

ORIGINAL RESEARCH

Comparative Evaluation of the Effects of Different Sterilization Methods on Cyclic Fatigue Resistance of NiTi Files: An *in vitro* Study

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ABSTRACT

In this study, effect of different methods of sterilization was evaluated. A total of new 50 ProTaper files nickel-titanium (NiTi) files (Tulsa-dentsply, USA), of standard # 20 size with taper of 0.06 and 25 mm length were taken, and divided into five groups according to method of sterilization employed with 10 files in each group.

Group 1: Control with no sterilization of files.

Group 2: Autoclaved files at 121°C at 15 psi for 15 minutes.

Group 3: Files wiped with 90% ethyl alcohol solution.

Group 4: Files submerged in glass bead sterilizer at 425° F for 10 seconds.

Group 5: Files immersed in 2% glutaraldehyde solution for 4 hours.

After five cycles of sterilization, in custom made cyclic fatigue testing model, time taken for fracture of files and number of cycles to failure (NCF) was calculated in each group. Results were analyzed statistically using analysis of variance (ANOVA) test at the 95% confidence level ($p < 0.05$).

Conclusion: Changes in the mechanical properties of NiTi endodontic instruments after five cycles of common sterilization procedures were insignificant.

Keywords: Cyclic fatigue, NiTi, Sterilization.

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INTRODUCTION

The superelasticity and shape memory properties of nickel-titanium (NiTi) alloy have contributed to important

practical applications in endodontics.¹ These properties occur as a result of the austenite to martensite transition, which in turn is because the alloy has an inherent ability to alter its type of atomic bonding. The martensitic transformation requires a reversible atomic process termed twinning that allows reduction in strain during the transformation.^{2,3}

This phase transformation is thermoelastic, i.e. can be induced by cooling or by the application of stress. When the metal is heated or the stress is released, the reverse transformation, martensite to austenite, takes place. The lower symmetry of martensite in relation to austenite makes the reverse transformation to undo the previously induced shape change causing shape recovery.⁴⁻⁶

Despite the increased flexibility of engine-driven NiTi endodontic instruments, their continuous rotation within curved root canals causes structural fatigue as a result of bending and torsional stresses.⁷

Two different separation mechanisms occur in rotary instruments: torsional (ductile) and cyclic fatigue (brittle) fracture. Instruments separated by torsional stresses usually present macroscopic plastic deformation, whereas instruments fractured by fatigue generally exhibit no specific macroscopic pattern. Torsional failure occurs when the tip of the instrument binds and the remaining file continues to rotate, ultimately leading to fracture while cyclic fatigue is caused by compressive and tensile stresses on a rotating file in a curved canal.⁸

Endodontic treatment involves direct contact with saliva, blood and infected pulp tissue, carrying bacteria, viruses or prions from patient to patient.⁴ Sterilization in the field of healthcare aims to prevent the spread of infectious diseases, which primarily relates to processing of reusable instruments to prevent cross-infection.⁵ The cleaning and sterilization of endodontic instruments between treatments sessions is essential to prevent cross infection.

Different methods to sterilize instruments involving heating and cooling include dry heat sterilizer, autoclave, ethylene oxide gas, glass bead sterilizer or hot salt sterilizer, etc.⁹ However, the effect of the heating and cooling cycles employed during sterilization on the mechanical properties and resistance to fracture of endodontic instruments have not yet been clearly stated.

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The purpose of the study was to evaluate the effects of different sterilization methods on cyclic fatigue resistance of NiTi files.

MATERIALS AND METHODS

In the present study, most accessible methods of sterilization like autoclaving, glutaraldehyde, glass bead sterilization and ethyl alcohol solution were used. A total of new 50 ProTaper files NiTi files (Tulsa – Dentsply, USA), of standard # 20 size with taper of 0.06 and 25 mm length were taken, and divided into five groups, according to method of sterilization employed with 10 files in each group.

- Group 1: Control with no sterilization of files.
- Group 2: Autoclaving of files at 121°C at 15 psi for 15 minutes.
- Group 3: Files wiped with 90% ethyl alcohol solution,
- Group 4: Files submerged in glass bead sterilizer at 425° F for 10 seconds.
- Group 5: Files immersed in 2% glutaraldehyde solution for 4 hours.

Custom made cyclic fatigue testing model of stainless steel block was prepared at radius of curvature of 2 mm with 60° and 90° angle of curvature at Army College of Dental Sciences, Secunderabad. Artificial canals were milled on stainless steel blocks with tapered shape corresponding to the dimensions of the instrument used. The artificial canals allowed for precise and simple placement of instrument inside the canal, ensuring three dimensional alignments and positioning of instrument at same depth. Screw and hole attachments were made in this block to allow for changing the position of handpiece corresponding to that of canals. A metal fixture was used to fix the dental handpiece in position and avoid any unnecessary movement of the handpiece during testing. Artificial canals were covered with tempered glass to prevent the instrument for slipping out and to allow for the observations of instrument during fatigue testing.

Files in all groups were subjected consecutively to five cycles of sterilization, inserted into artificial canals of 60° curvature and rotated at constant speed of 300 rpm using endodontic motor with 16:1 contra-angled handpiece powered by a torque-controlled electric stepper motor (Xsmart; Dentsply Maillefer, Baillagues, Switzerland) in this custom made experimental set until fracture occurred. Time taken for fracture of files in each group using stop watch was recorded and number of cycles to failure (NCF) was calculated (Figs 1A and B).

RESULTS

Results were analyzed statistically using Statistical Package for the Social Sciences (SPSS) software (SPSS, Oakbrook, IL). One-way analysis of variance (ANOVA) test was performed to determine any statistical difference among groups. The significance level was set at the 95% confidence level ($p < 0.05$).

The mean of the number of cycles to fracture for each group are listed in Table 1.

Number of cycles to failure = time of fracture in seconds multiplied by number of rotation per minute (RPM)/60.

$p = 0.073$ which is > 0.05 , thus results were not significant between groups in this study.

Although a small increase in absolute mean values occurred for autoclave sterilized endodontic files, there was no statistically significant difference between groups.

Table 1: The mean of the number of cycles to fracture for each group

Method of sterilization	Mean value (NCF)
Control	365
Autoclave	405
Ethyl alcohol	365
Glutaraldehyde	355
Glass bead sterilization	340



Figs 1A and B: Custom made cyclic fatigue testing experimental model set up

DISCUSSION

The objective of root canal preparation is to clean and shape the root canal system in three dimensions while maintaining the original shape.¹⁰ The introduction of NiTi instruments for root canal preparation in the year 1988 marked the beginning of a new era in endodontic instrumentation with their flexibility allowing better control of root canal shape.¹¹ Microorganisms are the major cause of endodontic disease, thus effective sterilization, infection control procedures and universal precautions in the dental surgery can prevent cross-contamination the increase in the success of the endodontic therapy.¹²

The choice of five sterilization cycles was based on literature reports stating that rotary NiTi instruments can be safely utilized to shape 10 curved root canals.^{13,14} As only curved root canals induce fatigue in the instruments, five cycles of sterilization correspond to clinical use during the average useful life of the instrument. Because the main interest was to detect possible cumulative changes in properties associated with the heating and cooling cycles, they were applied consecutively to the new and the previously fatigued instruments.

Unfortunately, there is no universal accepted testing protocol to measure the cyclic fatigue resistance of rotary NiTi files. An ideal model would involve instrumentation of curved canals in natural teeth. However in such tests, a tooth can be used only once and trajectory of root canal wall will change during instrumentation, making it impossible to standardize the experimental conditions.

The present device sought to overcome the other experimental designs in terms of model used for testing. The artificial canals were prepared using a novel method recommended by Plotino et al.¹⁵

In the current study, most accessible methods of sterilization were used and small increase in number of cycles to failure using autoclave sterilization was observed; however, this increase could not be statistically confirmed.

From the metallurgical point of view, the temperature used in sterilization may not be high enough to cause significant changes in the alloy structure. The required changes to increase hardness, cutting efficiency and fatigue life would be related to precipitation of Ti_3Ni_4 particles.⁶ However, it is possible that consecutive cycles of sterilization give rise to cumulative effects, leading to increases in hardness in rotary NiTi endodontic instruments after sterilization, as observed by Serene et al.² On the other hand, Hilt et al did not observe this effect on similar instruments.¹⁶

CONCLUSION

Changes in the mechanical properties of NiTi endodontic instruments after five cycles of common sterilization procedures were insignificant. From the point of view of the clinician, the results obtained in this study suggest that these sterilization procedures are safe and if sterilization does not make NiTi endodontic instruments stronger, it does not result in deleterious effects that could reduce their mechanical properties. This is an important result in itself, implying that sterilization, either in chemical form or in steam autoclaves, does not compromise the mechanical behavior of rotary NiTi endodontic instruments, assuring the possibility of their reuse after sterilization.

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