Print ISSN: 2321-6379
Online ISSN: 2321-595X

Original Article

Comparative Evaluation of Surface Roughness of Two File Systems, HyFlex Electro Discharge Machining and Protaper Gold, Sterilized using Autoclave: An Atomic Force Microscope Study

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Abstract

Aim: This study aims to determine the surface roughness (SR) of two file systems undergoing sterilization in an autoclave using an atomic force microscope (AFM).

Materials and Methods: A Total of 40 nickel–titanium (NiTi) files will be taken as samples. Group A HyFlex Electrical discharge machining (EDM) (*n* = 10), Group B ProTaper Gold (PTG) (*n* = 10), and Subgroup A1: Control (*n* = 5), Subgroup A2: Autoclaved (*n* = 5), Subgroup B1: Control (*n* = 5), Subgroup B2: Autoclaved (*n* = 5). NiTi rotary files were subjected to five autoclave cycles (the Control group was not autoclaved). Each cycle was carried out at 134°C, 30 psi pressure for 20 min. The analysis of SR was carried out on the file, at a distance of 6 mm starting from the tip of the file, using an AFM.

Statistical Analysis Used: The data were analyzed using Statistical Package for the Social Sciences (SPSS) 23.0 (IBM-SPSS Inc., Chicago, IL) software. An independent *t*-test was performed to statistically analyze the roughness average and root mean square roughness values.

Results: PTG with autoclaving showed better results than PTG without autoclaving, followed by HyFlex EDM without autoclaving and HyFlex EDM with autoclaving.

Conclusion: PTG can be used multiple times after autoclaving in day-to-day clinical use.

Key words: Atomic force microscope, Autoclave, HyFlex Electrical discharge machining, Protaper gold, Surface roughness

INTRODUCTION

The endodontic treatment aims to preserve patients' natural teeth by removing infected tissue and shaping the canal.[1] Nickel–titanium (NiTi) launched the era of rotary engine-driven canal preparation and has become a game-changer in endodontics[2] and has evolved over the last two decades, introducing different tapers and cross-sections.[3]

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www.ijss-sn.com

Month of Submission : 11-2025
Month of Peer Review : 12-2025
Month of Acceptance : 01-2026
Month of Publishing : 01-2026

Body-centered cubic austenitic and hexagonal close-packed martensitic, with an intermediate R-phase, are the main phases of NiTi alloy.[4]

A number of manufacturing techniques have been developed to strengthen the mechanical properties and reduce the frequency of file fractures. Thermal treatment applied in manufacturing NiTi files changes their mechanical properties.[5]

These instruments are classified as "critical items" and require a strict sterilization protocol using an autoclave, as they undergo cross-contamination. As seen in previous

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reports, pits and cracks on the surface of NiTi instruments can result in the progression of cracks at the material surface with repeated use.[6]

The effect of multiple sterilization cycles is reciprocated by surface roughness (SR) of NiTi files, seen after five or ten repeated autoclaving cycles, and can lead to file separation.[7]

ProTaper Gold ([PTG]; Dentsply Maillefer, Baillagues, Switzerland) thermal treatment and controlled memory properties make them stand out from ProTaper Universal.[2]

HyFlex electro discharge machining (EDM) (Coltene Whale dent) files are produced by EDM,[8] consisting of vaporizing and melting the particles of the material via electric sparks.[9]

The atomic force microscope (AFM) consists of a probe, which moves across the surface of the sample, and provides topography of the surface of the sample.[10]

Subjects and Methods

This study employed a total of 20 files ($n = 20$). These files were divided into two groups and two subgroups each.

Group A HyFlex EDM (25/~) ($n = 10$).
- Subgroup A1: Control ($n = 5$)
- Subgroup A2: Autoclaved ($n = 5$)

Group B PTG (25/8) ($n = 10$).
- Subgroup B1: Control ($n = 5$)
- Subgroup B2: Autoclaved ($n = 5$)

NiTi rotary files in the autoclaved subgroups were prepared and subjected to five autoclave cycles (the Control group was not autoclaved). Each cycle was carried out at 134°C, under a pressure of 30 psi for 20 min, followed by a drying time of 15 min. The analysis of SR was carried out on the file, at a distance of 6 mm starting from the tip of the file, using an AFM.

RESULTS

The data were analyzed using Statistical Package for the Social Sciences (SPSS) 23.0 (IBM-SPSS Inc., Chicago, IL) software. An independent *t*-test was performed to statistically analyze the roughness average (Ra) and root mean square (RMS) values.

- A statistically significant difference was found in the mean SR and RMS values in the files that were autoclaved compared to files that were not autoclaved in the ProTaper group ($P < 0.05$).

Table 1: Intragroup comparison in the mean surface roughness and root mean square values in the files that were autoclaved compared to files that were not autoclaved in the Hyflex group and ProTaper Gold group ($P < 0.05$)

	GROUP		N	Mean	SD	SE Mean	P Value
ROUGHNESS	WITH AUTOCLAVE	HYFLEX	5	31.6000	2.17256	0.97160	0.000*
		PROTAPER	5	15.8400	2.53041	1.13164	
	WITHOUT AUTOCLAVE	HYFLEX	5	21.4400	2.27332	1.01666	0.571
		PROTAPER	5	20.4400	3.03117	1.35558	
RMS	WITH AUTOCLAVE	HYFLEX	5	47.3200	3.87453	1.73274	0.000*
		PROTAPER	5	12.4560	2.08784	0.93371	
	WITHOUT AUTOCLAVE	HYFLEX	5	38.4240	3.82598	1.71103	0.000*
		PROTAPER	5	25.2200	2.44172	1.09197	

Table 2: Intergroup comparison in the mean surface roughness and root mean square values between autoclaved and non-autoclaved hyflex electro discharge machining and Protaper gold group

	GROUP		N	Mean	SD	SE Mean	P Value
ROUGHNESS	HYFLEX	WITH AUTOCLAVE	5	31.6000	2.17256	0.97160	0.000*
		WITHOUT AUTOCLAVE	5	21.4400	2.27332	1.01666	
	PROTAPER	WITH AUTOCLAVE	5	15.8400	2.53041	1.13164	0.032*
		WITHOUT AUTOCLAVE	5	20.4400	3.03117	1.35558	
RMS	HYFLEX	WITH AUTOCLAVE	5	47.3200	3.87453	1.73274	0.006*
		WITHOUT AUTOCLAVE	5	38.4240	3.82598	1.71103	
	PROTAPER	WITH AUTOCLAVE	5	12.4560	2.08784	0.93371	0.000*
		WITHOUT AUTOCLAVE	5	25.2200	2.44172	1.09197	

Intergroup comparison

- A statistically significant difference was found in the mean SR and RMS values when autoclaved HyFlex files were compared to autoclaved ProTaper files ($P < 0.05$).
- A statistically significant difference was found in the mean RMS values when non-autoclaved HyFlex files were compared to non-autoclaved ProTaper files ($P < 0.05$).

Intragroup Comparison

- A statistically significant difference was found in the mean SR and RMS values in the files that were autoclaved compared to files that were not autoclaved in the HyFlex group ($P < 0.05$).
- A statistically significant difference was found in the mean SR and RMS values in the files that were autoclaved compared to files that were not autoclaved in the ProTaper group ($P < 0.05$).

Intergroup Comparison

- A statistically significant difference was found in the mean SR and RMS values when autoclaved HyFlex files were compared to autoclaved ProTaper files ($P < 0.05$).
- A statistically significant difference was found in the mean RMS values when non-autoclaved HyFlex

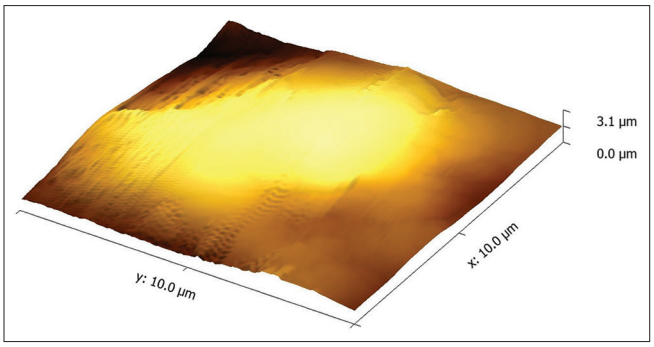

Figure 1: Atomic force microscopic image of a non-autoclaved HyFlex Electrical discharge machining system

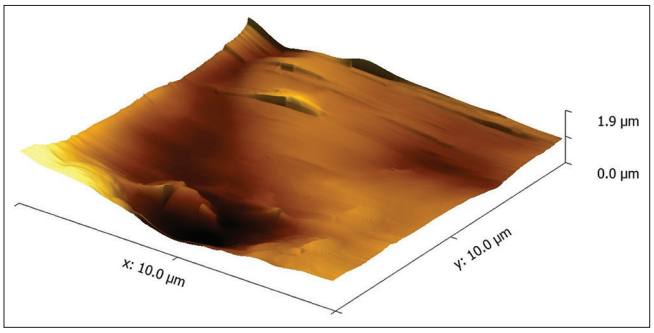

Figure 2: Atomic force microscopic image of autoclaved HyFlex Electrical discharge machining system

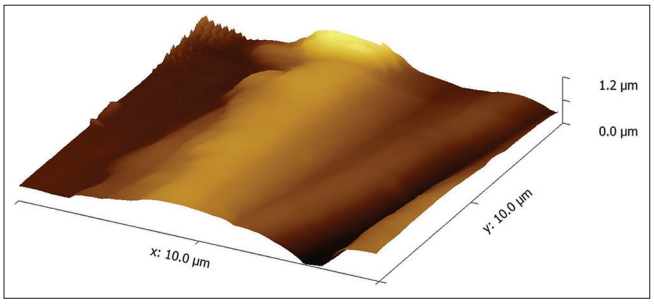

Figure 3: Atomic force microscopic image of non autoclaved protaper file system

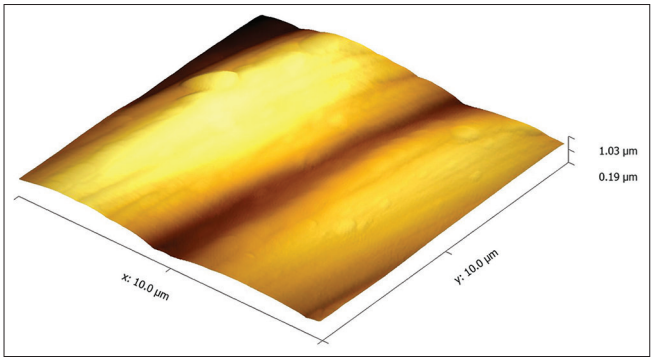

Figure 4: Atomic force microscopic image of autoclaved ProTaper file system

files were compared to non-autoclaved ProTaper files ($P < 0.05$).

- No statistically significant difference was found in the mean SR values when non-autoclaved HyFlex files were compared to non-autoclaved ProTaper files ($P > 0.05$) [Figures 1-4 and Tables 1 and 2].

DISCUSSION

One of the major goals of health practitioners is the prevention of cross-contamination of infectious diseases among dental staff and patients.[11] Endodontic treatments include various procedure that lead to blood contamination during the procedure. The spread of infectious diseases can be prevented by sterilization.[12] NiTi files are used repeatedly as they are expensive; the files are subjected to many autoclave sterilization cycles. The complete elimination or destruction of all forms of microbial life, including both vegetative and spore forms, is known as sterilization.[13]

Surface characteristics of NiTi instruments are to be considered when assessing instrument quality, as various conditions may lead to corrosion resistance. NiTi file corrosion occurs due to the selective removal of nickel from the surface when the instrument is exposed to sodium hypochlorite during root-canal preparation or the disinfection process.[2]

Micro pitting and cracks are produced due to alterations on the instrument surfaces, which can increase the likelihood of fracture. High SR values can be considered stress-concentration points, which lead to crack initiation and propagation during clinical use, ultimately resulting in instrument separation.[2]

Previous research has shown that debris and irregularities are present on the surface of new, unused endodontic files. These studies attribute the presence of such SR to the tedious manufacturing process of NiTi files and their packing.[2]

For the analysis of the SR of NiTi files, several techniques have been used. AFM and scanning electron microscope (SEM) are the methods that stand out to evaluate the surface characteristics of endodontic files. (NiTi wires also). AFM has the advantage that both quantitative and qualitative data can be assessed. SEM has the disadvantage that only qualitative data can be obtained, as the two-dimensional images created by SEM cannot be processed and considered for quantitative surface data.[2]

In a study conducted by Radian *et al.*, the PROTAPER value after autoclaving is still significantly lower compared with files that were not autoclaved. The

difference in the results of PTG can be attributed to the surface treatment differences, which have been proven earlier. Results clearly showed that multiple autoclave cycles enhance and have a positive effect on the surface topography of PTG as the SR decreases. Therefore, it would be helpful to sterilize the sealed new files before using them to remove debris and reduce SR, thereby leading to the betterment of the mechanical properties during clinical use.[2]

Pirani studied the metallurgical properties of HyFlex EDM files and HyFlex CM files in an environmental SEM/energy-dispersive X-ray spectroscopy analysis. They found irregularities in the surface of the HyFlex EDM files and attributed these to the production method used to manufacture the files. In that study, there was a statistically significant increase in the initial SR values of the HyFlex EDM files after five cycles of sterilization.[8]

In another study conducted by Alex *et al.*, the mean values of RMS SR were highest in Group I (HyFlex EDM control), followed by Group III (HyFlex EDM experimental), Group II (Wave One Gold control), and the lowest in Group IV (Wave One Gold experimental). This proves that the increase in SR directly correlates with usage in curved canals.[1]

Studying the HyFlex EDM micrographs disclosed a non-uniform structure where pits, pores, and voids caused the peculiar aspect of a rough-spark-machined crater-like irregular surface. Results from previous studies proved the presence of machining marks, surface irregularities, metal flashes, and irregular cutting edges as characteristic features of the manufacturing procedure in new NiTi instruments.[14]

SEM analysis demonstrated a minor irregular cutting edge in HyFlex EDM compared with ProTaper Next and One Shape. After repeated autoclaving, surface changes seen on NiTi files might be due to chemical composition as well as its structure. The authors stated that irregularities in surface patterns of HyFlex EDM files, without disruption of the cutting edge, occur after repeated usage.[14]

CONCLUSION

Within the limitations of the study, PTG after autoclaving shows the lowest SR after five cycles of autoclaving, compared to the Protaper control group, followed by the HyFlex EDM control group and autoclaved. Clinicians should be aware that while using these files produced with the same alloy but different methods in multiple patients, and take into consideration that the multiple autoclave cycles have a significant impact on the SR of these files alone.

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How to cite this article: Ama A, Rangappa J, Pola SS, Jarupala D, Kotha S, Kumar P. Comparative Evaluation of Surface Roughness of Two File Systems, HyFlex Electro Discharge Machining and Protaper Gold, Sterilized using Autoclave: An Atomic Force Microscope Study. Int J Sci Stud 2026;13(10):17-20.

Source of Support: Nil, **Conflicts of Interest:** None declared.