Effect of the temperature of sodium hypochlorite on the cyclic fatigue resistance of ProTaper Gold rotary files

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Abstract

Background. Instrument fracture is one of major challenges during root canal treatment. In order to reduce such errors, it seems necessary to investigate the effects of potentially impactful factors. One of such factors could be the temperature of an agitator.

Objectives. This study examined the effects of different temperature of the sodium hypochlorite solution on the cyclic fatigue resistance of ProTaper Gold (PTG) rotary files.

Material and methods. Forty-five PTG S1 rotary files were tested in a metal block that simulated a canal curvature angle of 60° and a curvature radius of 5 mm. They were randomly divided into 3 groups of 15 according to sodium hypochlorite temperatures of 22°C (group 1), 4°C (group 2) and 37°C (group 3). Files from each group were rotated at 300 rpm in the block at each temperature. The number of cycles to fracture was calculated and the fragment length was measured. The fractured surfaces were examined by means of scanning electron microscopy (SEM). The statistical analysis was completed using the Kolmogorov–Smirnov and Kruskal-Wallis tests, and the IBM SPSS Statistics for Windows software, v. 22.0, at a significance level of 5%.

Results. The cyclic fatigue resistance of the PTG rotary files was not significantly affected by the temperature of sodium hypochlorite ($p > 0.05$).

Conclusions. Increasing the temperature of sodium hypochlorite to 37°C or decreasing it to 4°C did not significantly affect the cyclic fatigue resistance of PTG rotary files.

Keywords: temperature, sodium hypochlorite, rotary instruments, cyclic fatigue, nickel-titanium

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Introduction

One of the most important goals in root canal therapy is to reduce the microbial load in the root canal system to an acceptable level. One important step in achieving this goal is the cleaning and shaping of the root canal.[1] Currently, rotary files are widely used for shaping root canals.[1,2] Research has shown that nickel-titanium (Ni-Ti) rotary files result in fewer procedural errors during the preparation and shaping of root canals, and more favorable outcomes as compared to stainless-steel files.[1–3] However, the use of rotary files may be associated with problems, such as file fracture within the root canal.[4]

The fracture of rotary files within the root canal can have 2 forms – torsional fracture and cyclic fatigue fracture. Torsional fracture occurs when the file tip is engaged in the root canal and the file shank is in rotation, leading to the fracture of the file tip. Cyclic fatigue fracture occurs when the file undergoes repeated stress and tension, and fractures within the root canal. Cyclic fatigue is responsible for the majority of fractures. Many studies have been undertaken in an attempt to reduce the risk of this type of fracture.[4–7]

Root canal therapy is most commonly performed using irrigation solutions, with sodium hypochlorite being the most freqeuntly used.[1] This irrigation solution exhibits high antibacterial activity and strong tissue solubility. Furthermore, according to some studies, its antibacterial activity and tissue solubility increase with an increase in temperature.[5,8] Some studies have reported that the sodium hypochlorite solution can cause the corrosion of Ni-Ti files due to its hypochlorite ion content. This would affect its mechanical properties and increase the odds of a sudden fracture.[9] Other studies, however, have reported that the sodium hypochlorite solution does not have any effect on the structure of heat-treated files.[10]

ProTaper Gold (PTG; Dentsply Tulsa Dental Specialties, Tulsa, USA) is a new generation of ProTaper rotary files. According to the manufacturer, PTG files have been designed based on advanced metallurgy and exclusive tapering, with high efficacy and a safe tip. Due to the heat-treatment process, the shape memory and higher plasticity associated with these files reduce the number of the preparation errors in curved canals. In addition, this generation of files is more flexible than the ProTaper Universal file type.[11,12]

Continuous advances in rotary file systems and their ever-increasing use have made it possible to decrease the number of procedural errors. Also, according to previous studies, an increase in the temperature of the sodium hypochlorite solution reduces the microbial load. On the other hand, a decrease in the file temperature reduces friction and failure during root canal treatment steps.[13,14] A limited number of studies have investigated the effect of temperature variations on the fracture resistance of these files. Therefore, the aim of this study was to investigate the effect of the temperature of the sodium hypochlorite solution on the fracture resistance of PTG rotary files.

Material and methods

Forty-five PTG S1 rotary files were tested in this study. The samples were examined using a scanning electron microscope (SEM) (Leica M205 C; Leica Microsystems, Wetzlar, Germany) for structural defects or deformities. Defective files were replaced by new ones with no structural defects.

The specimens were randomly divided into 3 groups (n = 15). A sodium hypochlorite (Wizard™; Rehber Kimya, Istanbul, Turkey) solution was used at 22°C (room temperature) in group 1, at 4°C in group 2, and at 37°C (body temperature within the root canal) in group 3. The concentration of the sodium hypochlorite solution was 5.25% for all groups.

For the cyclic fatigue test, a stainless-steel metal block with a simulated canal with a curvature angle of 60°, a curvature radius of 5 mm and a length of 25 mm was used (Fig. 1). It was designed in such a way so that the file could move freely within the canal. The file was inserted into a handpiece connected to an endodontic motor (Silver; VDW, Munich, Germany). The block and handpiece were fixed in place with a clamp. The engine speed was set at 300 rpm and a torque of 5.1 N·cm, based on the manufacturer's recommendations. Before starting the procedure, oil was poured into the canal to reduce friction. The file was inserted into the canal up to a length of 25 mm. The block was fixed inside a recipient that was filled with 5.25% sodium hypochlorite. The temperature was preset at 22°C, 4°C and 37°C with a tolerance limit of 1°C. Time was measured with a timer, starting from the moment when the file began to rotate. The timer was stopped a fracture was observed or after hearing a fracture sound, and the time was recorded. The time in minutes was multiplied by 300 rpm to calculate the number of cycles to fracture (NCF). The fragment length was measured under an SEM (Leica M205 C) at ×10 magnification. The 3 fractured instruments were cleaned with absolute alcohol in an ultrasonic bath. The fractured surface was examined using an SEM (Leica M205 C), as demonstrated in Fig. 2–7.

Statistical analysis

The mean (M) and standard deviation (SD) values were calculated in terms of NCF. The distribution of data was abnormal, as confirmed by the Kolmogorov–Smirnov test. The data was analyzed with the Kruskal–Wallis test. A confidence level of 95% was established. The IBM SPSS Statistics for Windows software, v. 22.0 (IBM Corp., Armonk, USA), was used for data analysis.

Fig. 1. Artificial stainless-steel canal

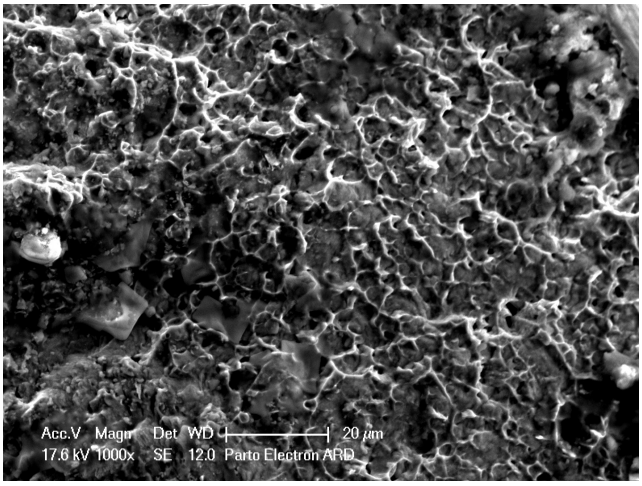

Fig. 3. Scanning electron microscopy (SEM) image of the ProTaper Gold (PTG) S1 instrument after cyclic fatigue testing using NaOCl at 4°C
×1,000 magnification.

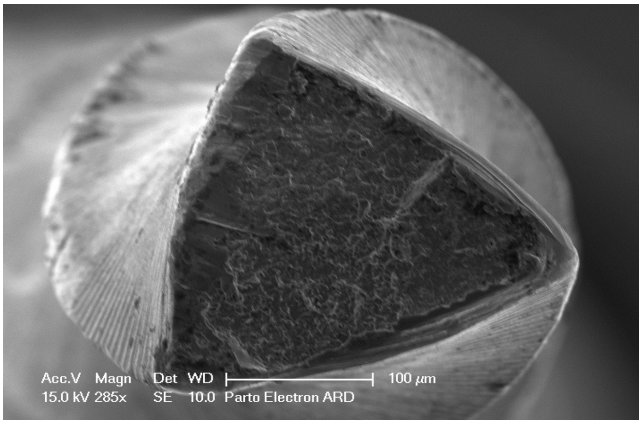

Fig. 4. Scanning electron microscopy (SEM) image of the ProTaper Gold (PTG) S1 instrument after cyclic fatigue testing using NaOCl at 22°C
×285 magnification.

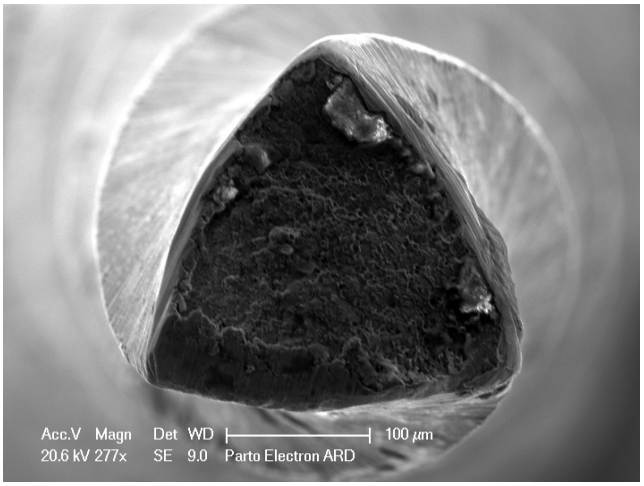

Fig. 2. Scanning electron microscopy (SEM) image of the ProTaper Gold (PTG) S1 instrument after cyclic fatigue testing using NaOCl at 4°C
×277 magnification.

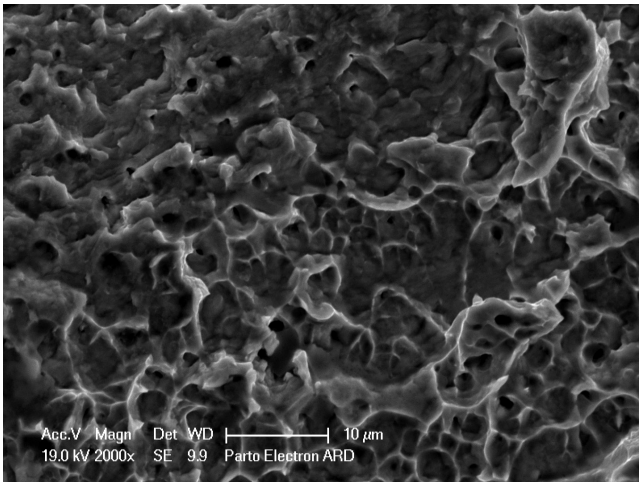

Fig. 5. Scanning electron microscopy (SEM) image of the ProTaper Gold (PTG) S1 instrument after cyclic fatigue testing using NaOCl at 22°C
×2,000 magnification.

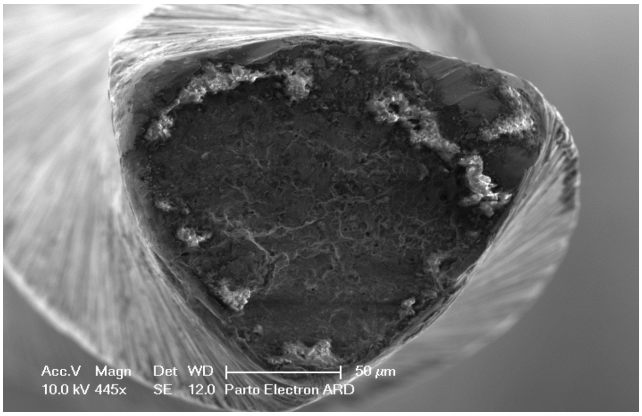

Fig. 6. Scanning electron microscopy (SEM) image of the ProTaper Gold (PTG) S1 instrument after cyclic fatigue testing using NaOCl at 37°C
×445 magnification.

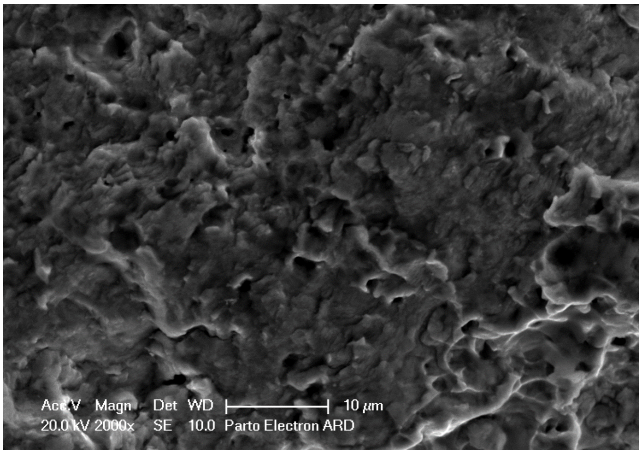

Fig. 7. Scanning electron microscopy (SEM) image of the ProTaper Gold (PTG) S1 instrument after cyclic fatigue testing using NaOCl at 37°C
×2,000 magnification.

Results

The *M* and *SD* values for NFC are presented in Table 1. The mean fracture resistance in group 1 was slightly higher than that in the other groups. The mean fracture resistance in group 2 was slightly lower than that in the other 2 groups; however, there were no significant differences in the mean NCF values between the 3 groups ($p > 0.05$). Table 1 presents the mean length of the broken pieces at 22°C, 4°C and 37°C; there was no statistically significant difference between the 3 groups in this respect ($p > 0.05$).

Table 1. Number of cycles to fracture (NCF) and length of the broken pieces in all study groups

Group	NCF	Length of the fractured piece [mm]
Group 1	1248.50000 ±299.17526	4.42 ± 0.45
Group 2	1076.50000 ±190.93411	4.98 ± 0.56
Group 3	1119.50000 ±117.81174	4.48 ± 0.71

Data presented as mean ± standard deviation (*M* ±*SD*).
Group 1 – NaOCl at 22°C; group 2 – NaOCl at 4°C; group 3 – NaOCl at 37°C.

Discussion

The introduction of rotary files has resulted in faster root canal therapy and fewer procedural errors during root canal preparation. One of the most common errors during root canal therapy is file fracture within the root canal. The highest probability of fracture is related to fatigue. Factors that affect fatigue resistance include the canal curvature, the length and anatomy of the root canal, the frequency of file use, the design of the file, the metal alloys used in the file, the sterilization process, the rotary machine factors, and the operator's experience.[15–18]

Recently, the effect of environmental temperature has been investigated as a factor affecting fracture resistance.[10,19] The majority of these studies have investigated the effect of temperatures higher than the temperature within the root canal. A temperature of 4°C is considered a low temperature of the sodium hypochlorite solution; also, the sodium hypochlorite solution is stable at this temperature.[20] Temperatures of 37°C and 22°C are considered root canal and environmental temperatures, respectively. A concentration of 5.25% was selected for the sodium hypochlorite solution in this study, since it is commonly used in root canal therapy.[21]

In this study, fatigue resistance was determined with a device that was similar to that used in previous studies.[1,8,22] The length of the broken pieces was not significantly different between the groups, which indicates the presence of a similar location of stress in the root canal, i.e., the middle of the curvature in the root canal, which is consistent with previous studies.[10,22]

Previous clinical studies have shown that when the irrigation solution is delivered into the root canal at different temperatures, the body tends to balance its temperature with the temperature within the canal, which is around 35°C.[21] One of the factors that can influence fracture resistance is the temperature at conversion from the austenitic phase to the martensitic phase during the fabrication of the file alloy. If this temperature is between room temperature and the temperature within the root canal, the file temperature reaches the phase transition temperature when the file is inserted into the canal, resulting in a decrease in fatigue resistance and an increase in the odds of fracture.[23]

One of the advantages of PTG Gold files over previous generations is that its phase transition temperature is higher than the temperature within the root canal.[23] In this study, unlike in previous studies, the temperature of the solution did not affect the fracture resistance of the files, which might be attributed to the phase transition temperature; therefore, in heat-treated files, temperature has a lesser effect on the fracture resistance of the files.[24]

In another study, the effect of 3 temperatures of the sodium hypochlorite solution (22°C, 37°C and 50°C) on the fracture resistance of files was investigated.[14] It was reported that a temperature of 37°C had no effect on fracture resistance, which is consistent with the results of the present study, while a temperature of 50°C increased the fracture

resistance of the rotary files.[14] Another study determined that a decrease in environmental temperature to 0°C increased the fracture resistance of the tested files.[19]

Previous studies have shown that contact between the sodium hypochlorite solution and Ni-Ti files might result in the corrosion of the files. If this corrosion does not occur in the area of file which is affected by high stress, it cannot affect the fracture resistance of the file.[9] According to the manufacturer's claims, in newer generations, files do not undergo corrosion due to more advanced metallurgy. For example, a study on the effect of high concentrations of the sodium hypochlorite solution at 22°C, 37°C and 50°C determined that the concentration of the sodium hypochlorite solution did not affect the fracture resistance of rotary files, which is consistent with the results of the present study.[4]

A similar study compared the effects of environmental temperature and the temperature within the root canal on the fracture resistance of ProTaper Universal and PTG files.[23] It concluded that temperature did not affect the fracture resistance of PTG files, while increasing the temperature decreased the fracture resistance of ProTaper Universal files, which is consistent with the results of the present study.[23]

Since the fracture resistance of files depends on different factors, including the type of file and the method applied in the study, it is suggested that other files and temperatures should also be evaluated. In addition, since this study was carried out in vitro, it is suggested that, if possible, clinical studies should be carried out on vital teeth.

Conclusions

Increasing the temperature of the sodium hypochlorite solution to 37°C or decreasing it to 4°C did not significantly affect the fracture resistance of PTG rotary files. In addition, the length of the broken pieces was not significantly different between the 3 groups. Since this study was carried out in vitro, it is suggested that further clinical studies be undertaken on vital teeth.

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