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Original Article

The comparison of cyclic fatigue resistance of two different reciprocal files according to different access angles into the root canal

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Abstract

Aim: Root canal preparation is one of the most important steps of root canal treatment. Preparation procedure includes disinfection and shaping protocols. Ni-Ti rotary file systems are usually used for shaping. The biggest disadvantage of the usage of Ni-Ti rotary file systems is that the file gets broken during the treatment. There are many reasons for the breakage of files. One of the reasons may be the increase in the access angle. The purpose of this study is to compare the cyclic fatigue of reciprocating Reciproc and WaveOne Gold rotary systems according to different angles of accessing the root canal of Ni-Ti files.
Methodology: In our study, 90 root canal files were used, 45 of which is Reciproc R25 (VDW GmbH, Munich, Germany) and the other 45 of which is WaveOne Gold Primary 25/07 (Dentsply, Maillefer, Ballaigues, Switzerland). Specially designed and manufactured stainless steel artificial roots whose curvature angle is 60° and curvature radius is 5 mm, which replicates the clinical conditions, were arranged. By enabling the files access the roots at 0°- 15°- 30° degrees, the lap numbers that they do till they break due to cyclic fatigue were examined.
Results: When looking at the lap numbers that the Reciproc and WaveOne Gold root canal files do till they break, at accessing the roots at the same angles WaveOne Gold root canal file makes more lap numbers at all angles when compared with the Reciproc root canal file. Significant results were found when the groups were compared within one another and between groups and among all numeric data in the statistical analysis performed. It was also found that WaveOne Gold root canal file had more cyclic fatigue resistance. When the groups were compared within one another, it was found that the increase in the root access angle decreases the cyclic fatigue resistance of the files ($p<0.05$). No significant difference was found in the statistical analysis for comparison of the length of the broken file pieces ($p=0.01$). It was analyzed that when the broken files were examined via scanning electron microscope, file breakages occurred due to cyclic fatigue.
Conclusion: Not only do the design features and production technology affect the breakage resistance due to cyclic fatigue of the root canal, the access angle to the roots affects the cyclic fatigue of the root canal files, as well.

Keywords: cyclic fatigue, Reciproc, WaveOne Gold, reciprocating motion, access angle, static test model

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Introduction

In root canal treatment, the treatment stages include certain procedures. The main procedures are: Cleaning of pathological and infected residues resulting from irreversible changes in the pulp due to caries or other reasons, instrumentation of the pulp chamber and its walls, irrigation agents and its medication with other agents, filling the canals with biocompatible agents (1).

The most important step affecting the success of treatment in root canal treatment is preparation process (2, 3). In root canal treatment, preparation stage includes both cleaning and shaping (4). In preparation, cleaning processes are done with both chemical agents and mechanical tools (5). Therefore, the preparation stage in root canal treatment is also called chemomechanical preparation (6).

Preparation can be done with manual hand tools or rotary tool systems that can be installed to the endomotor. With the use of Ni-Ti canal instruments, significant changes and developments have been seen in the field of endodontics (7). Ni-Ti instruments have a more flexible structure compared to other canal tools. They are more effective in scraping the pathological dentine in the root canals, and they show more successful results in preserving the anatomical shape of the root canal walls (8).

Although Ni-Ti rotary file systems have numerous advantages, they also have some disadvantages. One of these disadvantages is the breakage of the files due to fatigue (9-10). The fracture of Ni-Ti files in the canal has been generally examined under two headings. These fractures are due to cyclic and torsional fatigue (11). However, in some studies, it was stated that the fracture in the files occured as a combination of cyclic and torsional fatigue (12).

Cyclic fatigue is the condition that causes the breakage of files as a result of bending while working in the canal. In a study, it was determined that 93% of the fracture in the files was due to the cyclic fatigue (13). That's why we decided to work on cyclic fatigue.

Today, single file systems have become the general choice of endodontists in order to minimize the complications that may occur during root canal treatment. Because single file systems allow the treatment to be completed in a shorter time while reducing the possibility of iatrogenic error (14). New generation Ni-Ti single file systems perform rotational and reciprocal movements (15).

In reciprocal movement, the file performs two different movements while making preparation in the canal. The first is movement in the direction of cutting with a large angle; the second is movement at the opposite direction of the normal working direction with a narrower angle. In this way, the stress that may accumulate on the files and the breakage possibility of the files are reduced (16). In new generation Ni-Ti file systems, there are files made reciprocal movements that are produced by different companies. While preparing in the canal, there is a difference between the reciprocation angles of the files produced by the companies. The difference between these angles creates a different screwing effect and different breakage resistance in the files. The degree of curvature of the canal is an important factor in fractures of canal devices due to cyclic fatigue. The degree of curvature has a major role in fractures of root canal files (17). Accessing slopes of the files to the canals also causes fractures (18). The placement of the files into canals is not always at an angle of '0'(zero) degrees due to the anatomical position of the tooth, sometimes existing restorations or opened cavities due to caries. Root canal preparation made with files used at different angles creates different stresses on Ni-Ti files (19).

In this study, a new generation of two files, which were very popular recently and started to be used frequently because they completed the preparation process with a single file and reduced the time and risk of complications, were used. At the same time, it reduces the risk of apical transports as it moves reciprocally, reduces the screwing effect of the file, and therefore reduces the possibility of breakage due to cyclic fatigue of the files.

The aim of this study is to compare the cyclic fatigue resistance of two different reciprocal files at different access angles into the canal.

Materials and Methods

In this mechanism, which aims to keep the file stable by opening artificial root canal on a stainless-steel block, the curvature angle and radius were obtained according to Pruett's method (20). In the model we used in our study, an artificial canal with a curvature angle of 60°, a radius of curvature of 5 mm, and a width of 1.5 mm was created. Our model drawing consisting of these dimensions was obtained using the AutoCAD program (Autodesk, San Rafael, CA, USA) (Fig. 1, 2, 3).

Ethics committee approval was received for this study from Dicle University (Decision no: 2019/9). In this study, two root canal files with different surface properties, which are one of the single-file systems produced with M-Wire technology, whose torque and speed values differ according to the manufacturer's instructions, were used (Table 1). A total of 90 files were used, including 45 Reciproc R25 tapers and 45 WaveOne Gold 25/07 files. Files were divided into six different groups (n = 15). All the files used in the study were examined at x20 magnification under a stereomicroscope before being tested in the experimental setup. Files with manufacturing defects such as surface defects, cracks, or irregularities were not included in the study.

In this study, 90 root canal files, 15 in each group, were used. These 15 files were placed in the assemblies so that three different angles of 0 °- 15 °- 30 ° could enter the canal (Table 2).

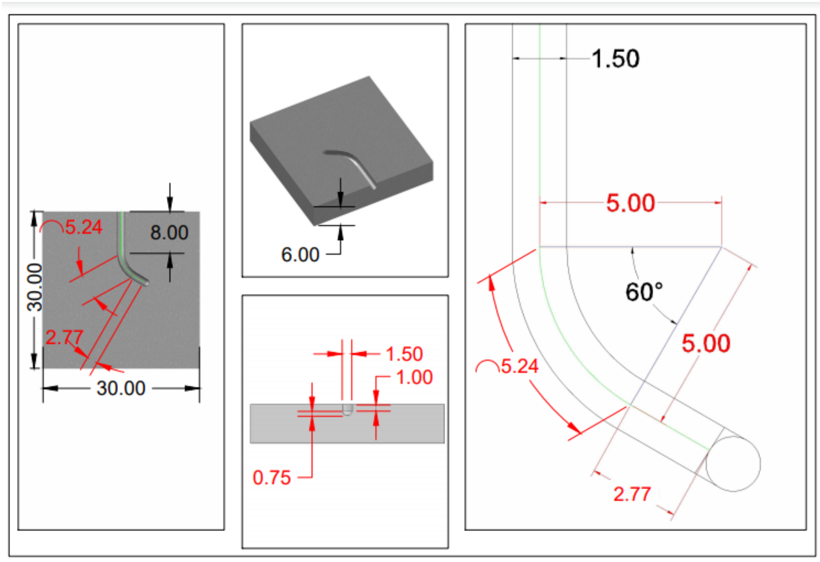

Figure 1. Technical drawing of the artificial root canal using AutoCAD software

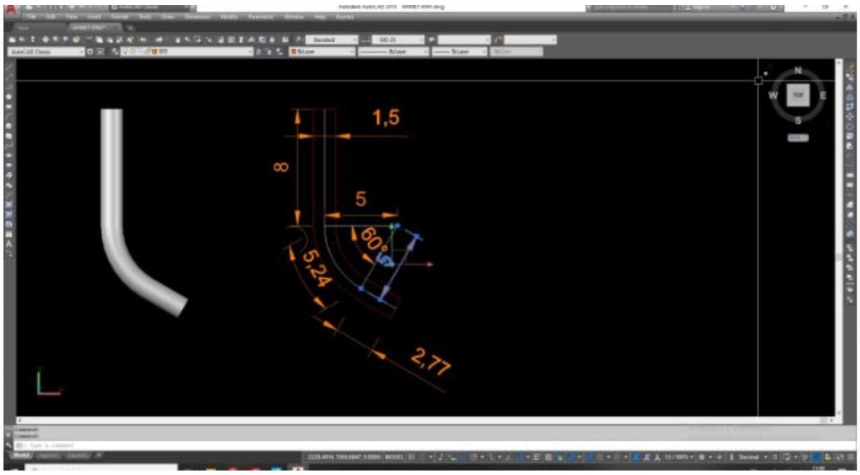

Figure 2. Drawing of the model used in the study using AutoCAD software

Figure 3. Experimental mechanism of the study

Table 1. Files used in the study

Rotary File System	Production Method	Company Name	Size
Reciproc	M-wire	WDV, Munich, Germany	R25, 25/.08
WaveOne Gold	Gold Alloy technology	Dentsply Maillefer, Ballaigues, Switzerland)	25/.07

Table 2. Experimental groups

Groups	Rotary File Systems	Canal Access Opener
Group 1	Reciproc R25	0°
Group 2	Reciproc R25	15°
Group 3	Reciproc R25	30°
Group 4	WaveOne Gold 25/07	0°
Group 5	WaveOne Gold 25/07	15°
Group 6	WaveOne Gold 25/07	30°

Artificial canals used in the study; Curvature angle 60 °, curvature radius 5 mm, curvature inner diameter 1.5 mm were selected according to the criteria that Pruett et al. determined (22). The length of the channels was determined as 16 mm, and the distance from the beginning of the curvature in the canal to the apex was determined as 5 mm. The production of these ducts was carried out on a CNC machine using AutoCAD (Autodesk, San Rafael, USA) program of stainless-steel blocks in computer setting. The upper part of the artificial canals obtained from the stainless steel used in the study was covered with glass prepared in the same size as the block so that the root canal file did not come out of the artificial canal slot. In this way, it was ensured that the canal tool rotates with a reciprocal movement without leaving the canal, and thanks to the glass, it was also possible to detect the moment when the file was broken.

A high fluid value synthetic oil, Akfix A40 Magic (Akkim, Istanbul, Turkey), was used to eliminate the friction that may occur between the file and the canal walls while the file is moving reciprocally in the artificial canals. After each file change, the inside of the canals was cleaned, and the synthetic oil was renewed.

In the study, the contra-angle handpiece part of the X-Smart Plus endomotor with 1/16 reduction is fixed to the steel table with a special mechanism in order to ensure standardization between groups. Artificial channels made of stainless steel are fixed to the lower table with a mechanism through which the angles can be adjusted and changed. In all groups, synthetic oil was used in artificial canals for root canal files to make reciprocal movement in the canals comfortably. Bosch PAM 220 (Bosch, Stuttgart, Germany) protractor with a 0 - 220 degree measuring range and 40 cm arm length was used to determine the angle of entry of the files into the canals. All groups were used in the channel after the angles were determined, and the assembly was fixed until it was broken. The upper part of the stainless-steel block was covered with glass so that the breaking moment of the files was clearly visible. The moment of the breaking of the files was recorded with video recordings and a digital stopwatch. In order to measure the number of turns (KYTS) that the files made until the time they were broken, the formula "KYTS Number of turns per minute (rpm) x time (sec) / 60" was used. The lengths of the broken file pieces were measured by using a digital caliper.

Scanning electron microscopy was used to examine the fracture model, which was created by taking one broken file from each group. Images of the fractured surfaces were taken by photomicrographs. SEM imaging device (Quanta FEG 250, Oregon, USA) was used within the body of Dicle University Science and Technology Application and Research Center to conduct the examinations. Before SEM analysis, the residues on the broken surfaces of the files were cleaned with ultrasonic devices. Observation of fracture origin points and fatigue lines on fracture surfaces examined at different magnification angles confirmed that the fracture occurred due to cyclic fatigue.

Statistical analysis

The data obtained in the study were analyzed with SPSS software version 22 (IBM SPSS Inc., Armonk, NY, USA). statistical program in Dicle University Faculty of Medicine, Department of Biostatistics. In order to compare the groups within themselves, the variance homogeneity test was applied to Levene first. Then, statistics of each file system in itself were made with ANOVA. If the p value was less than 0.05, Tukey HSD post hoc test was applied to determine the source of the difference. Paired-Samples t-test was applied in order to compare the number of turns made by different files with the same entry angle.

Results

In this study, a total of 90 files in six groups, 15 in each, were used. The number of turns made by the files in the canal until they were broken, and the lengths of the broken pieces were measured in mm.

Paired t-test analysis was used to evaluate whether there was any difference between the groups. The margin of error was determined as $p < 0.05$ for all tests applied. Statistically, $p<0.05$ was considered significant.

In the setup with an artificial canal of 16 mm length, made of stainless steel with 60° curvature angle, 5 mm curvature radius, and 1.5 mm inner diameter, all file groups were used until they were broken. The average of the number of rounds the files have performed until the moment they were broken is presented in Table 3.

Table 3. The average number of turns and standard deviation of the files used in the study until they were broken.

Groups	File Used	Canal Entry Angle	Average Number of Laps Until Breaking	Standard Deviation
Group 1	Reciproc R25	0°	1542,67	181,893
Group 2	Reciproc R25	15°	1216,33	135,138
Group 3	Reciproc R25	30°	706,67	102,097
Group 4	WaveOne Gold 25/07	0°	2017,16	170,343
Group 5	WaveOne Gold 25/07	15°	1451,33	157.07
Group 6	WaveOne Gold 25/07	30°	894,44	105,56

Group 1- Group 2, Group 1 - Group 3, Group 2 - Group 3 (The number of turns made by these three groups until their Reciproc root canal files were broken at 0 ° -15 ° -30 ° angles were statistically analyzed among themselves).

Group 4 - Group 5, Group 4 - Group 6, Group 5 - Group 6 (The number of turns of these three groups until their WaveOne Gold root canal files were broken at 0 ° - 15 ° - 30 ° angles were statistically analyzed among themselves.)

For $p<0.05$, normality was found in the distribution of the groups. Since the value distribution of the file groups was normal, it was decided to perform one-way ANOVA test. When the Reciproc and WaveOne Gold file systems were created with different entry angles and the groups were examined with one-way ANOVA, it was observed that there was a significant difference between the groups. Post-hoc Tukey test was applied in order to see from which file groups this difference derived.

Table 4. The average, minimum, maximum number of turns and standard deviation amounts of the files used in the study until they were broken.

		SS	Average	Min	Max
	Grup 1 (0°)	181,893	1542,666	1260,000	1895,000
	Grup 2 (15°)	135,138	1216,333	1005,000	1415,000

KYTS	Grup 3 (30°)	102,097	706,667	530,000	950,000
	Grup 4 0°	170,344	2017,167	1738,333	2286,667
	Grup 5 (15°)	157,070	1451,333	1230,833	1808,333
	Grup 6 (30°)	105,569	894,444	752,500	1108,333

As a result of the post hoc multiple comparisons, it was seen that all groups belonging to the Reciproc file system and all groups belonging to the WaveOne Gold file system showed a significant difference at $p < 0.05$ significance level among themselves. Since Group 1 - Group 4 (0°), Group 2 - Group 5 (15°), Group 3 - Group 6 (30°) Reciproc and WaveOne Gold were bivariate groups in statistical analysis between groups, Paired-T test was used. All groups were found to be significant at the $p < 0.05$ level within themselves.

In a total of 9 statistical analyzes, a significant difference was found between all groups (due to the P value less than $\alpha = 0.05$). The WaveOne Gold root canal file showed a longer lap number than the Reciproc root canal file at an angle of 0 ° - 15 ° - 30 °. As the angle of entry of the files into the canal increased, there was a significant decrease in the number of turns. The decrease in the number of turns of the Reciproc file was greater than that of the WaveOne Gold root canal file.

In the artificial canals obtained from stainless steel blocks, the whole group of files were used until they were broken. The fractured file lengths were analyzed by one-way analysis of variance (ANOVA) test. When the fractured file lengths were compared with one-way analysis of variance (ANOVA), no significant difference was found for $p<0.05$. In the photomicrographs taken by SEM analysis of the broken root canal files, a rough surface structure, micropores, superficial pits, fracture baseline were observed on the files. These findings show that fractures occur due to cyclical fatigue.

Discussion

In our study, artificial canals were created in stainless steel blocks in the mechanism which was generated to test cyclic fatigue. While determining the curvature angle and curve-type radius of the artificial canals, a model was obtained in accordance with the criteria that Pruett et al. emphasized in their studies (17). In the study, the curvature angle of the canals was determined as 60° and the curvature radius was 5 mm in the artificial canals, which were created by using the AutoCAD program on a CNC machine. The upper surface of the stainless-steel model was covered with abrasion-resistant glass, allowing the naked eye to see the moment when the root canal file was broken during the test in a transparent environment. At the same time, with the glass superstructure, the pieces that occurred when the channel tool was broken were prevented from splashing and disappearing.

During the operation of the root canal files, the stress-forming forces on the files increase in the areas where there is curvature in the root canals. These stress and tensile forces on the tool may vary depending on the curvature angle in the curvilinear canals, the radius of the curvature, the arc size, and position of the curvature (21,22). Many studies have shown that the cyclic fatigue resistance of files can vary depending on the canal curvature radius (23) and the curvature angle (24,25). In addition, researchers dwell on some studies which are showing that new pressure and tension points, which may occur in the files depending on the angle of entry of the files into the canal, increase the stress and affect the cyclic fatigue resistance (26).

Canal devices may break due to many factors. Many studies have shown that the main cause of these fractures is due to cyclic fatigue of the files (26). Pruett reported in a study of himself that the length of the curvature was the most common cause of fractures due to cyclical fatigue (17). Sometimes, in clinical conditions, roots with two different curvature structures can be present in the same canal. This "S" shaped canal structure is one of the factors that make the treatment difficult in root canal treatment (28).

In a study conducted by Alovisi et al. they reported that the insertion angle of the canal tools into the mesial canals of the mandibular 1st molar tooth was an average of 20°, but in a traditionally opened cavity, the angle of entry into the canal of the file could be 20° - 30° (29). In our study, the entrance angles of the canal were determined based on the figures in this study, and the entrance of the files into the canal was determined in three separate groups at 0 ° - 15° - 30° angle. In the experimental groups, two files with reciprocal motion were compared with each other and among themselves.

In this study, the first three groups of root canal files, which were separated into six groups, were divided into Reciproc files, and the second three groups (Group 4, 5, 6) were divided to make WaveOne Gold files. When the number of rounds of the files until fracture was evaluated statistically, a significant difference was found between all groups. It was determined that the number of laps which were made until the Reciproc canal file was broken at the entrance angle of 0° to the duct, the number of laps it made until it was broken at 15° and the number of laps it made with the 30° duct entry angle were compared, the highest number of laps was found when it was placed at a 0° angle to the canal. It was observed that the canal file, which made up the third group and entered the canal at an angle of 30°, was broken by the least number of turns. For the Reciproc file, it was determined that the cyclical fatigue decreased significantly as the angle of entry into the canal increased. The WaveOne Gold file, whose cyclic fatigue resistance increased as the angle of entry into the canal increased, and the number of turns made until it was broken; the WaveOne Gold file also showed a significant decrease in resistance and a decrease in the number of turns.

Reciproc and WaveOne Gold files, on the other hand, when compared to each other, where the files enter the canal with the same entry angles, Group 4 against Group 1, Group 5 against Group 2, and Group 6 against Group 3 were broken in a higher number in all groups. Therefore, the WaveOne Gold file was found to be more resistant to cyclic fatigue than the Reciproc file.

Many previous studies have investigated the effect of double curved canals on canal devices (4, 28, 29). However, as in this study, the number of studies investigating the effect of different angles of entry into the canal on cyclic fatigue of files is very few. The situation caused by the double curvature in the canal and the rigging of the angle of access of the file into the canal is different from each other. When the file enters the canal at an angle other than zero degrees, it has an effect on the files in terms of the increase in the curvature length (17).

Conclusions

In this study, the cyclic fatigue resistance of two different reciprocal files were compared at different angles in the artificial root canals made of stainless steel. The findings obtained are as follows:

1- The curvature radius of the artificial canals was created as 5 mm and the curvature angle as 60 °, and two different Ni-Ti files, which made reciprocal movement, were entered into the canal at three different angles, and fracture due to cyclic fatigue was evaluated.

2- When the access angles of both Reciproc and WaveOne Gold files were increased, a significant decrease in resistance was observed in both files due to cyclic fatigue fractures.

3- As opposed to the Reciproc file, the WaveOne Gold file has completed its fracture by making a longer number of turns at all angles when compared with the same entrance angles. Therefore, WaveOne Gold file has been found to be more resistant to cyclic fatigue regardless of different access angles.

4- When the angle of entry of the Reciproc file into the canal increased, the decrease in the resistance to fracture was higher than the WaveOne Gold file.

5- When the findings obtained in the study were evaluated, it was observed that, as a result of SEM analysis, widespread pits and micro-voids were formed on the files in all groups examined. These images showed that the files were broken due to cyclic fatigue in all groups.

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