

Cyclic fatigue life of Tango-Endo, WaveOne GOLD, and Reciproc NiTi instruments

Koray Yılmaz¹, Taha Özyürek^{2*}

¹Samsun Oral and Dental Health Hospital, ²Department of Endodontics, Faculty of Dentistry, Ondokuz Mayıs University, Samsun, Turkey

Objectives: To compare the fatigue life of Tango-Endo, WaveOne GOLD, and Reciproc NiTi instruments under static model via artificial canals with different angles of curvature. **Materials and Methods:** Reciproc R25, WaveOne GOLD Primary, and Tango-Endo instruments were included in this study ($n = 20$). All the instruments were rotated in artificial canals which were made of stainless steel with an inner diameter of 1.5 mm, 45°, 60°, and 90° angles of curvatures and a radius of curvature of 5 mm until fracture occurred, and the time to fracture was recorded in seconds using a digital chronometer. The data were analyzed using Kruskal-Wallis and *post-hoc* Dunn tests were used for the statistical analysis of data in SPSS 21.0 software. **Results:** Tango-Endo files were found to have significantly higher values than WaveOne GOLD and Reciproc files in terms of fatigue life ($p < 0.05$). However, there was no statistically significant difference between fatigue life of Reciproc and WaveOne GOLD files ($p > 0.05$). It was determined that increasing the angle of curvature of the stainless canals caused significant decreases in fatigue life of all of three files ($p < 0.05$). **Conclusions:** Within the limitations of the present study, the cyclic fatigue life of Tango-Endo in canals having different angles of curvature was statistically higher than Reciproc and WaveOne GOLD. (*Restor Dent Endod* 2017;42(2):134-139)

Key words: Cyclic Fatigue; Reciproc; Static Model; Tango-Endo; WaveOne GOLD

Received December 9, 2016;
Accepted February 14, 2017

Yılmaz K, Özyürek T

*Correspondence to

Taha Özyürek, DDS, PhD.
Research Assistant, Department of Endodontics, Faculty of Dentistry, Ondokuz Mayıs University, Samsun, Turkey 55137
TEL, +905052602749; FAX, +903624576032; E-mail, tahaozyurek@hotmail.com

Introduction

Nickel titanium (NiTi) rotary file systems offer easier and faster root canal shaping procedures than manual hand files.¹ NiTi files are designed for shaping the curved canals without damaging the anatomical structure; for this purpose, their elasticity was improved.²⁻⁴ But, even these features cannot prevent the undesired fractures of files.^{5,6} Among many factors playing roles in NiTi files' fracture, two of the most important factors are the cyclic and torsional fatigues.⁷ The fractures originating from cyclic fatigue are observed in files' continuous rotation within the curved root canals; the files are exposed to elastic deformation due to the changing compression and stress forces in these media.⁸ Because the files may fail due to the cyclic fatigue without any prior sign, the cyclic fatigue resistance is measured by the time to failure under a specific load.⁹

The variables such as NiTi files' speed, movement kinematic, metallurgic properties, and finishing procedures play roles in cyclic fatigue resistance.⁷ When compared to the systems performing continuous rotation, the reciprocation systems, which have been

developed by purposefully changing the working principles of traditional NiTi rotary files, have been designed in order to decrease the stress on the file and to prevent the failures originating from the cyclic fatigue.¹⁰ The reciprocation movement is called oscillation movement, and the files performing reciprocation movement decrease the stress on file by rotating in counterclockwise (CCW) direction before completing the cycle in clockwise direction; they have been reported to improve the files' fatigue life.^{7,11,12}

The commercially available Reciproc (RPC, VDW, Munich, Germany) and WaveOne GOLD (WOG, Dentsply Maillefer, Ballaigues, Switzerland) single file systems work based on the reciprocation movement at different speeds and angles. Reciproc works at 300 rpm speed in 150° CCW and 30° CW direction, while WaveOne GOLD operates at 350 rpm speed in 170° CCW and 50° CW direction and completes 360° in 3 cycles.¹³ Moreover, Reciproc file is made of M-Wire alloy and employs S-shaped cross-section having 2 cutting edges, while WaveOne GOLD has parallelogram cross-section with 2 cutting edges at apical end and is made of GOLD alloy.

Newly-introduced Tango-Endo (TE, EDS Dental, S. Hackensack, NJ, USA) rotary file system consisting of 2 files (sizes 30/0.02 and 30/0.04) made of conventional NiTi alloy has its unique reciprocation movement using a handpiece, which is specific to this system. Different from the other file systems employing the reciprocation movement, it does not finalize a complete cycle. The manufacturer claims that the cutting efficiency of this file has been improved under favor of 2-patented vertical blades and it is allowed to move until the apex with minimum resistance. The company also states that the file's cyclic fatigue resistance was also improved in this design.¹⁴

During our comprehensive literature research, no study on the TE files' cyclic fatigue life was found. The aim of this study was to compare the fatigue life of RPC, WOG, and TE files, which are among the file systems working based on the reciprocation movement, under a static model via artificial canals with different angles of curvature (45°, 60°, and 90°). The null hypothesis of this study was that there would be no difference between the fatigue life of RPC, WOG, and TE files.

Materials and Methods

RPC R25 (size 25/0.08), WOG Primary (size 25/0.07), and TE (size 30/0.04) instruments were included in this study ($n = 20$). All the instruments were inspected for any defect or irregularity using stereomicroscope (Olympus BX43, Olympus Co., Tokyo, Japan) under x20 magnification. Since there were no defective instruments, none of the instruments were discarded.

Artificial canals, which were made of stainless steel with an inner diameter of 1.5 mm, 45°, 60°, and 90° angles of

curvature and a radius of curvature of 5 mm, were used for static cyclic fatigue testing. The curvature of the artificial canals was located at the 5 mm coronal of the canal end. To reduce the friction of the files as it contacted the artificial canal walls, synthetic oil (WD-40 Company, Milton Keynes, UK) was used for lubrication.

The files were divided into 3 experimental groups ($n = 20$) and underwent the following procedures:

Group 1: Reciproc R25

The files in this group were used with VDW Silver Reciproc motor (VDW) connected to cyclic fatigue testing device and used with 'RECIPROC ALL' program until they broke.

Group 2: WaveOne GOLD

The files in this group were used with VDW Silver Reciproc motor connected to cyclic fatigue testing device and used with 'WAVEONE ALL' program until they broke.

Group 3: Tango-Endo

The files in this group were used with own handpiece connected to cyclic fatigue testing device and used with its 2,500 rpm until they broke.

All the instruments were rotated until fracture occurred, and the time to fracture was recorded in seconds using a digital chronometer.

A total of 6 fractured files, 2 from each group, were examined with SEM device (JSM-7001F, JEOL, Tokyo, Japan) to determine fracture types of the files and photomicrographs were taken from the fractured surfaces.

Statistical analysis

The normality of data distribution was examined utilizing Shapiro-Wilk test. Then Kruskal-Wallis and *post-hoc* Dunn tests were used for the statistical analysis of data in SPSS 21.0 (IBM SPSS Inc., Chicago, IL, USA) software. The level of statistical significant was set to 5%.

Results

The 'time to failure' values of RPC R25, WOG Primary, and TE files under static model and at 3 different angles of curvature are presented in Table 1. TE files were found to have significantly higher values than WOG and RPC files in terms of fatigue life ($p < 0.05$). However there was no statistically significant difference between fatigue life of RPC and WOG files. It was determined that increasing the angle of curvature of the stainless steel canals caused significant decreases in fatigue life of all of three files ($p < 0.05$).

The scanning electron microscopic images of the fracture surface revealed the feature of the mechanical characteristic of the cyclic fatigue failure in all the groups. The fracture surfaces demonstrated one or more crack initiation area(s), fatigue striation(s), and a fast fracture zone (Figure 1).

Table 1. The mean and standard deviation values of the time (unit: seconds) until tested NiTi files fractured

Group	Angle of curvature	Canal 1 45°	Canal 2 60°	Canal 3 90°
Tango-Endo		2171.36 ± 143.36 ^a	968.16 ± 63.91 ^a	290.44 ± 19.19 ^a
WaveOne GOLD		434.28 ± 128.68 ^b	276.60 ± 18.26 ^b	116.18 ± 7.66 ^b
Reciproc		415.63 ± 34.69 ^b	264.73 ± 22.10 ^b	111.18 ± 9.27 ^b

Different superscripts indicate statistically significant difference in the column ($p < 0.05$).

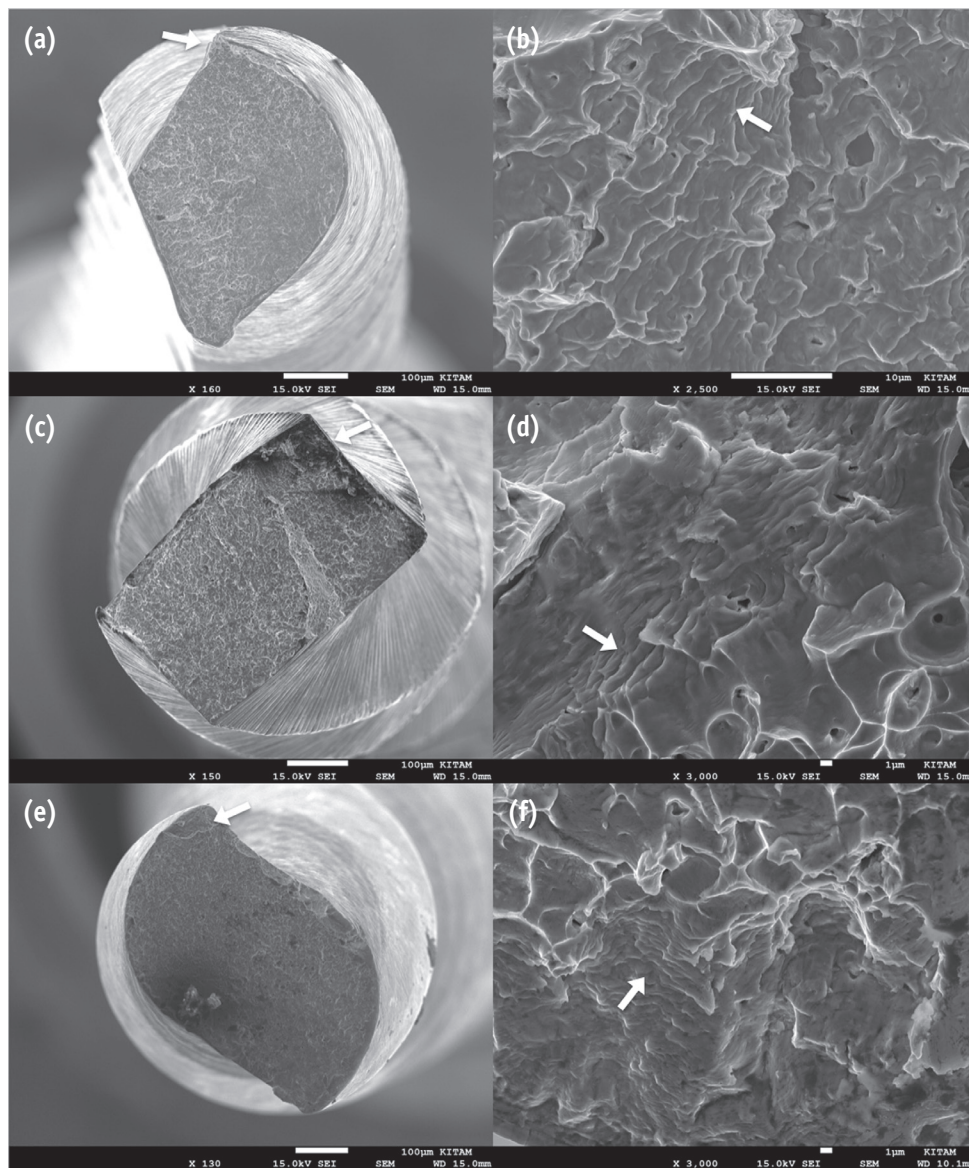


Figure 1. Scanning electron microscopic appearances of the Tango-Endo, WaveOne GOLD, and Reciproc files after cyclic fatigue testing. (a, c, and e) General view of Tango-Endo, WaveOne GOLD, and Reciproc, respectively, (white arrows, showing fracture zone); (b, d, and f) High-magnification view of Tango-Endo, WaveOne GOLD, and Reciproc instruments showing typical fatigue striations of cyclic fatigue (white arrows, showing fatigue striations), respectively.

Discussion

The objective in endodontic treatment is to efficiently shape and clean the root canal system and to obturate it hermetically.³ For this purpose, besides various shaping techniques, numerous files having different designs have been developed.¹⁵ The file systems, which were developed in recent years and operated in reciprocation movement, aim to decrease the number of file to be used in canal preparation.¹⁰ While shaping with single or limited number of files, the files are exposed to high level of stress thus cyclic and torsional fatigues can occur.¹⁶ These cyclic and torsional fatigues are among the most important factors playing roles in file failures. For this reason, in the present study, it was aimed to compare the cyclic fatigue life of three different, commercially available file systems operating in reciprocation movement.

One of the most important disadvantages of laboratory studies on comparing the cyclic/torsional fatigue resistance of files is the use of different factors (material characteristics and designs) that might have effect on the results.¹⁷ In *in vivo* studies on the cyclic fatigue resistance of files, it is difficult to obtain accurate results because the torsional fatigue cannot be eliminated.¹⁸ In their study on cyclic fatigue, Yao *et al.*¹⁹ have reported that the disadvantage of using the extracted teeth for imitating the clinical conditions is the difficulty of ensuring the standardization. Standard artificial canals in cyclic fatigue studies are useful from the aspect of minimizing the other factors that may affect the results.¹³ For this reason, standard artificial canals made of stainless steel were employed in the present study. The SEM images were captured from the fractured surfaces of the tested files to determine fracture types of the files. All the images confirmed that the tested files fractured due to cyclic fatigue. The TE file does not complete a cycle. The file performs an oscillating movement. Thus the number of cycles to failure (NCF) values could not be calculated for TE files and the cyclic fatigue life of the tested files was not compared.

According to the results of the present study, TE file was found to have statistically longer fatigue life in all 3 angles of curvature, when compared to RPC and WOG files. For this reason, the null hypothesis of the present study was rejected. But, on the other hand, no significant difference was found between WOG and RPC files in all of canals having 3 different angles of curvature.

There was no study that compares the cyclic fatigue life of TE in the literature. For this reason, the results of the present study cannot be directly compared to those of other studies. It has been reported that the reciprocation movement performed using Giromatic handpiece (Micro Mega, Besancon, France), which has a movement kinematic that is similar to TE files, in 90° CW and 90° CCW direction

and the reciprocation movement using M4 handpiece (SybronEndo, Glendora, CA, USA) in 30° CW and 30° CCW decreased the stress that the files were exposed to in canals and increased their fatigue life.^{20,21} From this aspect, we believe that the similarity of low-angle reciprocation movement via a specific handpiece might be the reason for longer fatigue life of TE files than those of RCP and WOG files. Furthermore, 0.30 mm apical diameter of TE files utilized in the present study differs from other files. In literature, the files having similar apical diameters have been compared before. But the aim of the present study in comparing the files having different apical diameters was to investigate the contribution of newly introduced file systems to the endodontic practice.

WOG has been introduced by the manufacturer company as an update to WaveOne (WO, Dentsply Maillefer) file. The reciprocation movement of the file was maintained, while the cross section, dimensions, and geometry were modified. The cross section of the file was changed to the parallelogram design containing 2 cutting edges. The files are manufactured with the heat-treatment procedure for gold alloy. On the contrary to M-Wire technology employing pre-production heat treatment, the heat-treatment for gold alloy utilizes the method of heating and then slowly cooling the file following the production phase. The manufacturer company claims that this new heat-treatment method improves the elasticity and cyclic fatigue resistance of this file.²²

There is limited number of studies investigating the cyclic fatigue resistance of WOG files in the literature.^{23,24} According to the results of the present study, the fatigue life of WOG was found to be shorter than TE, but no statistically significant difference was found when compared to RPC files. Similar to present study results, Özyürek²⁴ has reported the cyclic fatigue resistance of WOG files to be higher than RPC files. However, Topcuoglu *et al.*²³ have carried out a study on comparing the number of cycles to the failure of WOG, WO, and RPC files, and reported that the cyclic fatigue resistance of WOG files was higher than other files. We believe that the differences between these studies originate from comparing the NCF of files.

In the literature, there are many studies comparing the cyclic fatigue resistances of WO files, which have been used before WOG files, and RPC files at different angles of curvature.^{13,25-27} In their study, Scelza *et al.*²⁵ have compared the cyclic fatigue resistance of RPC and WO files, and found that of RPC to be higher. Similarly, in their study on canals having 60° angle of curvature, Arias *et al.*²⁸ have compared RPC files to WO files in terms of cyclic fatigue resistance, and found the cyclic fatigue resistance of RPC files to be higher. Kim *et al.*¹³ have repeated the same study at 45°, and obtained the same results. In the literature, there are also studies where the same results have been

obtained.^{13,26,29} On the contrary with these results, Pedullà *et al.*²⁷ have determined no difference between RPC and WO files. In the studies, the reason for higher cyclic fatigue resistance of RPC files than WO has been shown to be the differences between the cross section and core structures of files.^{13,25,28,29} On the contrary with WO, we believe that WOG files had similar fatigue life values with RPC because of the new alloy and production method of WOG.

Conclusions

Within the limitations of the present study, the cyclic fatigue life of TE files in canals having different angles of curvature was determined to be statistically higher than Reciproc and WaveOne GOLD files. No statistical difference was found between RPC and WOG files.

Orcid number

Taha Özyürek, 0000-0003-3299-3361

Conflict of Interest: No potential conflict of interest relevant to this article was reported.

References

1. Walia HM, Brantley WA, Gerstein H. An initial investigation of the bending and torsional properties of Nitinol root canal files. *J Endod* 1988;14:346-351.
2. Ankrum MT, Hartwell GR, Truitt JE. K3 Endo, ProTaper, and ProFile systems: breakage and distortion in severely curved roots of molars. *J Endod* 2004;30:234-237.
3. Peters OA. Current challenges and concepts in the preparation of root canal systems: a review. *J Endod* 2004;30:559-567.
4. Gergi R, Rjeily JA, Sader J, Naaman A. Comparison of canal transportation and centering ability of twisted files, Pathfile-ProTaper system, and stainless steel hand K-files by using computed tomography. *J Endod* 2010;36:904-907.
5. Gambarini G. Cyclic fatigue of nickel-titanium rotary instruments after clinical use with low-and high-torque endodontic motors. *J Endod* 2001;27:772-774.
6. Parashos P, Messer HH. Rotary NiTi instrument fracture and its consequences. *J Endod* 2006;32:1031-1043.
7. Wan J, Rasimic BJ, Musikant BL, Deutsch AS. A comparison of cyclic fatigue resistance in reciprocating and rotary nickel-titanium instruments. *Aust Endod J* 2011;37:122-127.
8. Lopes HP, Elias CN, Vieira VT, Moreira EJ, Marques RV, de Oliveira JC, Debelian G, Siqueria JF Jr. Effects of electropolishing surface treatment on the cyclic fatigue resistance of BioRace nickel-titanium rotary instruments. *J Endod* 2010;36:1653-1657.
9. Sattapan B, Nervo GJ, Palamara JE, Messer HH. Defects in rotary nickel-titanium files after clinical use. *J Endod* 2000;26:161-165.
10. Varela-Patiño P, Ibañez-Párraga A, Rivas-Mundiña B, Cantatore G, Otero XL, Martín-Biedma B. Alternating *versus* continuous rotation: a comparative study of the effect on instrument life. *J Endod* 2010;36:157-159.
11. You SY, Bae KS, Baek SH, Kum KY, Shon WJ, Lee W. Lifespan of one nickel-titanium rotary file with reciprocating motion in curved root canals. *J Endod* 2010;36:1991-1994.
12. De-Deus G, Moreira EJ, Lopes HP, Elias CN. Extended cyclic fatigue life of F2 ProTaper instruments used in reciprocating movement. *Int Endod J* 2010;43:1063-1068.
13. Kim HC, Kwak SW, Cheung GS, Ko DH, Chung SM, Lee W. Cyclic fatigue and torsional resistance of two new nickel-titanium instruments used in reciprocation motion: Reciproc *versus* WaveOne. *J Endod* 2012;38:541-544.
14. Tango-Endo brochure. Available from: <http://www.edsdental.com/productpdfs/TangoProfile.pdf> (updated 2017 Mar 3).
15. Arens FC, Hoen MM, Steiman HR, Dietz GC Jr. Evaluation of single-use rotary nickel-titanium instruments. *J Endod* 2003;29:664-666.
16. Yared G. Canal preparation using only one Ni-Ti rotary instrument: preliminary observations. *Int Endod J* 2008;41:339-344.
17. Cheung GS, Zhang EW, Zheng YF. A numerical method for predicting the bending fatigue life of NiTi and stainless steel root canal instruments. *Int Endod J* 2011;44:357-361.
18. Plotino G, Grande NM, Cordaro M, Testarelli L, Gambarini G. A review of cyclic fatigue testing of nickel-titanium rotary instruments. *J Endod* 2009;35:1469-1476.
19. Yao JH, Schwartz SA, Beeson TJ. Cyclic fatigue of three types of rotary nickel-titanium files in a dynamic model. *J Endod* 2006;32:55-57.
20. Hülsmann M, Stryga F. Comparison of root canal preparation using different automated devices and hand instrumentation. *J Endod* 1993;19:141-145.
21. Weine FS, Kelly RF, Bray KE. Effect of preparation with endodontic handpieces on original canal shape. *J Endod* 1976;2:298-303.
22. WaveOne GOLD brochure. Available from: https://www.dentsply.com/content/dam/dentsply/pim/manufacture/Endodontics/Obturation/Gutta_Percha_Points/WaveOne_Gold_Gutta_Percha_Points/W1G_Brochure_EN.pdf (updated 2017 Mar 3).
23. Topçuoğlu HS, Düzgün S, Aktı A, Topçuoğlu G. Laboratory comparison of cyclic fatigue resistance of WaveOne Gold, Reciproc and WaveOne files in canals with a double curvature. *Int Endod J* 2016 Jun 25. doi: 10.1111/iej.12674. [Epub ahead of print]

24. Özyürek T. Cyclic fatigue resistance of Reciproc, WaveOne, and WaveOne Gold Nickel-Titanium instruments. *J Endod* 2016;42:1536-1539.
25. Scelza P, Harry D, Silva LE, Barbosa IB, Scelza MZ. A comparison of two reciprocating instruments using bending stress and cyclic fatigue tests. *Braz Oral Res* 2015;29:1-7.
26. De-Deus G, Vieira VT, Nogueira da Silva EJ, Lopes H, Elias CN, Moreira EJ. Bending resistance and dynamic and static cyclic fatigue life of Reciproc and WaveOne large instruments. *J Endod* 2014;40:575-579.
27. Pedullà E, Grande NM, Plotino G, Gambarini G, Rapisarda E. Influence of continuous or reciprocating motion on cyclic fatigue resistance of 4 different nickel-titanium rotary instruments. *J Endod* 2013;39:258-261.
28. Arias A, Perez-Higueras JJ, de la Macorra JC. Differences in cyclic fatigue resistance at apical and coronal levels of Reciproc and WaveOne new files. *J Endod* 2012;38:1244-1248.
29. Plotino G, Grande NM, Testarelli L, Gambarini G. Cyclic fatigue of Reciproc and WaveOne reciprocating instruments. *Int Endod J* 2012;45:614-618.