30/.08, and 40/.08. However, the following tip and taper sizes: 20/.06, 40/.04, and 40/.06 were not statistically significant.

The GT® Series X ™ files were designed to reduce the possibility of breakage when compared to the original ProFile® GT® rotary files (16). The data demonstrates that the M-Wire is more resistant to fracture than the original NiTi material, but not for all the tip and taper sizes. For example, the GT® Series X ™ files did achieve more rotations before separation for tip and taper sizes: 20/.06, 40/.04, and 40/.06 but were not significantly different (Figure 2). Because all of the GT® Series X ™ files were not significantly better than the ProFile® GT® files, there are questions about whether the increased resistance to cyclic fatigue is because of the changes in design features rather than the material of the M-Wire.

Some of the design feature changes of the ProFile® GT® files include fewer cutting flutes, a wider and more open blade angle of 30 degrees to help reduce the core mass of the file, and variable radial land widths. These new design features claim to increase flexibility, cutting efficiency and resistance to cyclic fatigue (16). This study suggests that the significance to increased resistance to cyclic fatigue may be due to the design features of the new GT® Series X ™ files rather than the new M-Wire material because the resistance to fracture was not consistent for all tip and taper sizes. These results do not agree with previous studies about the M-Wire material (19, 20).

Johnson et al. stated that the M-Wire material is nearly 400% more resistant to cyclic fatigue than the original NiTi files when fabricated as Profile® 25/.04 instruments (19). Manufacturing each material in the design of a Profile® 25/.04 instrument allowed testing for resistance to fracture at a 90 degree curve of a 5-mm radius of the two materials without the variable of file design.

In contrast, Kramkowski et al. found that there was no significant difference between the ProFile® GT® files and the M-Wire GT® Series X ™ files when testing cyclic fatigue at 45 degrees in an apparatus using a constant cyclical axial motion.

Kramkowski et al. also stated that when testing the files for cyclic fatigue at 60 degrees the ProFile® GT® files were significantly more resistant to fracture than the M-Wire GT® Series X ™ files (20). File design could be the possible variable causing the M-Wire material not to improve resistance to fracture when compared to the ProFile® GT® files.

The results of this study, based on a 45 degree angle of curvature, are more consistent with the findings of Johnson et al. with the M-Wire material being more resistant to cyclic fatigue. There is significance in resistance to cyclic fatigue between ProFile® GT® files and M-Wire GT® Series X ™ files, which are manufactured with different materials, but not for all tip and taper sizes. Because all of the files are not statistically significant there must be other variables at stake when comparing the ProFile® GT® files and the M-Wire GT® Series X ™ files. Because of the inconsistency in data, results between studies would suggest that not enough evidence exists to state unequivocally that the M-Wire material significantly increases a files ability to resist cyclic fatigue.

In conclusion, the M-Wire GT® Series X ™ files were more resistant to fracture by cyclic fatigue than the ProFile® GT® rotary instruments for the following tip and taper sizes: 20/.04, 30/.04, 30/.06, 30/.08, and 40/.08. More studies are needed to determine if the M-Wire material is more resistant to cyclic fatigue than traditional NiTi and/or if the resistance is due to metallurgy or file design.

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VITA

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