Flexibility of Various Nickel-Titanium Rotary Endodontic Files

Chelsea Selin
Marquette University

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FLEXIBILITY OF VARIOUS NICKEL-TITANIUM ROTARY ENDODONTIC FILES

by

Chelsea Selin, D.D.S.

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Marquette University,
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ABSTRACT

FLEXIBILITY OF VARIOUS NICKEL-TITANIUM ROTARY ENDODONTIC FILES

Chelsea Selin, D.D.S.

Marquette University, 2014

Introduction: Nickel-titanium rotary files were originally developed to allow for greater flexibility when instrumenting root canals. The increased flexibility of nickel-titanium instruments allowed operators to negotiate canal curvatures with greater ease. File design is continually changing. Manufacturers are trying to produce files that will work more efficiently and safely. Knowing the properties of files marketed is especially important in helping to choose an appropriate file system. Current ISO standards require force measurements at a static point along the file. The purpose of this study was to evaluate the flexibility of four different nickel-titanium files at three different points along the file.

Materials and Methods: Flexibility of four different nickel-titanium rotary files (EndoSequence, ProFile, Vortex, and Vortex Blue) was measured. Each file was clamped at 3mm, 5mm, or 7mm (n = 10/length/file) and a universal testing machine was used to bend the files to a maximum deflection of 4.5mm. All data were statistically analyzed by two-way analysis of variance and post-hoc Tukey test ($P = 0.05$) to determine any significant differences.

Results: Statistically significant ($P < 0.05$) differences were present. In general, ProFile was the stiffest, displaying the greatest force and bending moment values. Vortex Blue was significantly more flexible, with lower force needed for deflection and bending moments.

Conclusion: Vortex Blue files showed greater flexibility compared with the other nickel-titanium rotary files studied.

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Chelsea Selin, D.D.S.

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INTRODUCTION

The goal of endodontic treatment is to prevent or resolve apical periodontitis through proper cleaning, shaping, disinfection and sealing of the root canal system (1). Non-surgical root canal therapy was defined by Schilder as the chemo-mechanical preparation of the root canal system followed by three-dimensional filling with an inert material to restore or maintain the health of the periradicular tissue (2). Schilder stated that the most important phase of endodontic treatment is cleaning and shaping of the root canal system. Root canal instrumentation should clean the canal of pulpal tissue, microbes, and affected dentin, and shape the canal for irrigation and obturation (2).

The purpose of instrumentation is to enlarge the apical third of the root canal system to allow for proper debridement, disinfection and sealing of the canal space while maintaining the original root canal anatomy (2). Complex canal anatomy causes instrumentation challenges, which may prevent adequate disinfection of the root canal system, or cause procedural errors such as instrument separation, transportation, perforation, or ledges to occur (3-5).

In 1985, Lim proposed the idea that a more flexible instrument would better negotiate the complex anatomy, helping to avoid procedural errors such as instrument separation, apical transportation, zipping, perforation, or ledges (6). Walia introduced nickel-titanium instruments in 1988, concluding that they were three times more flexible than traditional stainless steel instruments (7). This increased flexibility found with nickel-titanium instruments made it easier for clinicians to instrument curved canals. But, Camps proved that nickel-titanium instruments actually presented lower torque values at failure than stainless steel instruments resulting in a higher incidence of instrument separation (8). It was also shown that nickel-titanium instruments had less cutting efficiency than stainless steel instruments (9). To deal with these shortcomings, file manufacturers began introducing nickel-titanium files with greater taper to increase the cutting efficiency and reduce torsional fracture. These greater taper instruments proved to be more efficient, but the stiffness of the instruments also increased. As a result, clinicians observed more canal transportation towards the outer aspect of the curvature in the apical region of root canals (10, 11).

File design is continually changing. Manufacturers are trying to produce files that will work more efficiently and safely. Instruments with greater flexibility may cause fewer undesirable changes in the shape of curved canals (11). Knowing the properties of files marketed is especially important in helping to choose an appropriate file system.

In this study, the flexibility of different nickel-titanium rotary endodontic files (EndoSequence, ProFile, Vortex, and Vortex Blue) was measured. Current ISO standards (ISO 3630-1) measure the resistance to bending of root canal instruments by fixing the instrument 3mm from its tip and bending it to a deflection of 45 degrees (12). This grasp length at 3mm does not take into account curvatures along the length of the canal or the forces placed on various points along the instrument. The purpose of this study was to evaluate the flexibility of four different nickel-titanium rotary endodontic files at three different points, 3mm, 5mm, and 7mm from the tip of the file.

LITERATURE REVIEW

The goal of endodontic treatment is to prevent or cure apical periodontitis (1). Cleaning, shaping, disinfecting, and sealing of the root canal system help accomplish this goal (2). Cleaning and shaping of the root canal system is an important part of root canal therapy, as it determines the efficacy of subsequent procedures. Root canal instrumentation should clean the canal of pulpal tissue, microbes, and affected dentin, and shape the canal for irrigation and obturation (2, 13).

The complex anatomy in which root canal therapy must be performed was shown in 1921 by Hess (14). Kakehashi et al.'s study on germ-free and conventional laboratory rats proved that the presence or absence of bacteria is the cause of pulpal pathology and periapical breakdown (15). Other studies supported the need for cleaning of all canals in order to achieve healing (16).

Root canal instruments have evolved over time, from annealed piano wire instruments made by Fouchard in 1746, to watch springs used by Maynard in 1838, to barbed broaches made by Arthur in 1852 (17). Instrument design continued to progress, with the development of the first manufactured instruments for cleaning and shaping being introduced in 1875 (18). These first instruments were designed to remove debris and allow for the placement of intracanal medicaments. Proper cleaning and shaping of root canals was not possible with these early instruments, resulting in many failures (2). These failures established the need for standardized endodontic instruments (14).

Unreliable root canal preparations (19, 20) resulted from the lack of standardized instruments. In 1974, the Federation Dentaire Internationale and the International Standards Organization developed new standards for root canal instruments. In 1976, the American Dental Association followed when the Council on Dental Materials and Devices established new standards (No. 28) for root canal instruments (21).

Over the years, multiple cleaning and shaping techniques have been developed. In general, canals are prepared either from the apex up, or from the crown down. The standardized hand instrumentation technique used 0.02 taper hand files to working length. This technique relied on the shape of the instrument to shape the canal, but cleaning, shaping and obturation was found to be inadequate (22). The step-back technique, which involved a decrease in the working length with an increase in instrument size in a “stepwise manner,” allowed for greater tapered preparations and less ledging than those obtained with the standardized technique (23, 24). The step-down technique was introduced in the 1980s, which was modified into today’s popular crown-down instrumentation technique. This technique emphasized coronal shaping first, followed by shaping of the apical portion of the canal (25). This technique showed less chance of transportation of the apical portion of the canal (4, 26).

Mechanical instrumentation alone, with either stainless steel or nickel-titanium files, cannot sufficiently disinfect root canals (27). Irrigating solutions are necessary to help rid the root canal system of bacteria and debris. An ideal irrigating solution kills bacteria, dissolves necrotic tissue, acts as a lubricant, removes the smear layer, and is non-irritating (28, 29). Sodium hypochlorite (NaOCl) is considered to be the most ideal irrigating solution (30) because of its broad spectrum antimicrobial activity (30) and ability to dissolve organic (31) and necrotic tissue (32). But, sodium hypochlorite does not remove the smear layer. A demineralizing agent, such as ethylenediamine tetra-acetic acid (EDTA), is needed to act on dentin debris and remove the smear layer (33). Irrigation is an important aspect of the chemomechanical preparation of the root canal system. According to Zehnder, NaOCl should be used to disinfect and dissolve tissue, followed by EDTA to remove the smear layer, with a final rinse of NaOCl (30).

Regardless of the technique used, it was shown that there is an inability to maintain the natural shape of curved canals with the endodontic instruments available (5). Stainless steel alloys used as root canal instruments provide limitations when instrumenting curved canal due to their stiffness, especially the significant increase in stiffness as the size of the instrument increases (34). Lim and Weber concluded that stiffer files resulted in greater apical transportation and speculated that more flexible files might limit these outcomes (6).

The limitations of stainless steel instruments brought a need for change. In 1988, Walia et al. proposed the use of Nitinol nickel-titanium orthodontic wire to fabricate endodontic files (7). They suggested that nickel-titanium root canal instruments would result in less procedural errors when instrumenting curved canal due to its increased flexibility and low modulus of elasticity, and that they would be more flexibile and fracture resistant than stainless steel root canal instruments (7).

Nickel-titanium instruments have the unique mechanical properties of shape-memory and superelasticity which occur as a result of austenite to martensite transition (35). This reversible transformation allows the file to recover from a much higher strain without breaking than stainless steel files (36), which facilitates instrumentation of curved root canals (7).

With the advent of more flexible nickel-titanium instruments, it was believed by many clinicians that instrumentation would become easier in curved root canal systems. The properties of nickel-titanium endodontic files reduce the tendency to straighten, zip, ledge, or perforate the canals, and provide a better ability to negotiate curved canals (5, 24). Camps found that the 0.02 tapered nickel-titanium files far exceeded specification standards for flexibility. Since nickel-titanium files were found to be so much more flexible, it was believed that separation would rarely occur. However, it was discovered that nickel-titanium actually presents a lower torque value at failure than stainless steel instruments (8). It was also determined that nickel-titanium files had other problems. Rapid wear of the instrument caused inadequate dentinal material removal (37), and nickel-titanium files displayed lower cutting efficiencies than stainless steel (9).

Larger tapered rotary nickel-titanium files were developed because of this decrease in cutting efficiency and increase in separation. It was proposed that the larger taper would increase cutting efficiency, lessen breakage, cause less procedural errors, and would be easier to use. Therefore, cleaning and shaping of the canal system would be easier and more efficient (37).

It has been shown that it is difficult to adequately shape and clean the apical portion of a root canal (2, 38), especially in cases where canals are curved and thin (39-41). In fact, the most difficult area to clean and maintain natural canal shape is the apical area (38). In curved canals, instrumentation can lead to the procedural errors. Straightening, or transportation of the canal, is one of the most common procedural errors that occurs during the instrumentation of curved canals (42). It occurs when there is a deviation from the natural path of the canal, and is seen more often in curved canals than in straight canals (13). Other procedural errors that can occur are ledges, perforation, and instrument separation (43). Ledging is a deviation from the original canal curvature. It is caused when files are used short of the working length, blocking the canal or creating a new pathway. The incidence of ledge formation significantly increases with curvature of the root canal (44). A perforation can occur due to over-instrumentation on the curvature of the root as the canal is straightened out (strip perforation) or at the apex when the instrument does not follow the curvature of the canal (apical zip perforation) (13). These problems result from the use of endodontic instruments that are too stiff (45). Although rotary instrumentation with nickel-titanium files is significantly faster than hand filing, problems still arise. The properties for which nickel-titanium files were developed become greatly reduced when the taper of the file increases. Larger tapers of nickel-titanium files are stiffer and less flexible. While these changes resulted in more efficient instruments, the stiffness of the instruments increased. Consequently, clinicians observed more canal transportation towards the outer aspect of the curvature in the apical region of root canals (10, 11).

One of the most significant advances that alleviate the problem of straightening is nickel-titanium (45). Nickel-titanium rotary instruments allow for the preparation of canals that are better centered and with less transportation than stainless steel hand instruments (46, 47). Nickel-titanium decreased the incidence of procedural errors, such as ledges, transportations, and perforations (48, 49). Despite these advances, nickel-titanium files can still separate, most often due to fatigue (50).

Separation of nickel-titanium rotary instruments occurs as a result of torsional or flexural fracture (51). Cross-section is extremely important because it determines torsional and bending properties (52). During instrumentation, files are subjected to torsional and bending stress, which can lead to instrument failure or procedural errors (53). Instrument failure can occur because torsional strength is exceeded or due to flexural fatigue during the treatment of curved root canals.

Bending of instruments depends on root canal anatomy, which inflicts a curvature that the instrument must follow as closely as possible (54). The greater the bending moment, the more force there is exerted on the canal wall, and the greater chance the natural curvature of the canal will be straightened. Therefore, using instruments with lower bending moments will help to avoid the procedural error of canal transportation (52).

File design is continually changing. Manufacturers are trying to produce files that will work more efficiently and safely. Instruments with greater flexibility may cause fewer undesirable changes in the shape of curved canals (11). Knowing the properties of files marketed is especially important in helping to choose an appropriate file system. Variations in design of endodontic instruments have an effect on the instrument’s properties, such as cutting efficiency, torsional strength, and flexibility (55).

While the curvature of a canal is beyond the control of the clinician, it does determine the bending force that is put on a file. Improving the mechanical properties of rotary endodontic files can help manage problems encountered when instrumenting curved canals (56).

MATERIALS AND METHODS

EndoSequence (Brasseler USA Dental, Savannah, GA), ProFile (Dentsply Tulsa Dental Specialties, Tulsa, OK), Vortex (Densply Tulsa Dental Specialties), and Vortex Blue (Dentsply Tulsa Dental Specialties) nickel-titanium rotary files were selected for this study. All files were 25mm in length, ISO size 30, with a taper of 0.06.

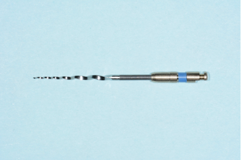
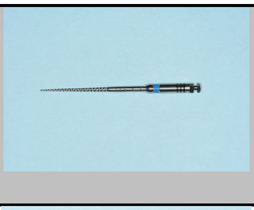
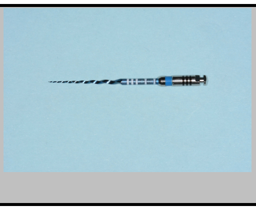
File	Design	Taper	Tip Size	File Length	Sample Size		
					3mm	5mm	7mm
EndoSequence **(BrasselerUSA Dental Instrumentation)**		0.06	30	25mm	10	10	10
ProFile **(Dentsply Tulsa Dental Specialties)**		0.06	30	25mm	10	10	10
Vortex **(Dentsply Tulsa Dental Specialties)**		0.06	30	25mm	10	10	10
Vortex Blue **(Dentsply Tulsa Dental Specialties)**		0.06	30	25mm	10	10	10

Table 1 – Files used

The files were measured at 3mm, 5mm or 7mm from the tip using a digital caliper and marked with a rubber stopper. The files were also measured and marked 20mm from the tip to represent the deflection point. The sample size was 10 for each file type at each length. Each file was secured between two metal plates on a load-sensing cell. A universal testing machine (Instron, model 5500-R, Norwood, MA) was used to bend the files to a maximum deflection of 4.5mm (Figures 1-7) at a rate of 2mm/minute at room temperature ($22^{O}C$ +/- $1^{O}C$).

Data was collected electronically via Merlin Software (Instron, Norwood, MA) and transferred to Excel (Microsoft Corporation, Redmond, WA) for further analysis (Tables 2-3). Statistical analysis was completed with IBM SPSS statistical software (IBM Corp., Armonk, NY). A two-way analysis of variance (ANOVA) and a post-hoc Tukey test was used as indicated.

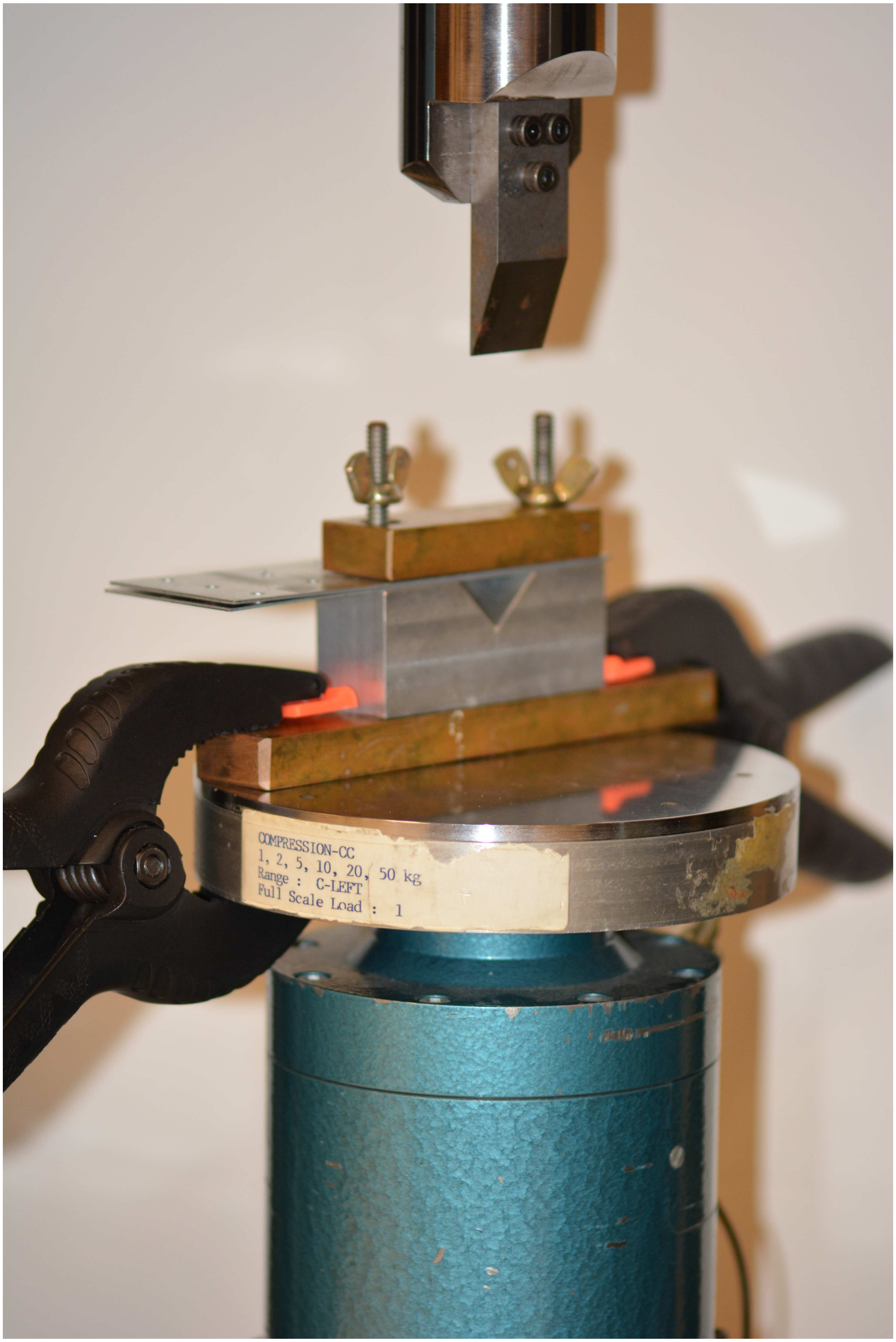


Figure 1 - Flexibility Testing Apparatus

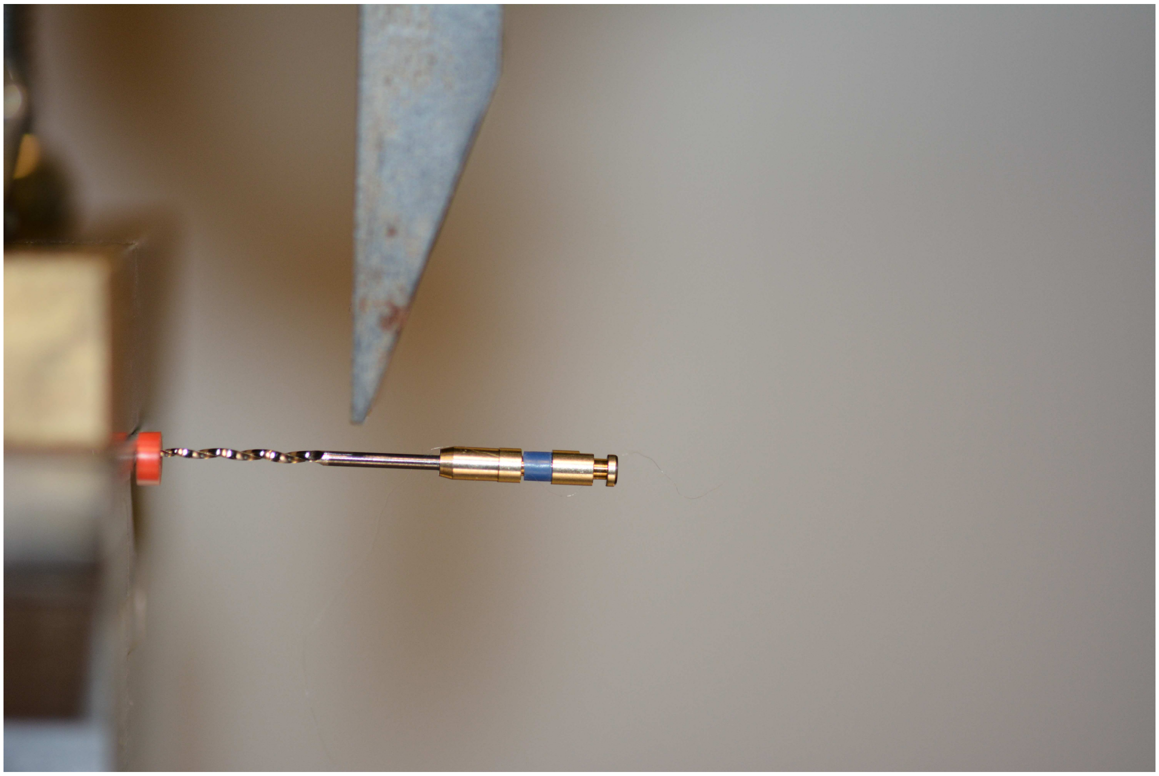


Figure 2 - Mounted File

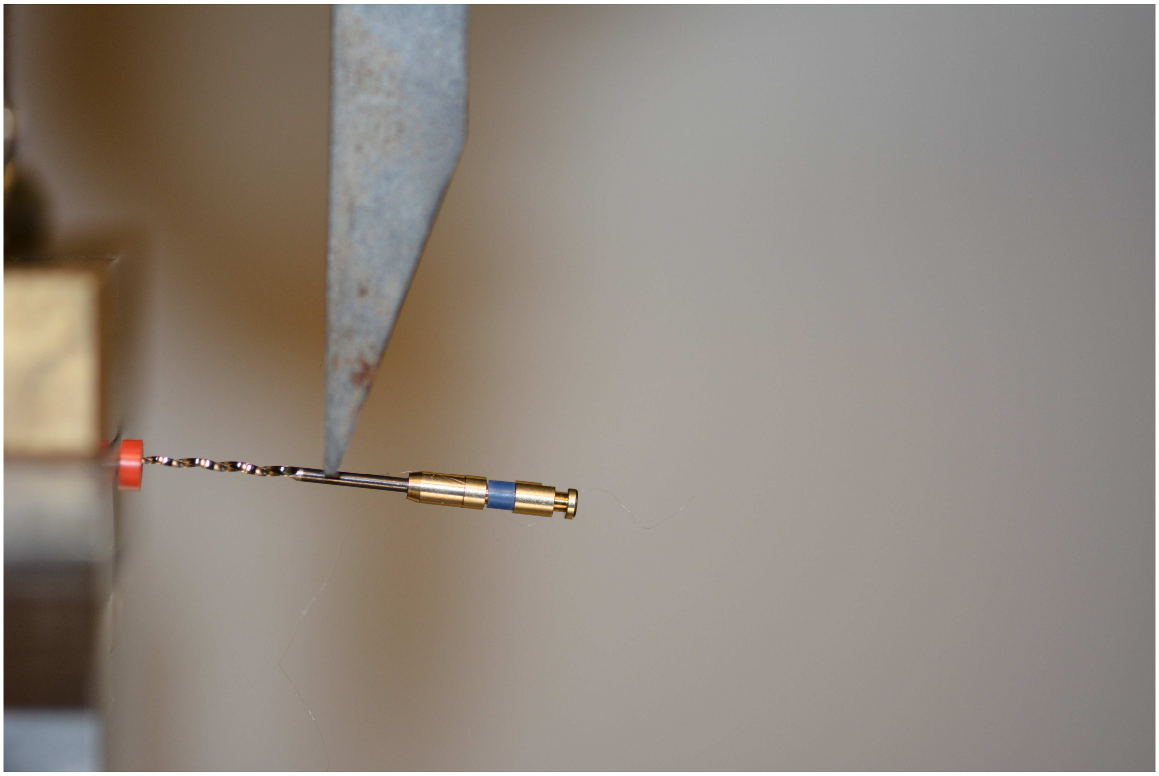


Figure 3 - 1mm Deflection

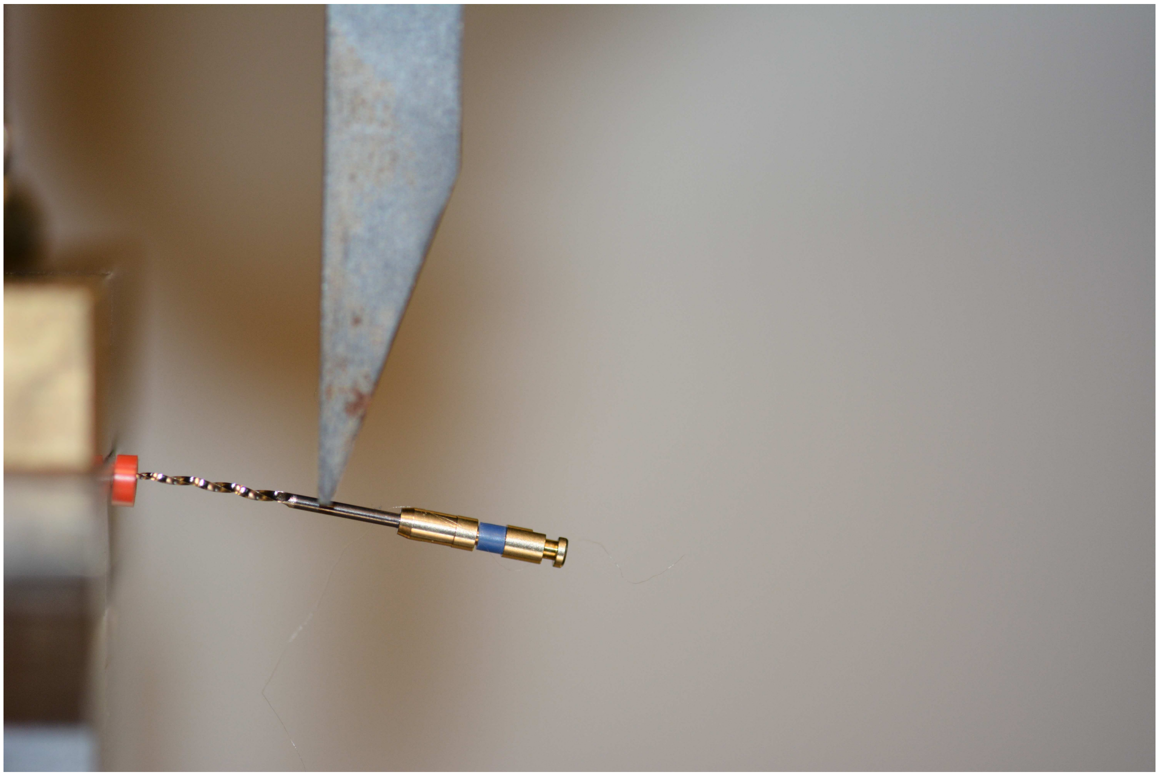


Figure 4 - 2mm Deflection

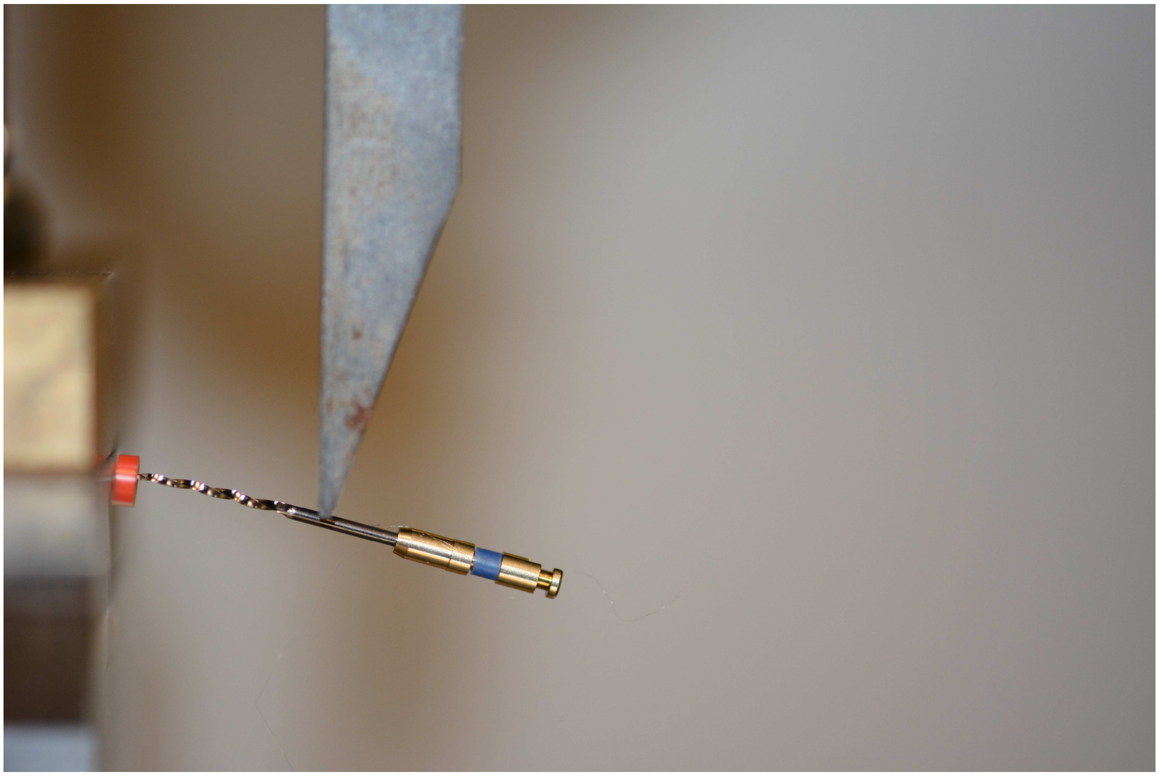


Figure 5 - 3mm Deflection

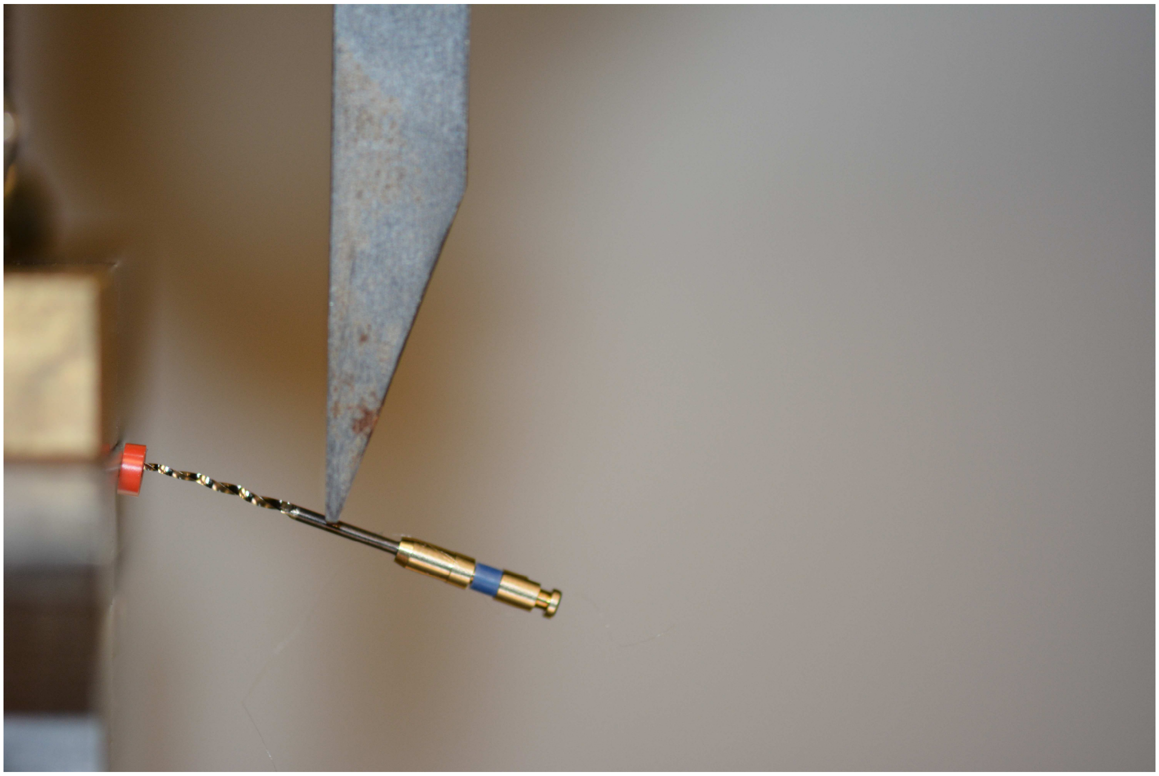


Figure 6 - 4mm Deflection

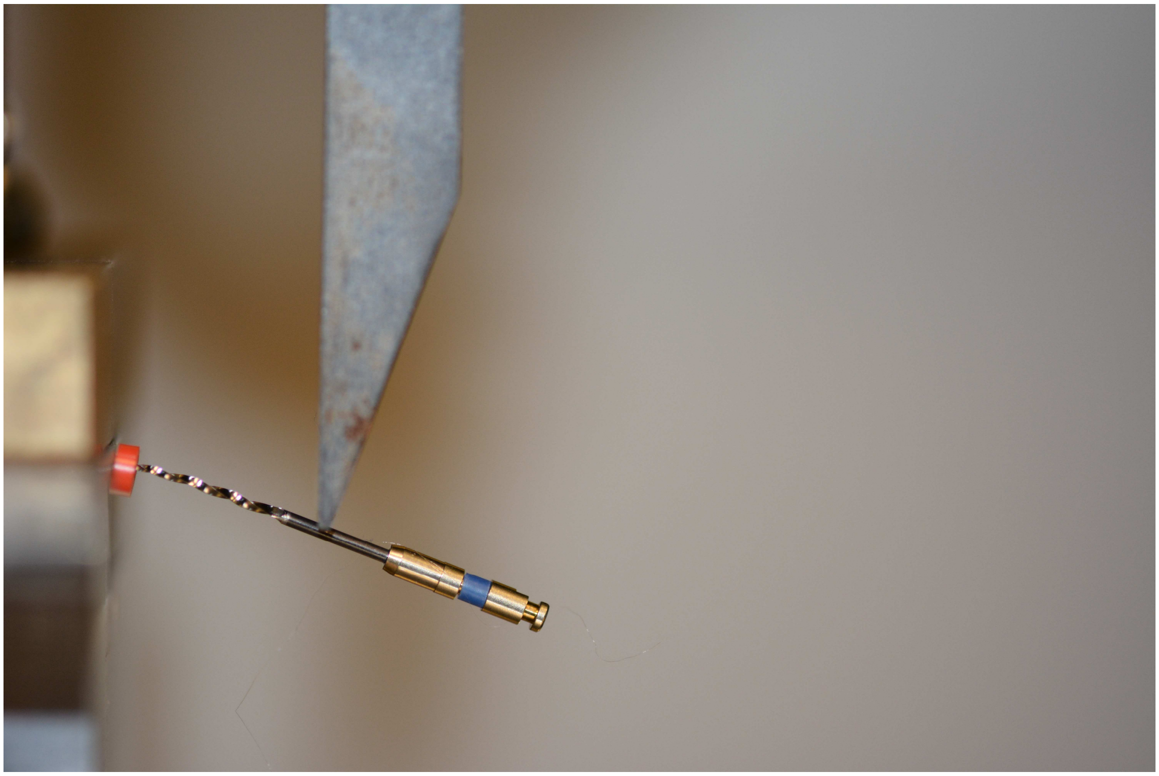


Figure 7 – Maximum Deflection (4.5mm)

RESULTS

Stiffness

Stiffness is significantly different between the files. The stiffness of ProFile is greater than EndoSequence, which is greater than Vortex Blue. Vortex is significantly stiffer than Vortex Blue, but not significantly different from ProFile or EndoSequence. Table 4 summarizes these results, with different letters signifying a significant difference ($P < 0.05$).

Force

In general, the force for ProFile, EndoSequence, and Vortex are significantly greater than Vortex Blue at all deflection points. The force required to bend ProFile is significantly greater than EndoSequence at all deflection points. The force required to deflect ProFile 0.25 mm to 1 mm is significantly greater than Vortex, but at a deflection of 1.5 mm greater there is no significant difference between the two. From 0.25 mm to 1.5 mm there is no significant difference between the force required to deflect Vortex and EndoSequence, but at deflection lengths of 2.0 mm to 4.5 mm, Vortex is significantly greater.

Bending Moment

Similar to force, the bending moment for ProFile, EndoSequence, and Vortex are significantly greater than Vortex Blue at all deflection points. The bending moment for ProFile is also significantly greater than EndoSequence at all deflection points. The bending moment for ProFile is significantly greater than Vortex at a deflection of 0.25 mm to 1.5 mm, but there is no difference at deflections of 2.0 mm to 4.5 mm. There is no difference in the bending moment for Vortex and EndoSequence at a deflection of 0.25 mm to 1.5 mm, but there is a significant difference at deflections of 2.0 mm to 4.5 mm.

Length

Across all file systems, there is a significant difference between 3 mm, 5 mm, and 7mm (7 mm > 5 mm > 3 mm).

File	Grasp Length (mm)	Stiffness (g/mm)	Force(g) @ 0.25mm	Force(g) @ 0.50mm	Force(g) @ 0.75mm	Force(g) @ 1.0mm	Force(g) @ 1.5mm	Force(g) @ 2.0mm	Force(g) @ 2.5mm	Force(g) @ 3.0mm	Force(g) @ 3.5mm	Force(g) @ 4.0mm	Force(g) @ 4.5mm
Endo-Sequence	3	7.39 ±1.47	2.15 ±0.35	4.14 ±0.69	6.11 ±1.06	7.89 ±1.39	11.16 ±2.06	14.12 ±2.64	16.76 ±3.23	18.91 ±3.56	20.58 ±3.83	21.38 ±4.13	21.80 ±4.10
Endo-Sequence	5	12.81 ±3.24	3.96 ±0.90	7.45 ±1.79	10.84 ±2.66	13.90 ±3.41	19.66 ±4.47	24.71 ±5.43	29.35 ±6.11	32.74 ±6.71	35.18 ±6.77	36.69 ±6.65	38.02 ±6.41
Endo-Sequence	7	40.74 ±6.09	12.36 ±1.45	23.66 ±3.14	34.63 ±4.79	44.10 ±6.12	61.18 ±8.28	74.91 ±10.37	84.66 ±11.42	89.75 ±11.77	92.99 ±12.27	95.93 ±12.39	98.93 ±12.63
ProFile	3	8.87 ±0.89	2.72 ±0.33	5.15 ±0.56	7.47 ±0.75	9.64 ±1.00	13.63 ±1.38	17.23 ±1.80	20.51 ±2.11	23.37 ±2.32	25.61 ±2.57	27.68 ±2.63	29.24 ±2.88
ProFile	5	19.31 ±1.94	5.66 ±0.60	10.83 ±1.07	15.88 ±1.48	20.54 ±1.99	29.05 ±2.94	36.68 ±3.70	43.65 ±4.29	49.33 ±4.74	53.67 ±5.31	56.24 ±5.64	57.69 ±5.70
ProFile	7	45.86 ±3.38	13.35 ±1.39	26.02 ±2.31	38.31 ±3.04	49.12 ±3.80	69.00 ±5.23	86.02 ±5.77	100.78 ±6.23	108.79 ±8.08	114.43 ±8.75	116.61 ±10.12	119.49 ±9.90
Vortex	3	7.11 ±0.99	2.00 ±0.26	3.87 ±0.46	5.76 ±0.70	7.45 ±0.94	11.01 ±1.26	14.28 ±1.54	17.49 ±1.82	20.37 ±2.08	23.32 ±2.90	24.61 ±3.15	26.42 ±2.96
Vortex	5	15.03 ±1.71	4.30 ±0.59	8.16 ±1.00	12.03 ±1.43	15.67 ±1.76	22.50 ±2.50	29.02 ±3.26	34.83 ±4.06	39.96 ±4.50	44.58 ±6.09	47.31 ±7.22	49.68 ±8.28
Vortex	7	44.54 ±4.44	12.83 ±1.22	24.00 ±2.32	35.46 ±3.42	46.39 ±4.40	68.17 ±5.29	87.65 ±6.00	103.63 ±6.87	113.74 ±7.49	120.50 ±6.98	124.40 ±11.21	130.08 ±12.76
Vortex-Blue	3	2.80 ±0.82	1.04 ±0.18	1.78 ±0.34	2.47 ±0.52	3.18 ±0.76	4.62 ±1.11	6.18 ±1.48	7.87 ±1.85	9.58 ±2.18	11.31 ±2.47	12.75 ±2.77	13.78 ±3.09
Vortex-Blue	5	5.58 ±2.02	2.05 ±0.97	3.62 ±1.36	5.04 ±1.78	6.46 ±2.30	9.50 ±3.21	12.79 ±4.00					
Vortex-Blue	7	22.40 ±11.34	6.67 ±1.74	11.68 ±4.12	17.17 ±6.95	22.91 ±9.61	35.21 ±14.28	47.06 ±16.61	57.28 ±16.21	64.88 ±14.68	70.27 ±13.86	73.70 ±14.29	76.65 ±14.38

Table 2 – Force exhibited by the files at various deflections

File	Grasp Length (mm)	Bending Moment (g*mm) @ 0.25mm	Bending Moment (g*mm) @ 0.50mm	Bending Moment (g*mm) @ 0.75mm	Bending Moment (g*mm) @ 1.0mm	Bending Moment (g*mm) @ 1.5mm	Bending Moment (g*mm) @ 2.0mm	Bending Moment (g*mm) @ 2.5mm	Bending Moment (g*mm) @ 3.0mm	Bending Moment (g*mm) @ 3.5mm	Bending Moment (g*mm) @ 4.0mm	Bending Moment (g*mm) @ 4.5mm
Endo-Sequence	3	36.63 ±5.89	70.43 ±11.69	103.92 ±18.08	134.09 ±23.57	189.76 ±35.08	240.10 ±44.85	284.92 ±54.92	321.45 ±60.54	349.91 ±65.12	363.49 ±70.25	370.59 ±69.66
Endo-Sequence	5	59.34 ±13.52	111.80 ±26.82	162.53 ±39.89	208.48 ±51.13	294.90 ±66.99	370.58 ±81.52	440.26 ±91.63	491.16 ±100.72	527.77 ±101.62	550.33 ±99.72	570.37 ±96.12
Endo-Sequence	7	160.73 ±18.81	307.64 ±40.88	450.21 ±62.32	573.30 ±79.52	795.34 ±107.68	973.85 ±134.84	1100.55 ±148.47	1166.81 ±152.95	1208.93 ±159.48	1247.07 ±161.11	1286.09 ±164.16
ProFile	3	46.23 ±5.56	87.48 ±9.46	126.94 ±12.80	163.96 ±16.93	231.68 ±23.53	292.88 ±30.66	348.69 ±35.94	397.29 ±39.47	435.34 ±43.71	470.53 ±44.77	497.02 ±48.99
ProFile	5	84.91 ±9.00	162.39 ±16.02	238.14 ±22.25	308.06 ±29.84	435.79 ±44.11	550.24 ±55.56	654.81 ±64.28	739.89 ±71.04	805.01 ±79.70	843.59 ±84.62	865.36 ±85.47
ProFile	7	173.61 ±18.04	338.27 ±30.00	498.04 ±39.49	638.52 ±49.46	896.99 ±68.02	1118.29 ±74.97	1310.09 ±81.00	1414.28 ±105.10	1487.65 ±113.76	1515.98 ±131.61	1553.32 ±128.75
Vortex	3	34.06 ±4.40	65.84 ±7.85	97.87 ±11.94	126.71 ±15.95	187.15 ±21.42	242.70 ±26.11	297.25 ±30.92	346.36 ±35.42	396.47 ±49.37	418.31 ±53.62	449.19 ±50.27
Vortex	5	64.46 ±8.84	122.47 ±14.96	180.41 ±21.44	235.12 ±26.45	337.49 ±37.56	435.34 ±48.83	522.42 ±60.96	599.37 ±67.45	668.74 ±91.29	709.63 ±108.23	745.16 ±124.25
Vortex	7	166.85 ±15.86	312.01 ±30.18	461.00 ±44.48	603.04 ±57.15	886.23 ±68.82	1139.48 ±77.94	1347.23 ±89.33	1478.57 ±97.34	1566.52 ±90.71	1617.19 ±145.68	1691.08 ±165.93
Vortex-Blue	3	17.70 ±3.05	30.18 ±5.70	41.95 ±8.79	54.08 ±12.91	78.47 ±18.84	105.14 ±25.22	133.76 ±31.38	162.82 ±37.09	192.31 ±42.07	216.77 ±47.08	234.34 ±52.52
Vortex-Blue	5	30.73 ±14.58	54.29 ±20.37	75.65 ±26.68	96.96 ±34.50	142.46 ±48.21	191.87 ±60.05					
Vortex-Blue	7	86.71 ±22.57	151.78 ±53.58	223.15 ±90.36	297.78 ±124.87	457.76 ±185.68	611.78 ±215.93	744.68 ±210.70	843.38 ±190.83	913.57 ±180.21	958.08 ±185.81	996.48 ±186.90

Table 3 - Bending moment exhibited by the files at various deflections

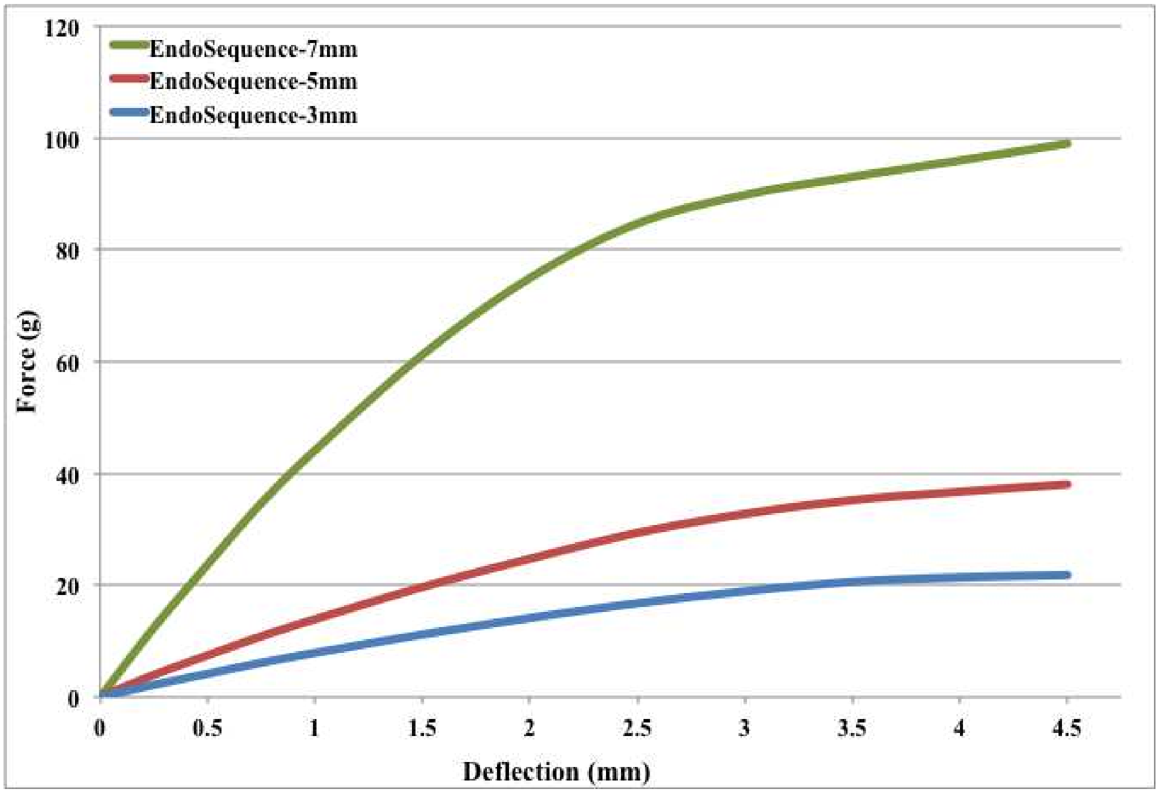


Figure 8 – Force vs deflection for EndoSequence at 3, 5, and 7 mm

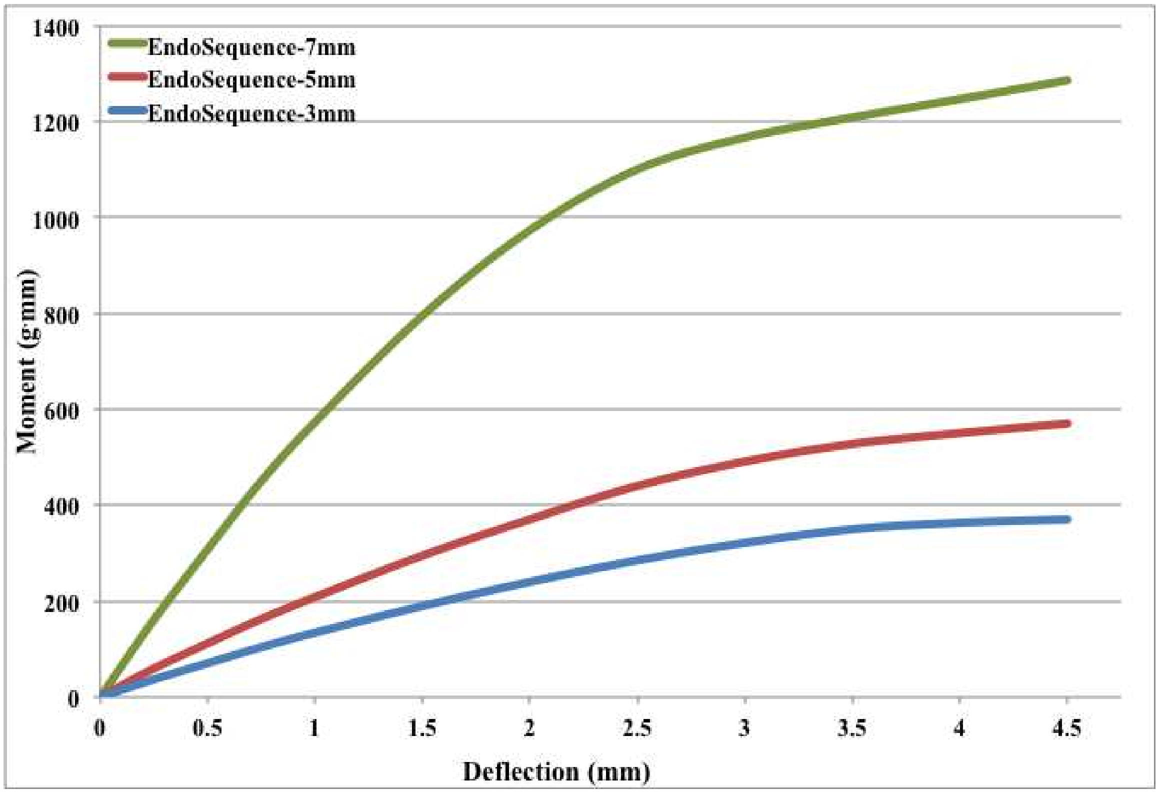


Figure 9 - Bending moments vs deflection for EndoSequence at 3, 5, and 7 mm

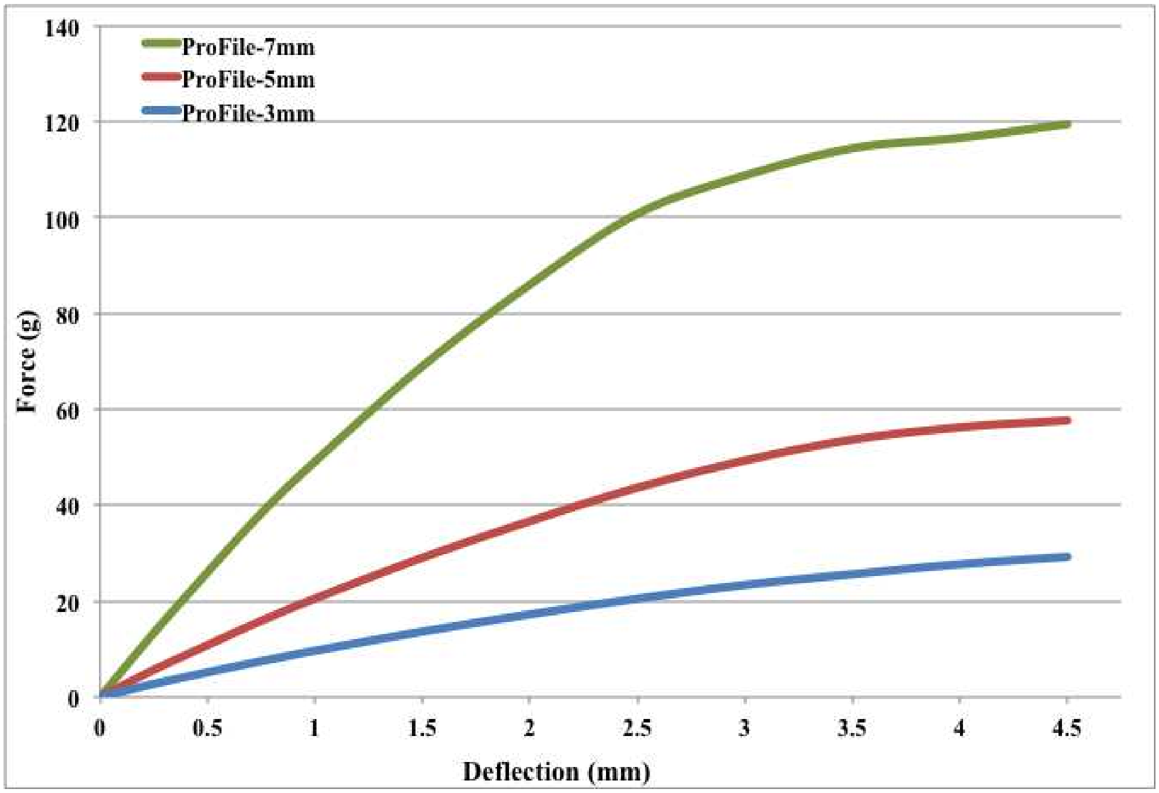


Figure 10 - Force vs deflection for ProFile at 3, 5, and 7 mm

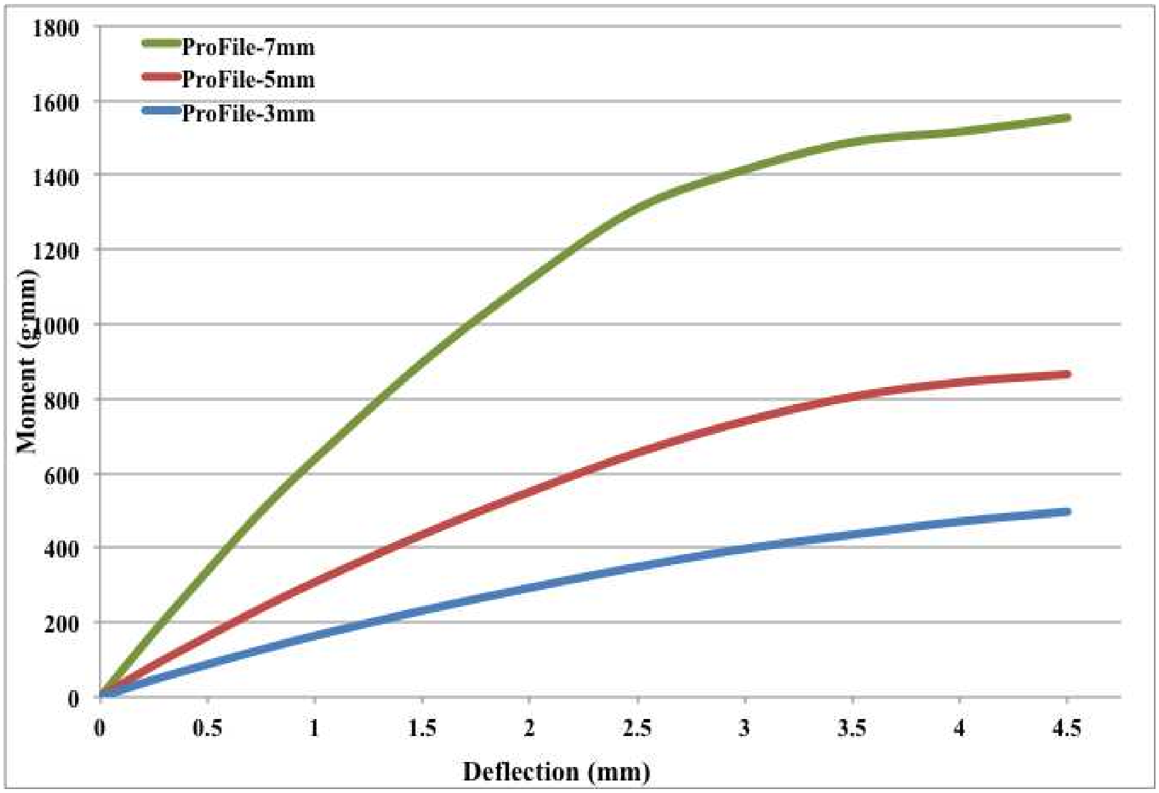


Figure 11 - Bending moments vs deflection for ProFile at 3, 5, and 7 mm

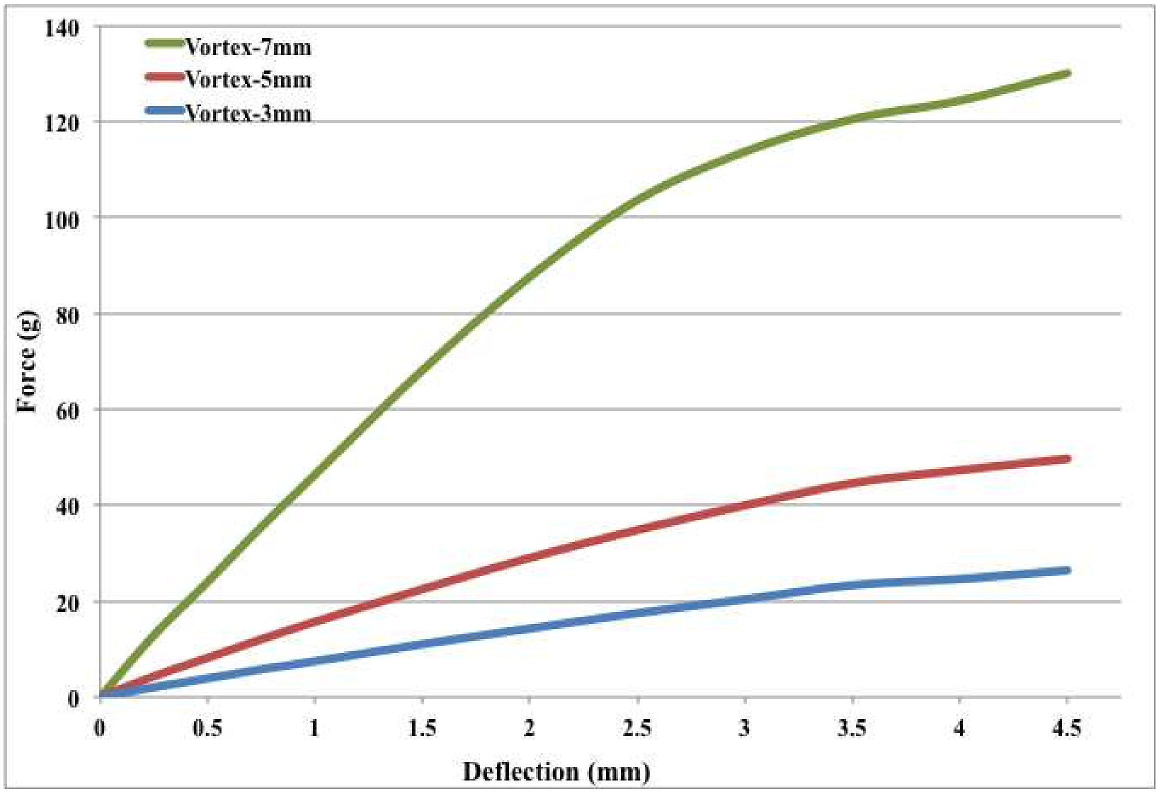


Figure 12 - Force vs deflection for Vortex at 3, 5, and 7 mm

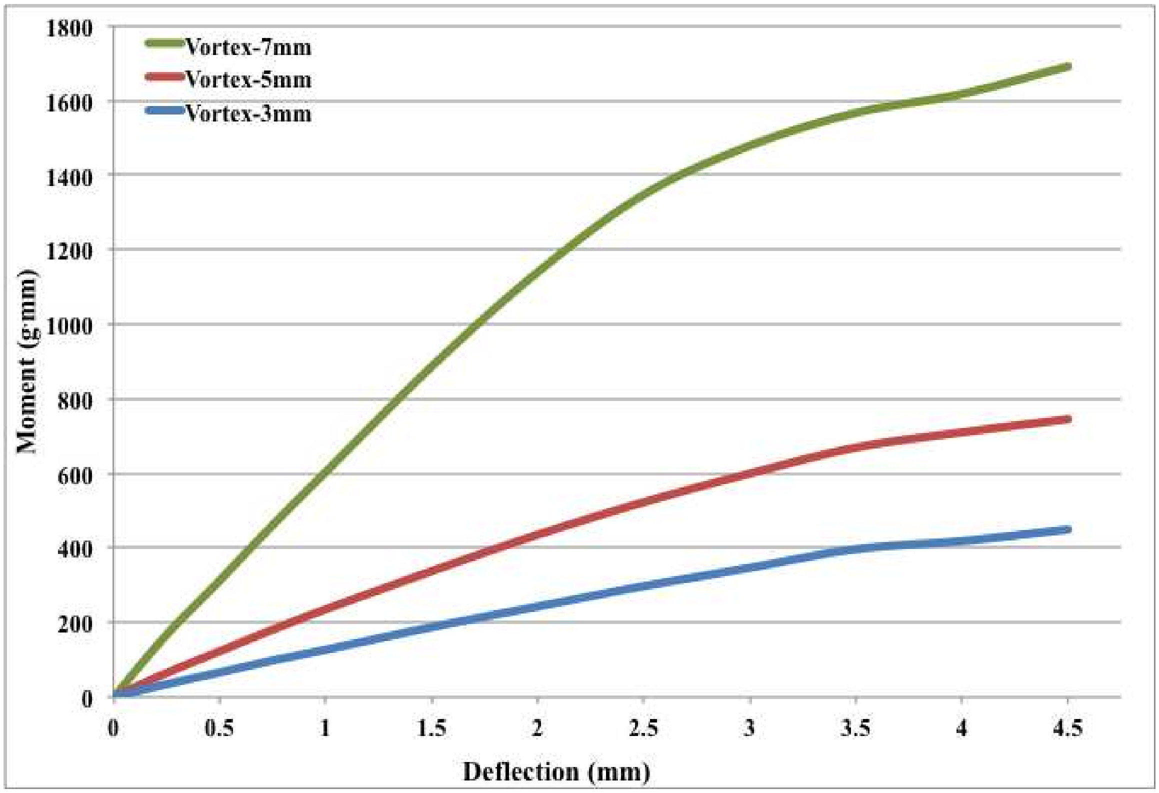


Figure 13 - Bending moments vs deflection for Vortex at 3, 5, and 7 mm

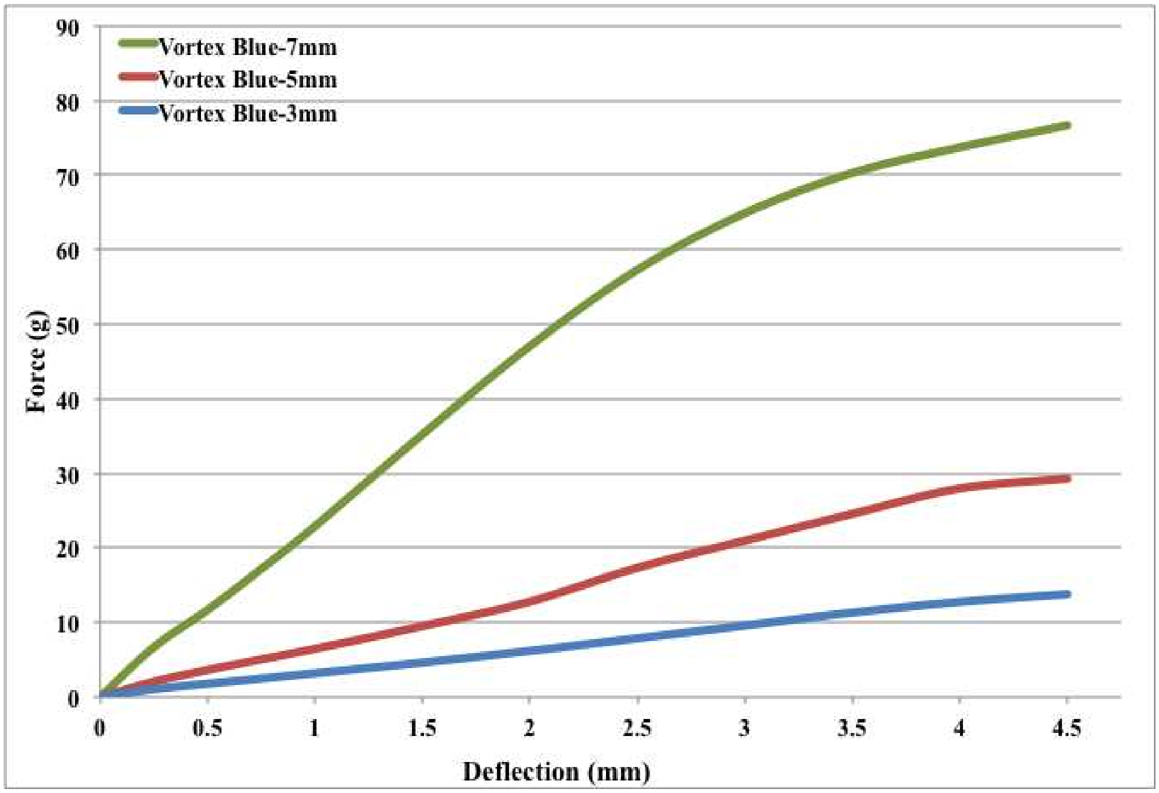


Figure 14 - Force vs deflection for Vortex Blue at 3, 5, and 7 mm

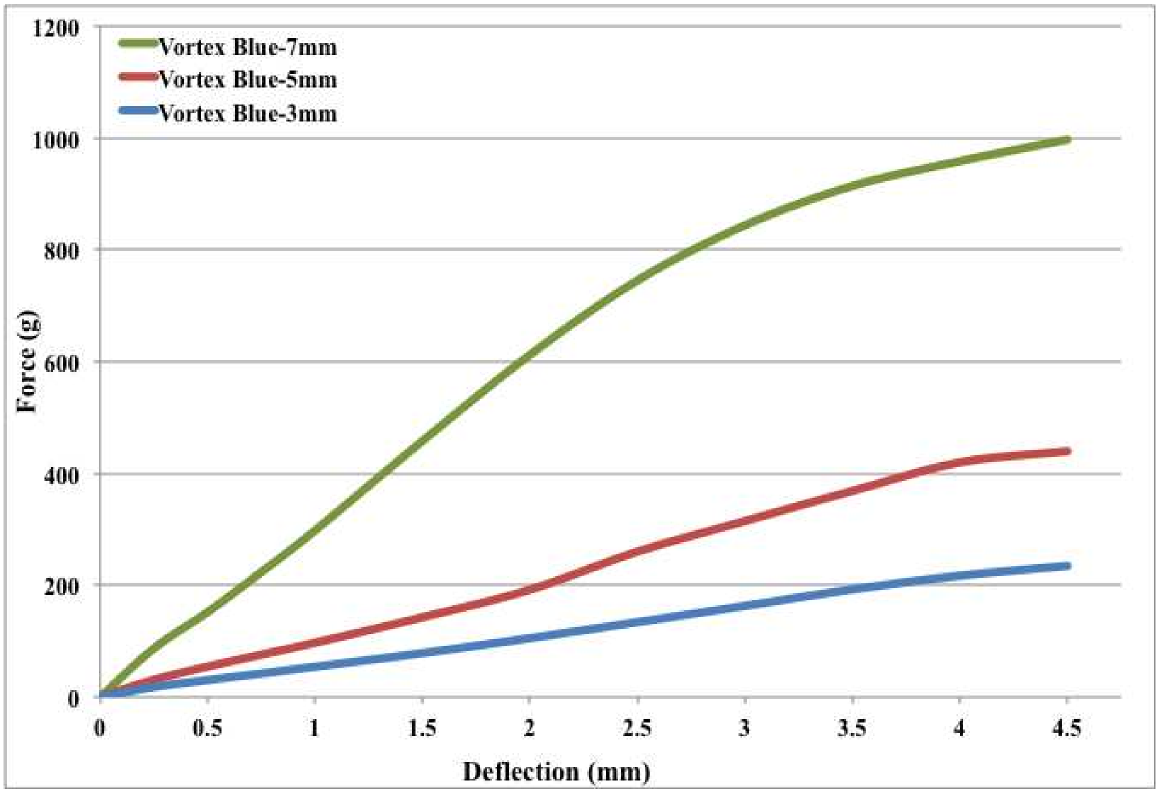


Figure 15 - Bending moments vs deflection for Vortex Blue at 3, 5, and 7 mm

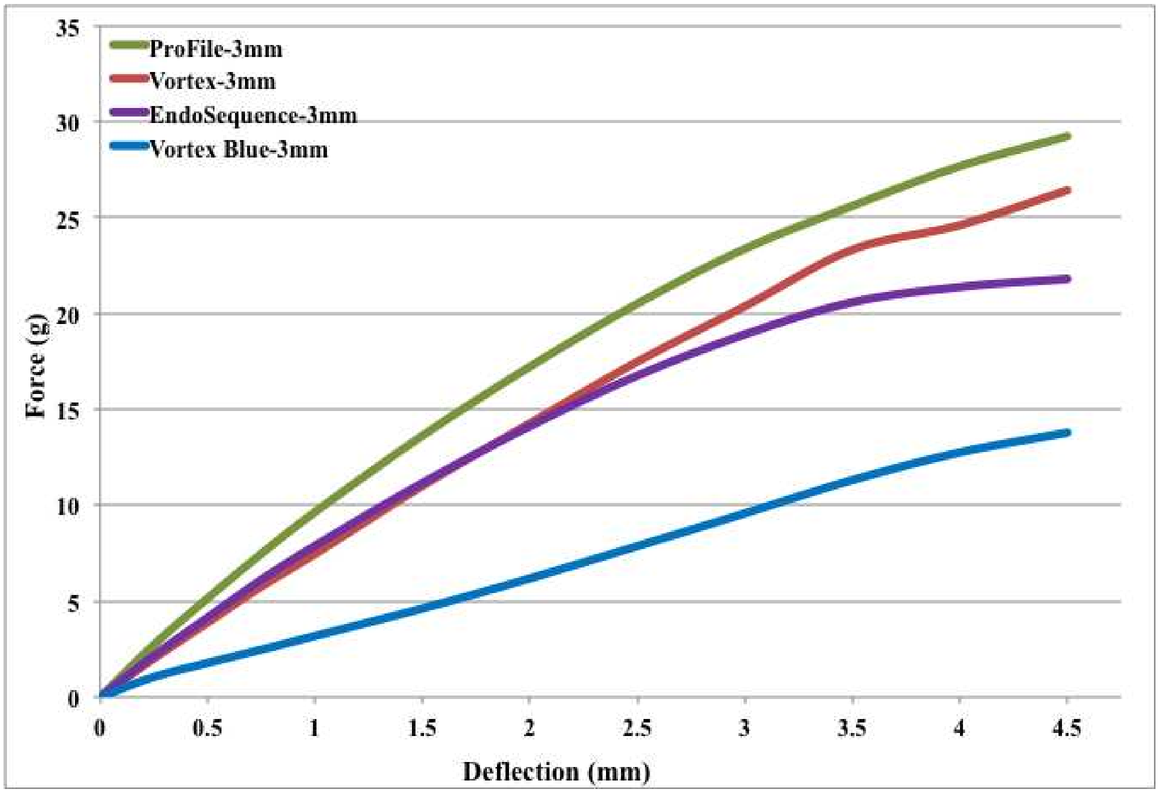


Figure 16 - Force vs deflection comparison of the files when grasped at 3 mm

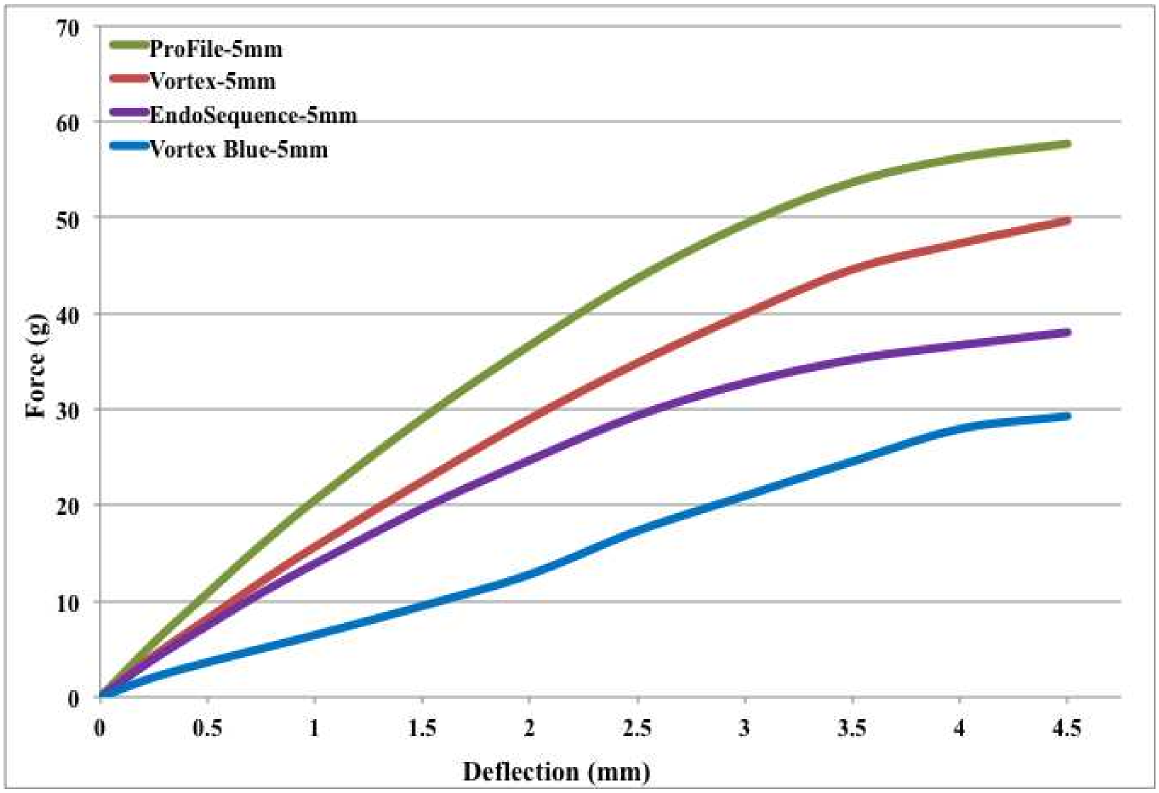


Figure 17 - Force vs deflection comparison of the files when grasped at 5 mm

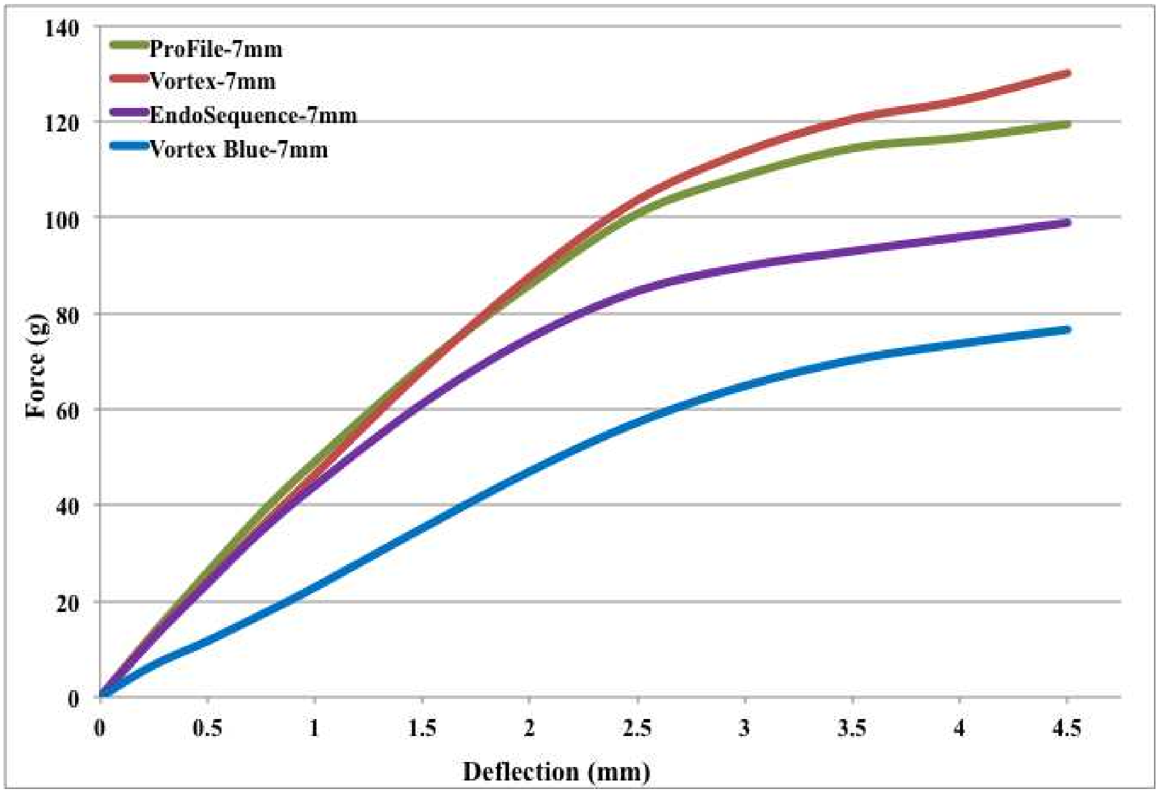


Figure 18 - Force vs deflection comparison of the files when grasped at 7 mm

STATISTICAL SIGNIFICANCE TABLE

	EndoSequence	ProFile	Vortex	Vortex Blue
Stiffness	B	A	AB	C
Force @ 0.25 – 1.0 mm	B	A	B	C
Force @ 1.5 mm	B	A	AB	C
Force @ 2.0 – 4.5 mm	B	A	A	C
Bending Moment @ 0.25 – 1.5 mm	B	A	B	C
Bending Moment @ 2.0 – 4.5 mm	B	A	A	C

Table 4 – Statistically significant ($P < 0.05$) differences between files. Different letters between files for a given stiffness, force, or moment indicate significance.

DISCUSSION

Ideally, a nickel-titanium rotary endodontic file should be flexible and resistant to fracture in order to achieve the goal of non-surgical root canal therapy of prevention or resolution of apical periodontitis through proper cleaning, shaping, disinfection and sealing of the root canal system (1). These properties influence the clinical performance of the endodontic instruments used. Therefore, it is important to have a good understanding of how the files work in order to select an appropriate instrument.

In this study, the flexibility of four different nickel-titanium rotary endodontic files was evaluated at different lengths along each file. The results of this study show that Vortex Blue files exhibit significantly greater flexibility than the other files studied, while ProFile was the stiffest file of the four files studied. ProFile instruments are made from conventional nickel-titanium, and have a U-file design in which the cutting edges are supported by radial lands (57). EndoSequence files are made from conventional nickel-titanium, with alternating contact points along the instrument's cutting length. There are no radial lands, decreasing the thickness of metal and creating a more flexible file. Other important design characteristics are the noncutting tip, electropolishing, and variable pitch and helical angles (58, 59). Vortex files are similar in design to EndoSequence files, with a triangular cross section, no radial lands, variable pitch, and a non-cutting tip. One difference is Vortex files are composed of M-Wire nickel-titanium (60, 61). The enhanced characteristics of M-Wire files are made through a thermalmechanical treatment process (62). It has been reported that M-Wire technology allows more flexibility and resistance to cyclic fatigue (63, 64). Vortex Blue files are similar in design to Vortex files, but undergo a proprietary processing technique to decrease springback to its original shape and are marketed for use in curved canals.

In this study, the stiffness of Vortex files were not significantly different from ProFile or EndoSequence. In fact, at deflections of greater than 2.0mm, the force and bending moment of Vortex was greater than that of EndoSequence. This can be supported by a study by Lopes et al. in which Vortex showed worse than expected flexibility and fatigue resistance (65).

Also noted was a significant difference in grasp length, with force being the greatest at 7 mm, followed by 5 mm, with 3 mm exhibiting the least amount of force. The data (Figures 8-15) shows a much greater increase in force and bending moment when grasp length is increased from 5 mm to 7 mm as compared with the change from 3 mm to 5 mm. This may be due to the greater bulk of material present at 7 mm, especially with ProFile's U-shape design compared with the triangular cross sections of EndoSequence and Vortex.

Greater flexibility may allow the file to better follow the natural curvatures of the canals with less unwanted forces that could result in apical transportation or ledging of the canals (66). From this study, Vortex Blue files were found to be the most flexible and may be better able to negotiate curved canals. Care should also be taken in canals that curve more coronally, as more force is required to bend the files at a higher grasp length.

CONCLUSIONS

1. Vortex Blue was significantly more flexible than all other files studied.
2. ProFile exhibited the least flexibility.
3. Grasp length greatly influenced the amount of force required to bend the file. As grasp length increased, the amount of force required to bend the file also increased.

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