

Original Article

Effect of immersion in sodium hypochlorite on cyclic fatigue resistance of RaCe, HyFlex CM and XP-endo shaper files

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ABSTRACT

Background: This study assessed the effect of sodium hypochlorite on cyclic fatigue resistance of RaCe, HyFlex CM and XP-endo Shaper files.

Materials and Methods: In this *in vitro*, experimental study, 90 RaCe, HyFlex CM and XP-endo Shaper files ($n = 30$ of each) were divided into two groups ($n = 45$). Group 1 included 15 files of each rotary system, which were immersed in 37°C sodium hypochlorite (5.25%) for 5 min. Group 2 files were immersed in 37°C saline for 5 min. The files underwent cyclic fatigue testing using simulated root canals in which, the rotary files could freely rotate until fracture. Time of fracture was recorded by a chronometer and the number of cycles until fracture was calculated. Data were analyzed using two-way ANOVA and Bonferroni test ($\alpha = 0.05$).

Results: No significant difference existed in the mean number of cycles or rotation time of files between saline and sodium hypochlorite ($P > 0.05$). The mean rotation time of RaCe was significantly shorter than that of HyFlex and XP-endo Shaper in both solutions ($P < 0.05$). The mean number of cycles of RaCe was significantly lower than that of HyFlex and XP-endo Shaper files in both solutions ($P < 0.05$). The mean number of cycles of HyFlex was significantly lower than that of XP-endo Shaper ($P < 0.05$).

Conclusion: Immersion of rotary files made of different alloys in 5.25% sodium hypochlorite for 5 min had no effect on their fracture resistance. However, type of file alloy affected its fatigue resistance such that XP-endo Shaper showed the highest and RaCe showed the lowest fatigue resistance.

Key words: Corrosion, cyclic fatigue, endodontics, sodium hypochlorite

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INTRODUCTION

The advent of rotary nickel-titanium (NiTi) files revolutionized root canal instrumentation and highly simplified endodontic treatments. They enable more efficient root canal shaping in a much shorter period of time compared to manual instrumentation.^[1] However, risk of file fracture during root canal shaping always exists.^[2] Removal or bypassing the broken

file segment is not always easy and may yield unpredictable results.^[3,4] The prognosis of teeth with broken instruments in their root canal system is questionable in most cases and such teeth are always a concern for dental clinicians.

File fracture may occur as the result of cyclic fatigue or torsional fatigue.^[5,6] Crack formation and

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propagation in files can be due to repeated bending and straightening of the file in canal curvatures and stress accumulation at the bending site during rotation, which is referred to as cyclic fatigue.^[7] Factors affecting the cyclic fatigue have been extensively studied, and evidence shows that cross-sectional design and flute of the file, its diameter and taper, root canal shape, and speed and torque of the handpiece can all affect the cyclic fatigue resistance of files.^[8,9] Attempts have been made to identify and modify the factors affecting the fracture resistance of files. These include changing the sequence of filing, use of torque control motors, changing the cross-sectional file design, file surface modifications by electro-polishing and magnetic electro-polishing and changing the file alloy.^[10]

Corrosion following exposure to sodium hypochlorite is another factor that negatively affects the cyclic and torsional fatigue resistance of files, making them susceptible to fracture.^[11-13] Sodium hypochlorite is the most commonly used root canal irrigating solution.^[14] However, it can cause corrosion of surgical instruments and endodontic files.^[15]

NiTi files are exposed to sodium hypochlorite as part of their disinfection protocol, during root canal irrigation^[16] and when the pulp chamber is filled with sodium hypochlorite irrigating solution.^[17] For this reason, the magnitude of corrosion of the NiTi file surface following its exposure to sodium hypochlorite is not known. The pattern of corrosion involves selective removal of ions from the NiTi file surface and micro-pitting.^[18] Defects created in the microstructure of the file surface lead to stress accumulation, crack formation and weakening of the instrument.^[19]

Rotary files are available in five generations. The conventional NiTi alloy was used in the first and second generations of rotary files. The Bio RaCe system is a second generation rotary system. The third generation rotary files had some alterations in their metal structure. Heat treatment is a thermal process and a fundamental approach for regulation of phase transition temperature, which affects the fatigue resistance of NiTi alloy in rotary files. HyFlex (Coltene) files are third generation rotary files. The fourth generation includes rotary instruments with reciprocating motion. The fifth generation rotary files are designed such that the center of rotation or the center of file is offset.^[20] They have asymmetrical

rotary movements not related to endodontic motors.^[21] RaCe files have a triangular cross-section and a safe tip. The surface of these files has been electro-polished, which confers cyclic and torsional fatigue resistance to metal. It also enhances the sterilization and cleaning of files.^[22]

CM wire was introduced to endodontics in 2010. CM wire NiTi files were manufactured via a unique thermomechanical process to have shape memory, which allows high flexibility without major deformation similar to other NiTi files.^[20] HyFlex CM files are made of CM wires and their manufacturer claims that they have a cyclic fatigue resistance 300% higher than that of other files. This decreases the separation and fracture of files.^[23]

Recently, a new heating process was introduced to compensate for the defects created during file manufacturing. This process affects the crystalline structure of files and forms a transitional phase due to the presence of Ti3Ni4. Next, a cooling process is performed. This process is employed for the fabrication of XP-endo Shaper files.^[24] XP-endo Shaper is the latest version of XP-endo files. This novel rotary system was designed to simplify the sequence of application of files. The XP-endo files are made of Max wire alloy and have high flexibility and fatigue resistance and easy and fast application in root canals. Depending on the canal shape, they undergo contraction or expansion in the root canal.^[25] The XP-endo Shaper files with 0.3 mm diameter and variable taper (0.1-0.4) were introduced in 2016. These files undergo phase transformation, which normally occurs at the body temperature between 32° and 37°C (mean of 35°C).^[26]

Elnaghy and Elsaka^[17] evaluated the effect of 5% sodium hypochlorite and saline at body temperature on fatigue resistance of Reciproc and WaveOne Gold files and concluded that both solutions decrease the cyclic fatigue resistance of the files.

In 2015, Topçuoğlu *et al.*^[18] evaluated the effect of immersion of ProTaper, DeRaCe and Mtwo retreatment files in 5% sodium hypochlorite on their cyclic fatigue resistance and showed that the cyclic fatigue resistance of DeRaCe file significantly decreased following immersion in sodium hypochlorite while the fatigue resistance of the other two files was not affected.

Considering all the above, this study aimed to assess the cyclic fatigue resistance of #30 (4%) RaCe,

#30 (4%) HyFlex CM and XP-endo Shaper NiTi rotary files following immersion in 5.25% sodium hypochlorite and saline solution at 37°C for 5 min.

MATERIALS AND METHODS

This *in vitro* experimental study was performed on 90 files ($n = 30$ of each of the RaCe, HyFlex CM and XP-endo Shaper). Sample size was calculated to be 15 files in each of the six groups considering 80% study power, $\alpha = 0.05$ and $d = 35.5$ and 43.5.

Thirty (#30, 4%) RaCe (FKG, Switzerland), 30 (#30, 4%) HyFlex CM (Coltene WaleDent, Switzerland) and 30 XP-endo Shaper files (FKG, Switzerland) were selected. To fabricate a block with simulated root canals, a stainless steel block measuring 12 mm × 50 mm × 80 mm was obtained. The shape of canals was drawn on a piece of paper with high details and was then transferred on the block. The canals were formed in resin according to the method described by Plotino *et al.*,^[27] which is a highly acceptable method for cyclic fatigue resistance testing. This was done using a frame that held the stainless steel block. This metal block was designed such that it contained simulated canals in resin compatible with the length and size of the files. The canals had 16 mm length, 1.5 mm width, curvature radius of 5, 2 mm depth and 60° of curvature. The canals were carved in the block.

The handpiece used in this study was an electric micromotor (Silver Reciproc, VDW, Switzerland) with an adjustable torque and 16-1 reduction gear. The speed and torque of the device were adjusted according to the manufacturers' instructions for each file. In order to firmly hold the handpiece in a reproducible position, a custom-designed jig was used and the handpiece was firmly attached to the jig using adhesive tape. The files were divided into two groups of 45. Each group ($n = 45$) had three subgroups of 15 of each of the RaCe (#30, 4%), HyFlex (#30, 4%) and XP-endo Shaper files, which were dynamically immersed in saline solution (Razi, Tehran, Iran) at 37°C for 5 min. Group 2 included the same number and type of files as in group 1, which were dynamically immersed in 5.25% sodium hypochlorite solution (Golrang, Tehran, Iran) at 37°C for 5 min. A laboratory heater (Vinteb, Tehran, Iran) was used to heat up the solutions to 37°C. The files were then removed from the solutions, rinsed with distilled water (Razi, Tehran, Iran) and dried with air. They were then

individually placed in glass test tubes (Padtan Teb, Tehran, Iran) and coded.

Each file in the 6 subgroups was mounted on the handpiece. Before turning on the handpiece, the metal block was immersed in water at 37°C to provide suitable conditions for operation of the XP-endo Shaper file. The metal block was then placed below the handpiece fixed to the jig. The handpiece was adjusted to the speed and torque recommended by each manufacturer with 16:1 reduction gear. The file was started to rotate inside the simulated canal and the time was recorded by a chronometer with 0.01 s accuracy until file fracture. Number of cycles of each file until fracture was calculated using the formula below:

$$NCF = \frac{\text{rounds per minute} \times \text{time (s)}}{60}$$

Number of cycles to failure (NCF) indicates cyclic fatigue resistance according to the number of cycles of each file in the curvature until fracture. Rounds per minute indicate the number of cycles per minute and time indicates the time duration of file rotation in the canal until fracture. The time shown by the chronometer for each file was recorded in all groups.

Data were analyzed using SPSS version 22 (IBM., NewYork, USA) via two-way ANOVA and Bonferroni *post hoc* test. $P < 0.05$ was considered statistically significant.

RESULTS

Table 1 shows the mean and standard deviation of rotation time in RaCe, HyFlex and XP-endo Shaper files in saline and sodium hypochlorite solutions. According to two-way ANOVA, the effect of file type on the mean rotation time was significant ($P < 0.001$). However, the effect of type of solution ($P = 0.819$) and the interaction effect of type of file and type

Table 1: Mean and standard deviation of rotation time in RaCe, HyFlex and XP-endo Shaper files in saline and sodium hypochlorite solutions ($n=15$) (s)

Solution	File type	Mean	SD
Saline	RaCe	32.45	6.51
	HyFlex CM	72.25	21.07
	XP-endo Shaper	83.86	15.09
Sodium hypochlorite	RaCe	29.27	10.80
	HyFlex CM	72.70	20.10
	XP-endo Shaper	84.08	23.21

SD: Standard deviation

of solution ($P = 0.901$) on the mean rotation time were not significant. Thus, the mean rotation time was not significantly different between the two solutions ($P > 0.05$).

According to the Bonferroni *post hoc* test, no significant difference existed in the mean rotation time of the three rotary systems in the two solutions ($P = 0.614$ for RaCe, $P = 0.943$ for HyFlex and $P = 0.971$ for XP-endo Shaper).

Table 2 presents the pairwise comparisons of the mean rotation time of files in the two solutions. The Bonferroni *post hoc* test showed that in both saline and sodium hypochlorite solutions, the mean rotation time of RaCe file was significantly shorter than that of HyFlex and XP-endo Shaper files ($P < 0.05$). No significant difference was noted in the mean rotation time of HyFlex and XP-endo Shaper files ($P > 0.05$).

Table 3 shows the mean number of cycles of files in saline and sodium hypochlorite solutions. According to two-way ANOVA, the effect of type of file on the mean number of cycles was significant ($P < 0.001$). However, the effect of type of solution ($P = 0.816$) and the interaction effect of type of solution and type of file ($P = 0.921$) on the number of cycles were not significant ($P > 0.05$). Thus, the mean number of cycles was not significantly different between the two solutions ($P > 0.05$). Also, the mean number of cycles of the three file types was not significantly different in any of the two solutions ($P > 0.05$).

According to the Bonferroni *post hoc* test, the difference in the mean number of cycles of the three rotary systems was not significant in any of the two solutions ($P = 0.643$ for RaCe, $P = 0.967$ for HyFlex and $P = 0.986$ for XP-endo Shaper).

Table 4 shows pairwise comparison of the files in terms of the mean number of cycles in the two solutions. The Bonferroni *post hoc* test showed that in both saline and sodium hypochlorite solution, the mean number of cycles of RaCe file was significantly lower than that of HyFlex and XP-endo Shaper files ($P < 0.05$). Also, the mean number of cycles in HyFlex file was significantly lower than that of XP-endo Shaper ($P < 0.05$).

DISCUSSION

Introduction of NiTi rotary systems enabled faster root canal preparation with fewer procedural errors.^[28] However, endodontic instruments are subjected to high level of stress, which may eventually lead to

Table 2: Pairwise comparisons of the mean rotation time of files in saline and sodium hypochlorite solutions (s)

Solution	File (I)	File (J)	Mean difference	P
Saline	RaCe	HyFlex	-39.799	<0.001
	RaCe	XP-endo Shaper	-51.405	<0.001
	HyFlex	XP-endo Shaper	-11.606	0.204
Sodium hypochlorite	RaCe	HyFlex	-43.423	<0.001
	RaCe	XP-endo Shaper	-54.807	<0.001
	HyFlex	XP-endo Shaper	-11.383	0.220

Table 3: Mean and standard deviation of number of cycles of RaCe, HyFlex and XP-endo Shaper files in saline and sodium hypochlorite solutions (n=15)

Solution	File type	Mean	SD
Saline	RaCe	324.50	65.10
	HyFlex CM	602.93	175.11
	XP-endo Shaper	1119.84	198.80
Sodium hypochlorite	RaCe	292.74	107.99
	HyFlex CM	605.79	167.49
	XP-endo Shaper	1121.08	309.40

SD: Standard deviation

Table 4: Pairwise comparisons of the mean number of cycles of RaCe, HyFlex and XP-endo Shaper files per minute in saline and sodium hypochlorite solutions

Solution	File (I)	File (J)	Mean difference	P
Saline	RaCe	HyFlex	-278.433	<0.001
	RaCe	XP-endo Shaper	-795.345	<0.001
	HyFlex	XP-endo Shaper	-516.912	<0.001
Sodium hypochlorite	RaCe	HyFlex	-313.051	<0.001
	RaCe	XP-endo Shaper	-828.341	<0.001
	HyFlex	XP-endo Shaper	-515.289	0.220

instrument fracture. Several factors such as size and anatomy of the root canal, frequency of use of instruments, manufacturing defects, design and alloy of the file, degree of root curvature, radius of curvature and clinician's experience all play a role in instrument fracture.^[29] the key findings of this study showed that immersion of files made of different alloys in 5.25% sodium hypochlorite solution for 5 min had no significant effect on their fatigue resistance compared to immersion in saline. However, the type of file alloy affected its fatigue resistance such that XP-endo Shaper showed the highest and RaCe showed the lowest fatigue resistance.

The effect of different factors on NiTi file fracture has been the topic of many investigations.^[29-31] In general,

NiTi files may break because of two reasons: (I) application of torsional forces to the file due to its involvement and friction with the root canal walls, (II) file fatigue due to repeated bending and straightening in curved canals, which is referred to as cyclic fatigue. The effect of torsional fatigue, cyclic fatigue and the combination of both on file fracture is still a matter of debate.^[5] Cyclic fatigue due to repeated use is an important reason for fracture of rotary files. Evidence shows that around 90% of fractures of NiTi rotary files are due to cyclic fatigue.^[5,32] In the process of fatigue, files develop small cracks at the points of stress accumulation. These cracks easily propagate and lead to file fracture.^[33] Exposure of NiTi files to sodium hypochlorite has been suggested as one possible factor that may decrease their fatigue resistance.^[29] However, studies on this topic mainly had an *in vitro* design; thus, generalization of results to the clinical setting should be done with care.

The present study evaluated and compared the number of cycles of each file until fracture in a simulated canal with 60° curvature following exposure to saline and sodium hypochlorite. In order to accurately perform the cyclic fatigue resistance test, we needed the files to rotate in a canal with a certain degree of curvature. According to Plotino *et al.*,^[27] use of standard simulated canals is superior to natural root canals for measurement of cyclic fatigue resistance of files since the use of simulated canals eliminates the effect of confounders (anatomical differences of natural root canals) on the results. A metal block with simulated canals with specific dimensions and angles was used for this purpose in the present study. The canal length, width, depth, curvature radius and curvature angle of the simulated canals were carefully determined. Although one may assume that the actual file length and file curvature in the canal may not be exactly compatible with the length and curvature angle of the simulated canal,^[34] it should be noted that this is a standard method for standardization of canals and decreasing errors caused by the effect of confounders.

This study aimed to assess the cyclic fatigue resistance of RaCe (#30, 4%), HyFlex CM (#30, 4%) and XP-endo Shaper rotary NiTi files after immersion in 5.25% sodium hypochlorite and saline at 37°C for 5 min. The results showed that the mean rotation time of files was not significantly different in the two solutions. Also, the mean rotation time among the three files in the two solutions was not significantly different. These findings were in contrast

to those of Berutti *et al.*,^[35] who evaluated the effect of 5 min of immersion in 5% sodium hypochlorite at 50°C on cyclic fatigue resistance of ProTaper files. Our results were also in contrast to those of Peters *et al.*,^[36] who evaluated the effect of 1 or 2 h of immersion in 5.25% sodium hypochlorite at 21°C and 60°C on cyclic fatigue resistance of RaCe and ProFile. Our results were in agreement with those of Pedullà *et al.*^[30,37] This controversy in the results of studies may be due to different methodologies, temperature of the solutions and immersion protocol. In the clinical setting, complete immersion of files in sodium hypochlorite solution rarely occurs and the file shank is often completely engaged in the hand-piece; this statement rejects the explanation provided by Berutti *et al.*,^[35] regarding galvanic corrosion because galvanic corrosion requires the presence of two different metals at the reaction site, which were assumed to be the file shank metal and NiTi alloy of the file in their study. Moreover, it has been shown that duration of immersion in sodium hypochlorite can affect the fatigue resistance.^[30,31]

Regarding the number of cycles until file fracture, our findings indicated that the mean number of cycles of RaCe file was significantly lower than that of HyFlex and XP-endo Shaper files in both saline and sodium hypochlorite solutions. Moreover, the mean number of cycles of HyFlex file was significantly lower than that of XP-endo Shaper.

Search of the literature by the authors yielded two studies on the cyclic and torsional fatigue resistance of XP-endo Shaper files. Our findings regarding XP-endo Shaper are probably attributed to the type of alloy used in XP-endo Shaper files, which is made of Max-wire. The manufacturer claims that this alloy has higher flexibility, super-elasticity and fatigue resistance. Evidence shows that the new alloys have higher phase transformation temperature than conventional alloys and phase transformation may occur at body temperature as well. Another explanation may be related to the low taper and fine core of the XP-endo Shaper, which increase its fracture resistance. The longitudinal cross-section of the file is another reason, which is not fully in contact with the canal walls during file rotation and increases the clinical service of the file. This is a characteristic of asymmetrical files. Moreover, it should be noted that high rotational speed of this file in the canal compared to other files, increases the NCF within the same rotation period in the canal.

Higher fatigue resistance of HyFlex files compared to RaCe files can be due to the different alloy used in its manufacturing process, which is made of M-wire. Instruments fabricated of M-wire have higher flexibility and cyclic fatigue resistance than conventional files made of NiTi. Kim *et al.*^[38] compared the cyclic fatigue resistance of Reciproc, WaveOne (both made of M-wire) and ProTaper files and concluded that both Reciproc and WaveOne have much higher cyclic fatigue and rotational fatigue resistance than ProTaper files. RaCe files evaluated in our study are made of NiTi alloy and previous studies have shown that HyFlex CM files have much higher fatigue resistance than files made of NiTi.^[39] This finding was in complete agreement with our results. Our Study and another studies about this topic will help dentist to reduce the possibility of file fracture and increase quality of treatment. Future studies are required to assess the actual behavior of files regarding cyclic fatigue and torsional fatigue resistance in natural root canals. Moreover, this study had an *in vitro* design. Thus, generalization of results to the clinical setting must be done with caution. Clinical studies are required to confirm the findings of this *in vitro* study.

CONCLUSION

Within the limitations of this study, the results showed that immersion of files made of different alloys in 5.25% sodium hypochlorite solution for 5 min had no significant effect on their fatigue resistance compared to immersion in saline. However, the type of file alloy affected its fatigue resistance such that XP-endo Shaper showed the highest and RaCe showed the lowest fatigue resistance.

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Conflicts of interest

The authors of this manuscript declare that they have no conflicts of interest, real or perceived, financial or nonfinancial in this article.

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