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COMPARING CYCLIC FATIGUE OF THE NEW GT® SERIES X(TM) FILES TO THE ENDO SEQUENCE™ ROTARY INSTRUMENTS

Nathan Wayment
Virginia Commonwealth University

Virginia Commonwealth University

This is to certify that the thesis prepared by Nathan Stratford Wayment entitled COMPARING CYCLIC FATIGUE OF THE NEW GT® SERIES X™ FILES TO THE ENDO SEQUENCE™ ROTARY INSTRUMENTS has been approved by his or her committee as satisfactory completion of the thesis requirement for the degree of Master of Science in Dentistry.

Karan J. Replogle, DDS, MS, Virginia Commonwealth University School of Dentistry

Al M. Best, PhD, Virginia Commonwealth University School of Medicine

Peter C. Moon, PhD, Virginia Commonwealth University School of Dentistry

Karan J. Replogle, DDS, MS, Interim Department Chair, Endodontics

Laurie C. Carter, DDS, PhD, Director Advanced Dental Education

Dr. F. Douglas Boudinot, Dean of the Graduate School

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COMPARING THE CYCLIC FATIGUE OF THE NEW GT® SERIES X™ FILES TO

THE BRASSLER® ENDO SEQUENCE 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

NATHAN STRATFORD WAYMENT
B.S., Weber State University, 2004
D.D.S., Virginia Commonwealth University, 2006

Director: KARAN J. REPLOGLE D.D.S., M.S.
INTERIM CHAIR, DEPARTMENT OF ENDODONTICS

Virginia Commonwealth University
Richmond, Virginia
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Abstract

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By Nathan Stratford Wayment, D.D.S.

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

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Major Director: Karan J. Replogle
Interim Chair, Department of Endodontics

The purpose of this study was to examine the number of rotations to failure of two different rotary file systems, EndoSquence Brassler USA (Savannah, GA) and GT® series X ™. Files sizes 20,30,40 with 0.04, 0.06 tapers of GT series X and Endo Sequence files size and taper used were 20, 30, 40 with 0.04 and 0.06 taper. Like tip and tapers were compared between systems. All files tested were 25mm in length. Files were allocated into 12 groups of 10 files each, and mounted to a universal testing machine. Each file was rotated at 300 rpms until fractured occurred. The number of rotations to fracture were calculated. A two-way ANOVA indicated that each of the 12 groups were significantly

different ($p < .0001$). The Brand Tip/Taper interaction indicated that the differences between the brands varied by Tip/Taper combination ($p < .0001$). The tip/taper combination 20/.04, the GT series X file rotated 1.4 times longer than the EndoSequence ($p = 0.0027$). The tip/taper combination 20/.06, the GT series X file rotated 1.61 times longer than the EndoSequence ($p = <.0001$). The tip/taper combination 30/.04, the GT series X file rotated 3.67 times longer, than the EndoSequence ($p = <.0001$). For the tip/taper combination 30/.06, the GT series X file rotated 2.63 times longer than the EndoSequence ($p = <.0001$). For the tip/taper combination 40/.06, the GT series X file rotated 4.05 times longer than the EndoSequence ($p = <.0001$). In comparing all these tip and taper combinations GT series X was significantly higher rotations to failure. Comparing tip/taper combination 40/.04, the GT series X file rotated 1.22 times longer, however, this was not significantly different than the Sequence ($p = 0.0707$). The results suggested that the number of rotations to failure for GT series X files were greater than the EndoSequence file of the same tip and taper combination.

CHAPTER 1 Introduction

The aim of root canal therapy is to clean and shape canal systems by gradual enlargement while conserving tooth structure. Maintenance of apical patency, avoidance of ledging, transportation or iatrogenic plugging of canals, which may alter canal morphology, is believed to affect overall success of root canal therapy (1,2,3,4,5,6). In 1988, Walia introduced and recommended using nickel titanium (NiTi) files, due to their ability to work in dilacerated canals without transportion of the canals (7,8). Despite the properties of super elasticity, NiTi files are more prone to file separation during usage than stainless steel files (6,7,8,9,10).

Researchers have found that file design, metallurgy and size, all play a role in a file's tendency for separation (1,11). File separations may be associated with torsional stress or fatigue. If the amount of torque produced during rotary instrumentation exceeds the elastic limit of the NiTi, torsional stress or fatigue occurs. Torsional fatigue occurs when a file binds in a portion of the canal, yet the coronal portion of the instrument continues to rotate. Torque is correlated not only to the force exerted apically, but also to preoperative canal volume. Hence, preparation of narrow and constricted canals subject rotary files to greater torsional loads.

File separations may also occur when a file undergoes cyclic fatigue. Cyclic fatigue (flexural fatigue) occurs through the repeated bending of a file that occurs as the file is rotated inside a curved canal (6,13,14,15). Flexural fatigue occurs during rotary instrumentation of curved canals as the rotating file undergoes phase changes with repeated flexing (6,11,15). Cyclic fatigue occurs when strain develops in the metal. Generally, cracks in the metal are created due to the surface imperfections of the metal. Imperfections or stress points are produced during manufacturing, manipulation, and tooling of the metal. Propagation of stress points occurs when applied stresses are continuously placed on the material. The result is separation of the material along the stress point when the material cannot withstand the applied stress (16).

Manufacturers design files with the purported ability to withstand cyclic fatigue. Files are marketed based on their ability to perform well, i.e. separate rarely, and often on their ability to out perform a competitor's file design. Some manufacturers base the files ability to withstand cyclic fatigue on the metallurgy of the file, the file design (shape), or special feature of the file such as electroplating or electropolishing (17).

Brasseler® (Savannah, GA) markets a NiTi file with a unique ACP™ (Alternate Contact Point) named the Endo Sequence. The manufacture promotes this file's ability to shape while remaining centered in the canal without the need of radial lands due to ACP™. The file is purported to demonstrate superior flexibility due to its triangle core design and electropolished finish. These file features increase its ability to withstand cyclic fatigue.

Recently, a new file system has been introduced by Dentsply Tulsa Dental Specialties Company® called GT® Series X™. This file system introduced a new nitinol alloy, M-Wire nickel titanium, developed by Ben Johnson. M-Wire is manufactured by sequential treatments of heat and annealing of the NiTi applied during the phase of manufacturing known as drawing. The file, GT® Series X™, as introduction of M-Wire by Dentsply Tulsa Dental Specialties Company®, is purported to have an increased ability to resist to cyclic fatigue and therefore, decrease instrument separation (12). In addition to incorporation of the M-Wire, the file design was altered to include greater spacing between the cutting surfaces and a reduction in the number of flutes. The core size was also reduced to increase flexibility (18).

In an effort to determine if the Brassler ® Endo Sequence or the M-Wire functioned differently under conditions of cyclic stress this study was designed. 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 Endo Sequence files by Brasseler® (Savannah, GA) using a bench top apparatus simulating a curved canal.

MATERIALS AND METHODS

A total of sixty 25mm GT® Series X^{TM} files were divided into six groups. Each group represents one of the six new GT® Series X^{TM} files. These six groups will be compared to sixty 25mm Endo Sequence files by Brassler® (Savannah, GA) divided into six groups of tip and taper sizes consistent with GT® Series X^{TM} file groups.

The method used to test time to fracture is similar to that used by Kitchens et al. (15). 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 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 (20). Lubrication with RC Prep 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 and attached to the Instron testing machine (Instron Corp., Canton, MA). Each file was rotated in the handpiece at 300 rpm until the file separated. The time to separation of the instrument was measured with a stopwatch. The number of instrument rotations completed before separation occurred was equated [time to fracture x speed] and compared.

The significance of each brand of files 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 is 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/taper combination and the brand*tip/taper interaction. The interaction test determined whether the brand differences were consistent across all tip/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/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**.

Figure 1: Rotations for Each of the Test Conditions

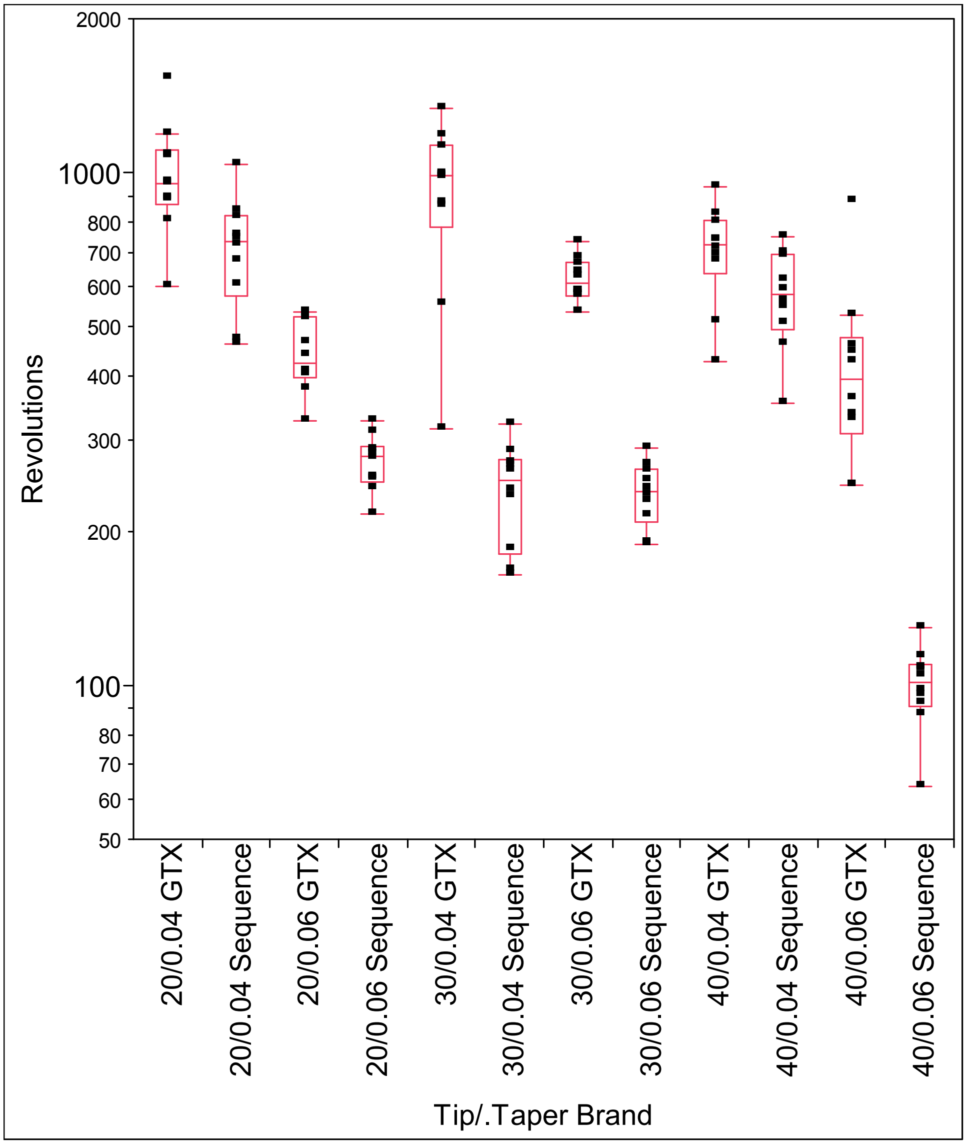


Table 1: Description of the Number of Rotations for Each of the Test Conditions

		Rotations to Failure		
Tip/Taper	Brand	Minimum	Median	Maximum
20/.04	GTX	599.00	954.25	1531.50
	Sequence	464.50	733.00	1034.50
20/.06	GTX	327.00	424.75	533.50
	Sequence	216.50	279.00	328.00
30/.04	GTX	317.00	983.75	1338.50
	Sequence	164.50	251.75	323.50
30/.06	GTX	533.50	607.50	736.00
	Sequence	188.50	238.25	291.00
40/.04	GTX	428.50	725.00	938.00
	Sequence	354.00	578.75	751.50
40/.06	GTX	245.00	395.25	882.50
	Sequence	63.50	101.00	129.00

A two-way ANOVA indicated that the 12 groups were significantly different ($F(11, 108) = 75.5$, $p < .0001$). The brand*tip/taper interaction indicated that the differences between the brands varied by tip/taper combination ($F(5, 108) = 22.2$, $p < .0001$).

The estimated geometric means for each condition are shown in **Table 2**. In this table, for each tip, taper, and brand the estimated geometric mean rotations to failure is shown, with 95% CI. For each tip and taper combination, the two brands were compared, and the result of this comparison is shown with the p-value in the right column. That the differences between the brands vary by tip/taper is indicated by the fact that some of the comparisons are significant (e.g., tip = 20, taper = .04) and others are not (tip = 40, taper = .04).

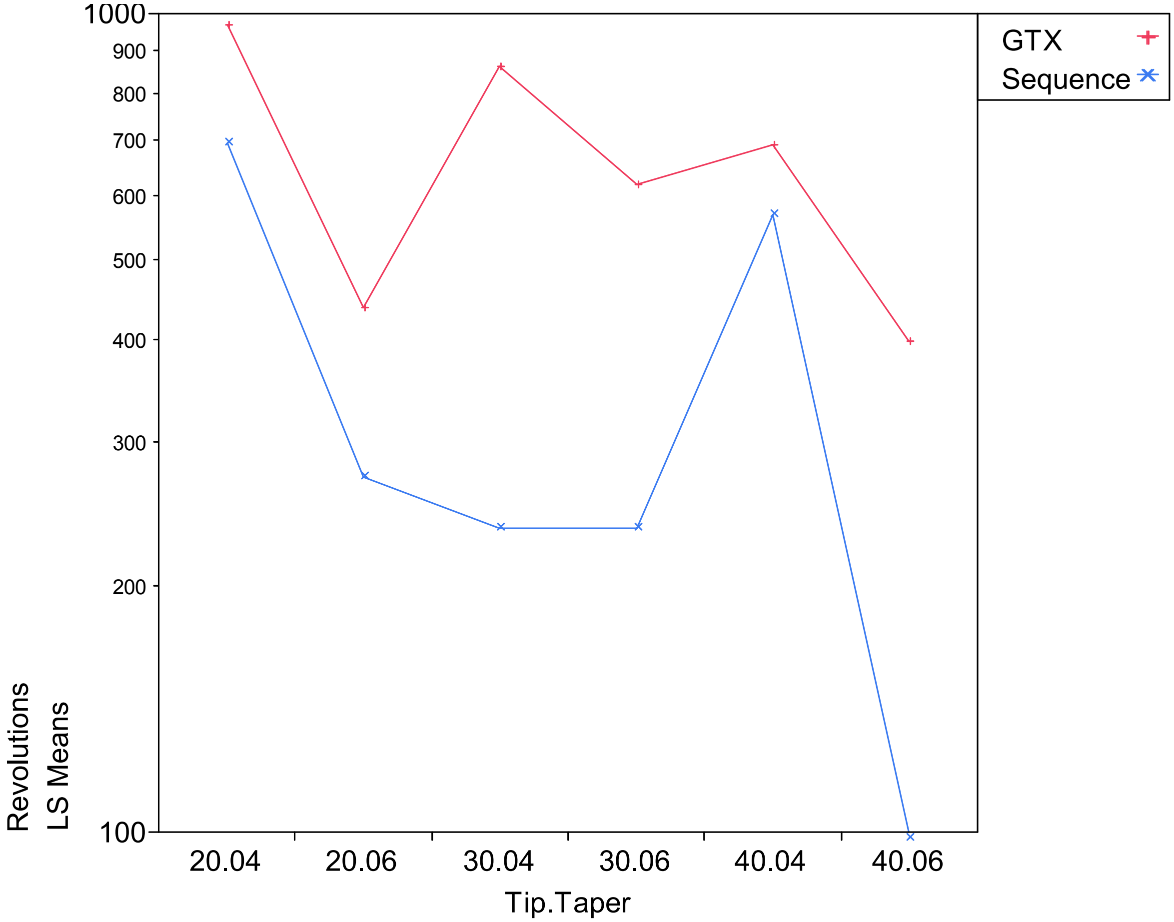
This is also shown in

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 GTX files. For the tip/taper combination 20/.04, the GTX file rotated 1.4 times as long, and this was significantly longer than the Endo Sequence (p = 0.0027). For the tip/taper combination 20/.06, the GTX file rotated 1.61 times as long, and this was significantly longer than the Endo Sequence (p = <.0001). For the tip/taper combination 30/.04, the GTX file rotated 3.67 times as long, and this was significantly longer than the Endo Sequence (p = <.0001). For the tip/taper combination 30/.06, the GTX file rotated 2.63 times as long, and this was significantly longer than the Endo Sequence (p = <.0001). For the tip/taper combination 40/.04, the GTX file rotated 1.22 times as long, but this was not significantly different than the Endo Sequence (p = 0.0707). For the tip/taper combination 40/.06, the GTX file rotated 4.05 times as long, and this was significantly longer than the Endo Sequence (p = <.0001).

Table 2: Estimated Rotations to Failure

Tip	Taper	Brand	Rotations			p-value
			Mean	95% CI		
20	.04	GTX	969.94	832.57	1129.97	
		Sequence	693.89	595.61	808.38	
		Ratio	1.40	1.13	1.73	0.0027
20	.06	GTX	436.63	374.79	508.68	
		Sequence	271.77	233.28	316.61	
		Ratio	1.61	1.30	1.99	<.0001
30	.04	GTX	861.44	739.44	1003.58	
		Sequence	234.67	201.44	273.40	
		Ratio	3.67	2.96	4.54	<.0001
30	.06	GTX	618.65	531.03	720.72	
		Sequence	235.12	201.82	273.91	
		Ratio	2.63	2.12	3.26	<.0001
40	.04	GTX	691.07	593.19	805.09	
		Sequence	566.44	486.22	659.90	
		Ratio	1.22	0.99	1.51	0.0707
40	.06	GTX	398.13	341.74	463.82	
		Sequence	98.34	84.41	114.56	
		Ratio	4.05	3.27	5.01	<.0001

Figure 2: Geometric Mean Rotations to Failure



Discussion

A marketing research firm polled dentists and found the most important characteristics when choosing a rotary file system was resistance to breakage, ability of the file to cut while remaining centered in the canal, and the file's cutting efficiency (12). Engine driven NiTi instruments are subjected to both tensile and compressive forces in the area of curvature of the canal during each full rotation. The NiTi instruments experience compressive forces on the inside of the curve and tensile forces on the outside of the curve. These forces are destructive and cause the files to weaken with each rotation. The lost tactile appreciation of files used during rotary instrumentation versus hand instrumentation is further reason to find more fracture resistant materials (6,13,19). It was with these factors in mind that this study was undertaken. Does the Brassler ® Endo Sequence or the M-Wire function differently under conditions of cyclic stress that would make one file or the other a file of choice for the dentist seeking a file that would withstand the stresses of cyclic fatigue?

In this study, files were tested using an apparatus that was designed and constructed to produce a low resistant surface upon which files could be rotated at 300 rpm while maintaining the same angle for comparable tip size and taper (15). It has been shown speed is not a factor in file failure but rather the number of rotations a file makes that leads to fracture (15).

It has also been shown that larger files tend to fracture with fewer rotations than smaller files (6,15). Our findings were consistent with those findings. All size 40/.06 files failed with fewer rotations than the size 20/.06 of the same brands. This appears to be related to greater stiffness of the larger files leading to more distortion and fracture propagation along the stress points. A greater amount of force is required to maintain the larger files at a constant angle of curvature; therefore, force is transferred to the rotating file leading to file fracture.

The Schneider method was employed to determine the angle at which the files would be tested (20). This method for angle determinations is very subjective and somewhat arbitrary. It is suspect to personal interpretation; however, all the files in this study were rotated at the same angles of deflection regardless of the actual Schneider angle as related to tip and taper.

Did the Brassler® Endo Sequence files or the M-Wire function differently under condition of cyclic stress? Results showed that the M-wire GT® Series X ™ files were more resistant to fracture than the Endo Sequence files by Brassler® (Savannah, GA) rotary instruments in all selected files. The M-wire GT® Series X ™ files were statistically significant to resistant to fracture for the following tip and taper sizes: 20/.04, 20/.06, 30/.04, 30/.06 and 40/.06. However, the tip and taper size, 40/.04, was not statistically significant.

Other studies have suggested that during the manufacture and grinding of the metal, surface imperfections are introduced in the NiTi . These imperfections result in areas of stress along the file. It is along these stress points that the file is more likely to separate when the file is fatigued. This manufacturing process can be significantly different for the same brand of files depending upon where the files are manufactured (16,18). In this case, a file is prone to fracture depending upon the number of stress points introduced into the file during manufacture. Its resistance to cyclic fatigue may then be dependent upon the manufacturing process and not upon whether it is M-Wire versus traditional nitinol.

Treatment of a file after manufacture may or may not result in resistance to fracture. The electro-polishing of Endo Sequence to remove surface irregularities may not contribute increased resistance to cyclic fatigue as suggested by the manufacture (17).

File design has been suggested to play a large role in a files ability to resist fracture. Johnson et al. concluded file design was not a factor in the increase resistance to cyclic fatigue of the new M-wire. The findings herein are consistent with Johnson et. al, suggesting that M-wire had an increased resistance to cyclic fatigue (18).

Kramkowski and Bahcall concluded M-wire did not improve resistance to fracture during testing (21). The study herein and the Kramkowski study utilized different methodologies and compared different rotary files.

The inconsistency in data results between studies suggest that not enough evidence exists to state unequivocally that the M-Wire material significantly increases a files ability to resist cyclic fatigue. However in this study it was concluded that the M-wire GT® Series X ™ consistently had more rotations to fracture by cyclic fatigue compared to Endo Sequence for all tip and tapers except for tip and taper 40/.04.

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