

Research Article



Investigation of fracture prevalence of instruments used in root canal treatments at a faculty of dentistry: a prospective study

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Conflict of Interest

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

Author Contributions

Conceptualization: Eskibağlar M, Ocak MS; Data curation: Eskibağlar M, Öztekin F; Formal analysis: Eskibağlar M, Özata MY; Investigation: Özata MY; Methodology: Özata MY, Ocak MS; Project administration: Eskibağlar M;

ABSTRACT

Objectives: The aim of this study was to examine the use of hand or rotary files by pre-graduation (fourth- and fifth-year) and postgraduate students in endodontic treatments and to determine the incidence of file fracture and the management of cases with broken instruments.

Materials and Methods: A total of 2,168 teeth undergoing primary endodontic treatment were included in this study. It was determined that 79 of these teeth resulted in broken tools. In the case of broken tools, the education level of the treating clinician, the tooth that was being treated, the canal and fracture level, the curvature of the tooth and the management of the broken instrument were recorded. Periapical radiographs of the patients were used to calculate curvature following the Schneider method.

Results: There was no significant difference in the incidence of broken tools according to education level ($p > 0.05$). The incidence of file fracture in molar teeth (73.4%) was higher than in other teeth ($p < 0.05$). More files were broken in the mandibular molar MB canal (20.25%) and in the apical third of the canals (72.1%). The risk of instrument fracture was high in teeth with moderate (44.3%) and severe (38%) curvature canals. The management of apically broken (80%) files mostly involved lefting ($p < 0.05$).

Conclusions: There was no statistically significant difference between fourth-year students, fifth-year students and postgraduate students in terms of instrument fracture.

Keywords: Endodontic file; File fracture; File fracture management; Separate file

INTRODUCTION

In endodontic practice, various procedural errors may occur at any stage of root canal treatment [1]. Intracanal file fracture, which poses a great challenge for routine root canal treatment, is one of the most common procedural errors that occurs during root canal treatment [2-4]. Endodontic appliances are made of various materials, including nickel-titanium (NiTi), stainless steel and carbon steel. The fracture of endodontic instruments can occur for a variety of reasons, including excessive strain or instrument fatigue from use as well as operators who are not fully trained [4-6].

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Stainless steel hand file fracture usually occurs after visible deformation of the instrument, whereas the fracture of NiTi instruments can occur without prior visible warning to the clinician [7]. It has been reported that the fracture prevalence of stainless steel hand files varies between 2% and 6%, while the fracture prevalence of NiTi rotary files varies between 1.04% and 13.54% [7-11]. Although many factors lead to instrument fracture, the most important factor is the experience of the clinician. In fact, the main problem that occurs when the biomechanical preparation process is performed by inexperienced clinicians is instrument fracture [12]. To reduce this possibility, it is important to ensure that clinicians receive adequate training [13]. Theoretical and practical training in endodontics is an important component of the undergraduate dental curriculum [14]. This training process should enable dental students on graduation to be able to manage uncomplicated root canal treatments for both single-rooted and multi-rooted teeth [15].

The education levels of fourth- and fifth-year students performing endodontic treatment at the faculty of dentistry and postgraduate students in the endodontics program are different from each other. Research exploring endodontic practices among undergraduate students revealed findings regarding the number of root fillings performed. Specifically, the study observed that third-year students displayed minimal root fillings (averaging only 0.71) in the laboratory setting, without any clinical experience. However, as the students progressed to the fourth and fifth years, a remarkable increase in root fillings was noted, with fourth-year students averaging 7.40 and fifth-year students averaging 7.47 root fillings, respectively. Moreover, the fifth-year students, on average, did a higher number of root fillings compared to their third and fourth-year students [15]. In addition, a systematic review showed that postgraduate students outperformed undergraduate students in primary endodontic treatment [16]. In this case, it is clear that the students' ability to manage endodontic treatments and possible complications differ according to their education level. Therefore, the aim of this study was to investigate the prevalence of hand file and rotary instrument fracture during root canal preparation among fourth- and fifth-year undergraduate and postgraduate endodontics students. The null hypothesis of the study is that fourth- and fifth-year students break more files than postgraduate students.

MATERIALS AND METHODS

Ethical approval (No. 2022/12-29) for this study was obtained from the Ethics Committee of Fırat University. According to 95% confidence ($1-\alpha$), 95% test power ($1-\beta$), and 2-way hypothesis, the total number of cases that should be included in the study was 124 [7].

Patients who underwent endodontic treatment between October 2022 and February 2023 were prospectively analyzed. The study included all maxillary and mandibular permanent incisors, premolars and molars. Retreatments and primary tooth endodontic treatments were excluded from this study. During this semester, the number of fourth-year students who treated patients in the endodontic clinic was 66, the number of fifth-year students was 72, and the number of postgraduate students was 16. A total of 2,168 teeth were included in the study. 1,205 teeth were treated by postgraduate students, 373 teeth were treated by fourth-year students, and 590 teeth were treated by fifth-year students.

Data were recorded for the patients, including the person performing the treatment (fourth-year, fifth-year, or postgraduate student), tooth type (molar, premolar, and incisor), type

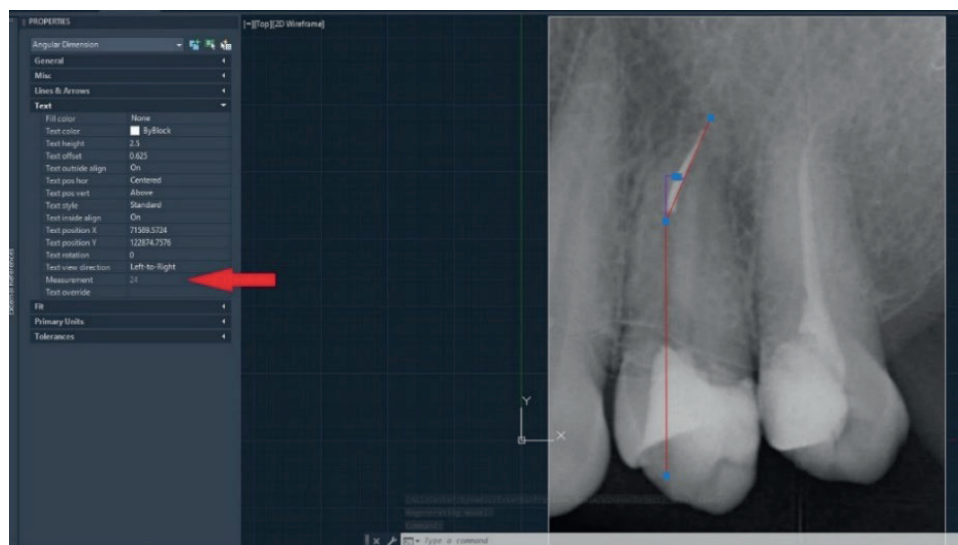


Figure 1. Calculation of curvature angle with AutoCAD software.

of instrument (hand or rotary file), location of the broken instrument (apical, middle, or coronal), and broken file length information. All clinicians used a K file (Mani Inc., Tochigi, Japan) as a hand file and a reciprocating file (Endoart Expert Gold, İnci Dental, Istanbul, Turkey) as a rotary file for biomechanical preparation. Each clinician was informed, and immediately after the file was broken, the length of the file was measured, the amount of separation of the file segmented was recorded, and a periapical radiograph (Planmeca Oy, Helsinki, Finland) image was taken. The length of the broken file was found by measuring the difference between the length of the file before and after separation with a ruler. Canal curvature angles were calculated following the Schneider method using [17], AutoCAD software (Autodesk, San Rafael, CA, USA) (**Figure 1**). The cases were divided into 4 groups based on canal curvature: 1) mild (curvature < 10); 2) moderate (curvature ≥ 10 and < 25); 3) severe (curvature ≥ 25 and < 45); and 4) ultra-severe (curvature ≥ 45) [18].

Periapical radiograph images (Planmeca Oy) of hand files and rotary instrument files broken at various levels in different teeth are shown in **Figure 2**. The localization of the broken files was determined under a dental operating microscope (Zumax Medical, Suzhou, China) (**Figure 3**). Ultrasonic tips (Guilin Woodpecker Medical Instrument, Guilin, Guangxi, China) were used to retrieve these instruments.

Statistical analysis

Data were analyzed with SPSS (v23; IBM, Armonk, NY, USA). Pearson's χ^2 test was used to compare categorical data, and multiple comparisons were made with Bonferroni correction. The analysis results were presented as frequencies (percentages). The level of significance was set as $p < 0.05$.

RESULTS

The distribution of teeth treated by postgraduate, fourth-, and fifth-year students according to tooth type is presented in **Figure 4**. The number of molar teeth treated by postgraduate students was 538, the number of premolars was 324, and the number of incisor teeth was 343.

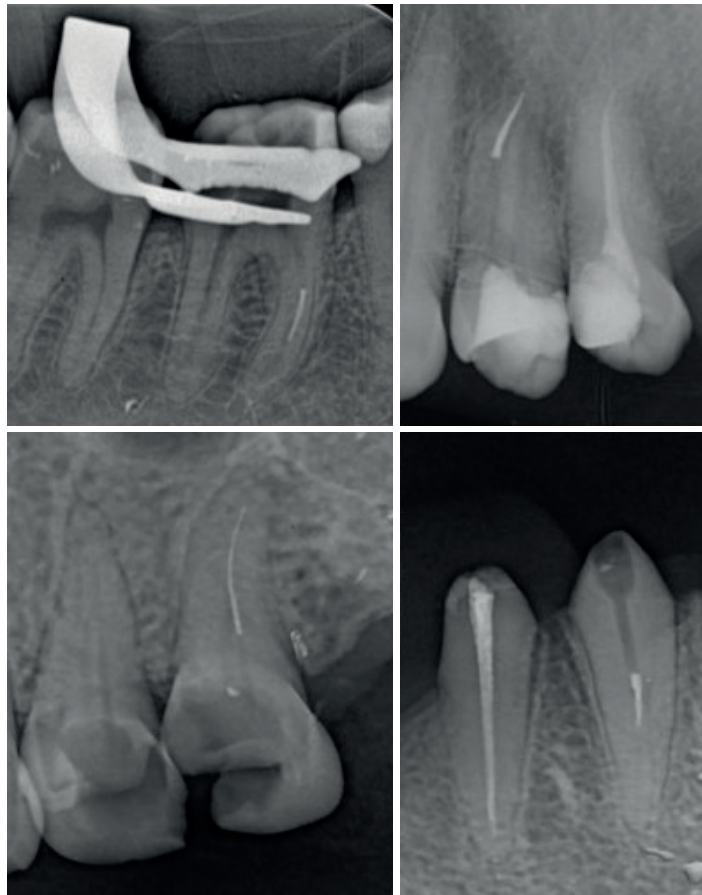


Figure 2. Periapical X-ray images of broken files.

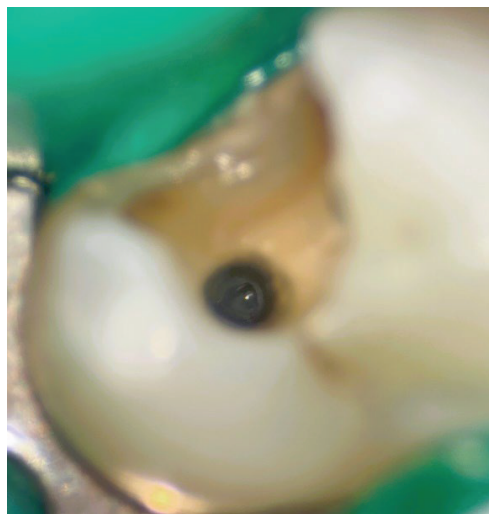


Figure 3. Dental operation microscope image of the broken instrument.

The number of molar teeth treated by fourth-year students was 17, the number of premolars was 191, and the number of incisor teeth was 165. The number of molar teeth treated by fifth-year students was 282, the number of premolars was 162, and the number of incisor teeth was 146.

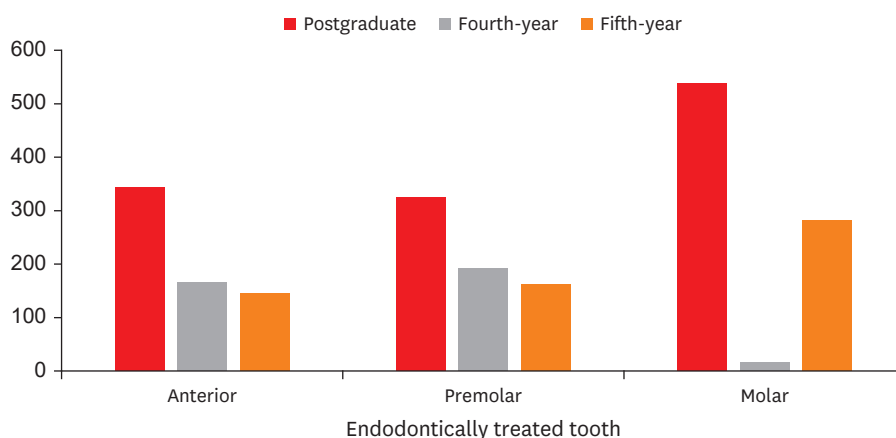


Figure 4. Distribution of endodontically treated tooth type according to students.

While NiTi reciprocating files were broken in 59 cases, hand files were broken in 20 cases. In the treatments performed by fourth- and fifth-year students, 20 cases with broken instruments were referred to the specialist clinic. In these cases, the procedures of removing, leaving or bypassing the broken instrument were performed by the specialist physician. In addition, the average length of the broken file was 2.42 mm in incisor teeth, 3.4 mm in premolars, and 3.63 mm in posterior teeth.

There was no statistically significant difference between the distribution of file fracture occurrence by education level ($p = 0.051$). For postgraduate students, the rate of fracture occurrence in the treatments was 3.2%. In comparison, it was 2.4% for the fourth-year students and 5.4% for the fifth-year students (**Table 1**). There was no statistically significant difference between the fracture frequency of endodontic files in the maxillary and mandibular teeth ($p = 0.922$) (**Table 1**). The incidence of fractures in incisor teeth was 0.9%, whereas it was 2.2% in premolars, and there was no significant difference in the presence of fractures in these 2 tooth groups ($p > 0.05$). There were significantly more file fractures in molar teeth (6.9%) than in other tooth groups ($p < 0.001$) (**Table 1**).

While the bypassed files did not differ by level ($p > 0.05$), there was a significant difference by level in the leaved and removed files ($p < 0.001$) (**Table 2**). While none of the files broken at the apical level could be removed, 5.3% of files broken at the middle level and 66.7% of files

Table 1. Comparison of the fracture presence/absence distribution by education level, jaw, and tooth type

Variables	Fractured instrument		p^*
	Presence	Absent	
Education level			0.051
Postgraduate student	38 (3.2)	1,167 (96.8)	
Fourth-year student	9 (2.4)	364 (97.6)	
Fifth-year student	32 (5.4)	558 (94.6)	
Arch			0.922
Mandibula	40 (3.7)	1,046 (96.3)	
Maxilla	39 (3.6)	1,043 (96.4)	
Tooth type			< 0.001
Incisor	6 (0.9) ^a	648 (99.1)	
Premolar	15 (2.2) ^a	662 (97.8)	
Molar	58 (6.9) ^b	779 (93.1)	

Values are presented as number of patients (%).

*Pearson χ^2 test; ^{a,b}There is no difference between rows with the same letter.

Table 2. Comparison of file management by fracture level

Management of file	Fractured file level			<i>p</i> [*]
	Apical	Middle	Coronal	
Retrieval	0 (0.0) ^a	1 (5.3) ^a	2 (66.7) ^b	< 0.001
By-passed	9 (15.8)	6 (31.6)	1 (33.3)	
Left	48 (84.2) ^a	12 (63.2) ^{ab}	0 (0.0) ^b	

Values are presented as number of patients (%).

^{*}Pearson χ^2 test; ^{a,b}There is no difference between rows with the same letter.

Table 3. Comparison of file management by fracture canal

Management of file	Fractured file location								<i>p</i> [*]
	Man-MB	Max-MB	MB2	D	P	B	ML	OR	
Retrieval	1 (4.8)	0 (0.0)	1 (16.7)	1 (14.3)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0.125
By-passed	4 (19.0)	4 (33.3)	0 (0.0)	4 (57.1)	1 (16.7)	1 (11.1)	0 (0.0)	2 (33.3)	
Left	16 (76.2)	8 (66.7)	5 (83.3)	2 (28.6)	5 (83.3)	8 (88.9)	12 (100.0)	4 (66.7)	

Values are presented as number of patients (%).

Man-MB, mandibular molar mesiobuccal canal; Max-MB, maxillary molar mesiobuccal canal; MB2, mesiobuccal 2; D, distal; P, palatal; B, buccal; ML, mesiolingual; OR, one root.

^{*}Pearson χ^2 test.

Table 4. Comparison of the distribution of the removal-left status of the file by curvature classification

Management of file	Canal curvature classification				<i>p</i> [*]
	Mild	Moderate	Severe	Ultra-severe	
Retrieval	1 (8.3)	2 (5.7)	0 (0.0)	0 (0.0)	0.028
By-passed	5 (41.7) ^a	10 (28.6) ^a	1 (3.3) ^b	0 (0.0) ^{ab}	
Left	6 (50.0) ^a	23 (65.7) ^a	29 (96.7) ^b	2 (100.0) ^{ab}	
Total	12 (100.0)	35 (100.0)	30 (100.0)	2 (100.0)	

Values are presented as number of patients (%).

^{*}Pearson χ^2 test; ^{a,b}There is no difference between rows with the same letter.

at the coronal level could be removed. The rate of left files was 80% at the apical level and 20% at the middle level, while no files were left at the coronal level. In terms of left files, the rate at the coronal level was significantly lower than at the apical level ($p < 0.05$).

There was no statistically significant difference between the distribution of the file removal-release status by the canal of the fracture ($p = 0.125$) (**Table 3**).

According to the curvature classification, most fractures were seen in the root canals with the most moderate curvature. This was followed by severe, mild, and ultra-severe curvatures, respectively (**Table 4**). A statistically significant difference was found between the distribution of the removal-left status of the file according to curvature classification ($p = 0.028$) (**Table 4**). The rate of bypassed files was 41.7% in canals with mild curvature, 28.6% in canals with moderate curvature, and 3.3% in canals with severe curvature. There were no bypassed files in canals with ultra-severe curvature. The bypass rate of files in canals with severe curvature was significantly lower than the rate in those with mild and moderate curvature ($p < 0.05$). The proportion of files left in canals with mild curvature was 50%, while it was 65.7% in those with moderate curvature, 96.7% in those with severe curvature, and 100% in those with ultra-severe curvature. The drop rate of files in canals with severe curvature was significantly higher than the rate in canals with mild and moderate curvature ($p < 0.05$).

DISCUSSION

Endodontic treatment depends on the quality of the cleaning and shaping of the root canal system, and the fracture of the files in the root canal during these procedures is often caused

by operator negligence [19]. File fractures are considered to be one of the most troublesome hazards that jeopardize endodontic treatment and can affect prognosis [20]. The results of this study show that the fracture rate of NiTi reciprocating files is 3 times higher than the fracture rate of stainless steel hand files. The length of the broken files in this study ranged from 1–14 mm, with an average length of 3.63 ± 1.15 mm.

Our study aimed to determine the fracture prevalence of hand and NiTi rotary files during root canal treatment performed by fourth-year, fifth-year, and postgraduate students in a dentistry faculty. According to the findings of this study, the fracture frequency of NiTi rotary files was higher than that of hand files. This finding is also consistent with the results of other studies [7]. However, it was observed that the prevalence of broken instruments was higher than in similar studies [7,10,19]. While NiTi rotary files usually break as a result of flexural or torsional loading, it has been reported that fractures in hand files occur due to excessive apical pressure and turning of the instrument [20,21]. In addition, many parameters are involved in the breaking of files [22]. For this reason, the fracture rate of NiTi files is higher than that of hand files, but it does not mean that NiTi files should break more easily than hand files [7].

Various studies have stated that the most important factor in the occurrence of file fracture is the ability of the clinician [23]. In our study, it was found that the prevalence of fractured instruments during root canal treatments was 2.4% for fourth-year students, 5.4% for fifth-year students, and 3.2% for postgraduate students. The null hypothesis was rejected because there was no statistical difference between the groups. In our study, postgraduate students treated an average of 75.31 cases per person during the semester in which the data were collected, while this number was 8.19 for fifth-year students and 5.65 for fourth-year students. Although the difference between the postgraduate and fifth-year students was not statistically significant, the lower prevalence of broken instruments supports this situation. However, with regard to the postgraduate and fifth-year students, the fact that they performed fewer treatments and that the teeth requiring endodontic treatment were chosen from relatively simple teeth may have led to this finding.

The biomechanical preparation in root canal treatment procedures performed by postgraduate students in our faculty of dentistry was as follows: After creating the glide path with a size 10 or 15 K-files, Endoart Expert Gold with a size 25 apical diameter was completed with a reciprocating file. In the biomechanical preparation process, the Endoart WISMY endomotor (İnci Dental) was used, and the standard treatment protocol was followed in accordance with the instructions provided by the manufacturers' instructions. In this study, the Endoart Expert Gold reciprocating file used for root canal preparation has a fixed 0.06 taper, while manual hand files have a 0.02 taper. In addition, the Endoart Expert Gold file has an S cross-section. The manufacturer claims that Endoart Expert Gold files have high cutting efficiency and high fracture strength due to their heat treatment technology. In the present study, the balanced force technique was used for the manual preparation of the root canals. For manual preparation, standard hand K-files were used, as they have a cutting tip and rectangular cross sections.

The preparation of different root canal anatomies was left to the discretion of the clinician. In the biomechanical preparation procedures of fourth- and fifth-year students, after the apical preparation, was made up to a size 20 K-file, it was completed with a size 25 apical Endoart Expert Gold reciprocating file. The postgraduate students performed manual glide-path creation before using the NiTi rotary instrument, which may have resulted in fewer file fractures, as it reduced the stress on the NiTi rotary file system. In addition, the rotary files

used had a fixed angle performing the reciprocating motion, but the use of files with different kinematics or variable taper may alter the incidence of fracture.

Molar teeth have more roots and usually more curvature canals than premolars and incisor teeth [24]. It has been reported that this leads to more frequent instrument fractures in molar teeth [19,25]. In our study, hand files and NiTi rotary files were broken more frequently in molars than in premolars and incisor teeth. In addition, it has been reported that the apical parts of the mesiobuccal roots of the maxillary and mandibular first molars are narrow and the curvatures are greater [24-26]. In this study, the most common location of broken files was in the apical part of the molar teeth, which is consistent with the results of similar studies [7,25,27]. We found more instrument fractures in teeth with a moderate curvature. In a similar study evaluating the Mtwo file (VDW, Munich, Germany), fracture was found to be more common in teeth with ultra-severe curvature [18]. It is possible that this difference may be caused by the different file designs, the kinematics of the file, and the clinician's experience.

Periapical rontgen images of the hand or NiTi rotary files were taken after they were broken, and they were referred to the specialist clinic. Attempts to remove or bypass these files using various methods were attempted under the dental operating microscope (Zumax Medical). While the most frequently extracted files were located in the coronal part of the root canal system, the most frequently bypassed root canal system was found to have mild curvature. The files in the coronal part are more accessible and the curvature is $< 10^\circ$, making it easier to remove or bypass the broken instruments. This finding is consistent with the results of similar studies [7,18]

Although many studies have stated that the files should be examined before use for the risk of instrument fracture, that deformed files should not be used, and that they should not be used after various numbers, they mainly focused on the way in which the files were used. In these studies, it was stated that NiTi files were more broken than hand files [28-32]. However, anatomical difficulties should not be ignored. According to the results of our study, the probability of instrument breakage in the apical part of the mesiobuccal canals is higher than in the other canals. Undergraduate and postgraduate students should have sufficient knowledge of the root canal anatomy of all teeth, especially molars, and pay attention to the biomechanical preparation of the mesiobuccal canals of the molars.

CONCLUSIONS

Although there is no statistical difference in the percentage of file fractures, when looking at the number of patients treated, it is clear that students treat far fewer cases than postgraduate students. Undergraduate students' involvement in more cases may increase their experience managing root canal endodontic treatments and file fractures. Graduation of students with the knowledge and skills to perform root canal treatment at a high standard will increase the quality of endodontic treatment applied to patients and will reduce the risk of file fracture.

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