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# Comparison of the Removability of Different Niti Rotary File Systems from Root Canals

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## Abstract

**Objective:** This study aimed to compare the removability of fractured nickel-titanium rotary instruments with different working principles in the middle and coronal thirds of the canal using ultrasonic tips and the BTR pen.

**Method:** Thirty-two mandibular molars were selected from recently extracted teeth that met the inclusion criteria. Teeth had to have a closed apex, no root caries, anomalies, fractures, cracks, or signs of internal or external resorption. The mesiobuccal roots were intentionally fractured, and the root inclination was confirmed to be ≤20° using Schneider's method. Teeth with a higher inclination angle were excluded. Access cavities were opened traditionally to allow direct canal access, and apical patency was verified with #10 K files. Canal lengths were measured, and teeth were embedded in acrylic blocks for easier handling. The teeth were divided into four study groups (n=8) based on the working principle of the instrument and the location of the fractured instrument (coronal or middle third). NiTi instruments with the same taper (0.6) and heat treatment (blue) were selected. A 4 mm mark was made on each file, and files were thinned to half their thickness at the designated breaking point using a diamond bur. A stage platform was created with Gates Glidden burs to improve the visibility of the broken instruments. After creating the platform, dentin around the broken files was removed by 2 mm with ultrasonic tips, and the broken pieces were extracted using a BTR Pen with a 0.3 mm thin wire loop.

**Results:** When analyzed by working principle, the removal time for fractured instruments in the middle third was significantly higher (p=0.0001). Within the coronal third, the removal time for reciprocal files was significantly longer (p=0.021). Similarly, in the middle third, the removal time for reciprocal files was statistically longer (p=0.004).

**Conclusion:** The BTR Pen was effective for both rotary file systems. The location of the fractured instrument influenced the removal time, with faster results in the coronal third due to better access and visibility. Additionally, the type of fractured NiTi rotary instrument also impacted the time required for successful removal, with rotary instruments in the middle third taking significantly longer.

**Keyword:** Broken file, Broken file removal, BTR Pen, NiTi rotary instruments, ultrasonic.

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## INTRODUCTION

Instrument breakage during root canal treatment is an obstacle to effective cleaning of the canal. As a result of inadequate cleaning, the success rate of root canal treatment may decrease. Therefore, the best way to manage this complication is to remove the broken fragment from the canal and continue cleaning and shaping procedures (1).

Based on the evidence provided by endodontic follow-up radiographs, Kerekes and Torstad reported that the probability of a fragment remaining in a root canal treated tooth is between 2% and 6% (2). In a similar study, Iqbal et al. reported this incidence between 1% and 5.1% (3, 4).

According to Grossman (5) and Crump & Natkin (6), the prognosis of teeth with fractured instruments is mainly based on the preoperative condition of the tooth and periapical tissues. The prognosis was found to be better in cases where vital pulp extirpation was performed.

In teeth which diagnosed with periapical lesions before root canal treatment, half of the improvement was observed. In addition, in almost all cases where no pathologic changes were observed in the periapical tissues before root canal treatment, the teeth remained asymptomatic despite incomplete expansion and filling due to the broken instrument (7). Ingle & Beveridge (8) found that 1% of the observed failures after endodontic treatment were due to broken instruments.

Although removal of the broken instrument is the most desirable method of maintenance, it has been reported that a complete bypass can also result in a good prognosis by clearing the entire working length of the root canal (9).

Canal anatomy and the location of the fractured instrument can make instrument removal stressful and time-consuming. On the other hand, broken instrument removal techniques may cause a number of complications such as excessive loss of dentin tissue, decreased root fracture resistance, perforations, pushing the broken fragment out of the root, and increased temperature on the root surface (10, 11). Successful removal of the broken instrument does not always guarantee that root canal treatment will result in a good prognosis. Therefore, the clinician must balance the successful removal of the broken instrument with the preservation of the existing tooth structure with minimal loss of material. Various devices and techniques have been developed to remove broken instruments during root canal

treatment (12). With the use of ultrasonic devices and tips in combination with dental microscopes, it is possible to remove the dentin surrounding the broken fragment (12, 13).

The Broken Tool removal (BTR Pen) system (Cerkamed Medical Company, Poland) is recently introduced broken tool removal system (Figure 1). The use of an ultra-thin working tip terminated with a high elasticity nitinol loop allows the broken tool to be captured within the canal. Its shape memory, which allows it to be placed in narrow and inclined root canals, prevents the loss of excess material from the tooth to remove the fractured instrument. Our knowledge of the BTR Pen is based on a very limited body of information, mostly clinical experience (1).

The aim of this study is to evaluate and compare the effectiveness of the BTR Pen in combination with ultrasonic tips on rotary instruments with different working principles and different cross-sectional areas on a time basis in the light of the above-mentioned information.

In this study, in which we compared the removability of 4mm files with different working principles (reciprocation and rotation) broken in the mesiobuccal canal of the lower molar teeth with ultrasonic and BTR Pen on the basis of time; the main aim was to evaluate the maintenance of this common complication.

The main objective was to evaluate the effect of magnification and endodontic wire loop (BTR Pen) on the removal of broken files based on the working principle of the files.

The null hypothesis of this study is that when the removal time of files with different working principles broken in the canal is compared, rotary files will take less time to be removed from the canal than reciprocal files.

It is planned that the data to be obtained in this study will give a basic idea about the removability of the files with different working principle and cross-sectional area broken in the canal in terms of time with the use of ultrasonic and BTR Pen.


**Figure 1.** BTR Pen Device

## METHODS

A total of 32 lower molars collected with consent from patients who were decided to be extracted during routine treatment were used in the study. The molars to be used were selected from teeth with closed apex, no root caries, no anomalies, fractures or cracks, no previous root

canal treatment, and no signs of internal or external resorption.

Teeth with open apex, caries on the root surface, anomalies, fractures or cracks in the root, previous root canal treatment, root inclination calculated higher than 20° according to Schneider's method, excessive crown destruction (teeth with only one wall left in the crown) and teeth with perforation in the root canal during instrument extraction were excluded from the study.

Forty-eight eligible lower molars were embedded in acrylic blocks and traditional access cavities were opened to provide direct access to all canals. The apical patency of the mesiobuccal root of all teeth was checked with #10 K files. The length of the mesiobuccal canals was measured and noted.

The NiTi reciprocal (EasyinSmile XtwoS Blue R25, horizontal section S-shaped) and rotary (Fanta, AF Blue Rotary File, horizontal section convex triangular) instruments to be broken in the teeth were selected with the same taper (0.6) and heat treatment (blue). A 4 mm marking was made on the files to be broken and all files were thinned with a diamond bur at half their thickness at the point to be broken. (Figure 2)

These teeth, whose access cavities were opened conventionally, were divided into 4 groups (n=8) according to the working principle of the root canal shaping instruments used and according to the intra-canal location where the root canal instrument would break.

In the 1st study group (RecipC) (n=8), the reciprocal files were broken 4 mm coronally.

In the 2nd study group (RecipM) (n=8), the reciprocal files were broken 4 mm in the middle third.

In the 3rd study group (RotaryC) (n=8) rotary files fractured 4 mm coronally.

In the 4th study group (RotaryM)(n=8) rotary files fractured 4 mm in the middle third.

The fracture locations of the broken files were checked by digital radiography (Figure 4A, 4C). Specimens with broken instruments that could not be broken in the planned direction were excluded from the study. The total time of the expansion and broken instrument removal stages after the control was measured with a stopwatch and recorded.

For the removal of broken instruments, an stage platform was created by working in a controlled manner with Gates Glidden milling cutters numbered 2 and 3 to provide full access to the instrument. After the fractured fragment was visualized with a 3x magnification Zumax loupe, DTE ultrasonic tips (E88) were used in the G3 mode of the DTE ultrasonic device to free the 2 mm dentin in the coronal part of the fractured fragment. The mobility of fractured instruments was checked with a 20 hand

plugger. The mobilized fractured fragment was grasped with the finest 0.3 mm wire loop tip of the BTR Pen and removed from the canal (Figure 2 and Figure 3). The tooth from which the instrument was removed was checked again by radiograph (Figure 4B, 4D)


**Figure 2.** Broken File

**Figure 3.** Broken File Extracted With BTR Pen


**Figure 4.** A: Control Radiograph for Coronally Located Fractured İnstrument
B: Control Radiograph Taken After Removal of The Coronally Located Fractured İnstrument
C: Control Radiograph for Middle Third Located Fractured İnstrument
D: Control Radiograph Taken After Removal of The Middle Third Located Fractured İnstrument

***Statistical analysis***

The sample size required for this study was calculated using G*Power version 2. Statistical analyses were performed with NCSS (Number Cruncher Statistical System) 2007 Statistical Software (Utah, USA) package program. In addition to descriptive statistical methods (mean, standard deviation), the distribution of variables was examined with the Shapiro-Wilk normality test, and two-way analysis of variance (Two-Way ANOVA) was used for intergroup comparisons of normally distributed variables. The results were evaluated at a significance level of $p<0.05$.

**RESULTS**

When the reciprocal files were compared within themselves, the mean removal time (min) of the coronally positioned fractured files in the RecipM group (50:09±2:45) was statistically significantly higher than the fractured files in the RecipC group (13:07±2:07) (p=0.0001).

When the rotational files were compared among themselves according to their position in the canal, the results were similar. The mean time (min) for removal of broken files in the RotaryM group (37:01±9:02) positioned in the middle third was statistically significantly higher than in the RotaryC group (9:02±2:34) positioned in the coronal third (p=0,0001).

When the study groups in the coronal third were compared according to the working principle of the files, the mean time (13:07±2:07) (min) required to remove the broken files in the RecipC group working with reciprocal motion was statistically significantly higher than the RotaryC group working with rotation (9:02±2:34) (p=0,021).

When the study groups in the middle triad were compared according to the working principle of the files; the mean removal time (50:09±2:45) (min) of the broken files working with reciprocal motion in the RecipM group was statistically significantly higher than the files working with rotational motion (37:01±9:02) in the RotaryM group (p=0,004).

The mean time to remove the broken instrument (31:01±19:26) (min) of the reciprocation group was statistically significantly higher than the rotation group (23:02±15:01) (p=0,0001). This result confirms the null hypothesis of our study.

The mean time to remove the broken instrument (43:02±9:44) (min) in the medial section was statistically significantly higher than in the coronal section (11:52±2:02) (p=0,0001) (Table 1, Graph 1).

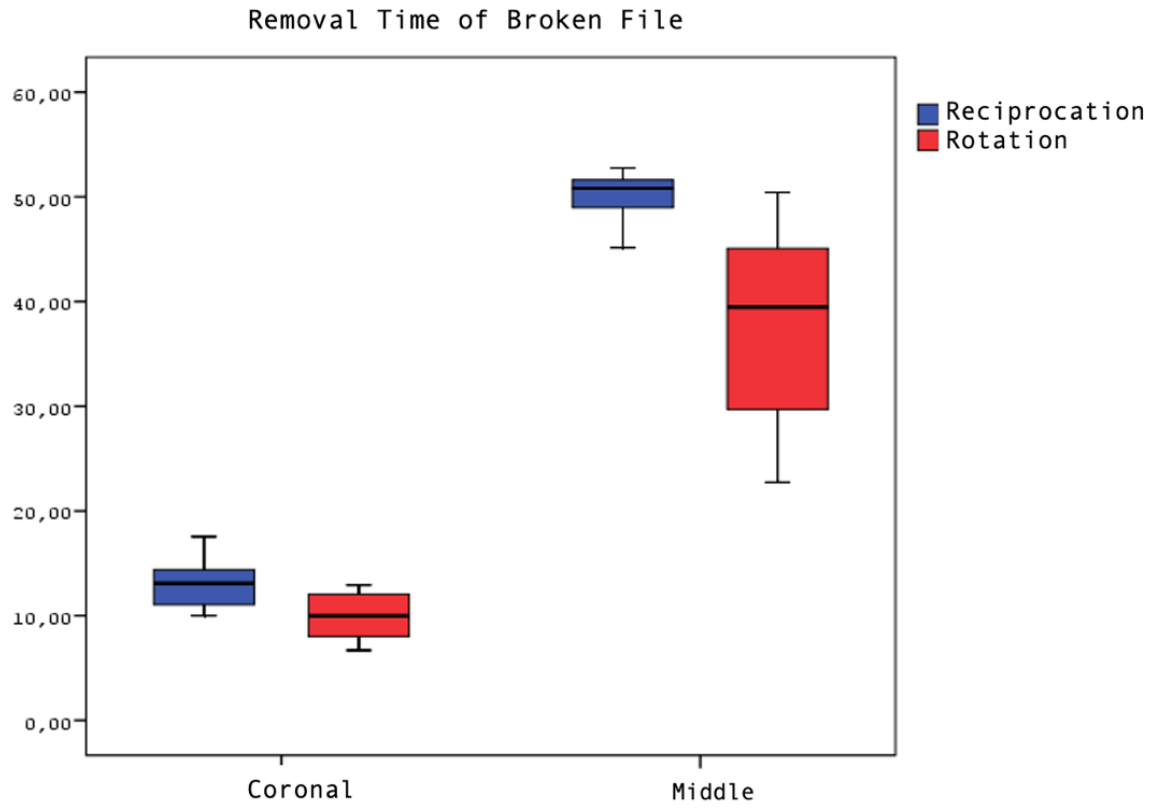
A statistically significant difference was observed between the mean duration of removal of the fractured instrument (min) when the Movement*Location groups were compared within themselves (p=0,021) (Table 2)

**Table 1.** Specification Of Movement Types And Fracture İnstrument Placement Over Time

| | Coronal | Middle | Total |
|---|---|---|---|
| **Reciprocation** | 13:07±2:07 | 50:09±2:45 | 31:01±19:26 |
| **Rotation** | 9:02±2:34 | 37:01±9:02 | 23:02±15:01 |
| **Total** | 11:52±2:02 | 43:02±9:44 | 27:01±17:01 |

**Table 2.** spesification of sum of squares, df, mean square, F and p for motion and location

| | Type III Sum of Squares | df | Mean Square | F | P |
|---|---|---|---|---|---|
| **Motion** | 480,37 | 1 | 480,37 | 16,72 | 0,0001 |
| **Location** | 8388,90 | 1 | 8388,90 | 292,05 | 0,0001 |
| **Motion*Location** | 171,82 | 1 | 171,82 | 5.98 | 0,021 |




**Graph 1.** Boxplot of groups and removal time

## DISCUSSION

The separation of the instruments used during endodontic treatment in the canal is a problem encountered by all clinicians performing root canal treatment. The frequency of broken instruments in molars was significantly higher than in premolars, canines or incisors. Especially the mesiobuccal canals of molars are the most frequently fractured canals due to the curvature of the canal anatomy (3, 14) Therefore, the present study was carried out on broken files in the mesiobuccal roots of lower molars.

The introduction of Nickel-Titanium (NiTi) alloy in endodontics has led to the production of more durable and flexible instruments (15). Since the first hand files, the use of this alloy has led to more reliable preparation(16). Today, NiTi rotary instruments have found a wide place in endodontics with a wide variety of instruments including different horizontal sections, taper and new variations of NiTi alloy(17)

Rotary tools, which often show no evidence of plastic deformation, are seven times more likely to fracture than hand tools(3, 18). Fractures in NiTi rotary tools are usually caused by flexural fatigue, torsional fatigue, or an interaction of both (19, 20). The cause of fracture of stainless steel hand tools is high torque (21).

Recent studies have investigated the fracture frequency of NiTi tools operating in reciprocal or rotational kinematics. In these studies, controversial results have been presented depending on the number of uses of the tools, the experience of the user and the operating system of the current file (22, 23, 24). In recent studies, the effect of different cross-sectional areas on fatigue strength is also a frequently investigated topic with controversial results. Cheung and Darvell, in a study of 4 rotary files with different cross-sectional shapes, concluded that cross-sectional area has no significant effect on cyclic fatigue induced fractures (25).

In vitro studies have shown that changes in the operating principle increase fracture resistance to cyclic fatigue when a larger cutting angle than the relief area is presented in the reciprocal motion (26). During the periodic change of the angle, the positions of the critical stress fields gradually change, so that the stress fields are effectively distributed to various points of the file, distributing the damage to the file and prolonging the life of the tool.

A recent study concluded that Reciproc files with overlapping cross-sectional areas have a longer service life than Mtwo files. The findings of the study support the view that increased flexibility and reciprocal motion during the use of files in curved grooves increases the cyclic fatigue life of NiTi files (27).

Although there are many studies that correlate the cross-sectional area and working principle of the file with the frequency of fracture, there is limited literature that attempts to establish a relationship between the working principle and the removability of the file. For this reason, in our study, we wanted to compare two different rotary files with different cross-sectional areas and different rotation and reciprocation working principles in terms of removability.

Three orthograde methods are utilized in the maintenance of broken instruments. In the first two, the fractured fragment maintains its position in the canal by filling the rest of the canal or bypassing the apical canal and filling

it. The third option is to remove the existing fragment from the canal, continue the washout shaping procedures and finish the canal treatment (28).

Various methods have been developed to remove the broken instrument in the canal. Ruddle (29) reported a case of ultrasonic trephine burs removing the dentin coronal to the broken instrument after creating an entry platform. The combination of the dental microscope and ultrasonics has been reported to increase the success rate and reliability of broken instrument removal (30). Broken instrument removal methods from the root canal must include equipment that can achieve high success rates in a short time with minimal dentin removal (31). The BTR Pen system is a newly introduced system developed to provide easy access to narrow and curved canals.

Successful removal of a broken instrument depends on the type of material, its location and length. The shorter the broken instrument, the more difficult it is to remove.

Success rates have been found to be higher for instruments of 5 mm or more. This may be due to the fact that the long fragments are attached to the root dentin at the ends and there is enough space in the coronal portion to allow bypassing and thus some loosening and movement of the instrument within the canal (e.g. with ultrasonic devices) (32).

One of the possible success factors in the removal of the broken instrument is the type of root canal. It has been observed that broken fragments can be removed more easily in teeth with wide root canals such as canines. In the distal canals of mandibular molars and palatinal canals of maxillary molars, success rates were found to be 67% and 60%, respectively, in a study by Hülsmann. The mesial canals of mandibular molars are often curved. The isthmus, which is frequently observed between the mesiobuccal and mesiolingual canals, has been recorded to allow bypassing the broken instrument with a rate of 58%. Considering the curvature of the canal, it would not be a surprise that the success of canal instrument extraction is higher in straight or slightly to moderately curved canals. It is also predictable that instruments located apical to the curvature have a lower removal rate than instruments located coronal to the curvature. It should be kept in mind that two-dimensional images can be misleading when the only data we have are radiographs (7). Considering all these findings and the limited magnification and illumination we will use in our study, the coronal and middle triads of the mesiobuccal canals of the lower molars were preferred for the placement of broken instruments.

When compared between leaving the instrument in the canal and removing it from the canal, removal from the canal is the more preferred option if it is feasible (33). A

standardized procedure that gives definitive results for this is still under investigation. Ormiga et al. (34) tried to remove the broken instrument from the canal by electrochemical thawing, but they did not achieve the expected result. In a study by Shahabinejad et al. ultrasonics was utilized and the success rate was found to be 80% as a result of the removal of the broken instrument by ultrasonics on 70 extracted teeth (28). The success of the ultrasonic technique has been investigated in many studies in vivo and in vitro. Terauchi et al. (31) achieved a success rate of 83.3% with apically located broken files in 30 extracted mandibular incisors. Souter et al. (11) reported success in 91.1% of the mandibular molars in an invitro study. Again, Souter et al. reported a success rate of 70% in an in vivo study on mandibular molars. Considering that the use of ultrasonics will remove less material from the root canal after the creation of an entry platform that will provide direct access to the fractured instrument, ultrasonic tips (DTE; E88) were used in our study to remove the surrounding dentin 2 mm coronal to the fractured fragment and to mobilize the fractured fragment.

The BTR Pen is a relatively new technique used in broken instrument maintenance. Its purpose is to make it easier to access the fractured instrument fragment in locations that are difficult to reach with a simple wire loop. According to the manufacturer's statement; it provides a significant advantage in terms of time and experience in removing difficultly located, long and high elasticity fracture fragments. According to the information obtained from the manufacturer's website, the BTR Pen can be used successfully in curved root canals and canals with wide apical openings without causing the fracture fragment to be pushed apically. Among the 0.3, 0.4 and 0.5 mm thin wire loops, 0.3 mm thin wire loops were preferred for the mesiobuccal canal of molar teeth, taking into account the manufacturer's recommendation.

The BTR-Pen system also suggests that a longer broken instrument fragment is easier to remove. Further studies and more results are needed to check the accuracy of this proposition. In our study, the size of the fragment to be fractured was determined as 4 mm.

In the present study, some complications and difficulties were encountered while using the BTR Pen and ultrasonic tips. It was observed that contact of the ultrasonic tip with the fractured file fragment caused shortening of the file length and abrasion. A similar finding was reported by Terauchi et al. (31) and Hülsmann and Schinkel (7). Due to the abrasion of the fracture fragment, it was necessary to remove more dentin around the fracture fragment before placing the BTR pen. In addition, if the fracture fragment was too stuck in the canal, dentin removal was continued until it was seen to be mobilized. Even when insufficiently

mobilized fragments were captured in the canal with the BTR Pen, the force applied for removal caused the 0.3 mm thin wire to break.

Among the groups in our study, the shortening of the file length by breaking at the contact between the ultrasonic tip and the broken file was more frequent in the reciprocating files than in the rotation group. This was thought to be one of the factors that may have led to a significantly longer removal time of the fractured fragments in the reciprocating groups in the comparison of the working time.

It is obvious that dentin loss will occur regardless of the method to be used to reach the broken fragment and remove the fragment from the canal. For this reason, no matter which technique is used in broken instrument removal, utmost care is required to remove the broken instrument from the canal. In our study, teeth with perforation in the root canal during broken instrument removal were excluded from the study.

Another limitation of our study was to ensure that the fragment was broken in the planned location. It is known that instrument fractures are frequently seen in the apical third of the root (28). In our study, fractures in the apical triangle were excluded due to limited magnification and illumination possibilities. In order to position the fractured fragment in the desired position (coronal or middle third), the EasyinSmile and Fanta files were thinned to half the thickness of the file with a diamond fissure cutter at the desired working length of 4 mm and inserted into the canal under pressure. This resulted in an inability to replicate clinical conditions..

## CONCLUSION

As a result of the findings of our study, it can be said that the working principle and cross-sectional area of the file fractured in the canal also have an effect on the removal time of the fractured fragment. Files with rotational motion were found to be easier to remove from the canal than those with reciprocal motion. At the same time, the removal of fracture fragments located coronal to the canal was realized in a shorter time than the middle triad. Further in vitro and in vivo studies are needed to determine the effect of the working principle on removability.

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**Ethics Committee Approval:** Approval for this study was obtained from the Ordu University Non-Interventional Research Ethics Committee (Date: 26/07/2024 Number: 95).

We state that the parents have given their written informed consent to be involved in the

study, in accordance with the Declaration of Helsinki.

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