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THE EFFECT OF SODIUM HYPOCHLORITE ON CYCLIC FATIGUE RESISTANCE OF TWO DIFFERENT ROTARY NI-TI INSTRUMENTS IN CURVED ROOT CANALS

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ABSTRACT

Aim: The objective of this research is to assess the impact of utilising sodium hypochlorite irrigant on the cyclic fatigue resistance of two distinct rotary files maintaining a constant radius while subjected to two canal curvatures of 60 and 45 degrees. **Material and methods:** total of 64 files with #25 with 6% aper were selected and divided into two groups (n=32) according to file type: Group I (W3-pro) (F1), Group II (Revo-s) (F2), Each group was further divided into 2 subgroups according to irrigation (n=16); Subgroup A (saline irrigation) and Subgroup B (sodium hypochlorite). Each file was immersed in the selected irrigant for 5 minutes. A specific stainless-steel block with an artificial canal of 45° curvature and 5 mm concave-tempered steel radius. All instruments of the groups were rotated until fracture occurred. Each file was tested for cyclic fatigue till fracture and the sample was prepared for SEM examination to detect mode of fracture. **Results:** At both curvatures 60 degrees and 45 degrees, group I was significantly higher than group II. While in 45 degrees, group I (no fracture) was significantly higher than group II. In B 60 degrees, group I was significantly higher than group II. While B 45 degrees, group I (no fracture) was significantly higher than group I. Group IA 60 degrees of curvature and Group IB 60 degrees of curvature were significantly the highest, while Group IA and IB 45 degrees of curvature revealed no fracture up to 10 minutes of rotation. Group IA 45 degrees of curvature was significantly the highest, while Group IB 60 degrees of curvature was significantly the lowest. **Conclusion:** The cyclic fatigue resistance of CM wire is greater than that of conventional wire. Fatigue resistance is inversely proportional to curvature severity. Irrigation in NaOCl does not affect cyclic fatigue resistance.

KEYWORDS: CM wire, cyclic fatigue resistance, NiTi files, static model and NaOCl irrigation.

INTRODUCTION

The shaping and cleaning of root canals are critical phases of endodontic treatment. Instrumentation serves to debride the root canal system, maintain the original shape and position of the apical foramen, and continuously taper the canal in a conical form. Ledge formation, transportation of the apical foramen, and non-tapered hourglass-shaped preparation are issues that are frequently encountered subsequent to instrumentation in curved root canals. As a result of their shape memory property and super-elastic behaviour, nickel-titanium (NiTi) rotary shaping systems were devised to avoid these negatives.

The continuous cycle of compressive and tensile stresses, or cyclic fatigue, is an additional serious challenge because it fractures the metal matrix of the file into microscopic fragments. As a result, these microfractures undergo propagation, coalescence, and potentially culminate in file fracture.

There is no forewarning of impending fracture due to the fact that these microfractures are unnoticeable even under a surgical operating microscope. Consequently, rotary Ni-Ti files ought to be discarded by clinicians following a specified number of uses. Assessing the cyclic fatigue of the file system is the primary determinant of when to delete a file. Considerable progress has been achieved in endodontic rotary instruments constructed from Ni-Ti alloys with regard to manufacturing processes, preparation methodologies, and file design. Nevertheless, these challenges continue to persist.

Microstructures and the thermomechanical treatment history of Ni-Ti alloys are factors that significantly influence their mechanical performance. Given the persistent issue of cyclic fatigue-induced separation of rotary instruments within the canal, particularly in root canals marked by severe curvatures, optimising the microstructure of Ni-Ti alloys via innovative thermomechanical processes or growing manufacturing technologies stands as one of several potentially effective strategies to enhance the fatigue resistance of rotary instruments. The manufacturers of CM-Wire and conventional Ni-Ti assert that their cyclic fatigue resistance is superior to that of conventional superelastic Ni-Ti alloys due to the development of them via a proprietary thermomechanical processing method.

NaOCl is regarded as the optimal irrigating solution because it suits the majority of the disinfection requirements. Since NaOCl has a significant impact on the majority of files, cyclic fatigue evaluation of files exposed to the solvent is critical.

We aimed to assess the impact of Sodium Hypochlorite irrigant on the cyclic fatigue resistance of two distinct rotary files with constant radius and 45- and 60-degree canal curvature, respectively. The null hypothesis states that the cyclic fatigue resistance of CM wire is greater than that of conventional wire.

MATERIALS AND METHODS

Sixty-four Ni-Ti rotary files were utilised, representing both brands.; W3-pro (………), & Revo-s (……….) (Thirty-two file of each brand). Only file with ISO tip size #25 (0.25mm) and constant taper 6% were used in this study.

Every instrument was examined for visible signs of deformation using a digital microscope[1] equipped with an 8X magnification. Instruments that were found to be defective were subsequently discarded.

Sample size was chosen to be 16 for each subgroup. This was in accordance with the recommendations of ASTM International which recommends number of samples for statistical analysis of fatigue data to be from 6 to 12.[2]

Files used in this study were classified into two main groups (each n=32) according to the file's system:

- **Group I (W3-pro group):** this group was composed of 32 W3-pro files size #25 (0.25mm) and 6% constant taper.
- **Group II (Revo-s group):** this group was composed of 32 Revo-s files size #25 (0.25mm) and 6% constant taper.

There were two subgroups within each group according to the type of irrigating solution to be immersed in: Subgroup A where samples were immersed in 5.25% NaOCl for 5 mins and Subgroup B where samples were immersed in saline for 5 mins.

Based on the radius and curvature, each subgroup was subsequently divided into two additional subdivisions (n = 8): Subdivision 1 where root canal curvature was 60°and radius was 3mm and Subdivision 2 where root canal curvature was 45° and radius was 5mm.

The artificial canals were designed using 3D Max software.[1] An equivalent size and taper (25/0.06) were employed, along with a 0.1 mm circumferential relief applied to the entire file. The length of every canal is 14 mm.[3] It was determined the canal curvature due to the 1st canal's 60° curve and 3 mm radius of curvature. The canal's maximum convexity occurs 5 mm from its apex. The radius of the second canal is 5 mm, whereas it curve 45°. Two mm from the canal's apex is the maximum convexity.[4]

A water bath glass container was utilised to simulate body temperature which is 37 ± 0.5 C for cyclic fatigue testing. The water temperature was regulated using an aquastic thermostat that was linked to a heat control system and assessed using a digital thermometer.[5] Files were mounted in an E-cube Endodontic motor with 16: 1 reduction hand piece (For each file, the motor settings were modified in accordance with the manufacturers' guidelines.): for W3-pro and Revo-s 350 rpm and 2 and 1.5 N cm torque were used respectively. The duration until fracture was monitored using a digital stopwatch.

A random selection of the fractured fragments (Fig. 1) was made for examination using a scanning electron microscope. The shattered fragments underwent an ultrasonic cleaning process using absolute ethyl alcohol for an estimated duration of ten minutes prior to scanning electron microscopy analysis. They were examined under a variety of magnifications in top view.

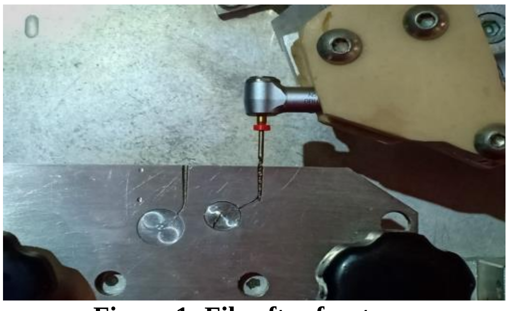

Figure 1: File after fracture.

Statistical analysis

After obtaining NCF for each file, SPSS software was utilised to conduct a statistical analysis of the data. An examination was conducted using one-way analysis of variance (1-way ANOVA) to determine the impact of each of the three independent variables on cyclic fatigue resistance, The effect of the interaction between the three variables and cyclic fatigue resistance was assessed using a three-way ANOVA. In the case of pairwise comparisons, a post hoc test was conducted when the P value was ≤ o 0.05. Significant statistical values were defined as P values below 5% (α=0.05) and were conducted with confidence intervals of 95% for all tests. The Shapiro Wilk and Kolmogorov Normality tests were performed to analyze the normality of all the data. The results were presented in the form of means, standard deviations (SD), minimum, maximum, and median values.

RESULTS

In Group I, group IA 60 degrees of curvature (41808.38 ± 7157.994) and Group IB 60 degrees of curvature (43883.00 ± 3182.25) were significantly the highest, while Group IA and IB 45 degrees of curvature revealed no fracture up to 10 minutes of rotation as shown in Table (1).

In Group II, group IIA 45 degrees of curvature (28961.19 ± 2597.912) was significantly the highest, then Group IIB 45 degrees of curvature (23101.31 ± 606.84), then Group IIA 60 degrees of curvature (11591.56 ± 2230.164), while Group IIB 60 degrees of curvature (7228.81 ± 885.21) was significantly the lowest as shown in Table (1).

For A 60 degrees curvature: group I (41808.38 ± 7157.99) was significantly higher than group II (11591.56 ± 2230.16). While A 45 degrees curvature, group I (no fracture) was significantly higher than group II (28961.19 ± 2597.912). In B 60 degrees curvature, group I (43883.00 ± 3182.25) was significantly higher than group II (7228.81 ± 885.21). While B 45 degrees curvature, group I (no fracture) was significantly higher than group II (23101.31 ± 606.84) as shown in Table (1).

Table 1: Mean and Standard Deviation of All Subgroups In Both Groups In Curvature 60 And 45 Degrees And Comparison Between Them Using Independent T Test.

		G I		G II		P value
		M	**SD**	**M**	**SD**	
Sub-group A	**Curvature 60**	41808.38	7157.994	11591.56	2230.164	<0.0001*
	Curvature 45	No file fracture up to 10 mis of rotation	No file fracture up to 10 mis of rotation	28961.19	2597.912	<0.0001*
Sub-group B	**Curvature 60**	43883.00	3182.25	7228.81	885.21	<0.0001*
	Curvature 45	No file fracture up to 10 mis of rotation	No file fracture up to 10 mis of rotation	23101.31	606.84	<0.0001*

M: mean SD: standard deviation, P: probability level which is significant at P ≤ 0.05, *Significant difference as p<0.05

The SEM revealed elevated regions at the peripheries and fibrous regions in the centres of the fractured planes. The presence of black dimplings and crack propagation zones provided further evidence for a ductile mode of fracture (Fig. 2-5)

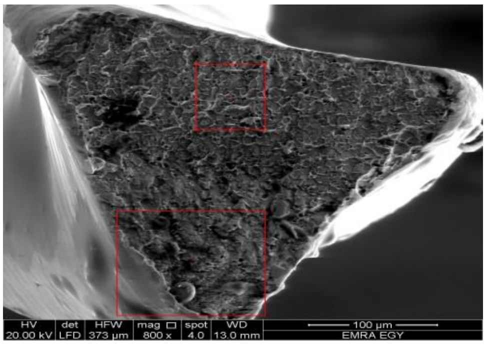

Figure 2: SEM photomicrograph of a fractured surface of Revo-s file in top view (x 800) showing central fibrous appearance, areas of elevations at the periphery and dimples.

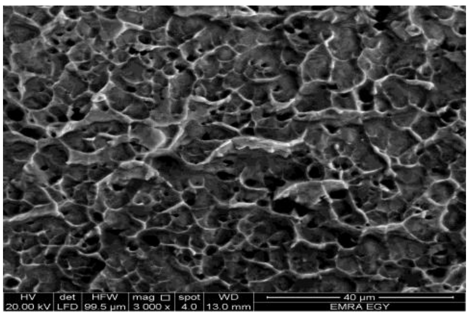

Figure 3: Higher magnification of the same sample (x 3000), showing dimples, and centrals fibrous area.

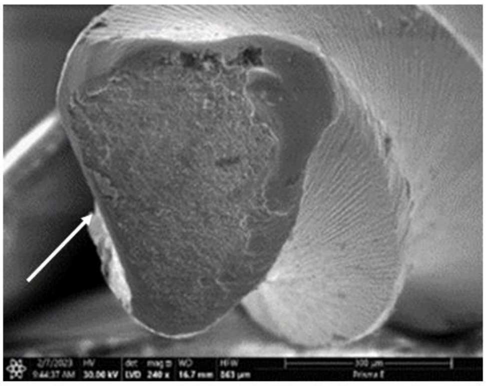

Figure 4: SEM photomicrograph of a fractured surface of W3-pro file (x 800) showing cracks and microstructure voids (white arrow).

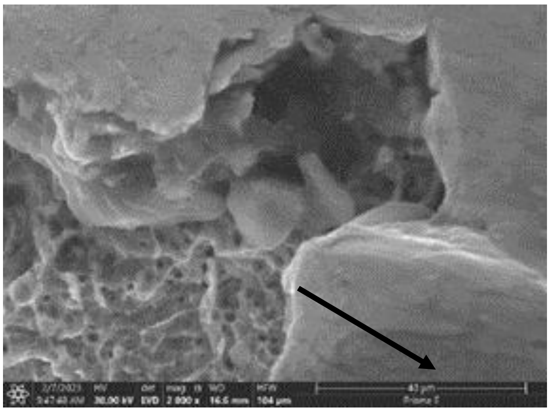

Figure 5: SEM photomicrograph of a fractured surface of another W3-pro file in top view (x 3000) showing areas of elevations at the peripheries (black arrow).

Table 1: Mean and Standard Deviation of all Subgroups In Both Groups In Curvature 60 And 45 Degrees And Comparison Between Them Using Independent T Test.

		G I		G II		P value
		M	SD	M	SD	
Sub-group A	Curvature 60	41808.38	7157.994	11591.56	2230.164	<0.0001*
	Curvature 45	No file fracture up to 10 mis of rotation	No file fracture up to 10 mis of rotation	28961.19	2597.912	<0.0001*
Sub-group B	Curvature 60	43883.00	3182.25	7228.81	885.21	<0.0001*
	Curvature 45	No file fracture up to 10 mis of rotation	No file fracture up to 10 mis of rotation	23101.31	606.84	<0.0001*

M: mean SD: standard deviation, P: probability level which is significant at $P \leq 0.05$, *Significant difference as $p<0.05$

DISCUSSION

Separation of files during endodontic treatment is a critical issue that may compromise the viability of the tooth. According to numerous studies, cyclic fatigue is the primary cause of file fractures.[6]] As a consequence, researchers and file manufacturers investigated cyclic fatigue in an effort to develop files with improved resistance to fatigue.

The great majority of studies about cyclic fatigue reports average NCF. These results were used by clinician only as guidelines to limit files use to certain number of uses. No method is well developed to predict with certainty the limit after which files would fail due to fatigue. This is an important point which was one major precursor for the concept of single file use.

Multiple studies[7,8]], have tried to predict file failure due to fatigue before actual file separation. The results are promising. However, no method is mature enough to be implemented clinically. With enough research and development, new practical and accurate technology could be utilized clinically to predict reliably file separation due to fatigue.

Heat treatment of Ni-Ti files has been demonstrated to be an effective method for enhancing the files' fatigue resistance. There have been various files marketed under the name "heat treated Ni-Ti files," including CM-wire and, more recently, conventional wire. Manufacturers do not disclose the proprietary technology used to produce heat-treated files.

In present study we used two file systems: w3 pro (CM wire) because of its availability, simple use, flexibility, durability and cheap price, and Revo-s (conventional wire) that the manufacturer asserts has increased flexibility and resistance to cyclic fatigue. The fatigue resistance of heat-treated files is purportedly enhanced by their manufacturers due to distinctive attributes resulting from treatments manufacturing processes and.proprietary thermomechanical alloy.

Cyclic fatigue resistance of a material is influenced by the diameter of the material at its maximum curvature point within an artificial canal.[3] The files for the current investigation were chosen to have identical apical diameters and tapers (25/.06). In order to verify that the diameters of the files were similar at the point of maximum curvature of the artificial canals.

The testing of Ni-Ti rotary instruments has conventionally occurred at room temperature. To obtain reliable data, the instruments must be tested at body temperature in order to model the clinical environment[9], it appears that the transformation temperatures of heat-treated alloys are considerably higher in comparison to conventional austenitic materials. Recent research has therefore demonstrated that the fatigue behaviour of rotary instruments differs when subjected to testing at room temperature Vs body or intracanal temperatures.[10] **Amandeep Dosanjh et al.**[11] suggested in a 2017 study that future research on cyclic fatigue be carried out at body temperature. In 2018, cyclic fatigue of various files was investigated exclusively at body temperature by Keskin **C. et al.**[12], also **Elnaghy AM.**[9]

Body temperature can be measured in two primary ways in order to assess the resistance of endodontic instruments in artificial canals to cyclic fatigue. The initial option, which is more widely used, involves a glass container containing water whose temperature is controlled by a thermostat to body temperature (35℃-37.5℃) and measured using a thermometer.[12] The second one; a temperature-controlled oven is used.[13] In the present study, the first protocol was chosen because it seemed closer to the actual way files are used clinically, where files are in contact with the lubricant irrigants, and working in the humidity of the oral cavity.

The NCF that an instrument can withstand under a particular loading condition is referred to as its cyclic fatigue resistance. The NCF is computed by multiplying the rotational speed by the time elapsed until fracture, given that it is cumulative.[10]

There are no standards agreed upon for cyclic fatigue testing of endodontic instruments. Numerous researchers have tried to develop standardized devices and techniques for cyclic fatigue testing.[23,24,25,26] The methodology used in these studies generally aims to standardize fatigue testing by controlling the artificial canal and the position of files in the canal.

The apparatus utilised in the current investigation was designed and built to conduct cyclic fatigue testing.[5] The primary objective of the device's design was to erase the human element from the file position evaluation process in the artificial canal. This was achieved by utilizing two stoppers that locked the motor (on linear motion guides) in place during testing. One of these stoppers had a hinge to release the motor and allow replacement files between tests.

Ideally cyclic fatigue testing would be performed by instrumenting natural teeth with curved canals. However, teeth geometry would change during preparation and could be used only one time leading to a problem in standardization23, for this reason, a non-tooth model was chosen for the investigation.

A number of non-tooth devices[13] were utilised to assess the resistance to cyclic fatigue in vitro under static or dynamic conditions were examined. Despite its close approximation to the trajectory of clinical brushing or pecking motions[14], the dynamic model has certain limitations due to the lack of constraint on the instruments under examination. In this study, since the testing instruments could be confined to a precise trajectory, a static structure was favoured.

Researchers have tried many techniques to standardize the shape of the artificial canal for fatigue testing. Of these techniques **Plotino's technique**[15]] was utilised for the present study., utilizing a canal that has the same dimensions of the file to be tested with added constant relief (or off-set) of 0.1mm or 0.2mm. This resulted in a tapered canal with variable depth just enough to engulf the file. In order to prevent instrumentation-induced wear on the canal walls, stainless steel artificial canals were utilised; consequently, the parameters remained constant throughout the test.[16] The artificial canal has a glass cover instead of acrylic one as Glass has higher hardness than NiTi and thus the risk of wear would be minimal when compared with acrylic.

The present investigation employed two artificial canals, the first of which had a radius of 3mm and an angle of curvature of 60 degrees, signifying a severe curvature[10], the radius 3 mm and 45 degrees of curvature of the second canal indicated a mild curvature.[17] The anatomy of a severely curved canal is considerably more complex than that of a mildly curved canal.

In thisstudy, the NCF of the instruments examined in the severe curvature canal was found to be lower in comparison to the mild curvature canal. This discovery is consistent with prior research.[18]

This was explained by **Pruett set al.**[4] found that as the angle of curvature increases, the radius of curvature decreases, or cyclic fatigue resistance decreases, andinstrument stress and strain increase.

Regardless of whether the testing protocol was considered or not, at both canal curvatures, W3 Pro performed noticeably better than Revo-s. This is consistent with the findings of other studies which found that files made of CM wire have a significantly higher cyclic fatigue resistance than files made of conventional Ni-Ti alloy.[18] The enhanced crystal structure arrangement of CM alloy increases its file flexibility and cyclic fatigue resistance. The R-phase and martensite are observed to increase in proportion in CM alloy. The shear modulus of the R-phase is the lowest among the three phases of Ni-Ti alloy. Martensite deforms and absorbs stress more effectively than austenite. This phenomenon can be associated with the twinning phase of martensite, wherein stressed lattices undergo internal motion without rupturing atomic bonds.[19]

Since Revo-s is composed of a standard Ni-Ti alloy, its mean NCF for both curvatures was the lowest.[20] The shape memory effect of the conventional Ni-Ti file causes it to tend to return to its original shape during a curvature rotation, thereby increasing the friction between the file and canal wall. (21) Conversely, the CM files exhibit greater proportions of martensite at both body temperatures and room temperature, possess a diminished capacity for shape memory, and thus experience reduced stress during rotation into root canal curvature.[22]

Results showed non-significant difference between both files before and after immersion in sodium hypochlorite 5.25% for 5 mins.[23]

Fracto visual (top view) The characteristic image of cyclic fatigue was extracted from randomly selected rotary endodontic files using SEM at varying magnifications.

Further investigations are needed to evaluate mechanical properties of new heat treated NiTi alloys and to develop and fully understand the mechanism of NiTi heat treatments.

REFERENCES

1. Shen Y, GSP. C. Methods and models to study nickel–titanium instruments. Endod Top Wiley Online Library, 2013.
2. Astm E., 2015; 739-91. Standard practice for statistical analysis of linear or linearized stress-life (SN) and strain-life (ε-N) fatigue data. ASTM International.
3. Grande NM, Plotino G, Pecci R, Bedini R, Malagnino VA, Somma F. Cyclic fatigue resistance and three-dimensional analysis of instruments from two nickel-titanium rotary systems. Int Endod J., 2006; 39(10): 755-63.

4. Pruett JP, Clement DJ, Carnes DL, Jr. Cyclic fatigue testing of nickel-titanium endodontic instruments. J Endod, 1997; 23(2): 77-85.
5. Gayatri K, Tammineedi S, Bolla N, Vemuri S, Basam RC, Sunil CR. Effect of autoclaving on the cyclic fatigue resistance of nickel-titanium rotary instruments: An in vitro study. J Conserv Dent., 2021; 24(5): 440-4.
6. Shen Y, Cheung GS, Bian Z, Peng B. Comparison of defects in ProFile and ProTaper systems after clinical use. J Endod., 2006; 32(1): 61-5.
7. Jamleh A, Kobayashi C, Yahata Y, Ebihara A, Suda H. Deflecting load of nickel titanium rotary instruments during cyclic fatigue. Dent Mater J., 2012; 31(3): 389-93.
8. Jamleh A, Sadr A, Nomura N, Yahata Y, Ebihara A, Hanawa T, Tagami J, Suda H. Nano-indentation testing of new and fractured nickel-titanium endodontic instruments. Int Endod J., 2012; 45(5): 462-8.
9. Elnaghy AM, Elsaka SE. Cyclic Fatigue Resistance of One Curve, 2Shape, ProFile Vortex, Vortex Blue, and RaCe Nickel-Titanium Rotary Instruments in Single and Double Curvature Canals. J Endod., 2018; 44(11): 1725-30.
10. Arias A, Macorra JC, Govindjee S, Peters OA. Correlation between Temperature-dependent Fatigue Resistance and Differential Scanning Calorimetry Analysis for 2 Contemporary Rotary Instruments. J Endod, 2018; 44(4): 630-4.
11. Dosanjh A, Paurazas S, Askar M. The Effect of Temperature on Cyclic Fatigue of Nickel-titanium Rotary Endodontic Instruments. J Endod, 2017; 43(5): 823-6.
12. Keskin C, Inan U, Guler DH, Kalyoncuoğlu E. Cyclic Fatigue Resistance of XP-Endo Shaper, K3XF, and ProTaper Gold Nickel-titanium Instruments. J Endod, 2018; 44(7): 1164-7.
13. Plotino G, Grande NM, Mercadé Bellido M, Testarelli L, Gambarini G. Influence of Temperature on Cyclic Fatigue Resistance of ProTaper Gold and ProTaper Universal Rotary Files. J Endod, 2017; 43(2): 200-2.
14. Li UM, Lee BS, Shih CT, Lan WH, Lin CP. Cyclic fatigue of endodontic nickel titanium rotary instruments: static and dynamic tests. J Endod, 2002; 28(6): 448-51.
15. Plotino G, Testarelli L, Al-Sudani D, Pongione G, Grande NM, Gambarini G., Fatigue resistance of rotary instruments manufactured using different nickel-titanium alloys: a comparative study. Odontology, 2014; 102(1): 31-5.
16. Kim HC, Cheung GS, Lee CJ, Kim BM, Park JK, Kang SI. Comparison of forces generated during root canal shaping and residual stresses of three nickel-titanium rotary files by using a three-dimensional finite-element analysis. J Endod, 2008; 34(6): 743-7.
17. Alexandrou G, Chrissafis K, Vasiliadis L, Pavlidou E, Polychroniadis EK. Effect of heat sterilization on surface characteristics and microstructure of Mani NRT rotary nickel-titanium instruments. Int Endod J., 2006; 39(10): 770-8.
18. Topçuoğlu HS, Topçuoğlu G, Kafdağ Ö, Arslan H. Cyclic fatigue resistance of new reciprocating glide path files in 45- and 60-degree curved canals. Int Endod J., 2018; 51(9): 1053-8.
19. Pedullà E, Lo Savio F, La Rosa GRM, Miccoli G, Bruno E, Rapisarda S, Chang SW, Rapisarda E, La Rosa G, Gambarini G, Testarelli L. Cyclic fatigue resistance, torsional resistance, and metallurgical characteristics of M3 Rotary and M3 Pro Gold NiTi files. Restor Dent Endod, 2018; 43(2): e25.
20. Lopes HP, Gambarra-Soares T, Elias CN, Siqueira JF, Jr., Inojosa IF, Lopes WS, Vieira VT. Comparison of the mechanical properties of rotary instruments made of conventional nickel-titanium wire, M-wire, or nickel-titanium alloy in R-phase. J Endod, 2013; 39(4): 516-20.
21. Ninan E, Berzins DW. Torsion and bending properties of shape memory and superelastic nickel-titanium rotary instruments. J Endod, 2013; 39(1): 101-4.
22. Kwak SW, Ha JH, Shen Y, Haapasalo M, Kim HC. Effects of Root Canal Curvature and Mechanical Properties of Nickel-Titanium Files on Torque Generation. J Endod, 2021; 47(9): 1501-6.
23. Pedullà E, Grande NM, Plotino G, Pappalardo A, Rapisarda E. Cyclic fatigue resistance of three different nickel-titanium instruments after immersion in sodium hypochlorite. J Endod, 2011; 37(8): 1139-42.