JOMDI

Journal of Medical and Dental Investigations

J Med Dent Invest 2024; 5: e240347
https://doi.org/10.5577/jomdi.e240347

Original Article Open Access

Comparison of cyclic fatigue resistance of different rotational and reciprocal file systems

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Received: 12 November 2024
Accepted: 19 December 2024
Published: 30 December 2024

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How to cite this article:

Akın Tartuk G, Kaya S, Al Tai TN. Comparison of cyclic fatigue resistance of different rotational and reciprocal file systems. J Med Dent Invest 2024;5:e240347.
https://doi.org/10.5577/jomdi.e240347

Abstract

Aim: The purpose of this study is to compare the cyclic fatigue resistance of the TruNatomy and ProTaper Next file systems, which work rotational movements, and Reciproc and WaveOne Gold file systems, which work reciprocal movements.
Methods: ProTaper Next X2 (25/.06), WaveOne Gold Primary (25/.07), Reciproc R25 (25/.08), and TruNatomy Prime (26/.04) files were used in the cyclic fatigue test. Four groups, 15 files from each group and a total of 60 files, were rotated in an artificial canal made of curved stainless steel with a curvature angle of 60 degrees, an inner diameter of 1.5 mm, and a radius of curvature of 3 mm. The breaking times of the files were determined with a digital stopwatch, and this value was converted into the number of cycles until breaking. Compliance with normal distribution was examined with the Shapiro–Wilk test. The number of cycles until fracture for the respective files, which did not follow a normal distribution, were compared using the Kruskal–Wallis test and multiple comparisons were made with the Dunn test. The analysis results were presented as mean ± standard deviation and median (minimum-maximum). The significance level was taken as $p<0.050$.
Results: While the TruNatomy system had the highest number of cycles until fracture occurred, no statistically significant difference was found between the Reciproc and WaveOne Gold systems. The ProTaper Next system showed the lowest cyclic fatigue resistance.
Conclusion: Within the limitations of the present in vitro study, TruNatomy, which makes rotational motion, showed the best cyclic fatigue resistance. The ProTaper Next system was the file with the lowest cyclic fatigue resistance. Obtaining similar results for files produced in different shapes and with different movement kinematics allowed us to conclude that cyclic fatigue is multifactorial.

Keywords: Cyclic fatigue, endodontic file, ProTaper Next, Reciproc, TruNatomy, WaveOne Gold

Introduction

Nickel-titanium (Ni-Ti) file systems are widely used in the mechanical preparation of root canals (1). These instruments have many positive features, such as having a lower modulus of elasticity and higher cutting efficiency compared to traditional stainless steel files. These mechanical properties greatly facilitate the biomechanical preparation phase of endodontic treatment (2). In addition to their positive features, however, the breaking of these file systems within the canal without visible deformation is a serious complication that affects the treatment prognosis (3).

File breakage can occur in two different ways: torsional fatigue and cyclic fatigue (4). The fracture that occurs as a result of torsional fatigue is a result of the tip of the file being locked in the canal while the other parts continue to rotate. When the torque exceeds the elastic limit of the metal, the tool breaks (5). In cyclic fatigue, the file is exposed to compressive and tensile forces in the inclined canal. Continuous repetition of these forces causes file breakage (6).

To increase the fracture resistance of files, various modifications to the Ni-Ti alloy and kinematics have been proposed (7). By applying various thermomechanical treatments to Ni-Ti wire, its fatigue resistance and flexibility have been increased (8). It has also been determined that back-and-forth movement increases the cyclic fatigue resistance of Ni-Ti instruments (9).

With the developments in Ni-Ti metallurgy, classical alloys have been replaced by heat-treated alloys such as M-Wire, CM (Control Memory) Wire, Blue Wire, and Gold Wire. Thermal treatments increased the flexibility and durability of the alloy (10). M-Wire is the result of the process of obtaining a superelastic structure containing martensite and R phases by applying various heat treatments before processing the alloy. This technology was used in the Reciproc (VDW, Munich, Germany) and ProTaper Next (Dentsply Maillefer, Ballaigues, Switzerland) systems (11). As a result of a heat treatment applied to the Ni-Ti wire, a 100–140 nm thick titanium oxide layer is formed on the metal surface, which changes the color of the metal. This alloy is called Gold Wire. WaveOne Gold (Dentsply Sirona, Ballaigues, Switzerland) is a file system using this technology (11). In the TruNatomy (Dentsply Sirona, Maillefer, Ballaigues, Switzerland) file system, 0.8 mm wire was used instead of the 1.2 mm wire used in the production of most file systems, and then it was subjected to a special heat treatment. It is stated that these processes increase the resistance and flexibility of the files against cyclic fatigue (12).

The Reciproc and WaveOne Gold file systems are designed to be used in a reciprocating motion. The operating mode of the Reciproc file system is 150 degrees counterclockwise and 30 degrees clockwise rotation, while in the WaveOne Gold file system, the files work 170 degrees counterclockwise and 50 degrees clockwise (13, 14). The ProTaper Next and TruNatomy file systems are designed to be used with rotational movements (12).

The purpose of this study is to compare the cyclic fatigue resistance of the Reciproc and WaveOne file systems used with reciprocal movement and ProTaper Next and TruNatomy file systems used with rotational movement in an artificially created 60-degree inclined canal. The null hypothesis (H0) of this study is that there is no difference between the groups.

Materials and Methods

Sample size calculation

As a result of the power analysis performed with G*Power 3.1 software (version 3.1.9.7) (Heinrich Heine University, Dusseldorf, Germany) to determine the number of samples to be used in the study, f = 0.25, a = 0.05 to evaluate the cyclic fatigue resistance of the files, and ß = 0.80, the number of samples required was determined to be at least 60 samples (15 for each group).

Sample preparation and grouping

A total of 60 files, and four different endodontic systems (n = 15) were evaluated in this study.

- Reciproc system R25 (size 25, .08 taper),
- ProTaper Next system X2 (size 25, .06 taper),
- WaveOne Gold system Primary (size 25, .07 taper),
- TruNatomy system Prime (size 26, .04 taper) files were used.

Cyclic fatigue testing

Cyclic fatigue test was conducted utilizing a unique apparatus that enabled a consistent simulation of an instrument situated within an artificial curved canal created from stainless steel. This canal was prepared to have a curvature angle of 60 degrees, an inner diameter of 1.5 mm, and a radius of curvature of 3 mm. The created canal was mounted on a subplate made of stainless steel. An adjustable apparatus was attached to the ground, which kept the contra-angle handpiece used during the work and the file attached to the end of the handpiece in a fixed position (Fig. 1). The study design is graphically illustrated in Figure 2.

The contra-angle handpiece part of the endomotor (X-Smart Plus; Dentsply Sirona, Maillefer, Ballaigues, Switzerland)) with 1/16 reduction is fixed to the steel table with a special mechanism in order to ensure standardization between groups. Files were passively inserted into the canal at a length of 16 mm. They were operated at the speed and torque settings recommended by the manufacturers. At the same time, a stopwatch capable of measuring with an accuracy of one-hundredth of a second was started. The rotation of the file was observed in a high-illumination environment. At the moment the fracture occurred, the stopwatch was stopped, and the time was recorded in seconds. The determined time was converted to the number of cycles occurring until fracture. The following formula was used for this:

Time to breakage (sec) X rotation speed of the file (rpm) / 60

Statistical analysis

Analyses were performed by using SPSS 23.0 software. (IBM Inc., Armonk, New York, NY, USA).

Data were analyzed with IBM SPSS V23. Compliance with normal distribution was examined with the Shapiro–Wilk test. The number of cycles to fracture, which did not follow a normal distribution for the respective files, were compared using the Kruskal–Wallis test, and multiple comparisons were made with the Dunn Test. Analysis results were presented as mean ± standard deviation and median (minimum-maximum). The significance level was taken as $p<0.050$.

Figure 1. Stainless steel cyclic fatigue testing device.

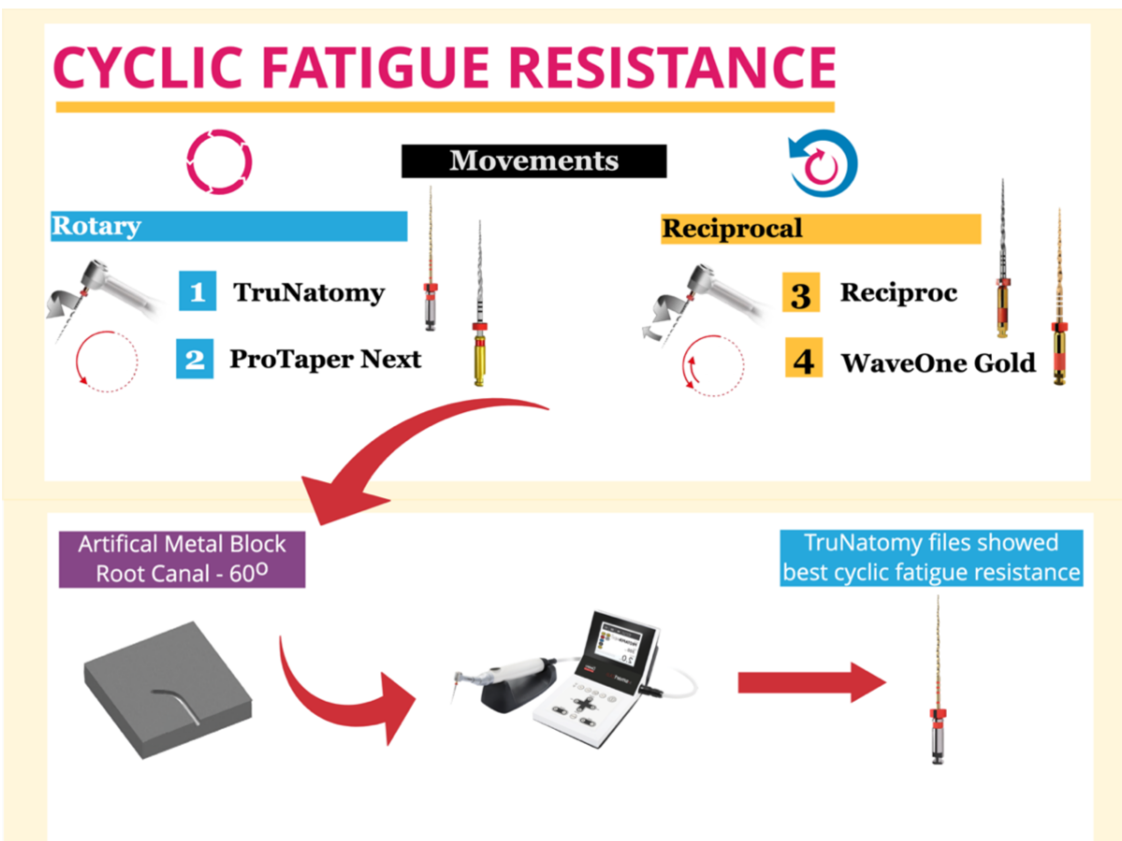

Figure 2. Graphical illustration of the step-by-step procedure.

Results

A statistically significant difference was found between the median values of the number of cycles to fracture for each of the file systems ($p<0.001$). The median value of the number of cycles to fracture in the Reciproc file is 875, the median value in the WaveOne Gold file is 1302, the median value in the ProTaper Next file is 368, and the median value in the TruNatomy file is 2483 (Table 1). The TruNatomy file system exhibited the greatest number of cycles until fracture occurred, although no statistically significant difference was found between the Reciproc and WaveOne Gold file systems.

The lowest number of cycles to fracture was found in the ProTaper Next file system, which differed from all other files. The Reciproc file was similar to the WaveOne Gold file in terms of the number of cycles before breaking.

Table 1. Comparison of the number of cycles to breakage for the respective files

Files	Number of cycles Mean ± SD	Median (min-max)	Test statistics	p*
Reciproc	1054.33 ± 333.19	875 (752 - 1965)[c]	48.875	<0.001
WaveOne Gold	1369 ± 131.87	1302 (1253 - 1560)[ac]		
ProTaper Next	447.67 ± 207.04	368 (244 - 795)[b]		
TruNatomy	2235.2 ± 505.29	2483 (1258 - 2741)[a]		

*Kruskal Wallis Test; a-c: There is no difference between files with the same letter

Discussion

Fracture of the rotary instrument in the canal is one of the serious complications of endodontic treatment. This complication may limit the access of irrigation solutions to the canal system, such that microorganism elimination cannot be achieved (15). Many factors can affect file fractures, such as the number of uses of the file, operator experience, rotation speed, preparation technique, production process, and design. Studies have reported that the majority of fractures occur due to cyclic fatigue (16, 17). For this reason, trying to increase the cyclic fatigue resistance of file systems and comparing the cyclic fatigue resistance of existing files is a subject covered extensively in the literature (12, 18-23).

Many factors, such as the cross-section, design, and kinematics of the endodontic instrument, affect the fracture resistance of the instruments (24). Clinicians' awareness of the features of endodontic instruments and their ability to select files appropriate to the case are among the measures that can reduce the risk of file fracture (25).

There are studies in the literature comparing cyclic fatigue resistance using dynamic and static models (19, 26). Although axial movements can be standardized in studies using the dynamic model, it has been considered doubtful that the variables are constant and repeatable in clinical situations (27). For this reason, the static model was preferred in order not to confuse the effect of the tool properties used in the cyclic fatigue test with the reasons arising from other mechanisms.

Yao et al. (28), in studies comparing cyclic fatigue, stated that extracted teeth cause many difficulties in ensuring canal standardization. For this reason, researchers generally prefer to use artificial canals in cyclic fatigue tests (12). For this reason, we chose to use an artificial canal made of stainless steel in our study.

The aim of this study was to compare the cyclic fatigue resistance of files that have gone through different production processes and have different kinematics. In order to ensure standardization in our study, files of similar sizes from different file systems were selected. The TruNatomy file system showed the highest cyclic fatigue resistance, while the ProTaper Next system showed the lowest cyclic fatigue resistance. According to our findings, no statistically significant difference was found between the Reciproc and WaveOne Gold file systems or between the TruNatomy and WaveOne Gold file systems. The null hypothesis of our study was rejected, considering all groups.

TruNatomy has the highest cyclic fatigue resistance. This may be due to many factors, such as the special heat treatment used during its production, the use of thinner Ni-Ti wire compared to other systems, and its production in a parallelogram design in cross-section (29, 30).

The Protaper Next file system has the lowest cyclic fatigue resistance. This may be due to the fact that it has a rectangular design that is not centrally located in the cross-section, its movement kinematics, the heat treatment applied, and the fact that there are regions with increasing and decreasing tapers in the file design (31).

In studies examining the effects of reciprocal and rotational movements on cyclic fatigue, it has been reported that reciprocal movement creates less compressive and tensile stress on the file and, therefore, causes less file breakage than rotational movement (9, 32, 33). In this study, the rotationally moving ProTaper Next system showed lower cyclic fatigue resistance than the reciprocally moving Reciproc and WaveOne Gold systems, and this is consistent with the results of other studies.

In many studies comparing the cyclic fatigue resistance of the Reciproc and WaveOne Gold file systems, which are used with reciprocal movement but produced with different technologies, the fact that there is no difference between the systems supports the result of our study (34, 35). Al-Obaida et al. (36) compared the cyclic fatigue of different file systems used with reciprocal movement. They stated that there was no significant difference between the WaveOne Gold and Reciproc file systems.

Riyahi et al. (12) compared the cyclic fatigue resistance of the TruNatomy and ProTaper Next file systems and concluded that TruNatomy was much better. Similar results were obtained in our study.

Conclusion

Within the limits of this study, TruNatomy, which makes rotational motion, showed the best cyclic fatigue resistance, while ProTaper Next, which also makes rotational motion, showed the lowest cyclic fatigue resistance. As a result, we believe that, apart from the movement kinematics of the files, their production methods and designs may also have an impact on cyclic fatigue resistance.

Disclosures

Peer-review: Externally peer-reviewed.

Author Contributions: Concept – G.A.T.; Design – G.A.T., S.K.; Supervision – S.K.; Materials – G.A.T.; Data collection &/or processing – G.A.T.; Analysis and/or interpretation – S.K., T.N.A.T.; Literature search – G.A.T., T.N.A.T.; Writing – G.A.T.; Critical review – S.K.

Conflict of Interest: There is no any conflict of interest.

Funding: There is no any funding.

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