2009

COMPARATIVE ANALYSIS OF TORSIONAL STRENGTH BETWEEN PROFILE® GT® AND GT® SERIES X(TM) NICKEL TITANIUM ROTARY INSTRUMENTS

Jake Reynolds
Virginia Commonwealth University

School of Dentistry
Virginia Commonwealth University

This is to certify that the thesis prepared by Jake Reynolds entitled Comparative Analysis of Torsional Strength Between ProFile® GT® and GT® Series X$^{\text{TM}}$ Nickel Titanium Rotary Instruments has been approved by his or her committee as satisfactory completion of the thesis or dissertation 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

B. Ellen Byrne, DDS, 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

April 21, 2009

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

by

JAKE REYNOLDS
D.M.D., Case Western Reserve University, 2004
B.S. Zoology, Idaho State University, 2000

Interim Program Director: KARAN J. REPLOGLE, DDS, MS
INTERIM CHAIR, DEPARTMENT OF ENDODONTICS

Virginia Commonwealth University
Richmond, Virginia
June 2009

Acknowledgement

Thank you to Dr. Al Best for his statistical design and to Dr. Spiro Megermis at the ADA research lab for his technical assistance and literary support. Also thank you to Dr. Karan Replogle, Dr. James Lance, and Mrs. Jocelyn Lance for their help and support in writing this thesis. Thank you to Tulsa – Dentsply for their donation of all rotary files used in this research project.

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Abstract

COMPARATIVE ANALYSIS OF TORSIONAL STRENGTH BETWEEN PROFILE® GT® AND GT® SERIES X^{TM} NICKEL TITANIUM ROTARY INSTRUMENTS

By Jake Reynolds, D.M.D.

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

Virginia Commonwealth University, 2009

Interim Program Director: Karan J. Replogle, DDS, MS
Interim Chairperson, Department of Endodontics

The purpose of this study was to compare the resistance to fracture by the twisting of two nickel titanium (NiTi) rotary file systems. The Profile® GT® (GT) and the GT® Series X^{TM} (GTX) files were tested to analyze the maximum torsional strength and the maximum angular deflection at the time of separation of the files. For each system, ten new files were tested at each of the following eight taper/size designations for a total of 160 files: 20/0.04, 20/0.06, 30/0.04, 30/0.06, 30/0.08, 40/0.04, 40/0.06, and 40/0.08. The American National Standards Institute / American Dental Association Specification No. 28

was implemented to evaluate torsional limits for these intruments. Files were mounted in a Maillefer Torsiometre machine, which records maximum torsional strength and angular deflection at separation for each file. A two-way ANOVA revealed significant differences after comparing the size and type of file. The GT files required significantly more torque to separate than the GTX files in all groups tested except the GTX file size 20/0.06, which required significantly more maximum torque than the GT file, with no significant difference between the GT and GTX files for size 30/0.04. The GT files exhibited values for angular deflection at separation that were significantly higher than those for the GTX files at sizes 30/0.04 and 40/0.08 and the GTX files exhibited higher values at size 30/0.08 with no significant difference between the brands at the remaining five file sizes. In summary, the GT files required significantly more torque to fracture and exhibited values for angular deflection at separation that were significantly higher than the GTX files for in 6 of 8 and 2 of 8 file sizes, respectively.

Introduction

Endodontic cleaning and shaping is performed using chemomechanical methodology of irrigation and instrumentation. Historically, shaping was achieved by using carbon steel and stainless steel instruments with the objective of forming a funnel shape that is a continuous taper from the canal orifice to the apical constriction (1). The invention of nickel-titanium (NiTi, nitinol) alloy and rotary instrumentation systems, that make use of the NiTi alloy, have attempted to decrease procedural errors such as transporting, zipping, and ledging by the increased elasticity of the instrument. Compared to stainless steel, NiTi has two to three times more elastic flexibility and superior resistance to fracture than stainless steel. (2).

Hilt et al. (3) discussed many factors that can affect the maximum torsional strength and/or angular deflection at separation of an endodontic file. Some of these factors were the following: "1) size and design of the instrument (4), 2) metal alloy combinations and stiffness (2, 5), 3) mode of manufacture (6), 4) flexibility and shape (7), 5) direction of rotation (8, 9), and 6) manufacturer's design variations of the individual file (10)." Any one of these factors or a combination of them may play a role in the unwanted fracture of an endodontic file as it binds on the dentinal wall of a tooth. Endodontic shaping and cleaning of a narrow or curved canal can also lead to file failure as a result of its design limits being exceeded (3).

The ProFile® GT® (GT) nickel-titanium rotary instruments (Tulsa Dental Products, Tulsa, OK) are a widely used and accepted instrumentation system. The GT taper files have a radial land design. A radial land is the surface between the cutting edges that projects axially from the center of the file as shown in Figure 1. The manufacturer claims that this design will lift debris out of the canal (11).

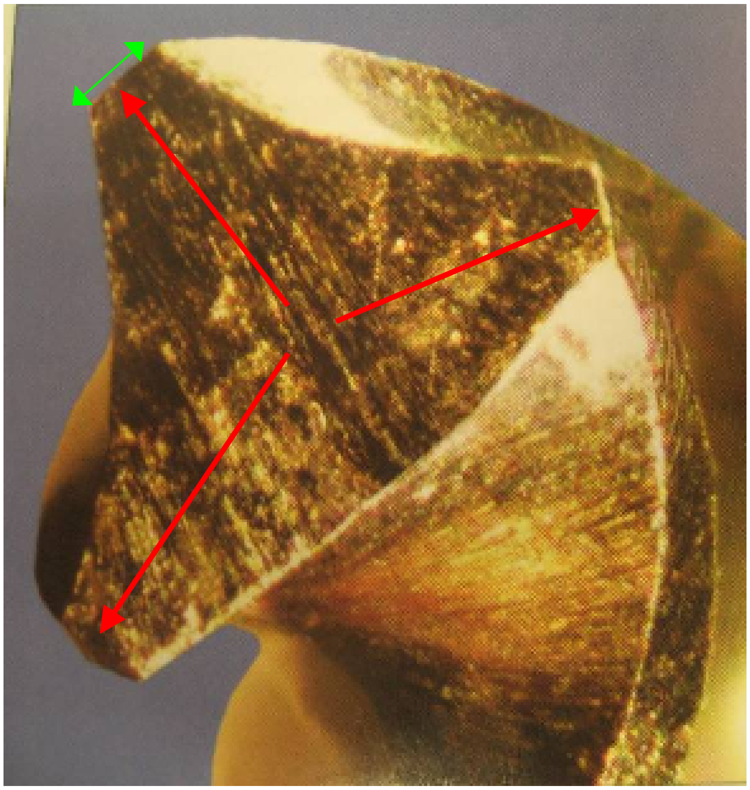
A new rotary NiTi file system now being marketed (Tulsa Dental Products, Tulsa, OK) is called the GT Series X rotary system (GTX). These files are fabricated from M-Wire™ NiTi which is “a variant NiTi alloy composed of 508 Nitinol, which has undergone a proprietary method of treatment, comprised of drawing the raw wire under specific tension and heat treatments at various temperatures resulting in a material that includes some portion of both the martensitic and the premartensitic R phase while maintaining a pseudoelastic state” (12). The GTX instruments also differ from the GT instruments in that they include fewer cutting flutes and wider, more open blade angles that significantly reduce core mass (11). As a result of these differences, the manufacturer claims the GTX instruments are faster cutting with increased flexibility to follow curved canals and have greater resistance to cyclic fatigue and file separation (11). The M-Wire™ NiTi was found to be nearly 400% more resistant to cyclic fatigue than other variants of NiTi, all with a ProFile® 25/.04 design. Torsional testing found differences between all 508 Nitinol groups and M-Wire™ NiTi (12).

The physical characteristics of cross-sectional stainless steel file designs have proven to have an effect on the resistance to torsional separation, as determined by Schafer and Tepel (13). The GT and GTX file systems have different NiTi alloys and slightly different cross-sectional designs which may result in torsional strength differences.

The American National Standards Institute / American Dental Association (ANSI/ADA) Specification No. 28 (14) is a static torque test to evaluate the torsional strength of an instrument. The protocol lists certain torsional property requirements for stainless steel endodontic hand files and the procedures for testing.

The purpose of this study was to compare the resistance to fracture by the twisting of two NiTi rotary file systems. The GT and GTX file systems were tested to analyze the maximum torque and angular deflection at file separation.

Figure 1: Radial lands projected axially from center



Materials and Methods

Torsional testing was conducted on ten new files of each brand, taper and size for a total of one hundred and sixty files. The GT and GTX files tested were 25-mm in length with the following tip size and taper: 20/0.04, 20/0.06, 30/0.04, 30/0.06, 30/0.08, 40/0.04, 40/0.06, and 40/0.08.

Each instrument was tested for maximum torsion strength and angular defection at separation according to a test procedure similar to the one set forth in ANSI/ADA Specification No. 28 (14) using a modified Maillefer Torsiometre, as shown in Figure 2. This apparatus measured torque with an accuracy of ±0.1 mNm and had a load cell capacity of 720 gm-cm. It also measured the angular deflection with an accuracy of ±2°. The apparatus consisted of a reversible geared motor revolving at a speed of 2 RPM which drove a test instrument by means of a separate hardened steel chuck. It also had a torque measuring device fixed on two linear bearings. Mounted to the shaft of the device was a chuck with jaws made of soft brass alloy used to clamp the file at the tip of the working part along a length of 3 mm. The equipment recorded the maximum torque during testing, along with the angular deflection at the failure point.

Before each group of file size was tested, the device was calibrated for the torque range of the instrument size to be tested. This was accomplished by using various sizes of brass weights on a balance bar attached to the torsiometre. The handle of each file was removed with wire cutters at the point at which the handle is attached to the instrument shaft. The instrument shank was set into the driving chuck leaving a maximum of 1 mm of the unground portion of the shank outside of the chuck and the chuck was tightened. The torque device was slowly slid along the linear ball bearing until the tip of the instrument entered 3 mm into the brass jaws, as shown in Figure 3. The instruments were straightened and centered into the jaws and the brass jaw chuck was tightened, as shown in Figure 4. When the clamping caused a pre-load stress on the instrument, the gear motor was activated in steps until the torque display read zero. Once the geared motor was set for clockwise rotation, as viewed from the shank of the root-canal instrument, the device was activated. The test device ceased operation automatically when the instrument separated. The maximum torsion strength and angular deflection at separation for each root canal instrument tested was recorded.

Figure 2: Maillefer Torsiometre

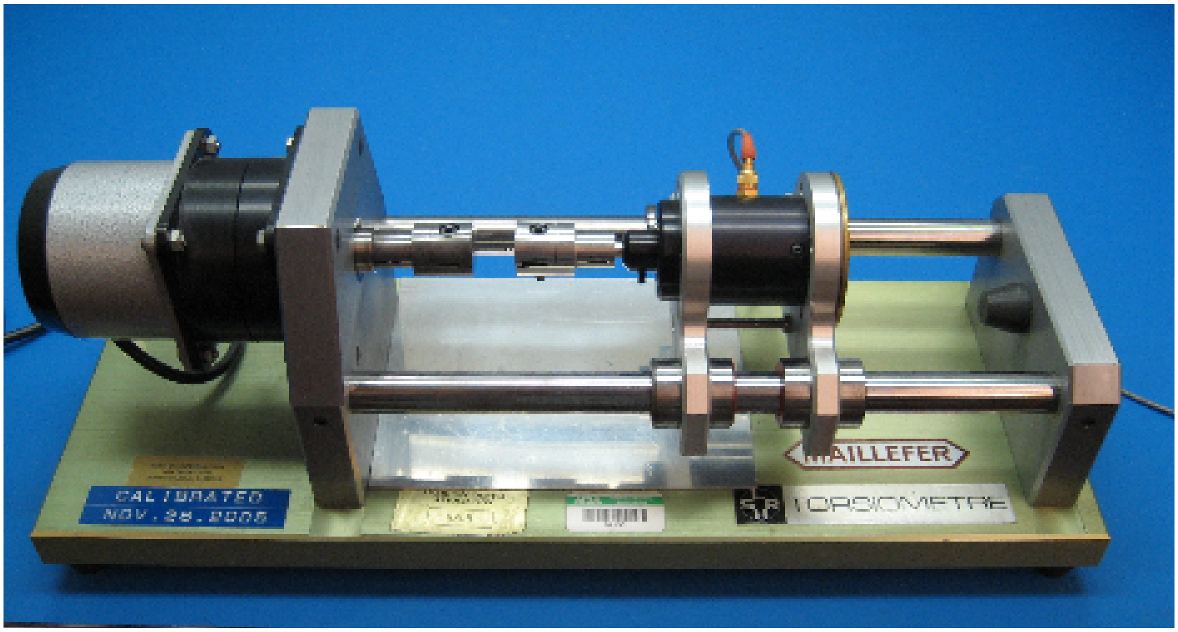


Figure 3: File tip 3 mm into brass jaws

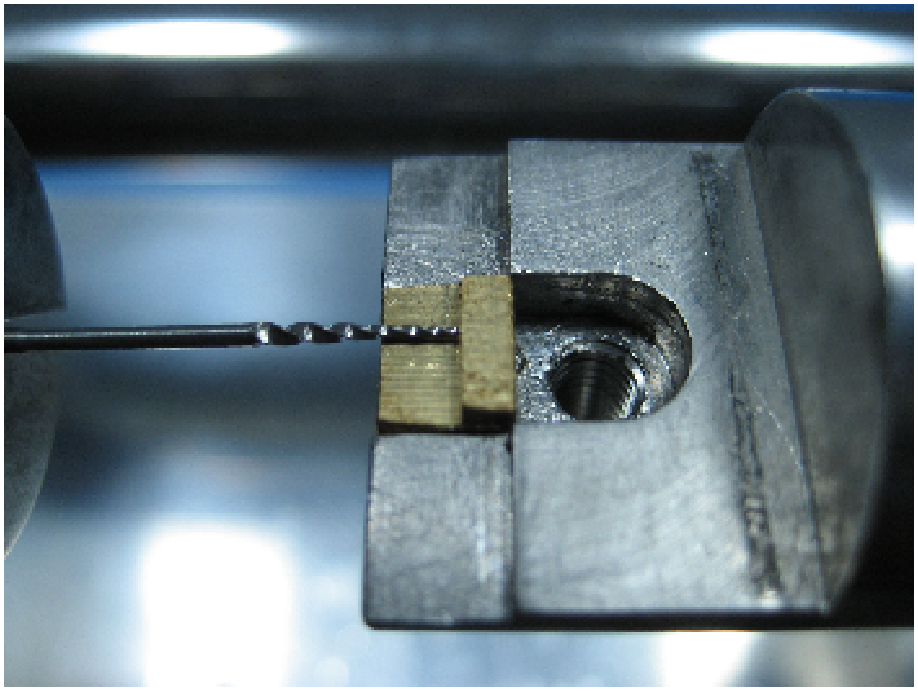
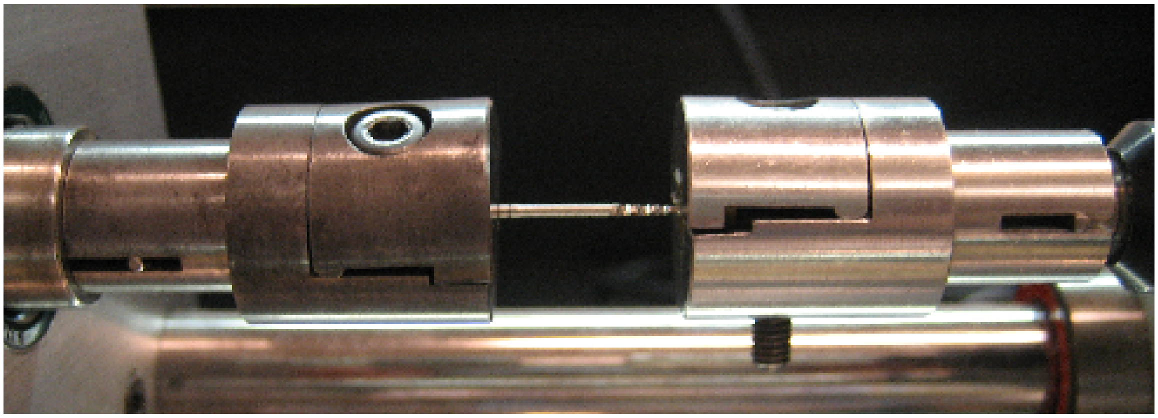


Figure 4: File perpendicular to axis of brass jaws and motor



Results

The maximum torsion strength before failure was skewed and so the log-transformed values were analyzed. This satisfied the assumptions of ANOVA, equal variability and normality. The angular deflection at separation values satisfied the assumptions of ANOVA without transformation and the original values were analyzed. 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 for maximum torque yield the geometric mean rotation, and are shown in the summary tables.

The two response variables, maximum torque and maximum angular deflection are reported separately. First, the maximum torque values for each condition are shown in Figure 55. The range of values for each of the test conditions are shown in Table 1.

The two-way ANOVA with brand, size, and the brand by size interaction indicated that the 16 groups were significantly different ($F(15, 144) = 407$, $p < .0001$). Since the brand-size interaction was significant ($F(7, 144) = 9.8$, $p < .0001$), the brand differences are not the same within each tip/taper combination.

The geometric mean torque estimates were compared for each tip/taper file size and the brand as shown in Table 2. Using a 95% CI and the p-values calculated, the significance was indicated. This comparison is also demonstrated without the raw data in Figure 6.

For the tip/taper combination 20/0.04, the GT file required 1.19 times more torque to fracture, and this was significantly more than the GTX file (p = 0.0001). For the tip/taper combination 20/0.06, the GT file required 0.92 times the torque to fracture, and this was significantly less than the GTX file (p = 0.0398). For the tip/taper combination 30/0.04, the GT file required 0.97 times the torque to fracture, and this was not significantly different than the GTX file (p = 0.5079). For the tip/taper combination 30/0.06, the GT file required 1.23 times more torque to fracture, and this was significantly more than the GTX file (p = <.0001). For the tip/taper combination 30/0.08, the GT file required 1.35 times more torque to fracture, and this was significantly more than the GTX file (p = <.0001). For the tip/taper combination 40/0.04, the GT file required 1.25 times more torque to fracture, and this was significantly more than the GTX file (p = <.0001). For the tip/taper combination 40/0.06, the GT file required 1.15 times more torque to fracture, and this was significantly more than the GTX file (p = 0.0011). For the tip/taper combination 40/0.08, the GT file required 1.11 times more torque to fracture, this was significantly more than the GTX (p = 0.0164).

Second, the rotational angle to deflection was analyzed. The angles observed are shown in Figure 7 and Table 3.

The ANOVA results indicated that the 16 groups were significantly different (F (15, 144) = 16.8, p < .0001). Again, the differences between the brands were not consistent across the tip/taper combinations [F (7, 144) = 6.6, p < .0001]. The LSMean for each experimental condition is shown in Figure 8 and Table 4.

For the tip/taper combination 20/0.04, the GT file rotated 50.5 degrees further, but this was not significantly further than the GTX (p = 0.2069). For the tip/taper combination 20/0.06, the GT file rotated -19.4 degrees further. This was not significantly further than the GTX (p = 0.6270). For the tip/taper combination 30/0.04, the GT file rotated 167.7 degrees further. This was significantly further than the GTX (p < .0001). For the tip/taper combination 30/0.06, the GT file rotated -39.4 degrees further. This was not significantly further than the GTX (p = 0.3243). For the tip/taper combination 30/0.08, the GT file rotated -164.7 degrees further. This was significantly further than the GTX (p = 0.0001). For the tip/taper combination 40/0.04, the GT file rotated -52.3 degrees further. This was not significantly further than the GTX (p = 0.1913). For the tip/taper combination 40/0.06, the GT file rotated -29.4 degrees further. This was not significantly further than the GTX (p = 0.4617). For the tip/taper combination 40/0.08, the GT file rotated 102.9 degrees further. This was significantly further than the GTX (p = 0.0108).

Figure 5: Maximum Torque for Each Test Condition

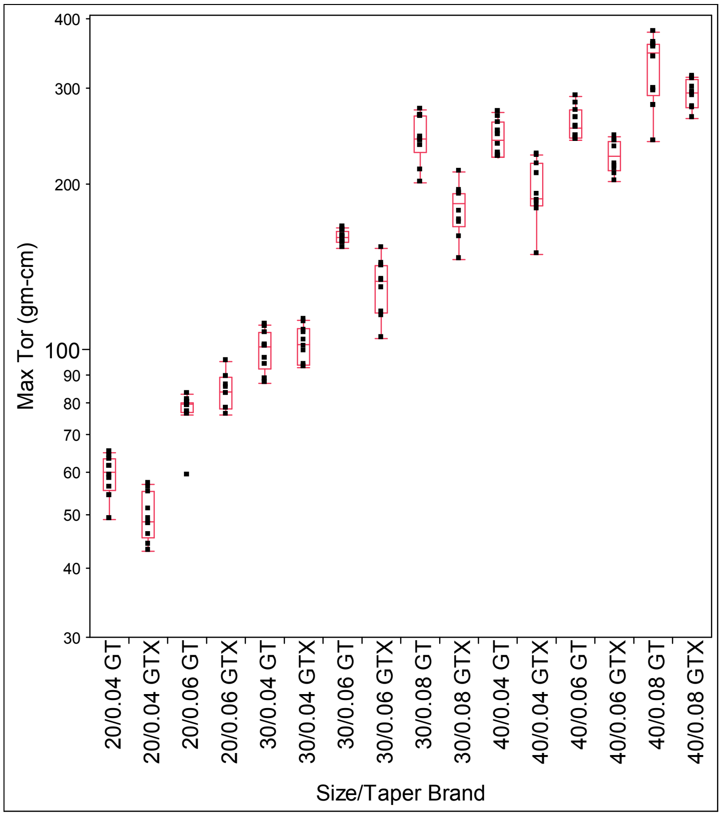


Table 1: Maximum Torque for Each Test Condition

		Maximum Torque (gm-cm)		
Tip/Taper	Brand	Minimum	Median	Maximum
20/0.04	GT	49.0	60.0	65.0
	GTX	43.0	48.5	57.0
20/0.06	GT	59.0	79.5	83.0
	GTX	76.0	84.0	95.0
30/0.04	GT	87.0	101.0	111.0
	GTX	93.0	102.5	113.0
30/0.06	GT	153.0	160.0	167.0
	GTX	105.0	133.5	153.0
30/0.08	GT	201.0	242.0	273.0
	GTX	146.0	184.5	211.0
40/0.04	GT	224.0	241.0	271.0
	GTX	149.0	189.0	227.0
40/0.06	GT	241.0	254.0	289.0
	GTX	202.0	225.5	244.0
40/0.08	GT	240.0	347.5	379.0
	GTX	264.0	293.5	314.0

Figure 6: Average Torque for Each Experimental Condition

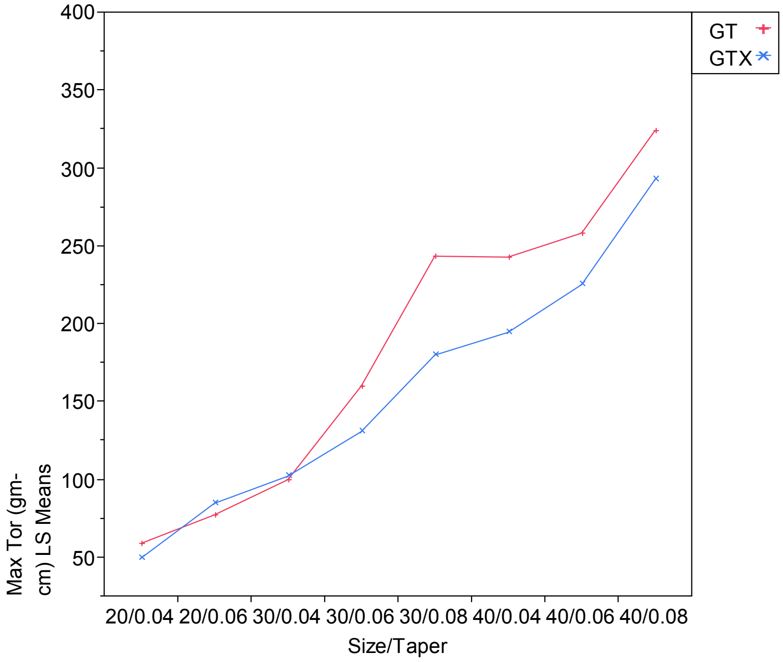


Table 2: Geometric Mean Torque Estimates for Each Condition

			Maximum Torque (gm-cm)			
Tip	Taper	Brand	Mean	95% CI		p-value
20	0.04	GT	58.81	55.50	62.31	
		GTX	49.48	46.70	52.43	
		Ratio	1.19	1.10	1.29	0.0001
	0.06	GT	77.09	72.76	81.69	
		GTX	84.02	79.29	89.02	
		Ratio	0.92	0.85	1.00	0.0398
30	0.04	GT	99.37	93.78	105.30	
		GTX	102.15	96.40	108.24	
		Ratio	0.97	0.90	1.06	0.5079
	0.06	GT	159.95	150.95	169.48	
		GTX	130.50	123.16	138.28	
		Ratio	1.23	1.13	1.33	<.0001
	0.08	GT	243.18	229.49	257.68	
		GTX	179.66	169.55	190.37	
		Ratio	1.35	1.25	1.47	<.0001
40	0.04	GT	242.21	228.58	256.65	
		GTX	194.11	183.19	205.68	
		Ratio	1.25	1.15	1.35	<.0001
	0.06	GT	258.00	243.49	273.39	
		GTX	224.81	212.16	238.22	
		Ratio	1.15	1.06	1.25	0.0011
	0.08	GT	323.52	305.32	342.81	
		GTX	292.54	276.08	309.98	
		Ratio	1.11	1.02	1.20	0.0164

Figure 7: Rotation to Deformation for Each Experimental Condition

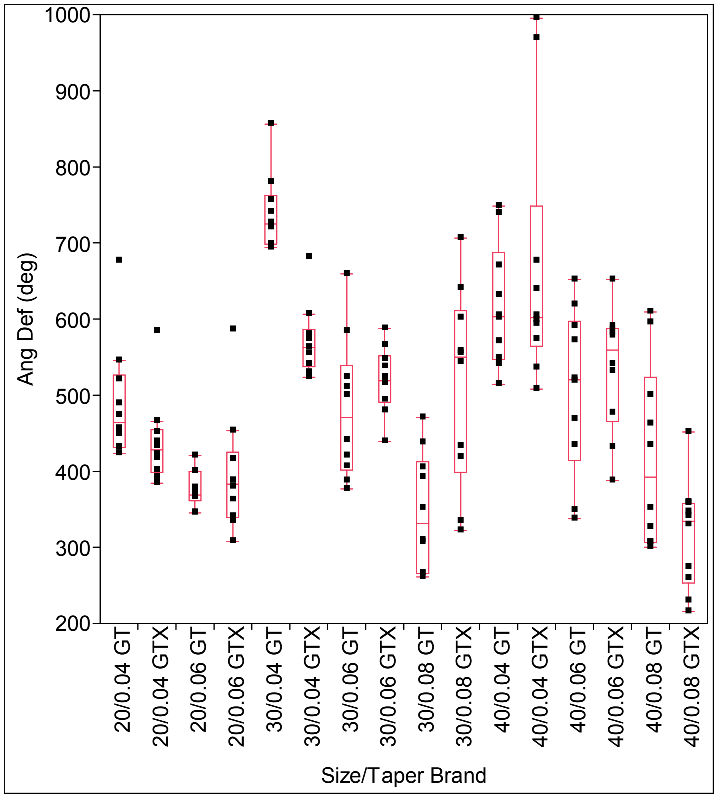


Table 3: Rotation to Deformation for Each Experimental Condition

		Angle Deformation (degrees)		
Tip/Taper	Brand	Minimum	Median	Maximum
20/0.04	GT	423	464.5	676
	GTX	384	427.5	585
20/0.06	GT	346	369.5	421
	GTX	308	383.0	586
30/0.04	GT	693	725.0	856
	GTX	523	562.5	681
30/0.06	GT	377	470.5	659
	GTX	439	519.5	588
30/0.08	GT	261	331.0	471
	GTX	322	549.5	706
40/0.04	GT	514	603.5	749
	GTX	508	601.5	996
40/0.06	GT	338	520.5	651
	GTX	387	559.5	652
40/0.08	GT	300	392.5	609
	GTX	216	335.0	452

Figure 8: Rotational Angle

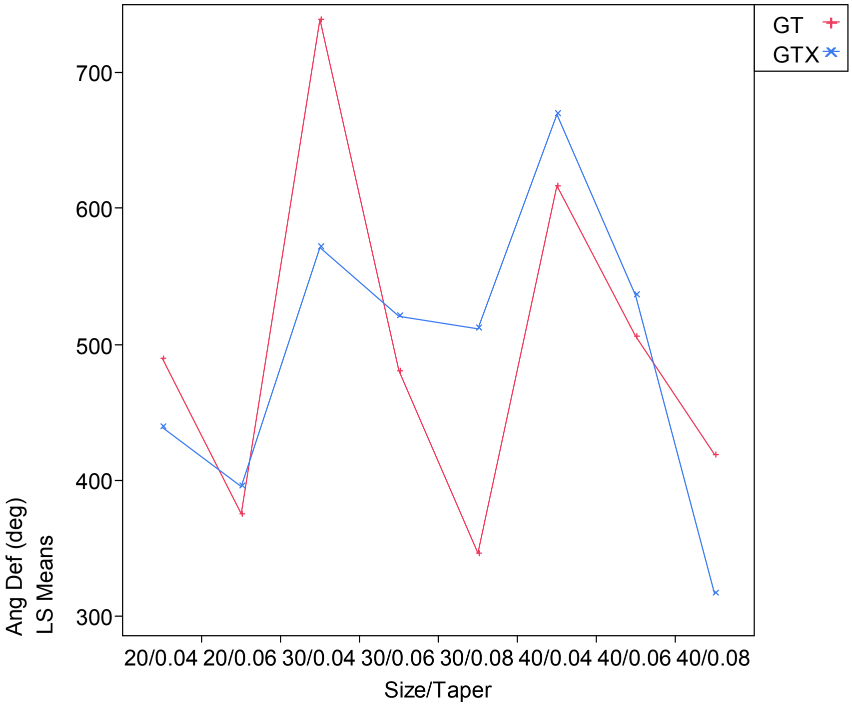


Table 4: Mean Angle for Each Experimental Condition

			Angle Deformation (degrees)			
Tip	Taper	Brand	Mean	95% CI		p-value
20	0.04	GT	489.50	433.82	545.18	
		GTX	439.00	383.32	494.68	
		Difference	50.50	-27.58	128.58	0.2069
	0.06	GT	376.00	320.32	431.68	
		GTX	395.40	339.72	451.08	
		Difference	-19.4	-97.47856	58.6786	0.6270
30	0.04	GT	738.90	683.22	794.58	
		GTX	571.20	515.52	626.88	
		Difference	167.7	89.62144	245.779	<.0001
	0.06	GT	481.20	425.52	536.88	
		GTX	520.60	464.92	576.28	
		Difference	-39.4	-117.4786	38.6786	0.3243
	0.08	GT	346.60	290.92	402.28	
		GTX	511.30	455.62	566.98	
		Difference	-164.7	-242.7786	-86.621	0.0001
40	0.04	GT	617.10	561.42	672.78	
		GTX	669.40	613.72	725.08	
		Difference	-52.3	-130.3786	25.7786	0.1913
	0.06	GT	506.30	450.62	561.98	
		GTX	535.70	480.02	591.38	
		Difference	-29.4	-107.4786	48.6786	0.4617
	0.08	GT	419.40	363.72	475.08	
		GTX	316.50	260.82	372.18	
		Difference	102.9	24.82144	180.979	0.0108

Discussion

The purpose of this study was to compare the resistance to fracture by the twisting of two NiTi rotary file systems. The Profile® GT® and the GT® Series X^{TM} files were tested to analyze the maximum torque and angular deflection at the separation. Results determining torsional strength differences may result in a difference in a files resistance to fracture which may have clinical implication.

A static torque test from the American National Standards Institute / American Dental Association (ANSI/ADA) Specification No. 28 “Root Canal Files and Reamers, Type K for Hand Use” (14) was used to evaluate the torsional limits for these instruments. The scope of Specification No. 28 stating that it pertains to “endodontic files and reamers for hand use only”, leads to question why it is still being used for the torsional strength testing of rotary files. Until a different methodology is created, it will continue to be used (12, 15).

The GT files required significantly more torque to separate than the GTX files in all groups tested except for the GTX files size 20/0.06 and the GTX file size 30/0.04. The GTX 20/0.06 files exhibited significantly greater values for average maximum torque than the GT 20/0.06 file, and there was no significant difference between the GT and the GTX files size 30/0.04.

The GT files exhibited values for angular deflection at separation that were significantly higher than those for the GTX files at two sizes, 30/0.04 and 40/0.08. On the other hand, the GTX files exhibited values for angular deflection at separation that were significantly higher than those for the GT files at size 30/0.08. There were no significant differences in the values for angular deflection at separation for the remaining groups. In summary, the GT files required significantly more torque to fracture than the GTX files in six of the eight groups tested. The GT files required significantly more angular deflection to fracture than the GTX files in two of the eight groups.

Upon further evaluation of the statistical outcome for the torsional strength values, it was noted that the p-values for the tip/taper groups 20/0.06, $p = 0.0398$, and 40/0.08, $p = 0.0164$, approximated the initially established alpha = 0.05. Therefore, the significance of GTX requiring more torque to fracture than GT with these two file sizes may not be a valid statement. To make the p-value more stringent then a Bonferroni corrected alpha level was calculated. The Bonferroni correction is a statistical adjustment for the p-value that effectively raises the standard of proof needed to show a statistical difference. The corrected alpha level would then be alpha = 0.0063. If this alpha were implemented, then the existing p-value = 0.0398 for 20/0.06 and the p-value = 0.0164 for 40/0.08 would no longer show a significant difference. The results would thus show that only the GT files required significantly more torque to fracture. The same applies to the angular deflection with the tip/taper 40/0.08 group. The results indicate that the GT required more angular deflection to separate, however, if the corrected alpha = 0.0063 were used then the p-value of this group would not show a significant difference. The results would show one group where GT required significantly more angular deflection and one group where GTX required significantly more.

One plausible reason for the results would be the difference in file design between the two systems. The GT has a triangular cross section with radial lands the same width along the working length of the file. The GTX also has radial lands, but the widths vary along the working length of the file. They are narrow at the tip region, wider at mid-file, and narrow again at the shank region. The GTX also has double the pitch distance and a decreased helical angle when compared to the GT (11). Due to these differences, the resistance to fracture by twisting of one design may be superior to another. It is important to recognize that the torque required for instrumentation of an individual canal could be reduced by a file's cross section and cutting efficiency, thus reducing possibility of fracture.

When clamping the working length of the file at 3 mm, one may consider that you could be clamping the GTX file at the transition point between the narrower lands at the tip and the wider lands at mid-file. This particular transition may be considered a weaker point in the file design, therefore, more prone to fracture when clamped at this particular juncture. Because the working length of each file size is different, this area of transition changes with each size. This could result in premature fracture of the GTX file when clamped at a transition point.

Johnson et al. (12) sought to eliminate the factors in file design by using a 25/.04 ProFile made of different NiTi alloys, including 508 Nitinol alloy and M-Wire™. They found no significant differences between variant NiTi groups and M-Wire™ NiTi.

Also, Kramkowski et. al. (15) performed a similar study comparing GT and GTX. The results had shown neither brand required significantly greater torque to fracture. The angular deflection also demonstrated neither brand was significantly superior to the other, except for the 20/0.04 GT which required significantly more rotation to fracture than the same size GTX.

However, in the present study, the GT files required significantly more torque to fracture than the GTX in several file sizes, therefore, the M-Wire™ NiTi, used in the GT Series X file design, was not overall more resistant to fracture compared to the NiTi used in the Profile GT file design.

Conclusion

The present study showed that GT files required significantly more torque to fracture than the GTX files in sizes 20/0.04, 30/0.06, 30/0.08, 40/0.04, 40/0.06, and 40/0.08. The GTX files demonstrated significantly more torque to fracture in size 20/.06, and in size 30/.04 there was no significant difference between the two file brands. Also, the GT files exhibited values for angular deflection at separation that were significantly higher than those for the GTX files in sizes 30/0.04 and 40/0.08. The GTX files exhibited values for angular deflection at separation that were significantly higher than those for the GT files at size 30/0.08, and there were no significant differences in values for angular deflection at separation between the two file brands for the remaining five file sizes.

Overall, the Profile® GT® files were more resistant to fracture due to torsional stresses than the GT® Series X^{TM} files. Further testing is recommended using the M-Wire™ in different file designs.

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Literature Cited

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APPENDIX A

Raw Data Table

No.	Size	Taper	Brand	Max Tor (gm-cm)	Ang Def (deg)
1	20	0.04	GTX	49	384
2	20	0.04	GTX	57	439
3	20	0.04	GTX	56	465
4	20	0.04	GT	56	546
5	20	0.04	GT	61	456
6	20	0.04	GT	64	489
7	20	0.04	GTX	48	392
8	20	0.04	GT	59	432
9	20	0.04	GTX	44	585
10	20	0.04	GTX	46	433
11	20	0.04	GT	54	473
12	20	0.04	GT	63	448
13	20	0.04	GTX	51	452
14	20	0.04	GT	61	423
15	20	0.04	GT	58	520
16	20	0.04	GTX	48	417
17	20	0.04	GT	65	432
18	20	0.04	GTX	43	422
19	20	0.04	GTX	55	401
20	20	0.04	GT	49	676
21	20	0.06	GTX	76	453
22	20	0.06	GTX	86	388
23	20	0.06	GTX	95	586
24	20	0.06	GT	80	372
25	20	0.06	GT	83	421
26	20	0.06	GT	79	400
27	20	0.06	GTX	83	379
28	20	0.06	GT	81	378
29	20	0.06	GTX	89	308
30	20	0.06	GTX	78	335
31	20	0.06	GT	59	400
32	20	0.06	GT	80	346
33	20	0.06	GTX	78	362

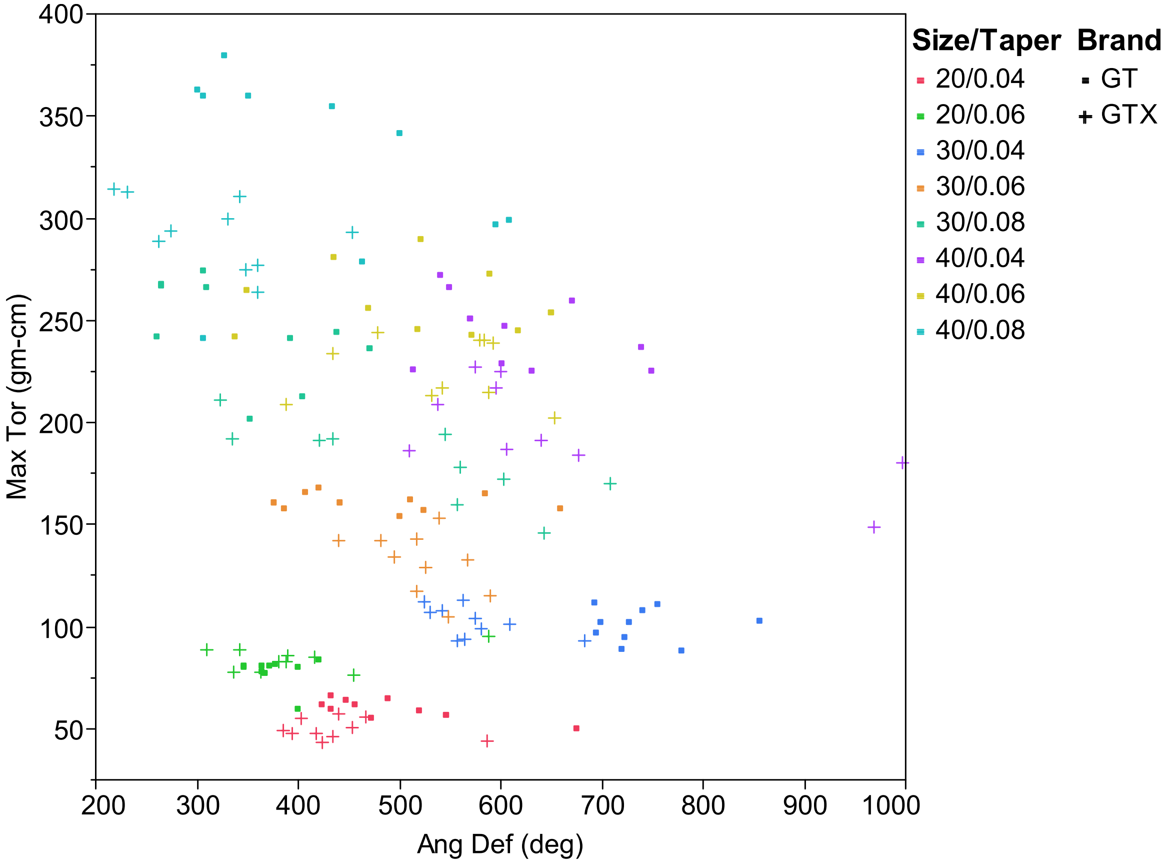
34	20	0.06	GT	80	365
35	20	0.06	GT	76	367
36	20	0.06	GTX	83	387
37	20	0.06	GT	77	365
38	20	0.06	GTX	89	341
39	20	0.06	GTX	85	415
40	20	0.06	GT	79	346
41	30	0.04	GTX	99	579
42	30	0.04	GTX	113	562
43	30	0.04	GTX	107	529
44	30	0.04	GT	107	741
45	30	0.04	GT	101	699
46	30	0.04	GT	94	723
47	30	0.04	GTX	94	563
48	30	0.04	GT	110	756
49	30	0.04	GTX	101	607
50	30	0.04	GTX	93	555
51	30	0.04	GT	102	856
52	30	0.04	GT	96	695
53	30	0.04	GTX	104	573
54	30	0.04	GT	111	693
55	30	0.04	GT	101	727
56	30	0.04	GTX	93	681
57	30	0.04	GT	88	720
58	30	0.04	GTX	112	523
59	30	0.04	GTX	108	540
60	30	0.04	GT	87	779
61	30	0.06	GTX	142	439
62	30	0.06	GTX	153	538
63	30	0.06	GTX	143	515
64	30	0.06	GT	165	407
65	30	0.06	GT	157	387
66	30	0.06	GT	157	659
67	30	0.06	GTX	129	524
68	30	0.06	GT	164	585
69	30	0.06	GTX	115	588
70	30	0.06	GTX	142	480
71	30	0.06	GT	167	421
72	30	0.06	GT	160	377
73	30	0.06	GTX	133	566
74	30	0.06	GT	160	441
75	30	0.06	GT	161	511
76	30	0.06	GTX	105	547
77	30	0.06	GT	156	524
78	30	0.06	GTX	134	494

79	30	0.06	GTX	117	515
80	30	0.06	GT	153	500
81	30	0.08	GTX	172	601
82	30	0.08	GTX	192	334
83	30	0.08	GTX	178	558
84	30	0.08	GT	212	405
85	30	0.08	GT	243	438
86	30	0.08	GT	266	265
87	30	0.08	GTX	170	706
88	30	0.08	GT	265	310
89	30	0.08	GTX	191	419
90	30	0.08	GTX	194	544
91	30	0.08	GT	241	261
92	30	0.08	GT	273	307
93	30	0.08	GTX	211	322
94	30	0.08	GT	235	471
95	30	0.08	GT	201	352
96	30	0.08	GTX	160	555
97	30	0.08	GT	240	392
98	30	0.08	GTX	192	433
99	30	0.08	GTX	146	641
100	30	0.08	GT	267	265
101	40	0.04	GTX	187	604
102	40	0.04	GTX	217	594
103	40	0.04	GTX	225	599
104	40	0.04	GT	271	541
105	40	0.04	GT	250	570
106	40	0.04	GT	265	549
107	40	0.04	GTX	209	536
108	40	0.04	GT	246	605
109	40	0.04	GTX	184	676
110	40	0.04	GTX	227	574
111	40	0.04	GT	236	739
112	40	0.04	GT	259	671
113	40	0.04	GTX	191	639
114	40	0.04	GT	224	631
115	40	0.04	GT	224	749
116	40	0.04	GTX	186	508
117	40	0.04	GT	228	602
118	40	0.04	GTX	180	996
119	40	0.04	GTX	149	968
120	40	0.04	GT	225	514
121	40	0.06	GTX	244	477
122	40	0.06	GTX	234	432
123	40	0.06	GTX	213	531

124	40	0.06	GT	264	349
125	40	0.06	GT	272	590
126	40	0.06	GT	245	519
127	40	0.06	GTX	215	586
128	40	0.06	GT	289	522
129	40	0.06	GTX	239	591
130	40	0.06	GTX	217	541
131	40	0.06	GT	253	651
132	40	0.06	GT	242	572
133	40	0.06	GTX	240	582
134	40	0.06	GT	244	618
135	40	0.06	GT	280	435
136	40	0.06	GTX	240	578
137	40	0.06	GT	255	469
138	40	0.06	GTX	202	652
139	40	0.06	GTX	209	387
140	40	0.06	GT	241	338
141	40	0.08	GTX	300	329
142	40	0.08	GTX	314	216
143	40	0.08	GTX	311	341
144	40	0.08	GT	296	596
145	40	0.08	GT	359	307
146	40	0.08	GT	362	300
147	40	0.08	GTX	294	273
148	40	0.08	GT	298	609
149	40	0.08	GTX	289	260
150	40	0.08	GTX	313	230
151	40	0.08	GT	379	327
152	40	0.08	GT	341	500
153	40	0.08	GTX	264	358
154	40	0.08	GT	359	351
155	40	0.08	GT	278	463
156	40	0.08	GTX	277	359
157	40	0.08	GT	240	307
158	40	0.08	GTX	293	452
159	40	0.08	GTX	275	347
160	40	0.08	GT	354	434

APPENDIX B

Plotted values of maximum torque and angular deflection with each file



VITA

Jake Reynolds, D.M.D.
Born in Ashton Idaho, May 24, 1976
Present Residence Glen Allen, Virginia, United States

Education:

July 2007 to July 2009	Virginia Commonwealth University School of Dentistry, Richmond, VA Certificate in Endodontics Masters in Dentistry
July 2000 to May 2004	Case Western Reserve University School of Dental Medicine, Cleveland, OH Doctorate in Dental Medicine
July 1997 to May 2000	Idaho State University Pocatello, Idaho B.S. in Zoology

Honors:
2009 “Comparative Analysis of Torsional Strength Between ProFile® GT® and GT® Series X$^{\text{TM}}$ Nickel Titanium Rotary Instruments” Publication pending, Presented at the American Association of Endodontics Annual Meeting.
2008 Chief Resident, Department of Endodontics, Virginia Commonwealth University

Professional Affiliations:
American Association of Endodontics
American Dental Association