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Assessment the impact of operator experience on cyclic fatigue resistance in reciprocating and rotary NiTi files: a comparative study between dental students and pediatric dentistry specialists

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Introduction: Devices reducing clinical practice time, and which get minimally affected by user experience are invaluable in pediatric dentistry. Additionally, knowing the fracture resistance of different nickel-titanium (NiTi) files for root canal preparation of primary teeth is important for treatment success. Thus, the present study aimed to compare the instrumentation time (IT) and fracture resistance of reciprocating T-endo MUST (TEM) and continuously rotating AF Baby File (ABF) NiTi files according to the use of pediatric dentistry specialists.

Methods: According to their clinical experience level, 3 experimental groups (EG)s were formed namely: no experience, 2-years (less-experienced), and 10-years experienced pediatric dentistry specialists' groups. The fourth group was the control group (CG). In each EGs, 10 TEM (25/.06) and 10 ABF 20/.04, and 10 ABF 25/.04 NiTi file systems were used in 20 artificial resin teeth. Instrumentation time was recorded for each tooth. In the CG, the same number of files were not used for instrumentation. The files in all groups were subjected to a dynamic cyclic fatigue test, and the data were analyzed using the Kruskal–Wallis test at 5% significance level.

Results: In all groups, TEM files showed a significant higher fatigue resistance as compared to ABF files. However, fatigue resistances were significantly lower in (EG)s both in TEM and ABF compared to (CG)s. The instrumentation time was found to be significantly lower in TEM compared to the ABF. Also, for both file systems, the experience level did not affect the fatigue resistance, and instrumentation time.

Discussion: The experience level of the pediatric dentist did not affect the cyclic fatigue resistance of the reciprocating and rotating NiTi files, but the instrumentation time was lower for the reciprocating NiTi files.

KEYWORDS

rotary file systems, dynamic cyclic fatigue, operator experience, T-endo MUST, AF Baby File

1 Introduction

A pulpectomy is recommended for irreversibly affected inflamed or infected primary teeth to prevent the premature loss of teeth (Boonchoo et al., 2020). The literature describes various techniques for root canal preparation in the primary teeth, including manual instrumentation with stainless steel hand files, rotary instrumentation with nickel-titanium (NiTi) files, and ultrasonic instrumentation (Kaya et al., 2017; Chauhan et al., 2019). Although the use of manual files for root canal preparation of primary teeth is common, the difficulty in the cooperation of the pediatric patient and being time-consuming are its main disadvantages (Chauhan et al., 2019). Devices that reduce clinical time are of great value in pediatric dentistry, and many studies comparing rotary and manual instrumentation have reported canal preparation with rotary files to be noticeably quicker and easier (Chauhan et al., 2019). NiTi files used for root canal shaping can maintain root canal shape better and overcome the problems associated with the stainless-steel file, namely, procedural errors, ledges, zips, and perforations in the root canal system (Ferreira et al., 2017). NiTi files can be basically divided into two groups according to their movement types as rotary or reciprocating files. Rotary files require more than one file to complete the root canal preparation compared to reciprocating files (Musale et al., 2019; Boonchoo et al., 2020). Precisely for this reason, the control of the operative torque represents an improvement of the technique, reducing the number of instruments useful for completing the endodontic treatment, saving money and time, and selecting those that best adapt to the specific endodontic treatment (Gambarini et al., 2020). With the asymmetric reciprocating motion, the file completes a full cycle, alternating counterclockwise and clockwise to varying degrees, and allowing the root canal preparation to complete with only one file (Yared, 2008).

In the light of the latest developments in technology, new NiTi files produced with different technologies have been introduced to the market that can also be used in primary teeth. AF Baby File (ABF; Fanta Dental Materials Co., Shanghai, China) is a rotary NiTi file system that is specially produced for children. The system consists of 4 files, the orifice opener file Open File (17/.08) 11 mm in length, and shaping files of 20/.04, 25/.04, and 30/.04 16 mm in length. It is produced from H-Wire alloy belonging to ABF NiTi and the cross-sections of the files are triangular. The files are recommended to be used in the order of 20/.04, 30/.04 in wide canals, and in the order of 17/.08, 20/.04, 25/.04 in narrow canals (AF Baby File Brochure, 2023).

T-endo MUST (TEM; Dentac, İstanbul, Türkiye) is a reciprocating single-file NiTi file system. The system consists of 4 files: glide path file TG (13/.04), shaping files M25 (25/.06), M40 (40/.04), and M50 (50/.04). TEM is produced with a proprietary heat treatment called TM-Wire. The glide path file (TG) in the system has a square cross-section and the shaping files have an "S" shaped cross-section. These file systems ensure the practitioners to use multi use single technique (MUST) with high flexibility and allow for an immediate usage from a sterile package. The files in the system are available in the market as 21, 25, and 31 mm (T-endo MUST Brochure, 2023).

There is no study that examines the effect of the different experience levels on the cyclic fatigue resistance of NiTi rotary file systems in pediatric dentistry. Therefore, the aim of this *in vitro* study was to examine the effect of the operator experience on cyclic fatigue resistance of reciprocating and continuous rotating NiTi files. The null hypothesis of this study was that there would be no significance difference in cyclic fatigue resistance between the NiTi files according to the experience level.

2 Materials and methods

2.1 Sample size calculation

According to a previous study (Muñoz et al., 2014), the number of samples for the cyclic fatigue test was determined using the G*Power 3.1 software (Heinrich Heine University, Duesseldorf, Germany) and the number of samples per group was found to be 8 with 95% power and 5% alpha-type error. For this reason, 10 NiTi files per group were used in this study.

2.2 Experimental groups

Three clinicians with different clinical experience levels were included and subsequently the experimental groups (Groups 1, 2, 3) of the study were formed. The groups in the study are shown in Figure 1. In Group 1, 2, and 3, a total of 60 artificial resin teeth (10 for TEM and 10 for ABF files, per group) were prepared by the members of the pediatric dentistry department, who has at least 10 years, 2 years, and no experience in root canal shaping with NiTi file systems, respectively. In Group 4, no root canal was prepared, 10 TEM 25/.06 and 10 ABF 25/.04 files were assigned as a control group in order to be used in the cyclic fatigue test.

Before the instrumentation, all the artificial resin teeth (VDW, Munich, Germany), 40 reciprocating 21 mm TEM M25 (25/.06), 40 rotary 16 mm ABF 20/.04, and 40 16 mm ABF 25/.04 NiTi file systems were examined under a stereomicroscope (x10 to x20) (AX10 Zoom V16; Carl Zeiss, Oberkochen, Germany) in terms of deformation and manufacturing defect. Since no defect was detected in the files, all of them were included in the study.

The artificial resin teeth used in the study consist of 3 roots (mesio-buccal, disto-buccal and palatal) and 4 canals (mesio-buccal 1, mesio-buccal 2, disto-buccal and palatal) mimicking the upper first molars. The patency of all canals was checked with #15 K-file (VDW) before use. To determine the root canal lengths, #15 K-file was advanced under magnification (OMS 3200 R2; Zumax, Suzhou, China) until it appeared from the apex, and this length was determined as the root canal length. The working length was calculated by subtracting 1 mm from this length. For the mesio-buccal 1, mesio-buccal 2, disto-buccal and palatal canals, the working lengths were obtained as 21 mm, 20 mm, 20 mm, and 22 mm, respectively. The determination of the working lengths and the marking of the reference points in all teeth were performed by an experienced pediatric dentist who was not included in the experimental groups.

2.3 Preparation of the resin teeth

Before starting the shaping process of the teeth, to ensure the standardization, clinicians were informed about the working principles of the NiTi file systems (TEM and ABF), to be used by

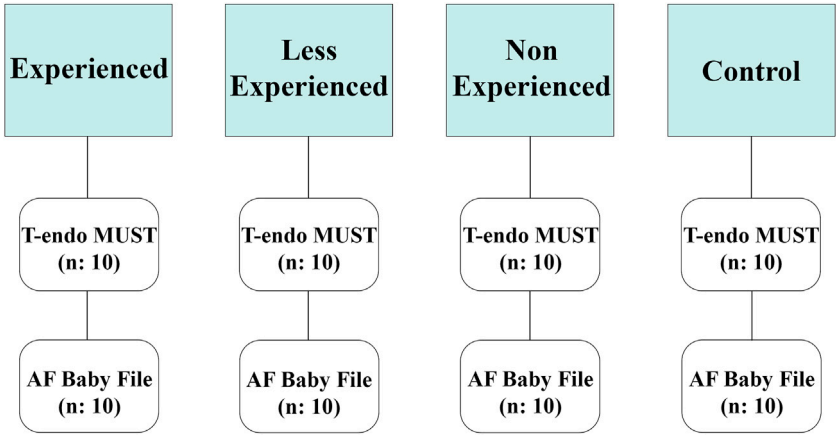

FIGURE 1
Experimental groups of the present study.

FIGURE 2
Dynamic cyclic fatigue test's device computer module.

an experienced pediatric dentist was not included in the experimental groups. The working lengths and reference points determined for working lengths were shown to the clinicians.

The resin teeth were fixed with the help of a vise and all shaping processes were performed in the same manner. A total of 10 mL of saline solution was used with 30-gauge side-perforated irrigation needles (Endo-Top; Cerkamed, Stalowa Wola, Poland) for each tooth.

TEM M25 (25/.06) NiTi files were used in the "T-endo MUST" program in the torque-controlled endodontic motor (Ai; Woodpecker, Guilin, China) library in accordance with the user instructions (300 rpm speed was programmed to move 160° counterclockwise and 40° clockwise, with a torque of 4.2 Ncm).

ABF 20/.04 and 25/.04 NiTi files were used in accordance with the user instructions (300 rpm and 2 Ncm torque), respectively. ABF files were used with a vertical back and forth pecking motion as for TEM files. All the files for both systems were removed from the root canals after every 3 pecking motions. The total time for root canal shaping was recorded in seconds for each tooth. File replacement and irrigation procedures were not included to total time, allowing the total time to be determined as the time spent shaping.

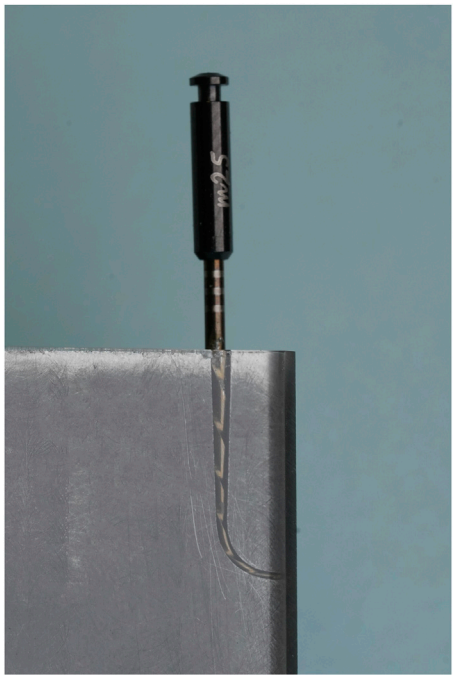

FIGURE 3
Artificial stainless-steel canal for dynamic cyclic fatigue test.

After shaping the root canals, all the files of the two systems were activated in an ultrasonic bath for 30 min in ethyl alcohol to remove the residues on it. Then each file was washed with 5 mL distilled water and subsequently dried with air.

2.4 Dynamic cyclic fatigue test

The modification of the dynamic fatigue test setup (Alnet, Istanbul, Türkiye), which was utilized in the previous studies (Özyürek et al., 2017; Keskin et al., 2018) was used to better

TABLE 1 Means and standard deviations of the number of cycles to fracture (NCF), and fracture length (FL) (mm) of T-endo MUST (TEM) and AF Baby File (ABF) files according to the groups.

	Control group		Non-experienced group		Less-experienced group		Experienced group		
	TEM	ABF	TEM	ABF	TEM	ABF	TEM	ABF	*p*-value
NFC	7,193.24 ± 247.24[a]	3,297.19 ± 232.02[b]	5,640.25 ± 799.67[c]	1956.69 ± 306.75[d]	5,382.88 ± 433.84[c]	2058.41 ± 241.80[d]	5,794.38 ± 501.92[c]	2156.61 ± 256.76[d]	< 0.05
FL	4.58 ± 0.31[a]	4.61 ± 0.32[a]	4.80 ± 0.35[a]	4.66 ± 0.43[a]	4.89 ± 0.44[a]	4.53 ± 0.29[a]	4.77 ± 0.54[a]	4.69 ± 0.40[a]	> 0.05

*Different superscripts [a, b, c, d] indicate the statistically significant difference among groups at 5% significance level.

imitate the clinical conditions (Figure 2). An endodontic micromotor with 6:1 reduction, with torque and speed adjustment, and a contra-angle handpiece (VDW Silver Reciproc, VDW) were used by connecting to the test device. Two different artificial canals suitable for the size and conicity of the files of two systems were used for the cyclic fatigue test. Both stainless steel artificial canals were fabricated with a length of 15 mm, a radius of curvature of 5 mm, an angle of curvature of 60°, and 0.1 mm larger than the NiTi files (Figure 3).

All test procedures were carried out in a specially produced heat-regulated oven (Alnet) in order to imitate the clinical conditions. The intra canal temperature was set to 37°C (Özyürek et al., 2017; Özyürek et al., 2018a).

In total, 40 TEM M25 (ten for per group) and 40 ABF 25/.04 (ten for per group) NiTi files were rotated in the dynamic fatigue device until they fracture. The time until the files fracture was recorded in seconds and the number of cycles to failure (NFC) was recorded following the formula:

$$\text{NFC} = \text{revolutions per minute (rpm)} \times \text{time to fracture (s)}/60$$

Fractured fragment lengths were recorded in mm with the help of a digital micro caliper. Two NiTi files from each group were examined by scanning electron microscope (SEM) to determine the fracture types. Photomicrographs at various magnifications (x300, x350, x4000) were taken from the fractured file surfaces with the SEM (Gemini SEM 500; Carl Zeiss).

2.5 Statistical analysis

The Shapiro-Wilk test was first applied to the data in order to determine whether the data were normally distributed or not. Since the data were not normally distributed, the Kruskal-Wallis test was used to statistically analyze the data with a 95% confidence interval and by using the IBM-SPSS 26.0 (IBM SPSS, Chicago, IL, United States) software.

3 Results

The mean and standard deviation of NCF values of the tested files according to the experience groups are shown in Table 1. The mean and standard deviation of total instrumentation times of the tested files according to the experience groups are shown in Table 2. The NCF values of TEM files were found to be significantly higher than ABF files in all groups ($p < 0.05$) For both file systems, all experimental groups showed lower NCF values than the control groups ($p < 0.05$). However, there was no significant difference observed in the NCF values among the experimental groups for the TEM and ABF files ($p > 0.05$).

Regarding the instrumentation time, TEM files needed significantly lower time for the preparation of root canals compared to the ABF files in all the experimental groups. However, the instrumentation time did not differ according to the experience level for both the file systems ($p > 0.05$). Additionally, considering the experience of operators and different file systems, fracture lengths did not differ among any of the groups ($p > 0.05$).

In the images taken at various magnifications (x300, x350, x4000) of the SEM analysis from each group, the rough surface, micropores, and fatigue striations specific to cyclic fatigue were determined (Figure 4).

4 Discussion

The current study has analyzed the effects of the experience level (inexperienced, less experienced, and experienced) of the pediatric dentists on the cyclic fatigue resistance and instrumentation time of the reciprocating and continuously rotating files. According to the evaluation, similar fatigue resistance and similar instrumentation time were recorded for each file system for each operator with different levels of experience. To the best of our knowledge, no study has made the comparison, thus, it is difficult to assess the findings of the current study considering the previous reports.

The fracture incidence of reciprocating NiTi files (WaveOne, Dentsply Sirona) clinically by endodontic residents was evaluated in a study by Shen et al. (2016). They reported that file fracture occurrence is quite low (about 1.17%) after a single use. Studies on clinical use show that the incidence of file fracture among undergraduate and graduate students is similar between endodontists. Coelho et al. (2018), reported similar results may be due to case selection (usually the root canal treatments of uncomplicated cases) and intensive preclinical training. However, investigators drew attention to the decrease in the incidence of file fractures. New heat treatment technologies and new types of motion may also have contributed to these results. In the present study, new generation heat-treated file systems were preferred, and files more resistant to cyclic fatigue were used. These factors may have minimized the effect of experience differences between the groups.

Cyclic fatigue resistance of endodontic files has been investigated in various static and dynamic models in the literature. In static test models, the canal file is bent at a fixed working length, and in tests with dynamic models, the canal file is rotated with forward-

TABLE 2 Means and standard deviations of the instrumentation time (IT) of T-endo MUST (TEM) and AF Baby File (ABF) files according to the groups.

	Non-experienced group		Less-experienced group		Experienced group		
	TEM	ABF	TEM	ABF	TEM	ABF	*p*-value
IT	348.96 ± 20.43[a]	662.01 ± 74.48[b]	340.13 ± 26.19[a]	561.33 ± 25.37[b]	330.15 ± 50.92[a]	554.56 ± 22.44[b]	< 0.05

*Different superscripts [(a, b)] indicate the statistically significant difference among groups at 5% significance level.

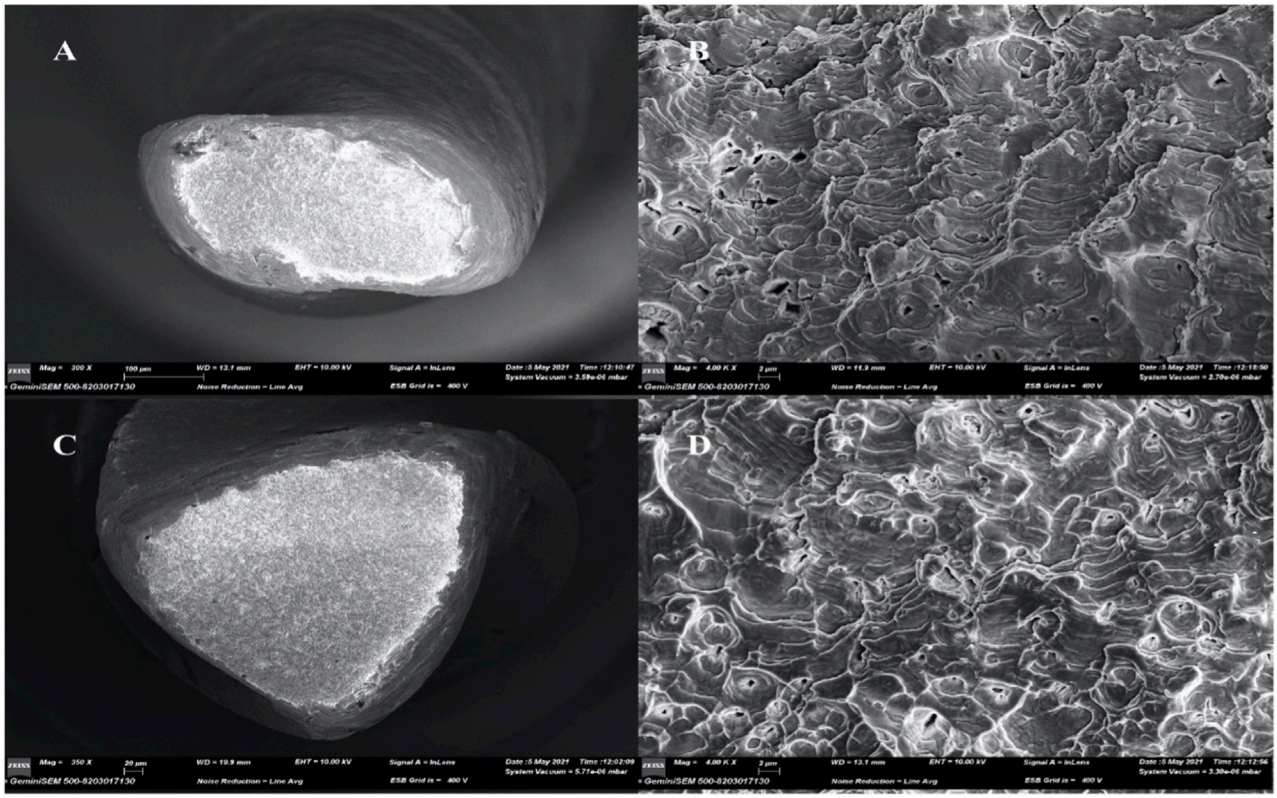

FIGURE 4
Scanning electron microscope (SEM) images at lower and higher magnifications for the T-endo MUST **(A)**, and AF Baby File **(C)** instruments' fractured surfaces after cyclic fatigue test. At a low magnification **(A,C)**, the surfaces appeared rough, and at a higher magnification **(B,D)** microscopic dimples characteristic of cyclic fatigue were observed. When the edges were carefully examined at high magnification **(B,D)**, fatigue lines due to cyclic fatigue.

backward (axial) movements until it fractures (Dederich and Zakariasen, 1986). Additionally, preparing the artificial canals in accordance with the files to be tested is important for the correct and reliable performance of the cyclic fatigue test. Although the use of root canals of extracted human teeth can better reflect clinical conditions, they do not constitute an ideal model because it is not possible to standardize human tooth root canals (Plotino et al., 2009). Since the present study evaluated the effect of the experience levels of pediatric dentists, it was carried out in non-clinical conditions, because the target group is children, in which standardization will be most difficult due to problems such as compliance with treatment and tooth morphology due to physiological resorption. So, the instrumentations with files were performed in the standardized artificial resin teeth, and for the fatigue test artificial stainless-steel canals, which are 1 mm larger than the files, were used to minimize the effects of the parameters that disrupt standardization. Also, a dynamic model including axial movement was used to provide better results in terms of mimicking a more satisfactory similarity of clinical conditions.

DeVasconcelos et al. (2016), compared the cyclic fatigue resistance of different file systems at room temperature (20°C) and body temperature (37°C), and reported that all experimental groups showed a significant decrease in fatigue resistance at 37°C. Thus, in the present study, the test setup was created at 37°C in order to better imitate the intracanal environment, to imitate the liquid environment existing in root canals, and to minimize the friction between the metal artificial canal and the tested NiTi files. It was placed in an oven with water and the tests were carried out in this way. Also, the heat treatment of the NiTi files can affect the cyclic fatigue resistance of the files (Hou et al., 2020; Seracchiani et al., 2021). According to the studies, the austenitic files have less resistance to cyclic fatigue compared to martensitic files (Kwak

et al., 2021; Kwak et al., 2022). In the present study different heat-treated NiTi files have been compared. One of the reasons that the significance different found between the groups in the present study.

According to the results of this study, TEM reciprocal NiTi files showed significantly higher cyclic fatigue resistance than ABF rotary NiTi files in all different experienced groups and control groups ($p < 0.05$). Thus, the null hypothesis of our study was rejected. These results show similarity to the results of studies in the literature reporting that reciprocating NiTi files have higher cyclic fatigue than rotary NiTi files (Özyürek et al., 2017; Özyürek et al., 2018b; Miccoli et al., 2020). Compared to the rotary movement, the reciprocating motion prevents the stress that occurs while the file is rotating in the canal from accumulating continuously in the same region, and distributes it along the shaft of the file, and in this case, the file becomes more resistant to fracture (Bonaccorso et al., 2009; Özyürek et al., 2017). In the present study, the possible reason for the higher resistance of TEM files to cyclic fatigue is the feature of the reciprocating motion, and thus, the dispersion of the stress on the file. Additionally, in the present study, the total instrumentation time for the preparation of artificial resin canals with the TEM reciprocal NiTi files showed significantly lower values than ABF rotary NiTi files. There is no study comparing the reciprocal and rotary NiTi files according to the instrumentation time in the literature. However, in our opinion, the difference in the instrumentation time is probably because the ABF system needs two files and TEM needs one file to prepare the canals.

5 Conclusion

Within the limitations of this study, the movement characteristics of the files in the root canals affect their resistance to cyclic fatigue. Since the user experience does not affect the fatigue resistance of NiTi files, inexperienced clinicians can use these files in primary and permanent teeth without the risk of fracture. On the other hand, it is recommended to be careful when interpreting the results obtained for clinical use, since there are some limitations such as different hardness values between resin and dentin, and because of the elimination of the difficulties that may arise from anatomical and clinical variations to ensure standardization in *in vitro* conditions.

Data availability statement

The raw data supporting the conclusion of this article will be made available by the authors, without undue reservation.

Author contributions

HÖ and TÖ contributed to the concept and design of the study. HÖ collected the data. HÖ wrote the first draft. All authors contributed to the article and approved the submitted version.

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Conflict of interest

Author TÖ is a research and development manager at the Dentac (Istanbul, Türkiye) company.

The remaining authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

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