Evaluation Of Effect Of Root Canal Irrigating Solutions On The Cyclic Fatigue Resistance Of Rotary Nickel-Titanium File - An In-Vitro Study

Dr. Hina Farooq Kanth¹, Dr. Sandhya Kapoor Punia²*

¹Post Graduate, Department of Conservative Dentistry and Endodontics, Darshan Dental College and Hospital, Udaipur, Rajasthan, India.
²Professor and Head, Department of Conservative Dentistry and Endodontics, Darshan Dental College and Hospital, Udaipur, Rajasthan, India.

*Corresponding Author: - Dr. Sandhya Kapoor Punia

Abstract

Aim- The aim of this in-vitro study was to compare the effect of NaOCl, EDTA, Propolis and Distilled water on cyclic fatigue resistance of Protaper Gold rotary NiTi instruments.

Method- A total of 40 commercially available rotary (n =40) Ni-Ti files were used to assess the effect of different root canal irrigants on their cyclic fatigue resistance. The files were divided into four groups (n=10 per group) as Group 1- Distilled water (Control group), Group 2 – 5.25 % NaOCl, Group 3 -17% EDTA and Group 4 - Propolis. The instruments were rotated in custom-made stainless steel artificial canal (angle of 60˚ and 5 mm radius), fixed in a glass container with irrigating solution until the instrument fractured. The time to fracture was registered for each instrument and the number of cycles to fracture (NCF) was calculated and statistical analysis was done.

Result- NiTi files used with Group 1 (Distilled water) exhibited best cyclic fatigue resistance (1386.50±37.12) amongst all the tested groups followed by Group 4 (Propolis) and Group 3 (EDTA). Group 2 (5.25 % NaOCl) showed least cyclic fatigue resistance (971.50 ± 48.879) compared to other groups (P>0.05).

Conclusion- NiTi files exhibited best cyclic fatigue resistance when used with distilled water and NaOCl irrigating solution significantly deteriorated the surface characteristics and cyclic fatigue resistance of rotary NiTi files.

Keywords: NaOCl, EDTA, Propolis, Rotary Protaper Gold, Cyclic Fatigue Resistance.

INTRODUCTION

The initiation and progression of pulpal inflammation and apical periodontitis are significantly influenced by microorganisms and their by-products. Therefore, the purpose of root canal therapy is to chemo-mechanically achieve a high level of root canal system disinfection. In order to achieve this, irrigants along with instrumentation are administered to the apical region of the canal and exert their bactericidal action. [1]

Initially carbon steel and stainless-steel instruments were used for chemo-mechanical preparation but due to their high stiffness and rigidity they led to procedural errors like ledge and elbow formation, zipping, canal stripping and apical perforation. [2]

Rotary instruments made of Nickel-titanium (NiTi) were therefore introduced by Walia et al in 1988. NiTi files have better flexibility and shape memory than carbon steel and stainless-steel instruments, as well as superior corrosion resistance. [3]

A multi-file system called the ProTaper Gold file system was first presented in 2014 and features progressive, varied taper along the cutting flutes of the same instrument. During crown-down preparation, this characteristic, along with a convex triangular cross-section, non-cutting tip design, enables the instruments to work in a specific area of the canal, minimizing file contact with the dentin walls and, as a result, minimizing stress on the instrument. [4]

NiTi instruments appear to be at high risk of separation despite these benefits. Torsional and cyclic fatigue are the main causes of NiTi instrument fracture. When the instrument's tip becomes stuck in the canal while the shank is still rotating, torsional fatigue develops and when an instrument rotates freely in a curve, cyclic fatigue develops because
tension/compression cycles are formed until fracture takes place at the point of greatest flexure. Thus, to ensure safety during endodontic instrumentation, the main objective has been to increase the resistance to file separation.[5]

Corrosion that may occur in the presence of irrigating fluids is another aspect that could restrict the resistance to fatigue and torsional fracture. The most popular irrigant utilised in the treatment of root canals is sodium hypochlorite (NaOCl). When it comes in contact with NiTi instruments during disinfection or when the solution is present in the pulp chamber, the instrument shows corrosive pattern and for this reason the time course and extent of corrosive action of NaOCl on NiTi surfaces are currently unclear.[6]

Ethylene diamine tetraacetic acid (EDTA) is a popular chelating agent introduced by Nygaard — Ostby in 1957. It interacts with calcium ions in dentin to create soluble chelates. According to studies, EDTA causes a mild corrosion that greatly lowers the cutting performance of NiTi files.[7]

Propolis has been researched as a new irrigating agent, owing to its antibacterial activity it is considered as an alternative to traditional irrigants. Propolis has been recommended for use in a variety of dental procedures, including periodontology, endodontics, cariology, and oral surgery.[8]

Since, no studies have been reported to evaluate the effect of propolis on the cyclic fatigue resistance of rotary Protaper Gold NiTi files. This study was conducted to analyze and evaluate the effect of distilled water, 5.25% Sodium hypochlorite, 17% EDTA and 50% Propolis on the cyclic fatigue resistance of rotary (PROTAPER GOLD F2) NiTi files.

MATERIALS AND METHOD

This study was conducted in the Department of Conservative Dentistry & Endodontics, Darshan Dental College and Hospital, Udaipur (Raj.), India. A total of 40 commercially available Protaper Gold F2 #25/0.08 (Dentsply-Maillefer, Switzerland) rotary (n = 40) Ni-Ti files were used to assess the effect of different root canal irrigants on their cyclic fatigue resistance. The files were divided into four groups according to the irrigant used as: Group A (n = 10) – Control group (Distilled water), Group B (n = 10) – 5.25% NaOCl, Group C (n = 10) – 17% EDTA and Group D (n = 10) – 50% Propolis.

All the 40 rotary Ni-Ti files were evaluated under Stereomicroscope (Lawrence & Mayo India Pvt. Ltd) at magnification 4X before subjecting them for cyclic fatigue resistance testing to detect the presence of any surface irregularities or fracture. The files without any defect were selected for the study.

All the specimen were tested for cyclic fatigue resistance using simulated artificial stainless-steel model with 60° angle of curvature, 25mm length and 5mm radius which was seated in a glass container with irrigating solution according to each test groups. The instruments were rotated using an electric speed-torque controlled motor as per the manufacturer instruction at speed 300 rpm and torque 4N in X-Smart (Dentsply Maillefer) endomotor.

A 20 mm long segment from the tip of the instrument was introduced into the artificial canal on stainless-steel block which was immersed in the irrigating solution during the test using the X-Smart (Dentsply Maillefer) endomotor for Protaper Gold F2 NiTi files. Each instrument was allowed to rotate according to manufacturer’s recommendation until it fractured. The instrument fracture was visually detected and the time to fracture was recorded by digital stopwatch (Figure 1). The number of cycles to fracture (NCF) was calculated according to the following formula:

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NCF = \frac{\text{Time (seconds)} \times \text{Speed (rpm)}}{60}
\]

A digital microcaliper was used to determine the length of each fractured fragment (FL).

**Figure 1** – Images of Cyclic Fatigue Resistance Testing of NiTi instruments - (A) An instrument was mounted in the Endomotor and then subjected to CFR testing with the irrigant, (B) Separated fragment of the NiTi instrument.
RESULTS
The data obtained was tabulated and analyzed using SPSS software V.21.0. The Mean and Standard deviation of the cyclic fatigue resistance of rotary NiTi files for the various groups are shown in Table I. Pair wise comparison using Post Hoc Tukey’s multiple intragroup comparison of Cyclic fatigue resistance for the Rotary Ni-Ti files given in table II.

Rotary NiTi files used with Group 1 (Distilled water) exhibited best cyclic fatigue resistance (1386.50±37.12) amongst all the tested groups followed by Group 4 (Propolis) and Group 3 (EDTA). Group 2 (5.25 % NaOCl) showed least cyclic fatigue resistance (971.50 ± 48.879) compared to other groups

| Table I: Descriptive statistics of Cyclic Fatigue Resistance (CFR) for Rotary NiTi files |
|---|---|---|---|
| **Group** | **N** | **Mean** | **Standard Deviation** |
| Group A (Control) | 10 | 1386.50 | 37.12 |
| Group B (5.25% NaOCl) | 10 | 971.50 | 48.879 |
| Group C (17% EDTA) | 10 | 1128.09 | 160.973 |
| Group D (50% Propolis) | 10 | 1148.30 | 109.185 |

| Table II: Pair wise comparison using Post Hoc Tukey’s multiple intragroup comparison of Cyclic fatigue resistance for the Rotary Ni-Ti files |
|---|---|---|---|---|---|
| **Groups** | **Mean Difference (L-J)** | **Std. Error** | **Sig.** | **95% Confidence Interval** |
| **Group A** (Control) | | | | |
| B. NaOCl | -415.00000* | 35.97 | 202 | 310 511.808 |
| C. Propolis | 238.00000* | 35.97 | 202 | 141 334.808 |
| D. EDTA | 228.30000* | 35.97 | 202 | 161 335.808 |
| **Group B** (NaOCl) | | | | |
| A. Control | -238.00000* | 35.97 | 202 | -141 121.808 |
| C. Propolis | 117.00000* | 35.97 | 202 | -40 240.808 |
| D. EDTA | 135.50000* | 35.97 | 202 | -25 276.808 |
| **Group C** (Propolis) | | | | |
| A. Control | -238.00000* | 35.97 | 202 | -141 121.808 |
| B. NaOCl | 117.00000* | 35.97 | 202 | -40 240.808 |
| D. EDTA | 135.50000* | 35.97 | 202 | -25 276.808 |
| **Group D** (EDTA) | | | | |
| A. Control | -238.00000* | 35.97 | 202 | -141 121.808 |
| B. NaOCl | 117.00000* | 35.97 | 202 | -40 240.808 |
| C. Propolis | 238.00000* | 35.97 | 202 | 141 334.808 |

* The mean difference is significant at the p<0.05 level

DISCUSSION
The most key component in achieving the biological and mechanical goals of root canal treatment is the efficient cleaning and shaping of the root canal system. This can be achieved by properly preparing, cleaning and ultimately obturating the root canal.[9]

Manufacturers have been enhancing the mechanical properties of the alloy since Walia et al. introduced NiTi instruments in Endodontics in the 1980s, reducing the failures encountered during the treatment, such as the risk of instrument separation, canal transportation, ledging and perforation, which was common with the stainless-steel files.[10]

Cycle fatigue fracture is one of the common reasons for failure of NiTi instrument. NiTi rotary instruments’ surfaces develop minute scratches and grooves during manufacturing. Microcrack initiation arises when tension is exerted on these machining marks. One of the main causes of unexpected fracture is the propagation of such microcracks. It is intended to reduce these surface irregularities by the use of surface treatment procedure.[1,11]

Austenite, Martensite, and R-phase are three different temperature-dependent microstructure phases of NiTi alloy. Martensitic and R-phase NiTi are soft, ductile, and easily deformable, but austenitic NiTi is robust and hard. The three phases’ chemical compositions have an impact on NiTi’s mechanical properties. At room temperature, the ordinary NiTi alloy is primarily in the austenite phase. By adjusting the transition temperature and subsequently the alloy’s properties, thermo mechanical treatments could maintain the alloy in the Martensite phase, R-phase, or mixed form.[12]

Most of the NiTi instruments used for cleaning and shaping of root canals are heat treated during manufacturing and remain in a stable austenitic structure at both room and body temperature. When they are introduced into the canals, they produce a stress induced martensitic structure (unstable) and once the stress is relieved and when the instrument is back to room temperature, it reverts back to austenitic structure.[13]

The soft, ductile characteristics of martensite play an important role in overcoming the fracture of an instrument. Numerous thermomechanical treatments have been applied to the conventional NiTi alloy to maintain stable martensite and R-phase formations at room temperature based on this behaviour and the characteristics of martensite.[14]
In 2012, Dentsply Tulsa Dental (Tulsa, OK, USA) first introduced gold heat-treated instruments, which have a distinctive gold appearance. ProTaper Gold, is a gold heat-treated NiTi shaping systems designed by Dentsply Maillefer in Ballaigues, Switzerland, have distinct geometry designs, movement kinematics and improved flexibility. Like, ProTaper Universal, it has a convex triangular cross section and variable taper. A high Austenite final (Af) temperature, similar to controlled memory wires, and a 2-stage transformation behaviour (austenite [A]-R phase-martensite [M]) are all characteristics of the ProTaper Gold's advanced metallurgy for improved flexibility.[15]

The result of this study indicated that the root canal irrigating solutions significantly influence the cyclic fatigue resistance of rotary Ni-Ti files. For the rotary Protaper Gold F2 NiTi files, least number of cycles to fracture was recorded by 5.25% NaOCl group (971.5 ± 48.88) followed by 17% EDTA group (1128.0 ± 100.97) and 50% Propolis group (1148.5 ± 109.16). The highest number of cycles to fracture was recorded by distilled water i.e. the control group (1386.5 ± 37.12) indicating that rotary files had maximum cyclic fatigue resistance (CFR) when used with distilled water followed Propolis and EDTA. Rotary files exhibited worst result when used with NaOCl.

This change in the number of cycles to instrument separation during the cyclic fatigue testing could be explained due to the corrosive properties of NaOCl. Corrosion is generally associated with specific solutions, so far, the most common is chloride. It is known that NaOCl, a chlorine containing solution, which is corrosive to metals.[16]

The formation of these corrosive zones, reduces the resistance to cyclic fatigue of the instrument by formation of the micro-pitted on the surface of file and during rotation various tensile and compressive forces are directed to these areas causing increase in stress and finally fracture of the file and thus decreasing the resistance to cyclic fatigue.[17]

Propolis has shown least eroding effects on the NiTi files and this could be accredited to the composition of propolis which is very complex. It comprises of organic compounds including sesquiterpenes, stilbene terpenes, phenoic compounds and esters, beta-steriods, flavonoids of all types (flavonols, flavones, flavonones, dihydroflavonols, and chalcones), terpenes and aromatic aldehydes and alcohols and do not include any chemicals that would alter NiTi files' characteristics.[18]

CONCLUSION

Under the limitations of this study, it was concluded that the irrigants play a vital role in the performance of endodontic instruments manufactured with heat treated NiTi alloy. NiTi instruments performed best with distilled water and worst with 5.25% NaOCl in terms of cyclic fatigue resistance.

CONFLICTS OF INTEREST

Authors declare that there are no conflicts of interest.

REFERENCES
