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

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Abstract:

Aims: This investigation aimed to examine the impact of autoclave sterilization on the cyclic fatigue of AF-F ONE, ProTaper Ultimate, and ProTaper Gold. **Materials and Methods:** 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. **Statistical analysis:** 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 [1]. 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[2].

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[3].

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 [4].

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[5].

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[6]. Autoclave sterilization cycles either exhibit no negative impacts or could possibly decrease the resistance of cyclic fatigue for certain NiTi files[7, 8], 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 [9,10].

A stereomicroscope at 20x magnification was initially employed to inspect the instruments for any deformities and to exclude them from the study [11]. 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) [12].

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[13].

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:

NCF = Speed (rpm) × Time to fracture (seconds)/60 [14].

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.

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 [15].

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 [16].

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 [17].

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[18], consistent with the findings of Al-Amidi AH and Al-Gharrawi HA (2023). [19]

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). [20,21]Divergent results reported increased

resistance in ProTaper Gold after ten cycles of autoclave sterilization in a study by Özyürek, Yılmaz & Uslu (2017). [11] 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[22, 23, 24]. 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.[25]

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.

Conflict of interest

The authors reported that they have no conflicts of interest.

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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