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# EFFECT OF TWO TECHNIQUES OF SEPARATED FILE REMOVAL SYSTEMS ON DENTIN LOSS AND FRACTURE RESISTANCE OF TEETH (IN VITRO STUDY)

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## *ABSTRACT*

**Purpose:** to evaluate the fracture resistance of teeth after removal of separated files using either the BTR Pen system or Zumax kit, the impact of the retrieval technique on the fracture resistance, and to assess the correlation between the amount of volume lost during retrieval and fracture resistance of teeth.

**Materials and Methods:** sixty mandibular first molar teeth were selected. Teeth were placed in acrylic resin blocks and were randomly assigned into two groups. Group A: the control group (n=20) and Group B: the study group (n=40). In the study group, five mm of ProTaper Next X2 rotary files were separated in the mesiobuccal canals. The study group was divided into two subgroups, 20 each. Group BI: the broken tool remover (BTR) pen system was utilized to retrieve separated instruments and Group BII: the Zumax kit was employed for retrieval of separated instruments. Cone Beam Computed Tomography (CBCT) was taken before and after retrieval for volumetric analysis. Fracture loading test was performed using the universal testing machine. Values were analyzed by SPSS software using F-test (ANOVA) and independent t-test.

**Results:** there was a significant increase (P=0.001) in canal volume in the study groups. Comparing the mean fracture resistance of the three groups, no significant difference among the groups was found (P= 0.384).

**Conclusions:** retrieving separated instruments from the coronal third of the root canal is regarded as a safe procedure and has no impact on tooth fracture resistance.

**KEYWORDS:** Dentin loss, Fracture resistance, Separated instruments

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## INTRODUCTION

The field of endodontics experienced a significant breakthrough with the introduction of Nickel-Titanium (NiTi) instruments. Continuous advancements have been made in the manufacturing processes and design characteristics of these instruments to enhance their effectiveness in root canal preparation. However, a significant disadvantage of these NiTi files is that they are prone to suddenly fracture without warning.

Despite the growing need for the retrieval of separated instruments and the existence of numerous techniques and devices, there is no universal protocol for the safe and successful retrieval of separated instruments.[1] Nowadays, the most feasible technique for the removal of separated instruments is the utilization of ultrasonic tips along with a dental operating microscope. [2-5] However, in cases where the file is firmly wedged within the canal and ultrasonic tips are ineffective in dislodging it, alternative methodologies can be employed to remove the fragment. These include loop devices such as the BTR Pen system that is designed to fit in narrow and curved root canals[6] or a microtube with a screw wedge, such as the Zumax broken instrument removal kit.

A study by Eid and Seyam[7] showed that the utilization of ultrasonic tips along with the DOM yielded an 80% success rate in removing separated instruments situated before and at the curvature, whereas only 50% of separated instruments located beyond the root curvature were successfully removed. Furthermore, Meng et al.[8] revealed a success rate of 76.47% when employing the microtube technique. Another study found that the Masserann kit achieved a success rate of 47.6% in the removal of separated instruments.[9]

Multiple studies have shown that teeth that have undergone endodontic treatment are susceptible to fracture in comparison with vital teeth. The most often mentioned reasons have been substantial loss of tooth structure, particularly in the pericervical dentin area, dehydration of dentin following mechanical preparation, and excessive pressure during obturation.[10-14] Regarding the retrieval of fractured instruments, the process of gaining access to the separated instrument and removing it requires the sacrifice of dentin, which increases the risks of procedural mishaps, such as root perforation or a decrease in root fracture resistance.[3] Consequently, it presents a challenge to disengage the separated instrument and retrieve it out of the canal without sacrificing an excessive amount of dentin. Studies have revealed that attempts to remove separated fragments result in the removal of a significant quantity of dentin from the root canal, resulting in a 30 to 40% decrease in root strength.[15, 16]

One previous study found that the removal of fractured instruments from the middle or apical one-third of teeth significantly impacts their strength, as the deeper the separated instrument is within the canal, the more root dentine is removed.[17] Another study showed that the employment of the BTR Pen required less force to fracture the root than the ultrasonic.[6] Furthermore, Vats et al [18] stated that the use of ultrasonics and Instrument Removal System resulted in a significant reduction in root fracture resistance.

Given the aforementioned information, the purpose of this study was to evaluate the fracture resistance of teeth after removal of separated files using either the BTR Pen system or Zumax kit, the impact of the retrieval technique on the fracture resistance, and the correlation between the amount of volume lost during retrieval and fracture resistance of teeth. The null hypothesis in this study assumed that there is no difference in fracture resistance between the two techniques.

## MATERIALS AND METHODS

The study was conducted on 60 sound mandibular first molar teeth with closed apices, and mesial roots with a root canal configuration classified as type IV according to the Vertucci

classification[19]. A conventional endodontic access cavity was prepared. Teeth were flattened to reach a uniform length of 15mm. Then, specimens were mounted in acrylic resin blocks and each block was labeled with a number. A glide path was established using stainless-steel K files #10 and #15. ProTaper Next X1 rotary file (Dentsply Sirona, USA) was used to instrument the mesiobuccal canals to the full working length with copious irrigation of 5 ml of 6% sodium hypochlorite.

**Grouping**

Teeth were randomly assigned to two groups:

***Group A:*** the control group, comprising 20 teeth.

***Group B:*** the study group, comprising 40 teeth.

**Instrument separation inside the root canal and post-instrument separation imaging**

In the study group, the ProTaper Next X2 rotary file was notched to half of the instrument thickness with a diamond disc mounted on a low-speed handpiece, in compliance with Abdeen et al.[20], at five mm from the tip. The file was introduced into the mesiobuccal canal, and at a speed of 350 rpm and torque of 3.5 N, it was rotated with pressure to be separated at the coronal third.

Teeth were inserted into custom-made rubber base blocks to ensure consistent positioning of the specimens. The custom-made rubber base blocks were engraved with numbers that corresponded to their respective acrylic block numbers. The specimens were scanned by CBCT scanner (J Morita Veraview X800) at 75 KVP, 7 mA, and 0.2m voxel size (CBCT-Scan I). The CBCT images were exported as Digital Imaging and Communications in Medicine (DICOM) files. Consequently, Materialise Mimics software (Materialise, Belgium) was utilized to perform volumetric analysis of the mesiobuccal canals.

Subsequently, the study group was divided into two subgroups, 20 each.

***Group BI:*** the BTR pen system was utilized to retrieve separated instruments.

***Group BII:*** the Zumax kit was employed for retrieval of separated instruments.

**Procedure for retrieving separated instruments**

The retrieval process was conducted as per the manufacturer's instructions, following a standardized sequence of steps. The procedure was carried out under a dental operating microscope (Carl-Zeiss Meditec, Jena- Germany) at a magnification of 17X.

***Group BI***

To establish straight-line access to the broken instrument, a circumferential staging platform was created by modified Gates Glidden drills #2, #3, and #4. These drills were modified by cutting off the guiding tips perpendicular to their long axis at their maximum cross-section diameter and they were used sequentially in a brush-like manner.[21] Then, Terauchi straight ultrasonic tip (TERAUCHI CO, LTD., Osaka, Japan) was inserted into the mesiobuccal canal, wedged between the separated instruments and canal wall, and vibrated in an anticlockwise direction for a dry troughing of the dentin around the separated instrument circumferentially for approximately three mm. The canal was filled with EDTA solution to remove dentinal dust and a Stropko irrigator was employed to provide a direct stream of air for optimal microscopic visibility. Working tips of 0.5mm diameter with a 0.1mm diameter nitinol loop were used. The loop was placed and squeezed over the visible coronal aspect of the broken instrument. The instrument was loosened by making lateral movements with the BTR pen and it was removed from the canal by pulling the BTR pen.

***Group BII***

The modified Gates Glidden drills were inserted to create staging platform. Terauchi straight ultrasonic tip was employed to trough the dentin

surrounding the head of the separated file, with a depth of approximately one mm. Initially, a one mm trephine bur was manually employed in a counterclockwise manner to ensure a grip. Then, it was driven on an endodontic motor and rotated in a counterclockwise direction at a speed of 1000 rpm, to remove the dentine surrounding the separated instrument, revealing the coronal aspect of the fragment for nearly three mm. The 1 mm extractor was attached to the handle and placed above the visible coronal portion of the file. The fragment was secured by mechanically engaging the instruments within the lumen of the extractor using a metal wedge. Subsequently, the assembly was pulled together until the file was successfully retrieved.

**Assessment after the retrieval of the instruments and fracture resistance testing**

1. Following retrieval, the specimens were rescanned using CBCT (CBCT-Scan II). Subsequently, the Materialise Mimics software was utilized to perform volumetric analysis of the specimens. The calculation of tooth structure that was removed during the retrieval procedure was calculated as follows: volume of root canal space in the CBCT after retrieval – volume of root canal space in the CBCT before retrieval).
2. Fracture resistance testing: each acrylic block was attached to the lower fixed head of the universal testing machine and was subjected to continuous static load using a stainless-steel plugger 0.7 mm diameter attached to the upper movable head of the testing machine. Axial compression mood of force applied at a crosshead speed of 1.0 mm/min up to specimen failure. The force required for failure (Newton) was recorded by machine software BlueHill Universal Instron England (Figure 1).[22]

**Statistical analysis**

Data was fed to the computer using IBM SPSS software package version 24.0. Quantitative data were described using mean and standard deviation for normally distributed data. For normally distributed data, comparison between two independent populations was done using independent t-test while more than two populations F-test (ANOVA) was used. Significance test results are quoted as two-tailed probabilities. The significance of the obtained results was judged at the 5% level.

**RESULTS**

The increase in the root canal space during retrieval procedure was measured in cubic millimeters in the two studied groups. The student t-test revealed that in Group A (BTR group), the root canal volume post-retrieval was significantly higher than the root canal volume pre-retrieval (P=0.001). The mean ±SD was 3.766±1.014 pre-retrieval and 5.292±1.304 post-retrieval. A comparative pattern was also noted in Group B (Zumax group), in which the root canal volume post-retrieval was significantly

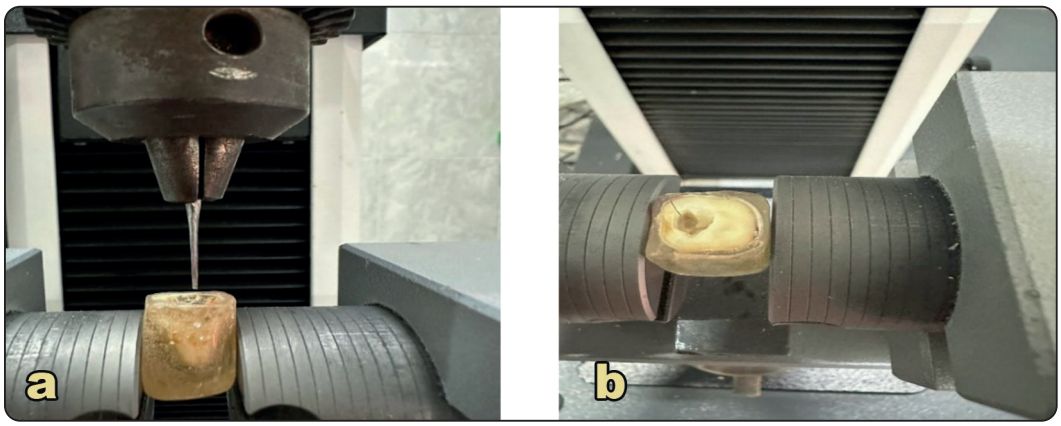


Fig. (1): (a) Load application at the mesiobuccal canal, (b) Specimen after fracture

higher than the root canal volume pre-retrieval (P=0.001). The mean ± SD was 3.798±2.623 pre-retrieval and 6.896±3.412 post-retrieval (Table 1).

The observed mean fracture resistance (Newton) was higher in Group A (control Group) (1285.3), followed by Group BI (BTR Group) (1059.5), and Group BII (Zumax Group) (1125.4). However, ANOVA test revealed no significant difference among the three groups (P= 0.384). Furthermore, comparing the mean fracture resistance between the BTR group and Zumax group, the BTR Group and control Group, and the Zumax Group and control Group, the independent test revealed no statistically significant differences existed (P =0.103, P=0.066, and P=0.071, respectively) (Table 2).

TABLE (1) Comparison between the two studied groups regarding the increase in root canal volume.

| | BTR group | Zumax group |
|---|---|---|
| Pre | | |
| Mean ± S.D. | 3.766 ± 1.014 | 3.798 ± 2.623 |
| Post | | |
| Mean ± S.D. | 5.292 ± 1.304 | 6.896 ± 3.412 |
| Mean difference (post – pre) | 1.53 ± 1.04 | 3.10 ± 1.69 |
| % effect difference | 40.62% | 81.62% |
| P value | 0.0051* | |

TABLE (2) Comparison between three studied groups regarding maximum load (N).

| **Maximum Load [N]** | **Control group** | **BTR group** | **Zumax group** |
|---|---|---|---|
| Min | 876.0 | 474.0 | 545.0 |
| Max | 1735.0 | 1465.0 | 1686.0 |
| Mean | 1285.3 | 1059.5 | 1125.4 |
| SD | 280.1.8 | 329.2 | 404.8 |
| ANOVA | | 1.065 | |
| P value | | 0.201 N.S. | |
| P1 | | 0.103 N.S. | |
| P2 | | 0.066 N.S. | |
| P3 | | 0.071 N.S. | |

## DISCUSSION

Tooth fracture is regarded as an undesirable consequence of endodontically treated teeth. This refers to the loss of tooth structure due to caries or as a result of various endodontic interventions, including access cavity and canal preparations.[11] Therefore, preservation of the tooth structure not only improves fracture resistance but also safeguards its integrity.

In the majority of cases, if not all, it is necessary to enlarge the canal coronal to the fragment when attempting to remove fractured instruments. These procedures facilitate enhanced visualization of the separated instruments. Nevertheless, there have been studies signifying that the enlargement of canals and sacrifice of root dentin pose significant risks as the root becomes more susceptible to postoperative fracture.[6] Therefore, the current study evaluated the effects of two different retrieval techniques, namely the BTR Pen system and Zumax kit, on the fracture resistance of the mesial root canals of extracted human permanent mandibular molar teeth using the Universal testing machine.

The selection of mandibular molar teeth for the present study was based on their relatively low survival rates, which can be attributed to their heightened vulnerability to fracture and the significant stresses they experience during mastication.[23] Furthermore, the mesiobuccal root canals in the experimental group were selected due to their narrow diameter and their increased susceptibility to fracture.[24]

The standardization of samples has a significant impact on fracture resistance testing studies involving natural teeth.[25] Therefore, in the present study, decoronation of the roots was done to ensure consistent experimental conditions and to eliminate the potential influence of access cavity preparation and the coronal dentinal tooth structure on the fracture resistance of the tested specimens. This aligned with previous studies.[26-29]

In the present study, samples were embedded in acrylic resin blocks without periodontal simulation.

This was in line with Marchionatti et al[30] and Nawafleh et al[31] who reported that no significant difference in fracture load was observed between the groups that had PDL simulation and those that did not. Furthermore, according to Singla et al[32] teeth were vertically placed within acrylic blocks to precisely imitate the stresses experienced during mastication.

Accessing and removing the fractured instrument necessitates the removal of dentin, which can result in a substantial reduction in root fracture resistance. This could lead to the extraction of single-rooted teeth and the amputation or hemisection of multi-rooted teeth.[2] On the other hand, Minimal invasive endodontics is presently a topic of considerable clinical contention. Consequently, new retrieval kits and techniques are being introduced to the market with the aim of achieving this objective.

The broken tool remover (BTR) pen is a loop device designed to fit in narrow and curved root canals and has the capability of retrieval in cases of tightly wedged separated instruments. Dulundu and Helvacioglu-Yigit[6] assert that the BTR Pen system, with its shape memory, eliminates the need for excessive canal enlargement, allowing for effective positioning within narrow and curved root canals. In the present study, working tips with a 0.5 mm diameter containing a wire of 0.1mm were used to acquire the greatest amount of strength.

The present study used the Zumax kit retrieval system. This is a two-phase tube technique. The first aims to gain access in a straight line up to the broken instrument. This is achieved by trephine burs, available in three sizes: 0.8 mm, 1 mm, and 1.2 mm. In our study, the one mm trephine bur was selected because of its slightly larger maximum cross-sectional diameter relative to the visible coronal portion of the separated instrument. The next step in the Zumax kit involves carefully inserting an extractor into the previously created pathway of the trephine bur to remove the instrument. An inherent limitation of this technique is its incapacity to remove a fractured instrument positioned beyond a root canal curvature.

Nevertheless, it is important to note that the existing literature did not provide data regarding the comparison of the impact of these retrieval techniques on root fracture resistance.

The results of the present study revealed that there was a significant difference in the changes in the volume of the root canal space before and after instrument retrieval in the two studied groups. These findings could be explained by the fact that to firmly grasp the instrument during retrieval, approximately three mm of the fragment's coronal end had to be exposed.

Regarding the fracture resistance test, the results of this study revealed that there was no significant difference between the control group and the study groups or between the two studied groups after the retrieval of separated instruments. These findings are in line with Madarati et al[15] who reported minimal or no complications in comparable instances.

These findings could be attributed to the coronal positioning of the separated instrument, which may be considered as a limitation. Therefore, it is recommended to conduct further studies to assess the force required to fracture the root after retrieval of separated instruments from the middle or apical thirds. Another possible explanation for these findings is the preservation of the pericervical dentin, which extends 4 mm above and below the level of the alveolar bone.[33] This came in agreement with Shyma et al[34] who stated that excessive removal of irreplaceable pericervical dentin from the area surrounding the crestal bone may contribute to a weakened tooth structure and an increased likelihood of root fracture.

Given our findings, no correlation was found between the amount of tooth structure lost during retrieval and fracture resistance of teeth. The null hypothesis has been accepted because there is no difference in fracture resistance between the two techniques

## CONCLUSION

Within the limitations of this in vitro study, it could be concluded that retrieving separated instruments from the coronal third of the root canal is regarded as a safe procedure and has no impact on tooth fracture resistance.

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