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Comparative Evaluation of Different Techniques and Devices for Removal of Intra Canal Separated Instruments with Different Lengths (An In Vitro Study)

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Aim: To evaluate the success rate, retrieval time, and root canal volume changes after retrieval of long and short-separated instruments using Zumax retrieval kit, BTR pen, and ultrasonic.
Materials and Methods: Ninety Race rotary files #30/.04 were intentionally separated apically in the mesiobuccal canals of mandibular molars. Samples were divided into three groups (n=30) according to instrument retrieval device; Group (1) Zumax kit, Group (2) BTR pen, and Group (3) Ultrasonic. Each group was subdivided into two subgroups (n=15) according to the length of the separated files ;3 mm or 6 mm. CBCT scans were performed before and after retrieval to evaluate dentine volume changes. Chi-square and two-way ANOVA tests at a level of significance of 0.05 analyzed the data.
Results: No significant differences were detected among the three groups regarding the success rate ($P>0.05$). Ultrasonic required significantly more time than Zumax kit and BTR during retrieving the long fragments($P<0.05$). BTR pen required more time significantly than ultrasonic and Zumax kit to retrieve the short fragments($P<0.05$). The volume of the removed dentine was significantly higher utilizing Zumax kit than BTR pen and ultrasonic($P<0.05$). Zumax kit removed more dentine significantly while retrieving short fragments.
Conclusion: Within the limitation of the present study, BTR pen provided a more conservative method for retrieving long-separated instruments, while ultrasonic technique could be used solely in the retrieval of short-separated fragments for more conservative instrument retrieval. Zumax retrieval kit removed more dentine, especially with short fragments.

Keywords: Broken instrument, dentine loss, instrument retrieval, ultrasonics.

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Introduction

Nickel-titanium (NiTi) rotary files can create smooth well-centered, and minimally transported canals with minimal mishaps.[1] Separation of rotary NiTi instruments has become a major concern as they may fracture due to either cyclic fatigue or as a result of torsional overloading. Cyclic fatigue stems from the metal undergoing repeated extension and compression during rotation around a curve. Conversely, torsional failure arises when the file's tip binds to the apical portion of the canal while the motor remains in motion.[2,3] When an instrument fracture has occurred, the best treatment is to remove it to allow adequate space for disinfection of root canal space and improve the treatment outcome.

Retrieval of the separated instruments is a favorable option enabling adequate debridement of the root canal system.[4] The most common retrieval techniques for separated instruments are ultrasonics, tube technique, and loop technique.[5] The primary concern while handling separated instruments is not only the retrieval of the instrument but also the preservation of the root's integrity.[6]

Complications during retrieval procedures might affect the prognosis of the final treatment, so successful retrieval chances must be balanced with suggested complications.[7]

This study was performed to compare the success rate, the retrieval time, and volume of removed dentine after retrieving separated instruments (short and long separated fragments) utilizing the Zumax broken instrument removal kit (Zumax, medical co., LTD. China), BTR pen (Cerkamed, Stalowa Wola, Poland) and ET25 ultrasonic tips (Satelec, Merignac, France). The null hypotheses assumed no differences in success rate, removed dentine, and retrieval time among the different techniques either with long or short fragments.

Materials and methods

Ethical consideration

The study was affirmed by the Research Ethics Committee of the Faculty of Dentistry, Mansoura University (Approved # M02050422; 17/3/2022). All the procedures of the study were conducted following the ethical standards of the Declaration of Helsinki.

Sample selection

Based on previous studies[8,9], power calculations were performed by G*Power 3.1 (Heinrich Heine University, Dusseldorf, Germany) at a test power of 90% and α=0.05 resulting in a total sample size of 90 teeth (15 teeth in each sub-group).

Ninety human mandibular first molars with closed apices extracted for periodontal reasons were selected for this study from the outpatient clinic, Faculty of Dentistry, Mansoura University. All teeth were ultrasonically cleaned and stored in a thymol solution.[10] The sample was examined with a dental operating microscope (Alltion AM-2000, Wuzhou City, Guangxi Province, China) to replace molars with root caries, fractures, or cracks. Only mesial roots with type IV Vertucci classification[11], and a 10°–20° angle of curvature were selected.[12]

Sample preparation

Access cavity preparation was performed in all samples followed by gaining patency of the mesiobuccal canals using K-file ISO size #10 (Dentsply-Maillefer, Ballaigues, Switzerland) for each tooth. The mesiobuccal canal working length was established by inserting k-file size #10 until it flushed with the apex and subtracting 1 mm from the file length. Instrumentation to the mesiobuccal canals using Race rotary files (FKG Swiss endo) up to size #20/.04 and copious irrigation with 6% sodium hypochlorite.

Ninety Race rotary files size #30/0.04 were notched to a depth of half the instrument thickness using a low-speed 0.3-mm thick

diamond disk.[10] Forty-five roots were notched at 3 mm (short fragment), and the rest of the samples at 6 mm (long fragment) from the file tip. Notched files were introduced into the mesiobuccal canals with a speed of 600 rpm, the torque was adjusted at 3N and then rotated with pressure till the occurrence of the separation. A periapical radiograph was performed for each molar to ensure the location of the fractured file in the apical portion of the mesiobuccal canal. Any mesiobuccal canal with a fractured file not in the apical portion was excluded and replaced. Following confirmation of the separated instrument position, all samples were embedded in a rubber base mold individually to facilitate handling and manipulation. CBCT scan was performed for the whole sample before retrieval procedures using (Morita 3D x-ray machine, Japan) by the limited field of view (40×40 mm), voxel size (80 microns), and parameters of 100kVp, 8 mA, 17.9 sec.

Sample classification

The samples were randomly allocated into three groups (n=30) according to the retrieval method. Each group was subdivided into two sub-groups (n=15) according to the length of the separated fragment sub-group (A) containing molars with long fragments;6mm and sub-group (B) containing molars with short fragments;3mm.

Group 1(n=30)

The separated files were retrieved using a Zumax broken instrument removal kit (Zumax Medical Co., Ltd, Suzhou, China). Gates-Glidden #2 and #3 (Mani Inc, Tachigiken, Japan) were modified by a high-speed diamond bur to cut off their tips at the maximum cross-section diameter, to create end-cutting drills.[13] The preparation of the staging platform using modified Gates was performed by Glidden #2 and #3 till the coronal tip of the separated instrument. A micro-trepan bur size (0.8 mm) was used to cut the dentin counterclockwise at 500-1000 rpm around the separated fragment with (0.5mm) depth each time until (1.5-2 mm) of the separated instrument was exposed. The corresponding extractor size of the same trepan bur was applied into the root canal to the site where the micro-trepan bur ended and was locked to grip the separated fragment and remove it.[14]

Group 2 (n=30)

BTR Pen (Cerkamed, Stalowa Wola, Poland) was used to retrieve the separated files. Modified Gates-Glidden sizes #2 and #3 were used to achieve the staging platform. Trephination in a counterclockwise direction by ultrasonic tips ET25 (Satelec Corp, Merignac, Cedex, France) exposing the most coronal part of the fractured file in a dry condition.[15] The power setting of the ultrasonic device Newtron P5 (Satelec Corp) was adjusted to 7.[10] Working tips with a 0.3 mm diameter containing a nitinol wire of 0.1mm were used. The loop was bent to 45° to enhance the application over the fractured instrument. The loop was applied inside the canal and pushed back to 90° upon the separated instrument, then tightened around the released separated instrument and pulled to retrieve it.[13]

Group 3(n=30)

Ultrasonic tips ET25 (Satelec, Merignac, France) were utilized for retrieving the separated files. The staging platform and preparatory phase were performed as described formerly. Instrument retrieval attempts were carried out in wet conditions utilizing EDTA with the ultrasonic tip that was inserted in the space on the inner wall and activated continuously at a power setting 10%–20% more than that used in the preparatory phase, with up-and-down strokes until the fractured instrument was retrieved.[16]

A periapical radiograph after retrieval was performed for every sample to ensure complete file retrieval.

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Post-retrieval CBCT scan

The post-retrieval CBCT was performed utilizing the same parameters and techniques as the preoperative CBCT and then the volumetric analysis was established.

Methods of evaluation

a) Success rate

Success was defined as the complete retrieval of the separated instrument within 45 minutes without perforation.(9,13)The calculation of the success percentage by the equation: (successful trials number in group/ teeth number in the same group) ×100.

b) Retrieval time

A stopwatch timer was used to record the time of the retrieval procedure, beginning from the preparation of the staging platform until the retrieval of the separated instrument successfully, with a maximum time of 45 minutes. The procedure was unsuccessful if it exceeded 45 minutes.[9]

b) Root canal volume changes

For volume analysis, each sample's preoperative and postoperative scans were registered using the ITKSNAP software (Rigid transformation model by mutual information, coarsest level set at ×4 and finest level at ×2). The volume of interest from the mesiobuccal canal orifice to the root apex was segmented in retrieval from the CBCT analysis by a blinded observer to the groups rather than the one who performed the retrieval (Figure 1).[17]

Figure 1: Segmentation for the mesiobuccal root canal to measure the dentine volume loss using ITKSNAP software.

Statistical analysis:

Values were analyzed using GraphPad Prism (version 10, GraphPad Software, San Diego, CA, USA). The normality of data distribution was confirmed by the Shapiro-Wilk test. The success rate was statistically analyzed using the Chi-Square Test. As the data was normally distributed, a two-way ANOVA test followed by the Post hoc Tuckey's test was utilized to compare means and standard deviation regarding the time of instrument retrieval and the removed dentine thickness. The level of statistical significance was set at $P<0.05$.

Results

Data statistics are detailed in (Tables 1-3) and illustrated in (Figure 2). No significant differences regarding the success rate between the three tested groups or between short or long fragments (P>0.05) (Table 1).

Regarding the retrieval time, a significant effect for tool type, fractured fragment length, and their interaction was observed. (p<0.05).

Regarding the time required for instrument retrieval, the ultrasonic technique significantly required more time than the other two groups in retrieving the long-separated fragments (P<0.001). In retrieving short ones, the BTR pen required significantly more time than the other two groups (P<0.001) (Table 2)

According to the volume of removed dentine, a significant effect for tool type(P=0.001) and fractured fragment length(P=0.04), and no significant effect was found for their interaction (P=0.17). The Zumax kit removed more dentine significantly than the other two groups (P=0.014). Retrieving short separated fragments with the Zumax kit significantly removed more dentine than long ones (p<0. 001) (Table 3).

Table 1: Showed the number and frequency of success(S) and failure (F) of retrieval of long and short-separated fragments among different test groups.

	Long fragment		Short fragment		Total	
Success (S)\\ Failure (F)	S	F	S	F	S	F
Zumax (n=30)	12 (80%)	3 (20%)	13 (86.7%)	2 (13.3%)	25 (83.3%)	5 (16.7)
BTR Pen (n=30)	15 (100%)	0 (0%)	11 (73.4%)	4 (26.6%)	26 (86.7%)	4 (13.3%)
Ultrasonic (n=30)	13 (86.7%)	2 (13.3%)	12 (80%)	3 (20%)	25 (83.3%)	5 (16.7%)
P value	0.207		0.659		0.918	

Statistically significant at $p < 0.05$

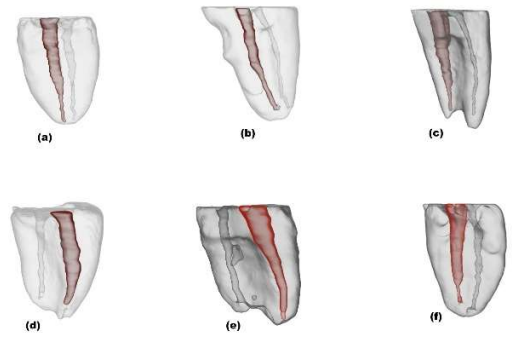

Figure 3: Segmented root canal representing the volume of dentine loss after retrieval. (a) ultrasonic with a long-separated fragment. (b) BTR pen with a long-separated fragment. (c) Zumax kit with a long-separated fragment. (d) ultrasonic with a short-separated fragment. (e) BTR pen with a short-separated fragment. (f) Zumax kit with a short-separated fragment.

TABLE 2: Mean ± SD of Time needed for retrieval procedure (min) within different groups

	Zumax (n=25)		BTR-pen (n=26)		US (n=25)		P value
Long	22.63^{Aa} ±6.37	(n=12)	20.90^{Aa} ± 0.99	(n=15)	33.44^{Bb} ± 2.404	(n=13)	0.0001
Short	19.78^{Aa} ±1.30	(n=13)	39.57^{Bc} ± 2.51	(n=11)	24.13^{Ab} ± 2.85	(n=12)	0.0001
Significance	$p = 0.06$		$p < 0.001$		$p < 0.001$		

Statistically significant at $p < 0.05$
Different upper case super scripts indicate significance in same columns
Different lower case super scripts indicate significance in the same rows.

Table 3: Mean ± SD of dentine volume changes after retrieval procedures (mm^3) within different groups (Long vs Short)

	Zumax (n=30)		BTR-pen (n=30)		US (n=30)		P value
Long	8.97^{Ab} ± 3.59	(n=15)	4.69^{Aa} ± 0.99	(n=15)	5.19^{Aa} ± 2.407	(n=15)	0.0089
Short	12.21^{Bb} ±2.65	(n=15)	6.32^{Aa} ± 2.51	(n=15)	4.97^{Aa} ± 2.63	(n=15)	0.0001
Significance	$p = 0.0145$		$p = 2082$		$p = 0.867$		

Discussion

There is a high demand for retrieving NiTi-separated files, and no specific procedure for successful retrieval has been approved.[7] However, dentin removal is a common practice in fractured instrument retrieval due to the anatomy of radicular spaces. As the preservation of root integrity is a significant predictor of long-term survival, a risk-benefit approach considering remaining dentin volume and incidence of perforation and not success alone, is integral to long-term success in retrieval cases success[18,19], so different techniques and devices resulted in higher success, shorter retrieval time, and minimum dentine removal should be considered.[20]

To our knowledge, limited data are available regarding the influence of the separated fragment length on the success rate of these retrieval techniques. Therefore, the present study was conducted to evaluate the success rate, retrieval time, and volume of the removed dentine after retrieval of separated instruments utilizing different techniques, Zumax retrieval kit, BTR pen, and ultrasonic

with different separated fragment lengths in the apical portion of the root canal.

This study utilized buccal canals of mandibular molars mesial roots as the highest frequency of separated instruments was presented, especially in the apical part.[21] Additionally, these canals are frequently narrow and thin, so there is a high risk of instrument separation and perforation during retrieval procedures.[7]

The present study indicated that there is no significant difference regarding the success rate of retrieving the separated instruments between the three techniques with different fragment length. Our study results followed the results of Shen et al.[22] as they reported that the length of the separated fragment didn't significantly affect the success rate of retrieving the separated instrument. On the contrary, a significantly higher success rate when dealing with long-separated fragments than short ones was reported[7]. A possible explanation of that report is they considered bypassing the separated fragment a successful criterion. Using the ultrasonic tips in separated instrument retrieval was discussed with variable success rates in several in vitro studies.[20,23–27] Our results followed the previous results[13,28,8,29], but it did not follow the results conducted by Abdeen et al.[9] as they reported that the tube technique has a significantly lower success rate during retrieving of separated instruments than ultrasonic and Loop techniques. This might be due to the different diameter sizes of the trepan bur used as the bur cut into the separated file, causing a secondary fracture.
Regarding the retrieval time of long-separated fragments, significantly more time was needed using the ultrasonic method than the other groups. This may be attributed to greater dentine engagement with long-separated files, so the ultrasonic vibrations alone were insufficient to release the separated fragment's whole length. Therefore, using a grasping tool like a loop or tube after trephination might be more time-saving and beneficial. This followed the results of Terauchi et al.[16] who reported that retrieving separated instruments longer than 5.7 mm was very difficult and time-consuming using ultrasonics alone, and it's better to use a grasping tool after the preparatory phase as a loop device. In contrast, our results indicated that the ultrasonic and the Zumax kit required significantly less time than the BTR pen for retrieving short-separated fragments. In the present study, much time was needed to remove sufficient dentine to create enough space for the wire loop application around the coronal part of an apical short-separated instrument. On the other hand, the Zumax kit trepan's bur could remove an adequate amount of dentine quickly in a short time, and the extractors could grasp the separated fragment accurately. The trepan bur needed significantly less time than ultrasonics while retrieving the separated instruments.[10] Terauchi et al.[16] reported that most separated instruments shorter than 4.6 mm can be removed only with ultrasonics by filling the canal with EDTA during the retrieval process after the preparatory phase to take the opportunity of cavitation and acoustic streaming to encourage instrument retrieval.[16]

The volume of the removed dentine is critical in evaluating the ability of the tooth to survive mechanical preparation and obturation completion without more complications.[8] According to the volume of the removed dentine in our study, the Zumax kit removed significantly more dentine than both the ultrasonic and the BTR pen. No significant differences were found between the ultrasonic and the BTR pen. The Zumax kit removed more dentine significantly while retrieving short-separated fragments than long ones. The increase in the volume of the removed dentine using the Zumax kit might

be due to the large diameter size of the trepan bur and the lack of visibility while utilizing it. When retrieving short fragments apically, the trepan bur went deeper to reach the coronal part of the separated fragments, which might result in more dentine removal. Our results followed previous research.[31,32,9,28] In contrast, Faus-Matoses et al.[30] reported in a study that there were no significant differences in the amount of removed dentine using the ultrasonic and tube techniques. Their results did not follow the results of this study, and this might be due to the smaller diameter of the trepan bur used in their study(0.7mm) than the size (0.8) of the trepan bur used in this study.

The null hypothesis in the present study was rejected because significant differences were found between the evaluated retrieval methods regarding retrieval time and dentine volume changes. However, the groups had no significant difference in the success rate, but the technique of removal of the separated instrument depended on the clinical scenario.

Conclusion

The BTR pen provided a more conservative method for retrieving long-separated instruments. Ultrasonic could be used solely in the retrieval of short-separated fragments. The Zumax retrieval kit removed more dentine, especially with short-separated fragments apically.

Declarations

Funding

This research was totally funded by the authors.

Availability of data and materials

The datasets used and/or analyzed during the current study are available from the corresponding author upon reasonable request.

Competing interests

The authors declare that there is no conflict of interest.

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