

Distribution Statement

Distribution A: Public Release.

The views presented here are those of the author and are not to be construed as official or reflecting the views of the Uniformed Services University of the Health Sciences, the Department of Defense or the U.S. Government.



UNIFORMED SERVICES UNIVERSITY OF THE HEALTH SCIENCES

POSTGRADUATE DENTAL COLLEGE
ARMY POSTGRADUATE DENTAL SCHOOL
BUILDING B-6837 NORMANDY DRIVE
FORT BRAGG, NORTH CAROLINA 28310



THESIS APPROVAL PAGE FOR MASTER OF SCIENCE IN ORAL BIOLOGY

Title of Thesis: An In-Vitro Study to Examine the Effects of Location of File Curvature on Cyclic Fatigue Resistance of SS White DC Taper Rotary Nickel-Titanium Files

Name of Candidate:

Ryan C Trautmann
Master of Science Degree
2 JUNE 2023

THESIS/MANUSCRIPT APPROVED:

IVEY.KYLE.STEVEN. Digitally signed by
1458843925 IVEY.KYLE.STEVEN.1458843925
Date: 2023.06.13 10:44:32 -04'00'

MAJ Kyle Ivey, DMD
COMPREHENSIVE DENTISTRY, FORT LIBERTY
Committee Chairperson

DELGADO.STEVEN.PA Digitally signed by
TRICK.1504231719 DELGADO.STEVEN.PATRICK.1504231719
Date: 2023.06.05 12:14:23 -04'00'

LTC Steven Delgado, DDS
ENDODONTICS, FORT LIBERTY
Committee Member

PHILLIPS.JAMES.LLOYD Digitally signed by
D.1062298274 PHILLIPS.JAMES.LLOYD.1062298274
Date: 2023.06.05 12:15:50 -04'00'

MAJ JAMES PHILLIPS, DMD
ENDODONTICS, FORT LIBERTY
Committee Member

An In-Vitro Study to Examine the Effects of Location of File Curvature on Cyclic Fatigue Resistance of SS White DCTaperH Rotary Nickel-Titanium Files

Authors: Ryan Trautmann, Steven Delgado¹, James Phillips¹, Thomas Beltran²

¹Fort Bragg Endodontic Residency Program, NC;

²Womack Army Medical Center, Fort Bragg, NC

Introduction

There have been drastic changes in the ways that endodontists instrument root canals with the introduction of Nickel-Titanium (NiTi) endodontic files in the 1980's. As providers transitioned from instrumentation with stainless steel to NiTi, there were found to be fewer procedural errors (1). NiTi rotary files have significant advantages over classic stainless steel hand instruments. These include increased file flexibility, leading to less transportation of the canal, production of better centered canals, superior shaping ability, efficiency, and less instrument separation (2-6,9).

Despite the advantages, NiTi rotary files are still susceptible to instrument separation in certain situations. The two mechanisms of instrument failure are through torsional fatigue and cyclic fatigue (7, 8). Torsional fatigue is when the tip of the locks into the canal while the coronal portion continues rotating, quickly causing separation of the instrument. Cyclic fatigue is when the file is in a continuous rotational motion and is passing around a curve in a canal. This causes alternating flexural and tensile forces on the instrument, eventually leading to separation without preceding signs of deformation (9).

It is known that there are numerous factors that can influence the fracture resistance of a file. Some of these factors are related to the physical properties of the file themselves such as size, taper, type of alloy and the manufacturing process that the file undergoes (10, 11). For example, the phase transformation of NiTi from austenitic to martensitic through heat treatment, has allowed for significantly more flexible files. This added flexibility enables rotary files to minimize iatrogenic complications such as ledges and perforations. There are also root canal anatomical factors which can play a role in instrument separation, including degree and radius of canal curvature (12, 13). Generally, cyclic fatigue and fracture resistance of files are tested while changing variables such as the angle and radius of curvature. This curvature is usually tested on the apical extent of the file until separation occurs. However, root canal anatomy varies greatly, and it is not uncommon to have canal curvature located in the coronal or middle thirds of the root.

SS White manufactures the DCTaperH NiTi variably tapered, size 25/06 rotary file. The maximum flute diameter of 0.80mm and flexibility due to its martensitic properties, make it an excellent option for conservative endodontic treatment. The heat treatment not only improves flexibility but also can increase cyclic fatigue resistance and lower the risk of endodontic file separation. The aim of this study was to determine how the location of curvature affects time to separation (TTS) for DCTaperH NiTi rotary Files (SS White, Lakewood, New Jersey).

Materials and Methods

A power analysis, using GPower Version 3.1, evaluated the sample size required for a one-way ANOVA between three groups. Results indicated a total sample size of sixty-six samples (22 per group) would be needed to detect a large difference / effect size ($f = .40$) with 80% power and significance level of 0.05. A total of sixty-six DCTaperH NiTi rotary files, size 25/v06 in 31mm length, were utilized and split into a total of three experimental groups ($n=22$ each). Files were individually subjected to a rotational speed of 500 RPMs in a custom designed jig. This jig had three preset pins to simulate a 60-degree curvature with a radius of 6mm. The adjustable handpiece allowed for repeatable, locking adjustment of the handpiece at different locations. The three experimental groups were distinguished based on the initial start of the curvature: 11mm, 16mm or 21mm from the tip of the instrument (See image 1). These locations attempted to simulate canal curvatures located at different locations along the root canal system, such as an apical, middle, or coronal root curvature respectively. All files were tested individually and the time to separation (TTS) was observed and recorded with a digital stopwatch.

Statistical Analysis

All data analyzed with the IBM SPSS version 25 (IBM Corporation, Armonk NY, USA). A value of $P < 0.05$ was considered significant for all tests. Data screened for normality and homogeneity of variance using the Shapiro–Wilk statistic and Levene’s test, respectively. Consequently, measures of central tendency and dispersion are reported as means with associated standard deviations. To evaluate differences in time to separation (TTS) between groups, a one-way analysis of variance (ANOVA) was used. The Tukey HSD post hoc test was used to assess significant differences.

Results

Sixty-six DCTaperH NiTi rotary files were tested to separation with different curvature locations on the file (See image 1). Table 1 shows the mean TTS between groups. A one-way ANOVA was performed to evaluate the impact of file length on TTS. The average TTS for the 11mm, 16mm and 21mm groups were 71.75 seconds, 16.26 seconds, and 2.82 seconds, respectively. This revealed that there was a decrease in time to separation as the curve location moved further away from the tip of the instrument. One-way ANOVA and Turkey HSD post hoc analyses revealed that there were significant differences between each of the three groups ($P < 0.001$).

Image 1: Jig setup

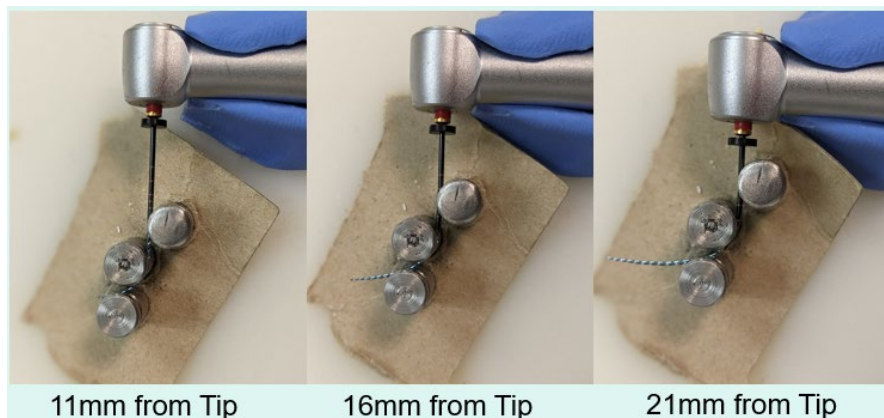
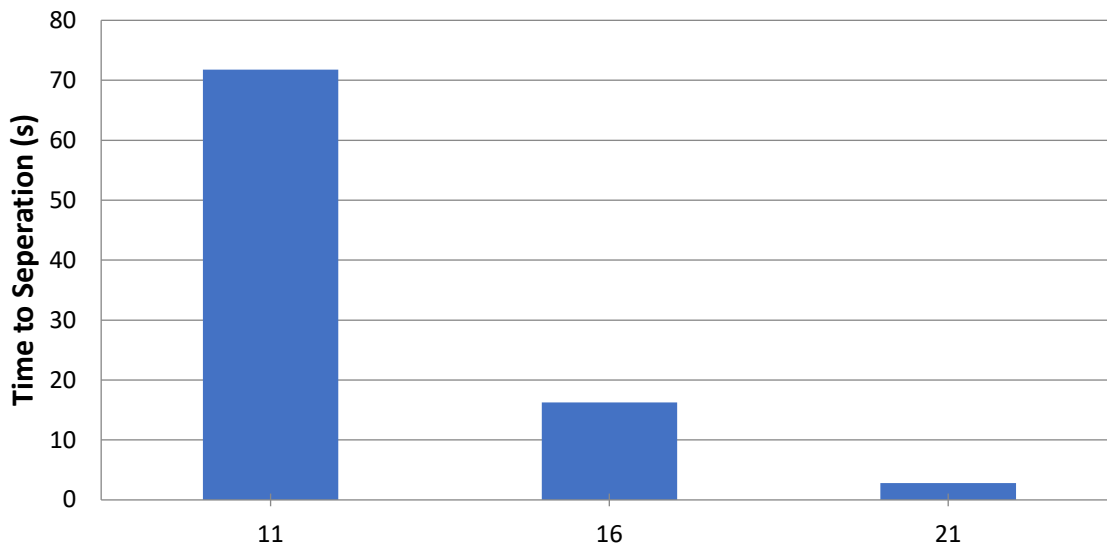


Table 1:

Mean TTS by Group			
Distance From Tip (mm)	N	Mean (Seconds)	Std. Deviation
11	22	71.75	14.17
16	22	16.26	6.19
21	22	2.82	0.29

Figure 1. Mean TTS by Group



Discussion

Clinicians generally divide root canal curvature location into three areas: apical, middle and coronal thirds. This study attempted to replicate these three general locations and how this location would influence the cyclic fatigue of the DCTaperH, 31mm size 25/v06 rotary files. The above results indicated that there was association with location of curvature and time to separation. The further the curvature was located from the tip of the instrument, the shorter the time to separation. Our results are in agreement with a study by Alghamdi et al (14) who also evaluated location of curvature and cyclic fatigue resistance. They tested five different types of files in a predetermined canal angle and radius of curve. Their preset canal curves were fabricated out of a zirconia oxide plate. The entry point to the curvature was lengthened or shortened and instruments were run until failure. Their study concluded that instruments were quick to separation when the curvature was also located more coronally on the file.

It has been estimated that the incidence of rotary instrument separation is around 3% (15) and historically, cyclic fatigue has been a significant factor in these iatrogenic events (9). The results of our study, as well those of Alghamdi et al., would support another clinical factor: canal

curvature location. This knowledge coupled with CBCT and an astute clinician, would allow practitioners to be more aware of the stress that a file may undergo in different locations of canal curvature.

In this benchtop study, there are limitations that must be acknowledged. First, the procedure was performed in a room temperature environment as opposed to a body temperature medium. There have been studies on files different from DCTaperH that have shown decreased time to separation when performed in a room temperature environment compared to a body temperature equivalent (16, 17). Alghamdi et al. was able to overcome this obstacle with their access to a zirconium block submerged in body temperature solution (14). They tested 5 different files of varying martensitic qualities and still showed that at body temperature, coronally located canal curvature caused a decrease in time to separation. There were also a few other clinical limitations which were encountered in our research. We rotated the files in a static position when testing for instrument separation which is not true of a clinical setting. Rarely are files held in a static position for significant lengths of time which may cause a decrease in time to separation as the file undergoes continuous stress without any chance for relief.

There is also the possibility of introduction of human error with the use of a stop watch. However, the significant differences in average time to separation would still seem to allow for a half second reaction delay and would likely still maintain a $p < 0.001$.

There are many clinical variables that could be manipulated in this type of study. One is the amount of curvature that is introduced into the file itself. Our study introduced a relatively sharp curvature which could have exacerbated the time to separation. A more gradual curve may have allowed for longer times to separation for each group. Another variable would be the type of file that could be used. We used a variably tapered 25/06 file that is a conservative file with a small maximum flute diameter. It has a variety of clinical applications and could be used as a step in a shaping protocol or as a final preparation size. It would be interesting to assess how different sized rotary files would be affected by curvature location. These would be potential avenues for further research to help identify if file size and curve location have an association on time to separation.

Another interesting concept is the angle of entry of the file into the canal orifice. Especially as conservative endodontic therapy becomes more prevalent, there are new unique stresses that will be introduced into our rotary files. A few recent studies have shown that increasing the angle of entry into the canal itself will also cause a decrease in fatigue resistance (18, 19). While this does pose a different scenario than canal curvature location, it does relate to the location of stress that is placed on a file influencing its cyclic fatigue. Both scenarios would suggest that stress placed more coronally on the file would lead to a decrease in cyclic fatigue resistance.

Conclusion

It is clear there are many factors involved in the cyclic fatigue properties of rotary instruments. Some of the most common clinical variables include angle and radius of curvature.

Within the limitations of this study, the clinical variable of canal curvature location may also be a factor in the cyclic fatigue resistance of DCTaperH 25/06 files.

The views expressed in this manuscript are those of the author and do not reflect the official policy or position of the United States Army, Department of Defense, or the U.S. Government.

Bibliography

1. Cheung, G., & Liu, C. (2009). A Retrospective Study of Endodontic Treatment Outcome between Nickel-Titanium Rotary and Stainless Steel Hand Filing Techniques. *Journal of Endodontics*, 35(7), 938–943. <https://doi.org/10.1016/j.joen.2009.04.016>
2. Bergmans, L., Van Cleynenbreugel, J., Wevers, M., & Lambrechts, P. (2001). Mechanical root canal preparation with NiTi rotary instruments: rationale, performance and safety. Status report for the American Journal of Dentistry. *PubMed*, 14(5), 324–333. <https://pubmed.ncbi.nlm.nih.gov/11803999>
3. Glosson, C. R., Haller, R. H., Dove, S., & Del Rio, C. (1995). A comparison of root canal preparations using Ni-Ti hand, Ni-Ti engine-driven, and K-Flex endodontic instruments. *Journal of Endodontics*, 21(3), 146–151. [https://doi.org/10.1016/s0099-2399\(06\)80441-3](https://doi.org/10.1016/s0099-2399(06)80441-3)
4. Esposito, P., & Cunningham, C. E. (1995). A comparison of canal preparation with nickel-titanium and stainless steel instruments. *Journal of Endodontics*, 21(4), 173–176. [https://doi.org/10.1016/s0099-2399\(06\)80560-1](https://doi.org/10.1016/s0099-2399(06)80560-1)
5. Sonntag, D., Guntermann, A., Kim, S. H., & Stachniss, V. (2003). Root canal shaping with manual stainless steel files and rotary Ni-Ti files performed by students. *International Endodontic Journal*, 36(4), 246–255. <https://doi.org/10.1046/j.1365-2591.2003.00661.x>
6. Schäfer, E., Schulz-Bongert, U., & Tulus, G. (2004). Comparison of Hand Stainless Steel and Nickel Titanium Rotary Instrumentation: A Clinical Study. *Journal of Endodontics*, 30(6), 432–435. <https://doi.org/10.1097/00004770-200406000-00014>
7. SATTAPAN, B., NERVO, G., PALAMARA, J., & MESSER, H. (2000, March). Defects in Rotary Nickel-Titanium Files After Clinical Use. *Journal of Endodontics*, 26(3), 161–165. <https://doi.org/10.1097/00004770-200003000-00008> .
8. Haikel, Y., Serfaty, R., Bateman, G., Senger, B., & Allemann, C. (2000, December). Dynamic And Cyclic Fatigue Of Engine-Driven Rotary Nickel-Titanium Endodontic Instruments. *Australian Endodontic Journal*, 26(3), 114–114. <https://doi.org/10.1111/j.1747-4477.2000.tb00295.x>
9. Parashos, P., & Messer, H. H. (2006, November). Rotary NiTi Instrument Fracture and its Consequences. *Journal of Endodontics*, 32(11), 1031–1043. <https://doi.org/10.1016/j.joen.2006.06.008>
10. Kim, T. J., Cheung, G., Lee, J. S. H., Kim, B., Hur, B., & Kim, H. (2009). Stress distribution of three NiTi rotary files under bending and torsional conditions using a mathematic analysis. *International Endodontic Journal*, 42(1), 14–21. <https://doi.org/10.1111/j.1365-2591.2008.01481.x>

11. Kim, H., Yum, J., Hur, B., & Cheung, G. (2010). Cyclic Fatigue and Fracture Characteristics of Ground and Twisted Nickel-Titanium Rotary Files. *Journal of Endodontics*, 36(1), 147–152. <https://doi.org/10.1016/j.joen.2009.09.037>
12. Di Fiore, P. M. (2007). A dozen ways to prevent nickel-titanium rotary instrument fracture. *Journal of the American Dental Association*, 138(2), 196–201. <https://doi.org/10.14219/jada.archive.2007.0136>
13. Lopes, H. P., Vieira, M. V. B., Elias, C. N., Gonçalves, L. S., Siqueira, J. F., Moreira, E. J. L., Vieira, V. T. L., & Souza, L. R. Q. (2013). Influence of the Geometry of Curved Artificial Canals on the Fracture of Rotary Nickel-Titanium Instruments Subjected to Cyclic Fatigue Tests. *Journal of Endodontics*, 39(5), 704–707. <https://doi.org/10.1016/j.joen.2012.12.027>
14. Alghamdi, S., Huang, X., Haapasalo, M., Mobuchon, C., Aleksejuniene, J., Hu, J., Wang, Z., Sobotkiewicz, T., & Shen, Y. (2020). Effect of Curvature Location on Fatigue Resistance of Five Nickel-titanium Files Determined at Body Temperature. *Journal of Endodontics*, 46(11), 1682–1688. <https://doi.org/10.1016/j.joen.2020.06.041>
15. Spili, P., P. Parashos, and H.H. Messer, The impact of instrument fracture on outcome of endodontic treatment. *J Endod*, 2005. 31(12): p. 845-50.
16. Klymus, M.E., et al., Effect of temperature on the cyclic fatigue resistance of thermally treated reciprocating instruments. *Clin Oral Investig*, 2019. 23(7): p. 3047-3052.
17. Plotino, G., et al., Cyclic Fatigue of Reciproc and Reciproc Blue Nickel-titanium Reciprocating Files at Different Environmental Temperatures. *J Endod*, 2018. 44(10): p. 1549-1552.
18. Pedullà, E., La Rosa, G. R. M., Boninelli, S., Rinaldi, O. G., Rapisarda, E., & Kim, H. C. (2018, December). Influence of Different Angles of File Access on Cyclic Fatigue Resistance of Reciproc and Reciproc Blue Instruments. *Journal of Endodontics*, 44(12), 1849–1855. <https://doi.org/10.1016/j.joen.2018.08.012>
19. Pedullà, E., La Rosa, G. R. M., Virgillito, C., Rapisarda, E., Kim, H. C., & Generali, L. (2020, March). Cyclic Fatigue Resistance of Nickel-titanium Rotary Instruments according to the Angle of File Access and Radius of Root Canal. *Journal of Endodontics*, 46(3), 431-436. <https://doi.org/10.1016/j.joen.2019.11.015>