ORIGINAL RESEARCH

Comparing the EdgeFile X3, GenEndo, HeroGold, and ProTaper Gold Rotary Instruments Regarding the Effect of Different Concentrations and Temperature of NaOCl on Cyclic Fatigue Resistance

Garima Tyagi[1], Prakash Kumar[2], Annu Kumari[3], Parul Shakarwal[4], Aditya Singh[5], Pallavi Kusum[6]

Abstract

Aim: This research was carried out with the objective of comparison between GenEndo, Protaper Gold, Hero Gold and EdgeFile X3 regarding the effect of different concentrations of NaOCl.

Materials and methods: About 720 study specimens were included in the study. They were divided into four groups. Each group consisted of 180 files. Group A: GenEndo, Group B: Protaper Gold, Group C: Hero Gold, Group D: EdgeFile X3. Each group of instruments were further subdivided into nine subgroups ($n = 20$ for each subgroup). Testing of the cyclic fatigue was carried out in artificial canals which were prepared inside the blocks of stainless steel. The stainless steel blocks with artificial canals were established in a receiver that was packed with experimental solutions like distilled water, 5.25% NaOCl and 2.5% NaOCl. The adjustment of temperature was done at 25, 37, and 60°C. The rotation of the instrument was carried out inside the artificial canal as per the instructions of the manufacturer. The instrument was rotated until it got fractured. The time taken by the instrument to fracture was recorded in seconds. The number of cycles to fracture (NCF) was analyzed with the help of the equation (NCF = time to fracture × rpm/60). Surfaces at the site of fracture were examined with the help of a scanning electron microscope (EVOLS10, ZEISS) at magnification (300x and 2000x).

Results: It was noticed that there was a statistically significant increase in cyclic fatigue when sodium chloride was used as an endodontic irrigant instead of distilled water. The increase in cyclic fatigue was also observed when 5.25% sodium chloride was used instead of 2.5% sodium hypochlorite. Cyclic fatigue increased on change in temperature from 25 to 37°C and from 37 to 60°C. The difference was statistically significant ($p < 0.05$). It was observed that resistance against cyclic fatigue on treatment with different irrigation solutions at different temperatures was in the order of GenEndo > Protaper Gold > Hero Gold > EdgeFile X3.

Conclusion: The resistance against cyclic fatigue in new NiTi rotary files can be affected significantly by different concentrations of sodium hypochlorite irrigant solution and the GenEndo rotary endodontic instrument has the maximum resistance against cyclic fatigue.

Clinical significance: Irrigation of the root canal with irrigants, such as sodium hypochlorite (NaOCl) has been recommended strongly. NaOCl is used in the range of 0.5 and 6.5% concentration owing to its antimicrobial activity and tissue dissolution activities, particularly at higher temperatures. It has been postulated that fatigue of rotary endodontic instruments can be influenced by adjoining medium and their concentration.

Keywords: Cyclic fatigue, EdgeFile X3, GenEndo, Hero Gold, Protaper Gold, Resistance, Sodium hypochlorite.

The Journal of Contemporary Dental Practice (2023): 10.5005/jp-journals-10024-3515

Introduction

In recent times, the use of Nickel–titanium (NiTi) alloy in the field of endodontics has increased significantly in comparison to stainless steel instruments owing to its useful mechanical properties, such as shape memory and superelasticity. These NiTi alloys are used in the manufacturing of instruments used in endodontic procedures. The instruments prepared from NiTi alloys have enhanced flexibility and increased resistance against cyclic fatigue when compared with instruments prepared from stainless steel-based alloys.[1] Fracture of NiTi alloys-based endodontic instrument is however a common problem nowadays as it affects the outcome of endodontic treatment.[2] Cyclic fatigue is considered one of the most important factors in the fracture of the endodontic instruments with subsequent failure of the instrument. Cyclic fatigue usually takes place when endodontic instruments are rotated in a curved root canal. It leads to the development of tension or compression cycles in a repeated pattern. These compression cycles develop mostly in the portion of the root canal having maximum curvature.

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How to cite this article: Tyagi G, Kumar P, Kumari A, *et al*. Comparing the EdgeFile X3, GenEndo, HeroGold, and ProTaper Gold Rotary Instruments Regarding the Effect of Different Concentrations and Temperature of NaOCl on Cyclic Fatigue Resistance. J Contemp Dent Pract 2023;24(9):715–721.

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The repeated generation of tension cycles leads to the fracture of instruments.

The mechanical properties of rotary endodontic instruments prepared from NiTi alloys are based on the phase conversion from the austenite phase to the martensite phase. This phase conversion takes place with the application of stress and a decrease in temperature.[3] To improve the fracture resistance of NiTi alloy-based rotary instruments, several improvements have been made in the process of manufacturing. These improvements included different thermal treatments and changes in the internal geometry of instruments. Several NiTi alloy-based rotary endodontic instruments have been introduced.[4]

ProTaper Gold NiTi rotary files (Dentsply Sirona, New Delhi, India) have been manufactured based on the geometrical features of ProTaper Universal endodontic instruments (Dentsply Siron, New Delhi, India). However, the metallurgic properties of ProTaper Gold instruments are superior owing to the advanced heat treatment-based process of manufacturing. As a result, the resistance against cyclic fatigue and flexibility is greater in ProTaper Gold as compared with Protaper Universal instruments.[5]

EdgeFile X3 (Dentsply Sirona, New Delhi, India) is another NiTi rotary instrument in which the NiTi alloy undergoes annealing heat treatment. It is parabolic in cross-section and taper is constant in these endodontic instruments. Manufacturers claim that these instruments are highly efficient and flexible contributing to their safety and resistance against fracture in curved canals.[6,7]

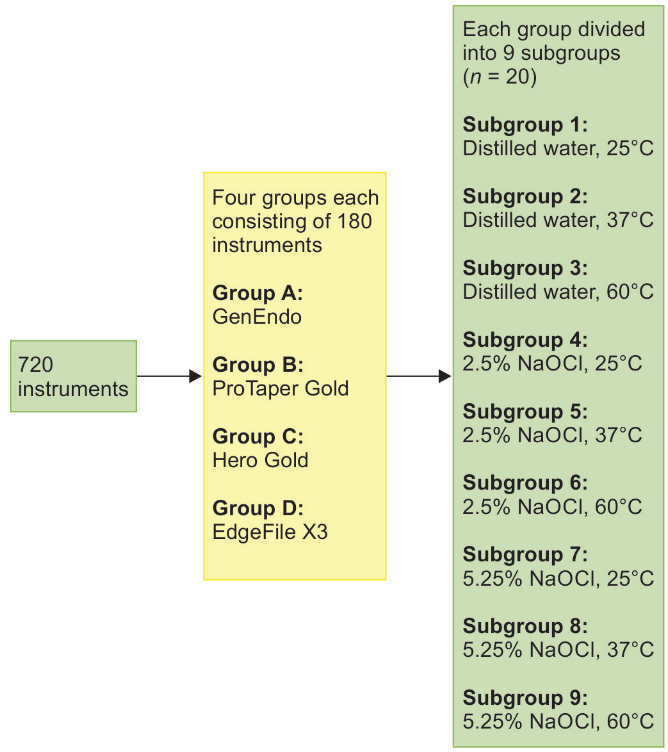
Most recently, GenENDO™ rotary NiTi files (Coltene, Newyork, USA) have been introduced. These files use heat-treated NiTi alloys to form T–wire files and are prepared specially to provide fast and better outcomes of the endodontic treatment. The complete system has been prepared to make the endodontic procedures quite simple with one endodontic file especially for flaring of the coronal portion, one endodontic file especially for the establishment of patency and maintaining glide path smooth, one endodontic file, especially for effective shaping and preparation of the root canal and one endodontic file for smooth cleaning and shaping.[8]

Hero Shaper rotary endodontic files (Dentsply Sirona, New Delhi, India) are another nickel–titanium-based rotary file. According to manufacturers, these files have changeable helical angulation and modified pitch that enhances as the taper enhances in the endodontic instrument. This modified structure prevents the twisting of the endodontic instrument.

Irrigation of the root canal with irrigants, such as sodium hypochlorite (NaOCl) has been recommended strongly.[9] In addition, flooding the root canal with an irrigant solution like sodium hypochlorite (NaOCl) is advised. However, the environment and its concentration may have an impact on the cyclic fatigue of NiTi devices. It has been postulated that fatigue of rotary endodontic instruments can be influenced by adjoining medium and their concentration.[10] By eliminating nickel from the surface of the instrument, NaOCl can create micropitting, which could affect the performance of NiTi devices. Cyclic fatigue further leads to the fracture of NiTi-based endodontic rotary instruments. The impact of the concentration of endodontic irrigation at different temperatures on the cyclic fatigue of these heat-treated Nickel-titanium alloys has not been studied till now.[11] Therefore, this research was carried out with the objective of comparison between GenEndo, Protaper Gold, Hero Gold and EdgeFile X3 regarding the effect of different concentrations of NaOCl at normal body temperature and comparing them with 60°C and room temperature.

Source of support: Nil
Conflict of interest: None

Flowchart 1: Flowchart represents the process of the experiment



Materials and Methods

It was an *in vitro* observational study. Clearance was obtained from the Institutional Review Board. The ethical clearance reference number was: UKD/2022/3456. NiTi rotary instruments were kept in three experimental solutions, namely, distilled water, 2.5% NaOCl (MS chemicals, Greater Noida, Uttar Pradesh, India) and 5.25% NaOCl (MS chemicals, Greater Noida, Uttar Pradesh, India). The files in these solutions were kept at three temperatures which were 25, 37, and 60°C.

Groups and Subgroups

About 720 instruments were included in the study. They were divided into four groups. Each group consisted of 180 files. Each group of instruments were further subdivided into nine subgroups ($n = 20$ for each subgroup) (Flowchart 1).

Group A: GenEndo ($n = 180$)

- *Subgroup A 1:* GenEndo in Normal saline at 25°C ($n = 20$).
- *Subgroup A 2:* GenEndo in Normal saline at 37°C ($n = 20$).
- *Subgroup A 3:* GenEndo in Normal saline at 60°C ($n = 20$).
- *Subgroup A 4:* GenEndo in 2.5% NaOCl at 25°C ($n = 20$).
- *Subgroup A 5:* GenEndo in 2.5% NaOCl at 37°C ($n = 20$).
- *Subgroup A 6:* GenEndo in 2.5% NaOCl at 60°C ($n = 20$).
- *Subgroup A 7:* GenEndo in 5.25% NaOCl at 25°C ($n = 20$).
- *Subgroup A 8:* GenEndo in 5.25% NaOCl at 37°C ($n = 20$).
- *Subgroup A 9:* GenEndo in 5.25% NaOCl at 60°C ($n = 20$).

Group B: Protaper Gold ($n = 180$)

- *Subgroup B 1:* Protaper Gold in Normal saline at 25°C ($n = 20$).
- *Subgroup B 2:* Protaper Gold in Normal saline at 37°C ($n = 20$).
- *Subgroup B 3:* Protaper Gold in Normal saline at 60°C ($n = 20$).
- *Subgroup B 4:* Protaper Gold in 2.5% NaOCl at 25°C ($n = 20$).
- *Subgroup B 5:* Protaper Gold in 2.5% NaOCl at 37°C ($n = 20$).
- *Subgroup B 6:* Protaper Gold in 2.5% NaOCl at 60°C ($n = 20$).
- *Subgroup B 7:* Protaper Gold in 5.25% NaOCl at 25°C ($n = 20$).
- *Subgroup B 8:* Protaper Gold in 5.25% NaOCl at 37°C ($n = 20$).
- *Subgroup B 9:* Protaper Gold in 5.25% NaOCl at 60°C ($n = 20$).

Group C: Hero Gold ($n = 180$)

- *Subgroup C 1:* Hero Gold in Normal saline at 25°C ($n = 20$).
- *Subgroup C 2:* Hero Gold in Normal saline at 37°C ($n = 20$).
- *Subgroup C 3:* Hero Gold in Normal saline at 60°C ($n = 20$).
- *Subgroup C 4:* Hero Gold in 2.5% NaOCl at 25°C ($n = 20$).
- *Subgroup C 5:* Hero Gold in 2.5% NaOCl at 37°C ($n = 20$).
- *Subgroup C 6:* Hero Gold in 2.5% NaOCl at 60°C ($n = 20$).
- *Subgroup C 7:* Hero Gold in 5.25% NaOCl at 25°C ($n = 20$).
- *Subgroup C 8:* Hero Gold in 5.25% NaOCl at 37°C ($n = 20$).
- *Subgroup C 9:* Hero Gold in 5.25% NaOCl at 60°C ($n = 20$).

Group D: EdgeFile X3 ($n = 180$)

- *Subgroup D 1:* EdgeFile X3 in Normal saline at 25°C ($n = 20$).
- *Subgroup D 2:* EdgeFile X3 in Normal saline at 37°C ($n = 20$).
- *Subgroup D 3:* EdgeFile X3 in Normal saline at 60°C ($n = 20$).
- *Subgroup D 4:* EdgeFile X3 in 2.5% NaOCl at 25°C ($n = 20$).
- *Subgroup D 5:* EdgeFile X3 in 2.5% NaOCl at 37°C ($n = 20$).
- *Subgroup D 6:* EdgeFile X3 in 2.5% NaOCl at 60°C ($n = 20$).
- *Subgroup D 7:* EdgeFile X3 in 5.25% NaOCl at 25°C ($n = 20$).
- *Subgroup D 8:* EdgeFile X3 in 5.25% NaOCl at 37°C ($n = 20$).
- *Subgroup D 9:* EdgeFile X3 in 5.25% NaOCl at 60°C ($n = 20$).

Process of Experiment

The length of each instrument was kept at 25 mm. The instruments were evaluated before the study for any deformities and defects at high magnification. However, no instruments were excluded after the evaluation.

Preparation of Artificial Root Canals

These artificial root canals were prepared inside the blocks of stainless steel with the help of LASER-based micromachine. The dimension of the artificial canals was kept following the width of the file examined. It was greater than the width of the instrument by 0.1mm. The curvature angle of the canals was kept at 60°, the radius of curvature was kept at 5mm, and the location of the center of curvature was 5 mm distance from the tip of the instrument. Glass was used to cover the artificial canal to avoid slippage of the instrument and to verify the timing of the fracture of the instrument.

Placement of Experimental Solutions and Adjustment of Experimental Temperature in Blocks of Stainless Steel Having Artificial Canals

The stainless steel blocks with artificial canals were established in a receiver that was filled with experimental solutions like distilled water, 5.25% NaOCl, and 2.5% NaOCl. The adjustment of temperature was done at 25, 37, and 60°C.

Testing of the Cyclic Fatigue

To create fixed and reproducible positioning of every experimental instrument inside the artificial canal, the handpiece of the rotary endodontic motor was fixed at a device. The insertion of the endodontic instrument in the artificial canal was carried out so that 19 mm of the instrument from the tip was inside the artificial canal. The rotation of the instrument was carried out inside the artificial canal as per the instructions of the manufacturer at 300 rotations per minute. The instrument was rotated until it got fractured. The time taken by the instrument to fracture was recorded in seconds. The number of cycles to fracture (NCF) was analyzed with the help of the following equation.

$$NCF = \text{time to fracture} \times \text{rpm}/60.$$

Analysis of Outcomes

All the experimental procedures were carried out by the same clinician. The artificial canal was changed on the appearance of any indication of corrosion which may appear due to the corrosive activity of NaOCl. The length of the fractured fragment was measured with the help of an electronic digital caliper. Four instruments that got fractured were selected from each group. They were washed in an ultrasonic bath with absolute alcohol and surfaces at the site of fracture were examined with the help of a scanning electron microscope (EVOLS10, ZEISS) at magnification (300x and 2000x) (Fig. 1).

The main study outcome was the NCF. The time taken by the instrument to fracture was recorded in seconds. The NCF was analyzed with the help of the following equation.

$$NCF = \text{time to fracture} \times \text{rpm}/60.$$

Statistical Analysis

The data were collected in the form of mean with standard deviations. The intergroup difference was evaluated using the Kruskal–Wallis *H* test (non-parametric ANOVA.). Intragroup groups, differences were compared using Mann Whitney *U* test. The confidence level was maintained at 95% with the result that a *p*-value below 0.05 indicated a statistically significant association. SPSS software version 22 (IBM, USA) was used for carrying out all statistical analyses.

Results

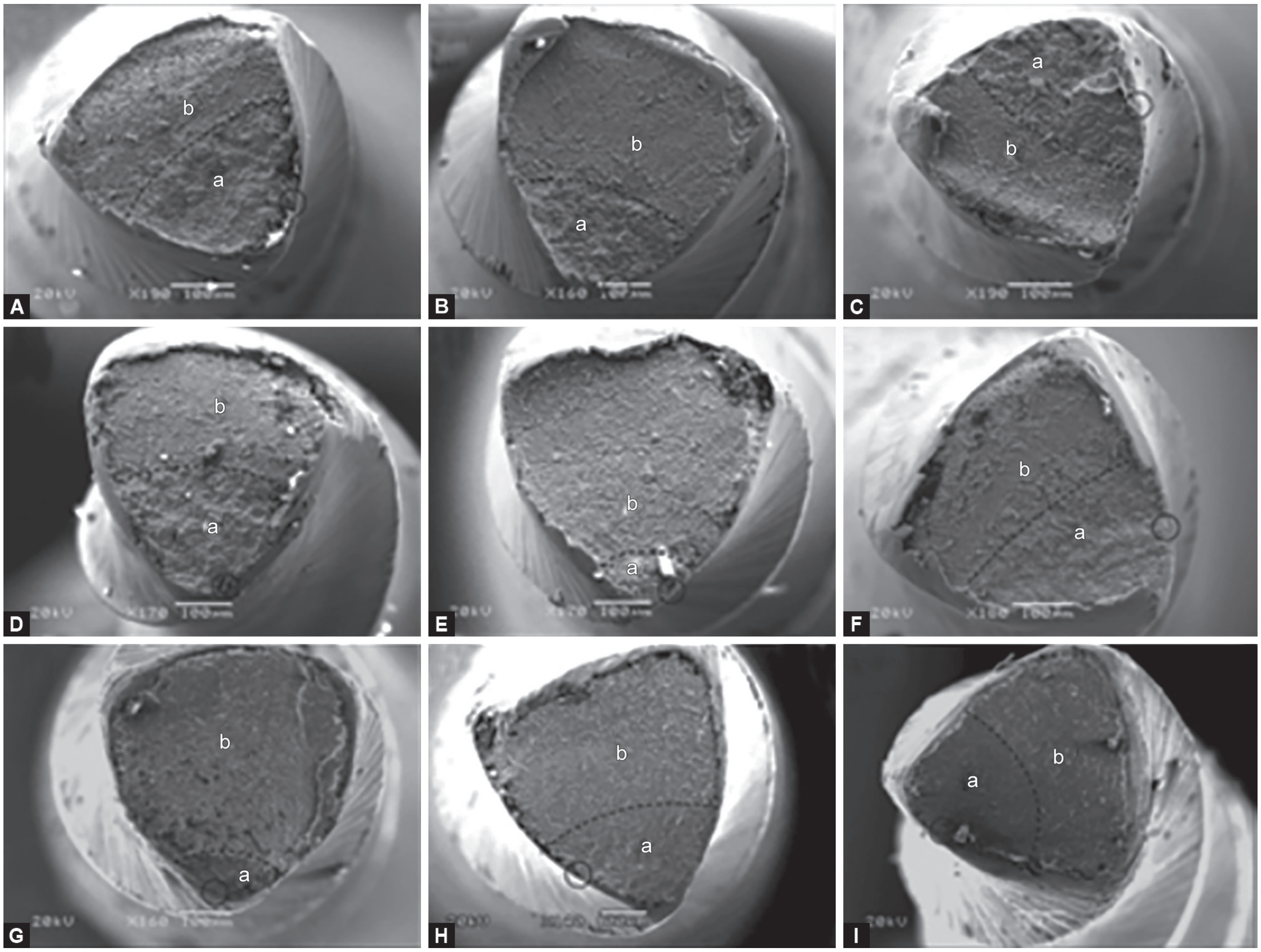
It was kept in mind during analysis that as the NCF increased, cyclic fatigue decreased and vice versa.

The Behavior of Specified File Systems Kept at the Specified Temperature in Different Concentrations of Experimental Solutions

It was observed that at one certain temperature, there was an increase in cyclic fatigue in GenEndo group on change in increase in the concentration of NaOCl; however, the difference was non-significant statistically. On the other hand, the difference was significant statistically in Protaper Gold, Hero Gold, and EdgeFiles.

The Behavior of the Specified File Systems Kept in a Specified Concentration of Experimental Solutions Kept at Different Temperatures

There was a finding that at a specified concentration, there was an increase in cyclic fatigue on an increase in temperature in Gen-Endo file; however, the difference was statistically non-significant.



Figs 1A to I: The scanning electron microscopic appearance of the PTG instruments after cyclic fatigue testing under different conditions. (A) 5.25% NaOCl at 25°C, (B) 5.25% NaOCl at 37°C, and (C) 5.25% NaOCl at 60°C. (D) 2.5% NaOCl at 25°C, (E) 2.5% NaOCl at 37°C, and (F) 2.5% NaOCl at 60°C, (G) Water at 25°C, (H) water at 37°C, and (I) water at 60°C. The black circle indicates the crack origin. a represents the fatigue striation area, and b represents the fast fracture zone with dimples

Meanwhile, the difference was statistically significant in Protaper Gold, Hero Gold and EdgeFiles.

The Behavior of Different File Systems Kept at the Same Concentration of Experimental Solutions at the Same Temperature

When different file systems were compared at the same concentration and temperature, then the cyclic fatigue was in the order of GenEndo < Protaper Gold < Hero Gold < EdgeFile (Tables 1 to 4).

The Behavior of Different File Systems at 25°C in Different Experimental Solutions

In our study, the value of NCF of GenEndo files at 25°C in distilled water, 2.5% NaOCl, and 5.25% NaOCl were 1245.2 + 382.3, 1123.4 + 265.7, and 1045.6 + 287.1, respectively. There was a decrease in the values of NCF on change of solution and an increase in concentration but the difference was non-significant statistically ($p > 0.005$). The value of NCF of Protaper Gold at 25°C in distilled water, 2.5% NaOCl and 5.25% NaOCl were 1139.1 + 277.3, 721.3 + 270.9, and 817.7 + 296.1, respectively. The value of NCF of Hero Gold at 25°C in distilled water, 2.5% NaOCl, and 5.25% NaOCl were 1106.2 + 266.3, 693.2 + 260.6, and 786.5 + 281.1, respectively. The value of NCF of EdgeFile X3 at 25°C in distilled water, 2.5% NaOCl, and 5.25% NaOCl were 1058.6 + 277.1, 641.2 + 169.8, and 744.4 + 298.0, respectively. The values of NCF decreased on the change of the solution from normal saline to 2.5% NaOCl, while the values increased on the change of the solution from 2.5% NaOCl to 5.25% NaOCl. However, the values of NCF at 5.25% NaOCl were lesser than those of distilled water in groups B, C, and D. The difference was significant statistically.

The Behavior of Different File Systems at 37°C in Different Experimental Solutions

The value of NCF of GenEndo files at 37°C in distilled water, 2.5% NaOCl, and 5.25% NaOCl were 951.8 + 289.1, 874.6 + 227.9, and 766.2 + 192.8, respectively. There was a decrease in the values of NCF on change of solution and an increase in concentration but the difference was non-significant statistically. ($p > 0.005$). The value of NCF of Protaper Gold at 37°C in distilled water, 2.5% NaOCl, and 5.25% NaOCl were 912.9 + 276.0, 602.3 + 225.6, and 551.1 + 174.4, respectively. The value of NCF of Hero Gold at 37°C in distilled water, 2.5% NaOCl, and 5.25% NaOCl were 862.9 + 276.0, 552.3 + 207.9, and 518.1 + 172.3, respectively. The value of NCF of EdgeFile X3 at 37°C in distilled water, 2.5% NaOCl, and 5.25% NaOCl were 822.7 +

Table 1: Data showing NCF of GenEndo under different concentrations of NaOCl and different temperatures

	NCF ± SD (25°C)	*NCF ± SD (37°C)*	*NCF ± SD (60°C)*	*p-value*
Distilled water	1245.2 + 382.3	951.8 + 289.1	721.6 + 112.6	0.121
2.5% NaOCl	1123.4 + 265.7	874.6 + 227.9	689.8 + 117.8	0.114
5.25% NaOCl	1045.6 + 287.1	766.2 + 192.8	542.7 + 91.9	0.217
p	0.461	0.654	0.261	

*Statistically significant ($p \leq 0.05$). NaOCl, sodium hypochlorite; NCF, number of cycles up to fracture; SD, standard deviation

Table 2: Data showing NCF of Protaper Gold under different concentrations of NaOCl and different temperatures

	NCF ± SD (25°C)	*NCF ± SD (37°C)*	*NCF ± SD (60°C)*	*p-value*
Distilled water	1139.1 + 277.3	912.9 + 276.0	367.7 + 116.9	0.023*
2.5% NaOCl	721.3 + 270.9	602.3 + 225.6	305.7 + 116.7	0.001*
5.25% NaOCl	817.7 + 296.1	551.1 + 174.4	285.4 + 90.8	0.042*
	0.001*	0.004*	0.003*	

*Statistically significant ($p \leq 0.05$). NaOCl, sodium hypochlorite; NCF, number of cycles up to fracture; SD, standard deviation

Table 3: Data showing NCF of Hero Gold under different concentrations of NaOCl and different temperatures

	NCF ± SD (25°C)	*NCF ± SD (37°C)*	*NCF ± SD (60°C)*	*p-value*
Distilled water	1106.2 + 266.3	862.9 + 276.0	329.3 + 121.7	0
2.5% NaOCl	693.2 + 260.6	552.3 + 207.9	275.9 + 116.9	0.005*
5.25% NaOCl	786.5 + 281.1	518.1 + 172.3	254.6 + 90.6	

*Statistically significant ($p \leq 0.05$). NaOCl, sodium hypochlorite; NCF, number of cycles up to fracture; SD, standard deviation

Table 4: Data showing NCF of EdgeFile X3 under different concentrations of NaOCl and different temperatures

	NCF ± SD (25°C)	*NCF ± SD (37°C)*	*NCF ± SD (60°C)*	*p-value*
Distilled water	1058.6 + 277.1	822.7 + 243.1	278.7 + 115.9	
2.5% NaOCl	641.2 + 169.8	513.7 + 216.8	214.8 + 147.6	0.001*
5.25% NaOCl	744.4 + 298.0	476.6 + 141.4	194.8 + 96.7	
The sequence of resistance against cyclic fatigue. Group A > Group B > Group C > Group D				

*Statistically significant ($p \leq 0.05$). Group A, GenEndo; Group B, Protaper Gold; Group C, Hero Gold; Group D, EdgeFile; NaOCl, sodium hypochlorite; NCF, number of cycles up to fracture; SD, standard deviation

243.1, 513.7 + 216.8, and 476.6 + 141.4, respectively. The values of NCF decreased on the change of the solution from normal saline to 2.5% NaOCl while the values increased on the change of the solution from 2.5% NaOCl to 5.25% NaOCl. However, the values of NCF at 5.25% NaOCl were lesser than those of distilled water in groups B, C, and D four groups. There was a decrease in NCF in the change of temperature from 25°C to 37°C in all groups but the difference was non-significant statistically in group A, whereas it was statistically significant in groups B, C, and D.

The Behavior of Different File Systems at 60°C in Different Experimental Solutions

It was observed that the value of NCF of GenEndo files at 60°C in distilled water, 2.5% NaOCl, and 5.25% NaOCl was 721.6 + 112.6, 689.8 + 117.8, and 542.7+91.9, respectively. There was a decrease in the values of NCF on change of solution and an increase in concentration but the difference was non-significant statistically ($p > 0.005$). The value of NCF of Protaper Gold at 60°C in distilled water, 2.5% NaOCl, and 5.25% NaOCl were 367.7 + 116.9, 305.7 + 116.7, and 285.4 + 90.8, respectively. The value of NCF of Hero Gold at 60°C in distilled water, 2.5% NaOCl, and 5.25% NaOCl were 329.3 + 121.7, 275.9 + 116.9, and 254.6 + 90.6, respectively. The value of NCF of EdgeFile X3 at 60°C in distilled water, 2.5% NaOCl, and 5.25% NaOCl were 278.7 + 115.9, 214.8 + 147.6, and 194.8 + 96.7, respectively. The values of NCF decreased on the change of the solution from normal saline to 2.5% NaOCl while the values increased on the change of the solution from 2.5% NaOCl to 5.25% NaOCl. However, the values of NCF at 5.25% NaOCl were lesser than those of distilled water in groups B, C, and D. The difference was significant statistically. There was a decrease in NCF in the change of temperature from 37°C to 60°C in all groups but the difference was non-significant statistically in group A while it was statistically significant in groups B, C, and D.

Discussion

The justification for the use of two concentrations of NaOCl can be given as that for its antibacterial and tissue-dissolving properties, NaOCl is utilized in concentrations ranging from 0.5 to 6%, especially at high temperatures. Since we wanted to analyze the effect of different concentrations of NaOCl on the cyclic fatigue of NiTi files because the concentrations of NaOCl inside the canals can vary depending upon the environment of the root canal and the presence of remnants of other root canal irrigants; therefore, we choose two concentrations of 2.5% and 5.25%.

The justification for the use of different temperatures can be given as that previous studies were carried out at room temperature. However, it is not clinically relevant because nickel–titanium alloy-based rotary files are used inside the root canals which are at body temperature. Therefore, we have evaluated the instruments at room temperature, body temperature, and a high temperature of 60° to get a better understanding.[12–16]

One of the most common reasons for the fracture of NiTi instruments is cyclic fatigue. The temperature of the environment has an impact on the resistance against cyclic fatigue.[17] Therefore, it is important clinically that the impact of different concentrations of sodium hypochlorite is analyzed along with the impact of temperature on the resistance against cyclic fatigue in rotary nickel–titanium alloys. In this research, we have compared the effect of different concentrations of sodium hypochlorite at different temperatures on the resistance against cyclic fatigue in four different rotary endodontic nickel–titanium-based instruments namely GenEndo, Protaper Gold, Hero Gold, and EdgeFile X3. No study has been conducted in the past to compare these files.

It was observed that at a certain temperature, there was an increase in cyclic fatigue in GenEndo group on change in increase in the concentration of NaOCl; however, the difference was non-significant statistically. On the other hand, the difference was significant statistically in Protaper Gold, Hero Gold, and EdgeFile. There was a finding that at a certain concentration, there was an increase in cyclic fatigue on an increase in temperature in the GenEndo file; however, the difference was statistically non-significant. Meanwhile, the difference was statistically significant in Protaper Gold, Hero Gold, and EdgeFile. When different file systems were compared at the same concentration and temperature then the cyclic fatigue was in the order of GenEndo < Protaper Gold < Hero Gold < EdgeFiles. In our study that there was an overall decrease in cyclic fatigue of the instruments when sodium hypochlorite was used in place of distilled water and the cyclic fatigue increased when the concentration of sodium hypochlorite was increased from 2.5 to 5.25%. The resistance against cyclic fatigue was decreased when the temperature of the irrigant was increased from 25 to 37°C and from 37 to 60°C. The resistance against the cyclic fatigue was maximum in the GenEndo file and minimum in the EdgeFile X3 files.

Huang et al. conducted a similar study to evaluate the effect of different concentrations of sodium hypochlorite at different temperatures and found results which were similar to the findings of our present study.[18] However, the file systems used in that study were different from our study. Cheung GS et al. carried out a study to evaluate the effect of sodium hypochlorite on the cyclic fatigue of nickel–titanium alloys and found that sodium hypochlorite harms the resistance against cyclic fatigue in these nickel–titanium alloys. These results are following the findings of the current study.[19]

Previous studies carried out by Peters OA et al., Shen Y et al., and Pedulla E et al, showed that there is no impact of different concentrations of sodium hypochlorite on the resistance against cyclic fatigue in the rotary nickel–titanium alloys instruments.[20–22] However, in our study, there is a negative impact of sodium hypochlorite on the resistance against cyclic fatigue. The variations in the results of these studies can be due to the differences in the method applied. In these studies, nickel–titanium alloy instruments were immersed in the sodium hypochlorite solutions for 3–5 minutes. They were then removed and analyzed for cyclic fatigue. However, in our study, cyclic fatigue was analyzed when the instruments were in contact with the irrigant solutions. Our study represents the actual clinical situation of root canal preparation where biomechanical preparation is carried out in the vicinity of the sodium hypochlorite solution. It is necessary therefore that cyclic fatigue be analyzed when the files are in contact with sodium hypochlorite which was not observed in previous studies.[23,24]

In our study, the dimensions of the artificial canals prepared were very similar to the dimensions of the instruments being analyzed. This helped in reducing any minor changes in the positioning of the instruments that could have affected the values of the NCF. In studies conducted earlier, distilled water or lubricants were used to analyze cyclic fatigue. However, we used different concentrations of sodium hypochlorite in our study because it is recommended clinically that the root canal should be kept wet with such active endodontic irrigants.[25,26]

It has been found that sodium hypochlorite can remove nickel from the surface of the instrument causing micropitting that can harm the properties of the nickel–titanium rotary files. When nickel–titanium files are exposed to sodium hypochlorite then there is a development of zones of corrosion causing a reduction in the resistance against cyclic fatigue in nickel–titanium alloy instruments. On increasing the concentration of sodium hypochlorite, chloride concentration increases causing a more negative impact on the nickel–titanium alloys.[27,28]

In our study, the GenEndo NiTi file showed maximum resistance against cyclic fatigue followed by Protaper Gold, Hero Gold, and EdgeFile X3 file. GenEndo files are the most recent rotary nickel–titanium alloy-based instruments having well-annealed and heat-treated alloys. These files use heat-treated NiTi alloys to form T-wire files. The cross-section and design of the GenEndo file provide better resistance against cyclic fatigue.

In our study, increase in the temperature caused a decrease in the resistance against cyclic fatigue in new heat-treated nickel–titanium alloy instruments. This can be attributed to the fact that the properties of the nickel–titanium files are due to the phase conversion based on the heat treatment.[29]

The clinical implication of this study was that endodontists will consider the effect of sodium hypochlorite while selecting NiTi instruments for their patients in an effective manner. There were some limitations of this study. The study was carried out in mechanically designed artificial canals instead of natural root canals. Cyclic fatigue can be affected by the debris produced during biomechanical preparation in the natural root canal. This aspect of debris was not addressed in this study. There can be a difference in the frictional resistance to instruments in natural canals as compared with artificial canals. So, in future, more *in vivo* studies should be carried out to get better results that can be applied to endodontic patients.

Conclusion

The findings of this study help us to conclude that resistance against cyclic fatigue in new NiTi rotary files can be affected significantly by different concentrations of sodium hypochlorite irrigant solution and the GenEndo rotary endodontic instrument has the maximum resistance against cyclic fatigue.

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