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ORIGINAL ARTICLE

Evaluation of Dentine Structure Loss after Separated File Retrieval by Three Different Techniques: An *Ex-vivo* Study

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ABSTRACT

Objective: To evaluate the success rate of retrieving separated instrument, the root canal volume changes using cone-beam computed tomography and the retrieval time using Ruddle's technique, Terauchi file retrieval kit (TFRK) and Endo Rescue kit.

Methods: Sixty human mandibular first molars were selected, and a 4-mm portion of #25/.04 rotary files were separated in the middle third of moderately curved mesio-buccal canals. Teeth were randomly assigned into three groups (n=20): R group, in which separated files were retrieved according to Ruddle's technique; T group, in which separated files were retrieved using TFRK and E group, in which separated files were retrieved using Endo Rescue kit. Values were analyzed using IBM SPSS. Results presented as mean±standard deviation and 95% confidence interval for the root canal volume and time and frequency (%) for success rate. Comparisons of differences in time, canal volume and success rate between groups were assessed.

Results: Retrieval was successful in R and T groups (70% and 80% respectively) without any significant difference between them (p=0.715), while E group hadn't any successful samples (0.0%) with significant difference compared to R and T groups (p<0.001, p<0.001). E group showed the highest increase in canal volume followed by R group, while T group exhibited the lowest increase in canal volume. There was no significant difference in the mean retrieval time between R and T groups (p=0.815).

Conclusion: TFRK provides a more conservative way for retrieval of separated instrument from the middle third of moderately curved canals.

Keywords: Broken instrument, cone-beam computed tomography, dentine loss, instrument retrieval, ultrasonics

HIGHLIGHTS

- The fundamental goal of management of a separated instrument is not only to remove the fragment but also to preserve the tooth integrity.
- Trephine burs should not be used in retrieving of separated instrument beyond the curve.
- The use of loop device with the ultrasonics in separated instrument retrieval helps to preserve the dentine and increase the success rate.

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INTRODUCTION

Throughout the years, several developments occurred in endodontic instruments and approaches to optimize the root canal treatment. Introduction of nickel-titanium (NiTi) files in endodontics was a significant advancement (1). However, the high frequency of file fracture within root canals became a serious con-

cern among endodontists (2). If the fragment is located in the middle or coronal thirds of the canal, or before the curvature and there are favorable conditions, such as sufficient root dentine thickness, an attempt to remove the fragment may be suggested, so that the root canal system can be cleaned and shaped effectively (3).

Ruddle described a technique to remove fractured files that includes the use of a dental operating microscope, modified Gates-Glidden burs, and ultrasonic instruments (4). Terauchi et al. (5) claimed to reduce the amount of dentine loss and time needed for retrieval of the fractured fragment by using the Terauchi file retrieval kit (TFRK) (DELabs, Santa Barbara, CA, USA). Endo Rescue kit (Komet Dental, Braseler GmbH & Co. KG, Lemgo, Germany) is another system for removal of the file fragments, which has not been previously evaluated.

The fundamental goal of management of a separated instrument is not only to remove the fragment but also to preserve the tooth integrity (3). The remaining dentine is regarded to be a significant determinant in the long-term outcomes in general, as well as concerns like fracture and perforation in particular (6). The evaluation of remaining dentine can be achieved in a variety of ways, including periapical radiography, serial sectioning, micro-computed tomography (micro-CT) imaging, and cone-beam computed tomography (CBCT) imaging, according to the literature (7–9). Recently, endodontic research has applied micro-CT imaging (10). However, due to too high radiation dose and specimen size limitations, this approach is only suitable for laboratory application. Micro-CT and CBCT imaging had a comparable results in evaluation of dentine around the fractured instrument (11). CBCT imaging of dentine thickness prior or after a fractured instrument removal has become popular (1).

The present study aimed to evaluate the success rate of retrieving the fractured instrument, the root canal volume changes using CBCT and the retrieval time using Ruddle technique, TFRK and Endo Rescue kit. The null hypotheses were that there were no differences in success rate, changes in root canal volume, and time taken for retrieval among the different techniques.

MATERIALS AND METHODS

Samples Size Calculation

Sample size calculation was performed using the Raosoft software package and the single proportion method was used. By assuming that 50% of the test teeth were sufficient for experiment. Based upon the research made by Pruthi et al. (12), the required sample size was 20 teeth in each group at a 95% confidence interval and a 5% margin of error.

Samples Selection

This study was approved by the Research Ethics Committee of Minia University (Approved # 132; 11/9/2020). The study was conducted in accordance with the World Medical Association Declaration of Helsinki. Sixty extracted human mandibular first molars for periodontal reasons were collected from the outpatient clinic, Faculty of Dentistry, Minia University. Teeth with closed apices and mesial roots with type IV root canal configuration according to Vertucci classification (13) and mesio-buccal canals with an angle of curvature of 10°–20° as described by Schneider (14) and the ratio between the internal long diameter and the short diameter was <2 at a level of 5 mm from the apex were selected and stored in 0.1% thymol solution (Formula e Acao, Sao Paulo, SP, Brazil) till the time of use.

Samples Preparation

A conventional access cavity was prepared, and patency was ensured in the mesio-buccal canal using a K-file ISO size #10 (Dentsply-Maillefer, Ballaigues, Switzerland). Working length was determined visually by inserting a K-file #10 until the tip became visible at the apical foramen and then a 0.5 mm was subtracted from this measurement. A glide path was established using K-files #10 and #15 in the mesio-buccal canal. The coronal 3 mm of the canal was instrumented using Fanta Blue orifice opener file (#17/.12) (Shanghai Fanta Dental Materials Co. Ltd., China) with a copious irrigation of 10 ml of 6% sodium hypochlorite. Fanta Blue rotary file #25/.04 was then notched to half of the instrument thickness with a diamond disc at 4-mm from the tip and then it was introduced into the mesio-buccal canal at a speed of 350 rpm and a torque of 3N and rotated with pressure until separation. The mode of file fracture was a result of a combination of cyclic fatigue and torsional failures. After that, a periapical radiograph was taken to confirm the position of the separated instrument in the middle third of the canal.

All samples were embedded in a modeling wax blocks as they provided repetitive placement of the samples, thus facilitating reproducibility of pre- and post-retrieval CBCT scans (15) (Fig. 1). Then, a rubber base impression model of the CBCT x-ray machine bite block was taken with a space to fix the sample position (Fig. 2). A CBCT pre-operative scan was taken using Papaya 3D plus x-ray machine (Genoray, Gyeonggi-do, Republic of Korea) with a limited field of view image (40×50 mm) with a voxel size of 75 microns with parameters of 88 kVp, 8 mA, 7.7 sec. Volumetric analysis of the samples was obtained using Materialise Mimics software (Materialise nv, 3001 Leuven, Belgium) (Fig. 3).

Samples Classification

The teeth were randomly divided into 3 groups of 20 teeth each according to the technique used for removal of the separated fragment.

R Group

The separated files were retrieved according to the technique described by Ruddle (4). Stagging platform was achieved using modified Gates-Glidden #3 (Mani Inc, Tachigiken, Japan). Then, the ultrasonic tip ET25 (Satelec Corp, Merignac, Cedex, France) was used at the lowest power setting to trephine circumferentially in a counterclockwise direction to expose the coronal aspect of the file in dry conditions. This procedure was continued until the file was freed and retrieved by the ultrasonic tip.

T Group

The separated files were retrieved using Terauchi's file retrieval kit according to the manufacturer's instructions. Stag-

Figure 1. Tooth was fixed in a wax block

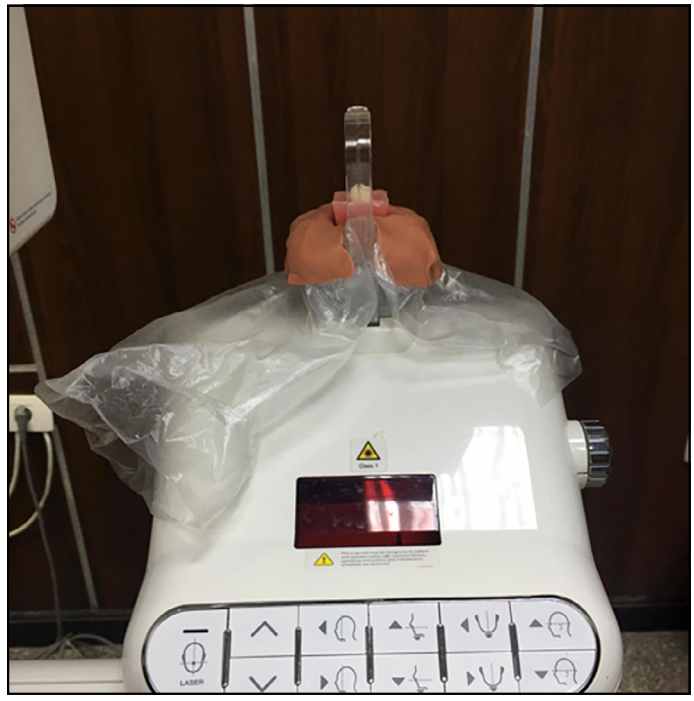

Figure 2. Mounting of the wax block in the x-ray machine using rubber base impression material to facilitate the pre and post replica of x ray image

ging platform was achieved using GG-3M. Then, TFRK-MT was used to expose the coronal 1 mm of the file in a counterclockwise rotation motion in a speed of 600 rpm. The ultrasonic tip TFRK-6 or TFRK-12 was used to cut a 90° semicircular space in the inner curve around the file which is then extended to 180° in a counterclockwise motion using TFRK-S ultrasonic tip at the lowest power setting in a dry field condition until the file was loosened. After that, the canal was filled with 17% EDTA solution and activation was done by using TFRK-S in a picking motion in the space created between the file and the inner curve of the canal wall for 10 seconds. If the file was not retrieved, the canal was dried, and TFRK-L loop device was used to grab the fragment to retrieve it.

E Group

The separated files were retrieved using Endo Rescue kit according to the manufacturer's instructions. Preparing a straight-line access to the file using G180 bur at a speed of 800 rpm. Then, exposure of the coronal part of the file was done using RKP bur at a speed of 300 rpm. After that, RKT bur was then used in a counterclockwise direction and a speed of 300 rpm to surround and seize the file to retrieve it.

The procedure of retrieval was performed by a single experienced endodontist who had practice on the techniques used before conducting the experiment and under a dental operating microscope (Magna Labomed, Labo America Inc., 920 Auburn Court Fremont, CA 94538, USA) at a magnification of 25X. Using a stop-watch timer, the time needed to complete

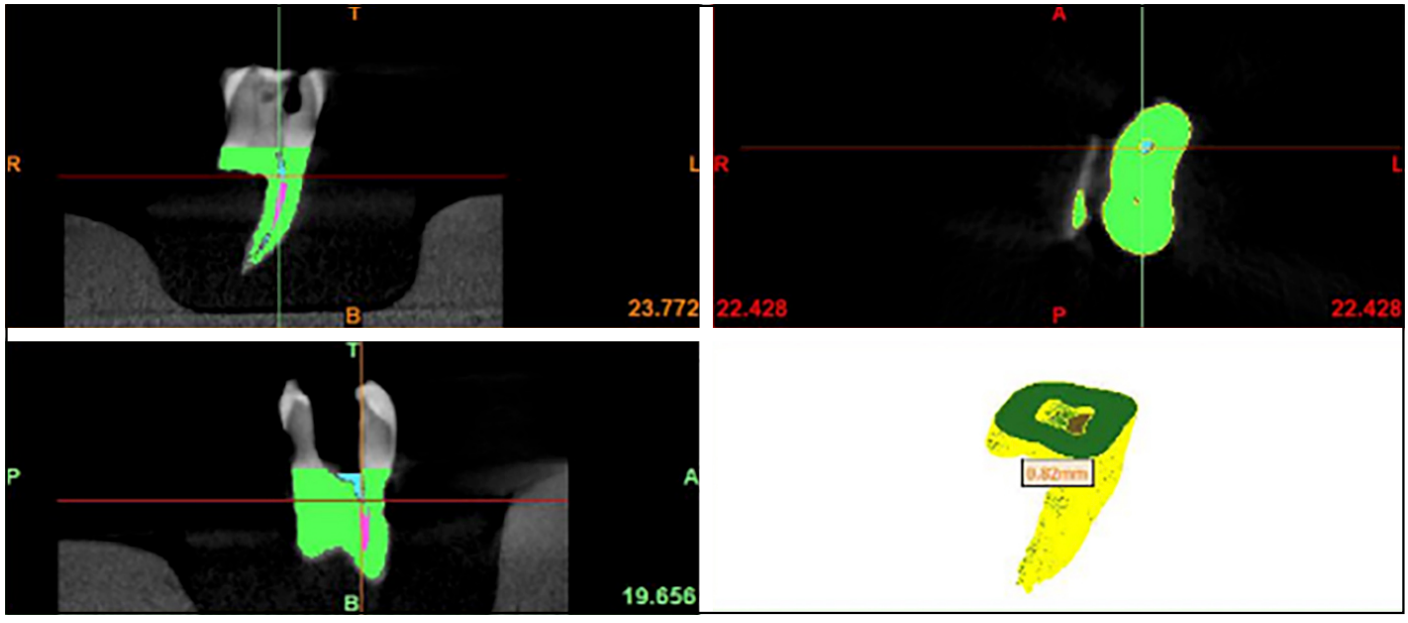

Figure 3. CBCT volumetric analysis of the root before file retrieval using Materialise Mimics software

CBCT: Cone-beam computed tomography

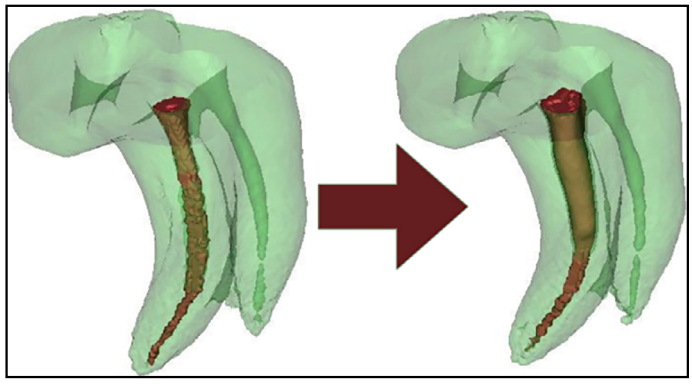

Figure 4. Examples of the 3D analysis of the mesio-buccal root canal volume before (left) and after (right) the file retrieval

the entire procedure was recorded, starting from the staging platform step until the retrieval was completed. When the separated fragment was not removed within 45 minutes, the trial was considered as a failure. Success percentage was calculated by the equation: (number of successful trials in each group/ teeth number of the same group) ×100.

A second post-operative CBCT scan was taken in all teeth using the same technique and parameters used for the pre-operative scan and volumetric analysis of the samples was obtained using Materialise Mimics software as in the pre-operative scan. Volumetric analyses were accomplished by an author other than the one who performed the retrieval, blinded to the groups. A comparison of the root canal volume measured in the CBCT before and after file retrieval was made. The tooth structure that was removed in the process was calculated as: volume of the root canal space in the CBCT analysis after retrieval – volume of root canal space in the CBCT analysis before retrieval (Fig. 4) (16).

Statistical Analysis

Values were analyzed using Statistical Package for Social Sciences (IBM SPSS, IBM Corp., Armonk, N.Y., USA). Results presented as mean±standard deviation and 95% confidence interval for the root canal volume and time. Frequency (%) for the success rate. Normality of data distributions were checked by Shapiro-Wilk Test. For normal distribution parametric values, unpaired student "*t*"-test were utilized to compare the time and One-Way ANOVA test followed by Tukey test for comparison of the canal volume, while Pearson Chi-square test utilized for comparing the success rate. P<0.05 was considered statistically significant.

RESULTS

The highest success rate was reported in T group followed by R group without any statistically significant difference between them, while E group showed no successful samples (Table 1). E group had a statistically significant higher increase in root canal space volume compared with R group and T group, which were statistically different between them (Table 2). There was no significant difference between the mean retrieval time in R and T groups, while time of group E was not recorded as there weren't any successful samples (Table 3).

DISCUSSION

The management of a fractured instrument is a challenging task that may be also important for the long-term success of endodontic therapy. One of the most crucial factors affecting the management of separated instruments retrieval is the canal curvature (2). One hundred percent of the attempts to retrieve instruments separated before the canal curvature have been reported to be successful (17), while the success rate was 60% and 31% for those which were at and beyond the curve respectively (18). Furthermore, the removal rates from canals with minimal curvature (<5°), moderate curvature (5–20°), and severe curvature (>20°) have been reported to be 100%, 83% and 43% respectively (19). Because of limited accessibility, smaller dimension, and root canal irregularities, the success rate in removing fractured instruments in mandibular molars has been reported to be lower than that in maxillary molars (19). According to a recent review, preparation and retrieval time in respect to canal curvature and file size are positively correlated with the length of the fractured instrument (2). For these reasons, in the present study a 4-mm portion was separated in the middle third of moderately curved mesio-buccal canals of mandibular first molars.

The use of dental operating microscope during file retrieval is of prime importance to avoid undue removal of dentine and further weakening of the root. As a consequence, all the procedures in the present study were conducted under the microscope at a magnification of 25X. This provided the best conditions possible in the attempt to preserve the tooth structure during retrieval attempts (20).

The technique described by Ruddle (4) for removal of intracanal fractured fragments was selected as it is widely considered the gold standard retrieval method (21–23). Terauchi et al. (5) developed a new system that includes a loop device in addition to ultrasonic tips and a trephine bur. It has been

TABLE 1. The success rate of separated fragment retrieval in the different groups

Success rate	R group (n=20)		T group (n=20)		E group (n=20)	
	n	%	n	%	n	%
Successful	14	70.0	16	80.0	0	0.0
Significance	–	–	*p=0.715		*p<0.001 **p<0.001	

*: Significant difference versus R group, **: Significant difference versus T group. R: Ruddle technique group, T: Terauchi's file retrieval kit group, E: Endo Rescue kit group

TABLE 2. Increase in root canal volume after retrieval procedure (mm^3) in the different groups

Root canal volume increase	R group (n=20)	T group (n=20)	E group (n=20)
Mean±SD	2.33±1.03	1.28±0.78	3.18±0.83
95% CI	1.85–2.61	0.91–1.64	2.79–3.57
Significance	–	*p<0.001	*p<0.001 **p<0.001

*: Significant difference versus R group, **: Significant difference versus T group. R: Ruddle technique group, T: Terauchi's file retrieval kit group, E: Endo Rescue kit group, SD: Standard deviation, CI: Confidence interval

TABLE 3. Time taken for file retrieval (min) in the different groups

Time taken for file retrieval	R group (n=14)	T group (n=16)	Significance (p)
Mean±SD	42.02±5.66	42.42±3.35	0.815
95% CI	38.75–45.29	40.63–44.20	

R: Ruddle technique group, T: Terauchi's file retrieval kit group, SD: Standard deviation, CI: Confidence interval

claimed that the broken fragment can be gripped in the loop device and removed without further canal enlargement if it still does not exit even after 0.7 mm of coronal exposure (5). The tube mechanics of Endo Rescue kit dictates the engagement of the file to a hole inside the tube; when the tube engages the fragment, it wedges and locks it in place.

The results of the present study revealed that R group had a success rate in file fragment removal of 70%. This was in line with results by Ward et al. (24), Alomairy et al. (20), Shehabinejad et al. (25) and Terauchi et al. (21). The success rate found for T group was 80% and this was in agreement with Terauchi et al. (21), Pruthi et al. (12) and Kumar et al. (26). However, the difference between R and T groups was not statistically significant, being these findings in agreement with Terauchi et al. (21), Pruthi et al. (12) and Kumar et al. (26). In the present study, the statistically lower success rate reported in E group was probably because after removing the dentine around the coronal segment of the fragment to expose it to the tube, the bur cut into the file itself from one side causing secondary fracture of the file.

For root canal volume measurements, T group had a significantly lower increase in the overall mean root canal volume (1.28±0.78 mm^3), if compared with R group (2.33±1.03 mm^3). This was in agreement with Terauchi et al. (21) and Kumar et al. (26). The volume changes in the E group were the largest (3.18±0.83 mm^3), because of the additional space required for the tube. However, this result was not in agreement with Yang et al. (23), who stated that trephine bur group had a lesser canal volume increase compared to ultrasonic group. The difference may be due to the use of microtube technique in both groups in their study. CBCT was used in the current study, although its lower image resolution compared to micro-CT, to stimulate the clinical situation.

In order to avoid operator fatigue, secondary fracture, or excessive dentine removal that could result in fracture or perforation, Souter et al. (27) suggested scheduling the removal of the fractured fragments to take place over the course of 45 to 60 minutes. The present study showed that there was no significant difference in retrieval time between R and T groups. This was in agreement with Pruthi et al. (12) and Kumar et al. (26). While, it was not in agreement with Terauchi et al. (21), who stated that TFRK required significant less time than Ruddle's technique. This might be attributed to the different teeth type used, as mandibular incisors were selected in their study. Because of their more complex canal anatomy, posterior teeth could present a greater challenge for instrument retrieval than anterior teeth (2).

In the present study, the null hypotheses is rejected, as there was a significant difference among the three study groups regarding the success rate, the root canal volume changes and the time needed for retrieval.

CONCLUSION

Under the conditions of the current *ex-vivo* study, it can be concluded that TFRK provides a more conservative way for retrieval of a separated instrument from the middle third of moderately curved canals. Future clinical trials using TFRK are required.

Disclosures

Conflict of interest: The authors deny any conflict of interest.

Ethics Committee Approval: This study was approved by The Minia University Faculty of Dentistry Research Ethics Committee (Date: 11/09/2020, Number # 132).

Peer-review: Externally peer-reviewed.

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Authorship contributions: Concept – M.A.A., E.E.S.H., M.T.; Design – M.A.A., M.T.; Supervision – G.P., E.E.S.H.; Data collection and/or processing – M.A.A., M.T.; Analysis and/or interpretation – M.A.A.; Literature search – M.A.A.; Writing – M.A.A., G.P., M.T.; Critical Review – G.P., E.E.S.H.

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