



Influence of Autoclave Sterilization on Cyclic Fatigue of AF- F-ONE , ProTaper Ultimate, and ProTaper Gold NiTi Instruments (A Comparative Study)

Sarah Najeeb Mahmood ¹, Maha M. Yahya ¹, and Haider Al-Waeli ²

¹ College of Dentistry, Mustansiriyah University, Department of conservative, Iraq

² Graduate periodontics Program / Dalhousie University/ Canada

Correspondence: Sarah Najeeb Mahmood

Email: Sarah_Najeeb@uomustansiriyah.edu.iq

Received: 28 February 2024; Accepted: 12 June 2024; Published: 30 June 2024

Abstract

Aim of the study: This investigation aimed to examine the impact of autoclave sterilization on the cyclic fatigue of AF-F ONE, ProTaper Ultimate, and ProTaper Gold.

Material and method: Sixty #25 rotary files were categorized into three main groups (n=20 for each type) as follows: AF-F ONE (Group A), ProTaper Ultimate (Group B), and ProTaper Gold (Group C). Additionally, within each group, there were subdivisions into sterilized and non-sterilized subgroups (n=10). Sterilized instruments underwent five cycles of sterilization by autoclave. Cyclic fatigue resistance was evaluated using a simulated canal featuring a single curvature (60° angle, 5-mm radius). Files were operated until fracture, and time and number of cycles to fracture (NCF) were recorded. One-way ANOVA, Post hoc Tukey test, and independent t-test.

Results: ANOVA indicated a significant difference among non-sterilized groups ($p < 0.05$). Tukey's test showing a notable difference between AF-F ONE and ProTaper Ultimate/ProTaper Gold ($p < 0.05$), but not between the latter two ($p > 0.05$). The fracture resistance of AF-F-ONE is significantly decreased after autoclave sterilization ($p < 0.05$), while ProTaper Ultimate and ProTaper Gold remained unaffected ($p > 0.05$).

Conclusion: Autoclave sterilization significantly affected the cyclic fatigue of AF-F ONE, whereas ProTaper Ultimate and ProTaper Gold demonstrated resilience.

Keywords: Cyclic fatigue, ProTaper Ultimate, AF-F ONE, autoclave sterilization, NiTi Instruments

Introduction

Nickel-titanium (NiTi) materials yield files with superior pliability and enhanced adaptability to curved root canals (Gavini, Santos and Caldeira, 2018). Although there are numerous benefits offered by NiTi instrument, encountering file failure during clinical procedures remains a significant challenge. The fractures in NiTi files typically result from either torsional stress or cyclic fatigue respectively. Cyclic fatigue-

induced fractures occur when files undergo repeated compression and tension forces inside the curved canals (Sattapan et al., 2000).

To mitigate the occurrence of fractures in instruments, producers have conducted research on novel file designs and manufacturing techniques. One such innovation is the ProTaper Ultimate (PT Ultimate) file, characterized by a



parallelogram cross-section design, regressive taper, varying acute angles at different sections, and an alternating off-set machining process. This geometric innovation ensures that the center of mass of the instrument does not align with the center of rotation (Martins et al., 2023).

The AF-F One file, developed by Fanta Dental in Shanghai, China, and introduced in 2020, boasts a unique design with a flat-shaped and S-shaped cross-section. This distinctive design offers several advantages, including reduced blade engagement, an extended fatigue lifespan, and efficient debris removal from the canal. Featuring two active cutting points, an AF-R wire, and a non-cutting tip (Di Nardo et al., 2020).

On the other hand, ProTaper Gold (PTG) has gained widespread usage, consisting of three files for shaping and five files for finishing. Characterized by a convex triangular cross-section and a progressively tapered design, ProTaper Gold incorporates a non-cutting tip that facilitates safe navigation through the secured portion of the canal (Karataş et al., 2016).

The sterilization procedures for NiTi instruments include thermomechanical processing and additional heat treatment, significantly influencing their shape memory

and super-elastic properties. However, the impact of these procedures is highly contingent on the metallurgy, design, and manufacturing processes of NiTi files (Plotino et al., 2012). Autoclave sterilization cycles either exhibit no negative impacts or could possibly decrease the resistance of cyclic fatigue for certain NiTi files (Hilfer et al., 2011; Kim et al., 2020), there remains a lack of research on the consequences of autoclave sterilization specifically on ProTaper Ultimate, and AF-F ONE. Consequently, this investigation aimed to assess the influence of autoclave sterilization on the cyclic fatigue of AF-F ONE, ProTaper Ultimate, and ProTaper Gold.

The null hypothesis:

No differences among the cyclic fatigue resistance of ProTaper Ultimate, AF-F ONE, and ProTaper Gold instruments with and without undergoing several autoclave cycles.

Materials and Methods:

Three unique types of endodontic instruments (n=20 for each type, total n=60) were utilized, categorized into three groups. group A: AF-F ONE (tip size #25, taper 0.06), group B: ProTaper Ultimate file (tip size #25, taper 0.08), group C: ProTaper Gold file (tip size #25, taper 0.08). Every category was

additionally subdivided into two subcategories (n=10), distinguishing between sterilized and non-sterilized instruments.

The artificial canal was designed using AutoCAD 2018 and crafted with an electrical discharge wire cutting machine. This custom-made canal featured a 60° angle of curvature, a 5 mm radius, a curvature center positioned approximately 5 mm from the canal's terminus, with a curve length of 5.25 mm. The working length was set at 18 mm, the inner diameter was measured at 1.5 mm (Larsen, Watanabe and Glickman, 2009; Plotino et al., 2014).

A stereomicroscope at 20x magnification was initially employed to inspect the instruments for any deformities and to exclude them from the study (Yılmaz et al., 2017). The instrument groups (A2, B2, C2) were placed in autoclavable files holders and subjected to five cycles of autoclave sterilization at 134°C for 35 minutes (Sterilization was carried out for 20 minutes, followed by a drying period of 15 minutes) (Elbatal et al., 2016).

To ensure precise positioning and alignment within the artificial canal, a dental handpiece (X-Smart Plus Electric Motor) was mounted on a dental surveyor. To minimize friction, a synthetic lubricant (Glycerin) was applied to the entire artificial canal wall. The

instruments within each category were maneuvered inside the simulated canals without any pecking motion until a fracture observed (Mohammed and Al-Zaka, 2018).

The speed and torque settings for each category were configured in accordance to the producer's instructions:

AF-F ONE files: Speed 500 rpm, Torque 2.6 Ncm

ProTaper Ultimate files: Speed 400 rpm, Torque 4-5 Ncm

ProTaper Gold files: Speed 300 rpm, Torque 3.10 Ncm

The time of fracture, measured in seconds, was recorded from the initiation of rotation within the canal until a fracture occurred. The number of cycles to fracture (NCF) was determined utilizing the equation (Al-Halawi, Mehdi and Jasim, 2017):

$$\text{NCF} = \text{Speed (rpm)} \times \text{Time to fracture (seconds)} / 60.$$

Statistical analyses, including the Shapiro-Wilk test, one-way analysis of variance (ANOVA), post hoc Tukey tests, and independent t-tests, were performed using SPSS software. The degree of significance was set at 5%, with p values greater than 0.05 considered statistically nonsignificant and

values equal to or less than 0.05 regarded as significant ($p > 0.05$: not significant; $p \leq 0.05$: Significant).

Results:

Table (1) displays key statistics (Min, Max, Mean, SD, SE) for cycles to fracture (NCF) in ProTaper Ultimate, F-ONE, and ProTaper Gold, categorized as sterilized and non-sterilized instruments. Prior to analysis, a Shapiro-Wilk test (Table 2) affirmed a normal data distribution ($p > 0.05$ for all files). One-way ANOVA (Table 3) showed a

significant difference among non-sterilized groups, but not among sterilized groups.

Post hoc Tukey Test (Table 4) revealed a significant NCF difference between AF-F ONE and ProTaper Ultimate, and ProTaper Gold, while no difference was found between ProTaper Ultimate and ProTaper Gold. Independent t-tests (Table 5) indicated ProTaper Ultimate and ProTaper Gold remained unaffected by sterilization, whereas AF-F ONE showed a significant decrease in resistance to cycling fatigue.

Table 1: Descriptive statistical analysis for the NCF of each group for both sterilized and non-sterilized instruments.

Sterilization	Endodontic files	Min.	Max.	Mean	SD	SE
Non sterilized	ProTaper Ultimate	1052.00	1380.00	1236.1000	93.01428	29.41370
	AF -F ONE	1356.00	1876.00	1598.5000	201.08829	63.58970
	ProTaper Gold	1050.00	1420.00	1248.9000	130.63728	41.31114
sterilized	ProTaper Ultimate	1102.00	1303.00	1224.5000	65.62562	20.75264
	AF -F ONE	1012.00	1567.00	1254.7000	176.01455	55.66069
	ProTaper Gold	1045.00	1430.00	1259.8000	134.78032	42.62128

Table 2: Shapiro-wilk test for sterilized and non-sterilized instruments.

Sterilization	Samples	Statistic	Df	Sig
Non-sterilized	ProTaper Ultimate	.917	10	.330
	AF -F ONE	.906	10	.252
	ProTaper gold	.946	10	.622
Sterilized	ProTaper Ultimate	.875	10	.114
	AF -F ONE	.969	10	.882
	ProTaper gold	.933	10	.477

Table 3: One way ANOVA test for NCF among groups in both sterilized and non-sterilized instrument

Canals	Score	Sum of squares	df	Mean Square	F	Sig.
Non-sterilized	Between Groups	845725.867	2	422862.933	19.176	.000
	Within Groups	595388.300	27	22051.419		
	Total	1441114.167	29			
sterilized	Between Groups	7280.467	2	3640.233	.204	.816
	Within Groups	481082.200	27	17817.859		
	Total	488362.667	29			

Table 4: Post hoc Tukey test between groups in non-sterilized instruments

I) Groups	J) Groups	Mean Difference (I-J)	Std. error	Sig	Lower bound	Upper bound
ProTaper Ultimate	AF-F ONE	-362.40000*	66.40997	.000	-527.0580	-197.7420
	ProTaper Gold	-12.80000	66.40997	.980	-177.4580	151.8580
AF-F ONE	ProTaper Ultimate	362.40000*	66.40997	.000	197.7420	527.0580
	ProTaper Gold	349.60000*	66.40997	.000	184.9420	514.2580
ProTaper Gold	ProTaper Ultimate	12.80000	66.40997	.980	-151.8580	177.4580
	AF-F ONE	-349.60000*	66.40997	.000	-514.2580	-184.9420

Table 5: Independent t test between sterilized and non-sterilized instruments

Endodontic files	T	df	Sig. (2-tailed)	Mean difference	Std. Error Difference	Lower	Upper
ProTaper Ultimate	.322	18	.751	11.60000	35.99775	-64.02846	87.22846
AF-F ONE	4.068	18	.001	343.80000	84.50895	166.25329	521.34671
ProTaper Gold	-.184	18	.856	-10.90000	59.35641	-135.60319	113.80319

Discussion:

Within the domain of root canal instrumentation, the introduction of various

new NiTi rotary systems aims to enhance instrument lifespan and mitigate issues such as intracanal instrument separation, which

can significantly impact treatment outcomes (Dioguardi et al., 2021).

Clinicians engaged in dental procedures are routinely exposed to diverse microorganisms present in blood and saliva, posing a risk for infectious diseases. Ensuring aseptic conditions and preventing cross-contamination have become pivotal, highlighting the importance of instrument sterilization. Common methods employed in endodontic practice for sterilization include hot dry air and autoclave sterilization (Viana et al., 2006).

Given the clinical relevance of sterilization, this study specifically investigated the consequence of several autoclave cycles on the cyclic fatigue resistance of ProTaper Ultimate, AF-F ONE, and ProTaper Gold. Understanding how these NiTi rotary systems respond to autoclave sterilization is crucial for optimizing instrument performance and maintaining aseptic conditions during endodontic procedures.

Similar to this study, existing research has explored the consequence of autoclave sterilization on the cyclic fatigue resistance of NiTi instruments. Numerous investigations into the cyclic fatigue resistance of NiTi instruments have utilized artificial canals. Artificial canals offer a standardized

environment, minimizing anatomical variations found in natural teeth (Yahata et al., 2009).

In this assessment of ProTaper Ultimate, F-ONE, and ProTaper Gold files before and after autoclave sterilization, a notable reduction in cyclic fatigue resistance was noted in the sterilized AF-F ONE instruments. This suggests that autoclaving significantly reduces cyclic fatigue resistance, potentially due to changes in metallurgical properties induced by high temperature and pressure during autoclaving. The transition from the martensite phase to the more rigid austenite phase might render the file more susceptible to fatigue crack propagation (Shen et al., 2013), consistent with the findings of Al-Amidi AH and Al-Gharrawi HA (2023) (Al-Amidi and Al-Gharrawi, 2023).

Contrastingly, cyclic fatigue resistance of ProTaper Ultimate and ProTaper Gold was not affected by autoclave sterilization, aligning with findings by Phumpatrakom et al. (2022) and Almohareb RA et al. (2023) (Phumpatrakom et al., 2022; Almohareb et al., 2023). Divergent results reported increased resistance in ProTaper Gold after ten cycles of autoclave sterilization in a study by Özyürek, Yılmaz & Uslu (2017) (Yılmaz,

K., Uslu, G., & Özyürek, 2017). This disparity may stem from methodological differences, as this study investigated cyclic fatigue resistance after five sterilization cycles.

Among non-sterilized instruments, F ONE exhibited higher NCF values compared to other files. This might be ascribed to its manufacturing process, incorporating AF-R Wire, a flat design, and S-shaped cross-sections that reduce blade engagement and friction. These features may contribute to increased cyclic fatigue resistance, especially when instruments can move more freely or straighten during fatigue tests (Plotino et al., 2009; De-Deus et al., 2017; Gambarini et al., 2019). The smaller taper of AF-F-ONE compared to ProTaper Ultimate and ProTaper Gold may also contribute, as instruments with narrower tapers tend to demonstrate increased resistance to cyclic fatigue (Faus-Llácer et al., 2021).

For sterilized instruments, no significant difference was observed between files, as NCF of AF-F-ONE decreased after sterilization, while ProTaper Ultimate and ProTaper Gold remained unaffected.

Conclusion

Autoclave sterilization notably diminished the cyclic fatigue resistance of AF-F ONE, underscoring the importance of understanding the specific impact on individual instruments. Conversely, ProTaper Ultimate and ProTaper Gold showcased resilience to autoclave.

Supplementary Material

None.

Funding

This research received no external funding.

Data Availability Statement

Data are available from the authors upon reasonable request.

Conflict of interest

The authors reported that they have no conflicts of interest.

Acknowledgments

Sarah Najeeb Mahmood, Maha M. Yahya would like to thank Mustansiriyah University/Baghdad-Iraq (www.uomustansiriyah.edu.iq) for their support in the present work.

References

1. Al-Amidi, A.H. and Al-Gharrawi, H.A. (2023) 'Effect of autoclave sterilization on the cyclic

- fatigue resistance of EdgeFile X7, 2Shape, and F-one nickel-titanium endodontic instruments', *Journal of Conservative Dentistry*, 26(1), pp. 26-30. https://doi.org/10.4103/jcd.jcd_611_21
2. Al-Halawi, M., Mehdi, J. and Jasim, H. (2017) 'Evaluate the effect of canal curvature on Fracture Resistance and Cyclic Fatigue of Three NiTi Rotary Instruments (A comparative in vitro study)', *Journal of Oral and Dental Research*, 4(2), pp. 1-11.
 3. Almohareb, R.A., Barakat, R.M., Algahtani, F.N. and Alkadi, M.F. (2023) 'Cyclic fatigue resistance of EdgeTaper Platinum, Protaper Gold, and TruNatomy Prime rotary files before and after autoclave sterilization', *PeerJ*, 11, e14656. <https://doi.org/10.7717/peerj.14656>
 4. De-Deus, G., Silva, E.J.N.L., Vieira, V.T.L., Belladonna, F.G., Elias, C.N. and Plotino, G. (2017) 'Blue thermomechanical treatment optimizes fatigue resistance and flexibility of the Reciproc files', *Journal of Endodontics*, 43(3), pp. 462-466. <https://doi.org/10.1016/j.joen.2016.10.039>
 5. Di Nardo, D., Miccoli, G., Mazzoni, A., Seracchiani, M., Gambarini, G. and Testarelli, L. (2020) 'Centering Ability of a New Nickel-Titanium Rotary Instruments with a Peculiar Flat-side Design: An In Vitro Study', *Journal of Contemporary Dental Practice*, 21(1), pp. 539-542. <https://doi.org/10.5005/jp-journals-10024-2829>
 6. Dioguardi, M., Arena, C., Sovereto, D., Aiuto, R., Laino, L., Illuzzi, G., Laneve, E., Raddato, B., Caponio, V.C.A., Dioguardi, A., Zhurakivska, K., Troiano, G. and Muzio, L.L. (2021) 'Influence of sterilization procedures on the physical and mechanical properties of rotating endodontic instruments: a systematic review and network meta-analysis', *Frontiers in Bioscience-Landmark*, 26(11), pp. 1697-1713. <https://doi.org/10.52586/5062>
 7. Elbatal, L.M., El Batouty, K.M. and Obeid, M.M. (2016) 'Effect of repeated autoclaving on cyclic fatigue of three nickel-titanium rotary instruments', *ENDO - Endodontic Practice Today*, 10(1), pp. 15-22.
 8. Faus-Llácer, V., Kharrat, N.H., Ruiz-Sánchez, C., Faus-Matoses, I., Zubizarreta-Macho, Á. and Faus-Matoses, V. (2021) 'The Effect of Taper and Apical Diameter on the Cyclic Fatigue Resistance of Rotary Endodontic Files Using an Experimental Electronic Device', *Applied Sciences*, 11(2), p. 863. <https://doi.org/10.3390/app11020863>
 9. Gambarini, G., Galli, M., Seracchiani, M., et al. (2019) 'In Vivo Evaluation of Operative Torque Generated by Two Nickel-Titanium Rotary Instruments during Root Canal Preparation', *European Journal of Dentistry*, 13(4), pp. 556-562. <https://doi.org/10.1055/s-0039-1698369>
 10. Gavini, G., Santos, M.D. and Caldeira, C.L. (2018) 'Nickel-titanium instruments in

- endodontics: a concise review of the state of the art', *Brazilian Oral Research*, 32(suppl 1), e67. <https://doi.org/10.1590/1807-3107bor-2018.vol32.0067>
11. Hilfer, P.B., Bergeron, B.E., Mayerchak, M.J., Roberts, H.W. and Jeansonne, B.G. (2011) 'Multiple autoclave cycle effects on cyclic fatigue of nickel-titanium rotary files produced by new manufacturing methods', *Journal of Endodontics*, 37(1), pp. 72-74. <https://doi.org/10.1016/j.joen.2010.09.011>
 12. Karataş, E., Gündüz, H.A., Kırıcı, D.Ö. and Arslan, H. (2016) 'Incidence of dentinal cracks after root canal preparation with ProTaper Gold, Profile Vortex, F360, Reciproc and ProTaper Universal instruments', *International Endodontic Journal*, 49(9), pp. 905-910. <https://doi.org/10.1111/iej.12541>
 13. Kim, W., Oh, S., Ryu, G.J., Kim, T.H., Kim, S.J., Kim, D.H., Lee, B.N., Kum, K.Y., Chang, S.W. and Jang, J.H. (2020) 'Effect of autoclave sterilization on cyclic fatigue and torsional fracture resistance of NiTi rotary instruments', *Odontology*, 108(2), pp. 194-201. <https://doi.org/10.1007/s10266-019-00453-3>
 14. Larsen, C., Watanabe, I. and Glickman, G. (2009) 'Cyclic fatigue analysis of a new generation of nickel titanium rotary instruments', *Journal of Endodontics*, 35(3), pp. 401-403. <https://doi.org/10.1016/j.joen.2008.12.010>
 15. Martins, J.N.R., Silva, E.J.N.L., Marques, D., Ajuz, N., Rito Pereira, M. and Pereira da Costa, R. (2023) 'Characterization of the file-specific heat-treated ProTaper Ultimate rotary system', *International Endodontic Journal*, 56(4), pp. 530-542. <https://doi.org/10.1111/iej.13880>
 16. Mohammed, A.H. and Al-Zaka, I.M. (2018) 'Cyclic Fatigue of Different Glide Path Systems in Single and Double Curved Simulated Canal: A Comparative Study', *International Journal of Medical Research & Health Sciences*, 7(11), pp. 72-78.
 17. Phumpatrakom, P., Klinsontorn, N., Jutrakulkeeree, T., Thanarojwongsa, V., Klaisiri, A. and Aguilar, P. (2022) 'Effect of autoclave sterilization on cyclic fatigue of EdgeTaper platinum and ProTaper gold nickel-titanium rotary instruments: An in vitro study', *Saudi Endodontic Journal*, 12(1), pp. 114-119. https://doi.org/10.4103/sej.sej_281_20
 18. Plotino, G., Costanzo, A., Grande, N.M., Petrovic, R., Testarelli, L. and Gambarini, G. (2012) 'Experimental evaluation on the influence of autoclave sterilization on the cyclic fatigue of new nickel-titanium rotary instruments', *Journal of Endodontics*, 38(2), pp. 222-225. <https://doi.org/10.1016/j.joen.2011.10.017>

19. Plotino, G., Grande, N.M., Cotti, E., Testarelli, L. and Gambarini, G. (2014) 'Blue treatment enhances cyclic fatigue resistance of vortex nickel-titanium rotary files', *Journal of Endodontics*, 40(9), pp. 1451-1453. <https://doi.org/10.1016/j.joen.2014.02.020>
20. Plotino, G., Grande, N.M., Cordaro, M., Testarelli, L. and Gambarini, G. (2009) 'A review of cyclic fatigue testing of nickel-titanium rotary instruments', *Journal of Endodontics*, 35(11), pp. 1469-1476. <https://doi.org/10.1016/j.joen.2009.06.015>
21. Sattapan, B., Nervo, G.J., Palamara, J.E. and Messer, H.H. (2000) 'Defects in rotary nickel-titanium files after clinical use', *Journal of Endodontics*, 26(3), pp. 161-165. <https://doi.org/10.1097/00004770-200003000-00008>
22. Shen, Y., Zhou, H.M., Zheng, Y.F., Peng, B. and Haapasalo, M. (2013) 'Current challenges and concepts of the thermomechanical treatment of nickel-titanium instruments', *Journal of Endodontics*, 39(2), pp. 163-172. <https://doi.org/10.1016/j.joen.2012.11.005>
23. Viana, A.C., Gonzalez, B.M., Buono, V.T. and Bahia, M.G. (2006) 'Influence of sterilization on mechanical properties and fatigue resistance of nickel-titanium rotary endodontic instruments', *International Endodontic Journal*, 39(9), pp. 709-715. <https://doi.org/10.1111/j.1365-2591.2006.01138.x>
24. Yahata, Y., Yoneyama, T., Hayashi, Y., Ebihara, A., Doi, H., Hanawa, T. and Suda, H. (2009) 'Effect of heat treatment on transformation temperatures and bending properties of nickel-titanium endodontic instruments', *International Endodontic Journal*, 42(7), pp. 621-626. <https://doi.org/10.1111/j.1365-2591.2009.01563.x>
25. Yılmaz, K., Uslu, G. and Özyürek, T. (2017) 'In vitro comparison of the cyclic fatigue resistance of HyFlex EDM, One G, and ProGlider nickel titanium glide path instruments in single and double curvature canals', *Restorative Dentistry & Endodontics*, 42(4), pp. 282-289. <https://doi.org/10.5395/rde.2017.42.4.282>