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Comparison of the cyclic fatigue resistance of nickel-titanium rotary instruments manufactured using controlled memory wire

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Objective: To compare the cyclic fatigue resistance of HyFlex CM, Typhoon CM, and EdgeFile X3 NiTi files with a Controlled Memory alloy under a static model.

Methods: Twenty HyFlex CM 25.06, 20 Typhoon CM 25.06, and 20 EdgeFile X3 (25.06) instruments were included in this study. The cyclic fatigue tests were performed using a static cyclic fatigue testing device, which have an artificial stainless steel canal with 60° angle of curvature and a 5 mm radius of curvature. The files were randomly divided into three groups (Group 1: HyFlex; Group 2: Typhoon; Group 3: EdgeFile X3). All the instruments were rotated until fracture occurred, and the time to fracture was recorded in seconds using a digital chronometer. The number of cycles to failure (NCF) was calculated. The data were analyzed statistically using Kruskal–Wallis test ($p<.05$).

Results: The EFX3 C2 (4523.15±582.70) file system had the highest NCF, followed by the HF CM (4439.15±517.27) and TYP CM (4395.15±387.36) files. However, there was no statistically significant between-group difference in the NCF ($p>.05$).

Conclusion: Within the limitations of the present study, there was no statistically significant difference between the cyclic fatigue resistance of the HF CM, TYP CM, and EFX3 NiTi files.

Keywords: Cyclic fatigue resistance; EdgeFile X3; endodontics; HyFlex CM; typhoon CM.

Rotary files made of nickel titanium (NiTi) alloy are widely used in endodontics to prepare root canals.[1] Although NiTi alloys have many advantages, failures occur in files during endodontic treatments because of metal fatigue of the alloy.[2] It is difficult to prevent this undesirable situation, with breakage occurring due to torsional or cyclic fatigue. Torsional fatigue occurs when the tip or part of the instrument becomes stuck inside the canal and the shaft of the file continues to rotate.[3] When the torque exceeds the elastic limit of the metal, the tip of the instrument fractures.[4] When the instrument is used in curved canals, tensile or compressive stress occurs along the shaft of the instrument.[5] In cyclic fatigue, the continuous repetition of these forces leads the instrument to break unexpectedly.[6]

In response to the failures seen in NiTi files, the manufacturers of these files altered the structure or manufacturing methods of the alloys. Subsequently, NiTi rotary files made of NiTi controlled memory (CM) wire was introduced to the market.[7,8] According to the manufacturers, the cyclic fatigue resistance of this CM alloy, which is produced by heat-treating conventional NiTi alloy-based files using thermomechanical processes, is much higher than that of conventional NiTi files.[9] Examples of these new CM-based files are HyFlex CM (HF CM; Coltene/Whale-

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dent, Inc., Cuyoboga Falls, OH, USA) and Typhoon CM (TYP CM; Clinician's Choice Dental Products, New Milford, CT, USA). Another file system released very recently and made of a CM alloy, the EdgeFile X3 (EFX3; EdgeEndo, New Mexico, USA), has a modified convex triangular cross-section. This file system consists of seven files, with a fixed taper: one orifice opener, NX (25.12); two coronal enlarging files, N1 (17.04) and N2 (17.06); and four apical finishing files, C1 (20.06), C2 (25.06), C3 (30.06), and C4 (40.06).

In a comprehensive literature review, there were no studies that compare the cyclic fatigue resistance of EFX3 NiTi files. The aim of this study was to compare the cyclic fatigue resistance of HF CM, TYP CM, and EFX3 C2 NiTi files with a CM alloy under a static model. The null hypothesis of the present study was that there would be no difference between the cyclic fatigue resistances of the tested NiTi files.

Materials and methods

Twenty HF CM (25.06) files, 20 TYP CM (25.06) files, and 20 EFX3 C2 (25.06) NiTi files were used in the present study. All the files were examined under a stereomicroscope (Olympus BX43, Olympus Co., Tokyo, Japan) at 20x magnification to detect deformation and manufacturing defects.

For the cyclic fatigue test, stainless steel artificial canal having a 5 mm radius of curvature, 60° curvature of angle, and 1.5 mm internal diameter were used. The center of canal's curvature was located at 5 mm coronal to the apical ending of the artificial canal. According to the manufacturer's instructions, the files were used with a VDW Silver Reciproc (VDW, Munich, Germany) endodontic motor at 500 rpm 300 g cm^{-1} for HF CM files, 400 rpm 300 g cm^{-1} for TYP files, and 300 rpm 300 g cm^{-1} for EFX3 C2 files.

In all the groups, to minimize the friction between the files and the walls of the artificial canal and to allow free rotation of the files within the canal, synthetic lubricant (WD-40 Company, Milton Keynes, U.K.) was used. All the files were operated within the artificial canal until failure occurred, and the duration to failure was recorded using a digital chronometer. The duration to failure was then calculated for each file using the formula: NCF = revolution per minute (rpm) x duration (sec)/60.

Six files, two files from each group, were examined under a scanning electron microscope (JEOL, JSM-7001F, Tokyo, Japan) to detect fracture type of the files.

Statistical analysis

Based on a Shapiro–Wilk test, the obtained data were not distributed normally. Then a Kruskal–Wallis test was performed for statistical analysis using SPSS 21.0 (IBM SPSS Inc., Chicago, IL, USA) software. Statistical significance was set at 5%.

Table 1. Mean and standard deviations of NCF of tested NiTi files

Group	NCF (mean±standard deviation)	p
EdgeFile X3	4523.15±582.70	> .05
Typhoon CM	4395.15±387.36	
HyFlex CM	4439.15±517.27	

NCF: Number of cycles to failure; NiTi: Nickel titanium; CM: Controlled memory.

Results

The mean and standard deviations of NCF of the HF CM, TYP CM, and EFX3 C2 NiTi files under a static model are presented in Table 1. The EFX3 C2 (4523.15±582.70) file system had the highest NCF, followed by the HF CM (4439.15±517.27) and TYP CM (4395.15±387.36) files. However, there was no statistically significant between-group difference in the NCF ($p>.05$).

The scanning electron microscopy images of the fracture surface revealed the nature of the mechanical characteristic of the cyclic fatigue failure in all the groups (Fig. 1).

Discussion

For successful root canal treatment, the removal of pulpal tissue, microorganisms, and their products is critical important.[10,11] One of the most important problems that clinicians encounter in clinical practice is factures of the files during root canal preparation because such fractures hinder complete cleaning of the root canal system.

In studies examining the cyclic fatigue resistance of NiTi files, it is difficult to eliminate all potential factors (e.g., metal alloy, file design, and diameter) that can affect the study results.[12] Although using extracted human teeth in cyclic fatigue studies represents clinical conditions well, it is not possible to standardize the anatomical variations of teeth.[13] Thus, the use of extracted teeth in cyclic fatigue studies is not ideal.

The use of artificially designed standard canals in cyclic fatigue studies can minimize various factors that can influence the study results. Therefore, in the present study, standard stainless steel artificial canals were employed. According to the results of the present study; there was no statistically significant difference in the cyclic fatigue resistance of the HF CM, TYP CM, and EFX3 files ($p>.05$). Thus, the null hypothesis of the present study was accepted.

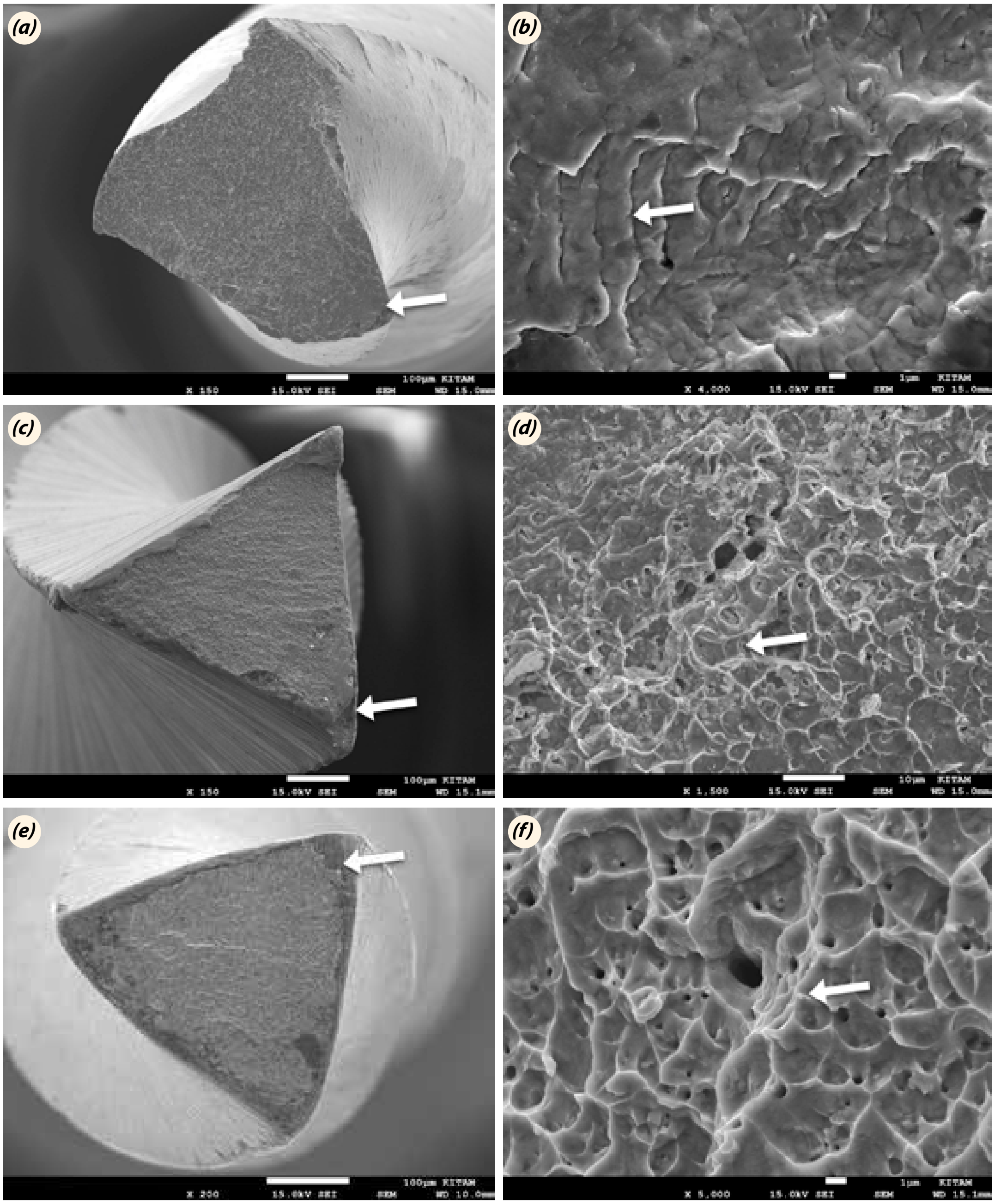

Fig. 1. SEM appearances of the HyFlex CM, Typhoon Cm and EdgeFile X3 files after cyclic fatigue testing. A-C-E: General view of EdgeFile X3 **(a)**, HyFlex CM **(c)** and Typhoon CM **(e)** instrument B-D-F: High-magnification view EdgeFile X3 **(b)**, HyFlex CM **(d)** and Typhoon CM **(f)** instrument showing fatigue striations typical of cyclic fatigue.

Capar et al.[14] compared the cyclic fatigue resistance of ProTaper Next (PTN, Dentsply Maillefer, Ballaigues, Switzerland), Revo-S (Micro Mega, Besancon, France), OneShape (Micro Mega, Besancon, France), and HF CM files and reported that the HF CM file had the highest resistance to cyclic fatigue. Authors attributed the high cyclic fatigue resistance of the HF CM file to the thermomechanical processes applied during its production and emphasized that other CM files could also show high resistance to cyclic fatigue. Another study compared the cyclic fatigue resistance of EndoWave (J Morita Corporation, Osaka, Japan), ProTaper Universal (PTU; Dentsply Maillefer, Ballaigues, Switzerland), ProFile Vortex (Dentsply Tulsa Dental Specialties, Tulsa, OK, USA), TYP CM, and HF CM files.[15] The HF CM file showed the highest cyclic fatigue resistance, followed by the TYP CM file. In contrast to the present study, the authors reported that the differences between HF CM and TYP

CM were statistically significant. The different results in the present study might be due to the use of different radii of curvature in the artificial canals. In the same study, the researchers reported that the files with CM technology had 150–390% higher cyclic fatigue resistance than other M-Wire or conventional NiTi files. This result supports our finding because in the present study tested NiTi files showed extremely high NCF values. Authors attributed this finding to the austenite phase of conventional NiTi alloys at mouth and room temperatures. At room temperature, CM alloys exist in both austenite and martensite phases[16] because martensite is softer than austenite, and the higher martensite content of files made of CM alloy has a positive effect on their cyclic fatigue resistance. Elnaghy[17] compared PTN, Twisted Files (TF; SybronEndo, Orange, CA, USA), HF CM, and PTU and reported that the TF group had the highest cyclic resistance and that there was no statistically significant difference in the cyclic fatigue resistance of the HF CM group versus the PTN group. Pereira et al.[18] compared the cyclic fatigue resistance of PTU, ProFile Vortex, Vortex BLUE (Dentsply Tulsa Dental Specialties), and TYP files and found that the TYP group had the highest cyclic fatigue resistance.

Pedulla et al.[19] compared the cyclic fatigue resistance of PTU, ProTaper Gold (Dentsply Maillefer), HyFlex EDM (Coltene/Whaledent) and HyFlex EDM showed statistically high cyclic fatigue resistance than the other files. Similar to Pedulla et al.[19] study, Kaval et al.[20] compared the cyclic fatigue resistance of PTU, ProTaper Gold (Dentsply Maillefer), HyFlex EDM (Coltene/Whaledent) and HyFlex EDM showed statistically high cyclic fatigue resistance than the other files.

According to the results of the present study, there was no statistically significant difference in the cyclic fatigue resistance of the EFX3 NiTi file and that of the HF CM and TYP CM files ($p>.05$). As there are no previous studies of the cyclic fatigue of the EFX3 file in the literature, the results of the present study cannot be directly compared with those of other studies. Due to different design's of the tested NiTi files, the similar cyclic fatigue resistance of all the files in the different groups in the present study might be due to file's same CM technology.

Conclusion

Within the limitations of the present study, there was no statistically significant difference between the cyclic fatigue resistance of the HF CM, TYP CM, and EFX3 NiTi files.

Conflict of interest: None declared.

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