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EFFICACY OF TWO SEPARATED FILE REMOVAL SYSTEMS. (A COMPARATIVE IN VITRO STUDY)

Farah Tarek Barakat * *and* Muhammad Ibrahim Attia**

ABSTRACT

Purpose: to compare the success rate of BTR-pen system versus Zumax kit in retrieval of separated rotary files, retrieval time, and root canal volume changes.

Materials and Methods: Forty mandibular first molar teeth were selected. Five mm of ProTaper Next X2 rotary files were separated in the mesiobuccal canals. Teeth were randomly assigned into two experimental groups according to the file removal system used, 20 each. In group A, the broken tool remover (BTR) pen system was employed for the retrieval of separated instruments, and in group B, the Zumax kit was utilized for the retrieval of separated instruments. The evaluation methods included success rate, volumetric changes of the root canal using Cone Beam Computed Tomography (CBCT), and retrieval time. Values were analyzed using IBM SPSS, and comparisons of differences in retrieval success rate were done by Chi-square test, while changes in retrieval time between groups were assessed by student t-test.

Results: The success rate of the separated fragment retrieval in groups A and B was 80% and 90%, respectively, with no significant difference (P = 0.31) between them. There was a significant increase (P=0.001) in canal volume in both groups. Group A showed significantly less increase (P=0.0051) in the root canal volume than Group B. The time consumed for successful removal of the fragment was significantly higher (P=0.001) in the BTR group (29.53±3.69) than in the Zumax group (22.88±7.15).

Conclusions: Both the BTR-Pen system and Zumax kit are successful in the retrieval of separated rotary files.

KEYWORDS: Loop technique, Separated files, Tube technique.

* Instructor, Department of Endodontics, Pharos University, Alexandria, Egypt
** Assistant Professor, Department of Endodontics, Pharos University in Alexandria, Egypt

INTRODUCTION

Over the years, significant progress has been achieved in instruments and techniques aimed at enhancing the efficacy of root canal treatment. One significant advancement that revolutionized the field of endodontics was the introduction of Nickel-Titanium (NiTi) instruments. These files have the capability to produce easier, faster, more tapered preparations with fewer procedural errors, and a remarkable ability to shape and prepare root canals, especially those with moderate and severe curvature. [1]

There have been constant developments in the manufacturing procedures and design features of these instruments to improve their efficiency in root canal preparation. Nevertheless, a notable drawback associated with these NiTi files is their tendency to fracture suddenly without warning.[2] In instances when this circumstance exists, the procedure of removing the instrument is deemed to be more desirable in comparison to leaving it within the canal.[3] Conversely, it is a difficult procedure that necessitates training, expertise, and understanding of the available methods and techniques.

Even though there is no standardized technique for predictable management of instrument separation, there are different approaches to overcome this mishap with variable levels of efficiency. One of the most prevalent techniques is the employment of a dental operating microscope in conjunction with ultrasonic tips.[4] This method entails trephining the dentin around the broken file in anticlockwise motion with specially made tips until the separated instrument becomes loose and jumps out of the canal.

Nevares et al[5] showed that the employment of ultrasonic tips resulted in the successful removal of 85.3% of visible separated instruments, whereas only 47.7% of nonvisible instrument fragments had been removed. Another study reported a success rate of 55% in removing separated instruments using the Masserann kit. However, it was found that this kit resulted in significant removal of dentin and was deemed to have limited effectiveness in posterior teeth with thin and curved roots.[6]

The broken tool remover (BTR) pen, a tool with thin and flexible working tips, is a popular loop technique that is said to increase retrieval effectiveness so that broken instruments can be grasped to the greatest extent possible**.** Because of its shape memory, it can be placed in small and curved root canals without requiring extensive canal enlargement.[7] The functionality of the tool is determined by three variants of working tips, which, depending on the size, are distinguished by different loop strengths.

The Zumax broken instrument removal kit is a tube technique, which entraps and pulls out the fragment. This system consists of an extractor, a tweezer with a crab-claw tip, and trephine burs of three different sizes.[8]

The occurrence of procedural mishaps, such as root perforation or reduced root strength leading to vertical root fracture, may arise as a consequence of excessive enlargement during retrieval. Therefore, the fundamental goal of management of a separated instrument is not only to remove the fragment but also to preserve the tooth integrity. The assessment of the dentin loss is considered a crucial factor in predicting long-term outcomes. Different techniques can be employed to evaluate it, such as periapical digital radiography, micro-computed tomography (micro-CT) imaging, and cone beam computed tomography (CBCT) imaging. [9, 10].However, the utilization of CBCT for the assessment of root canal volume changes has gained significant traction in the field.[11]

The goal of this in-vitro study was to evaluate the success rate of BTR-pen system versus Zumax kit in retrieval of separated rotary files, retrieval time, root canal volume changes. The null hypothesis in this study assumed that there is no difference in success

rate, time taken for retrieval or root canal volume changes between the two techniques.

MATERIALS AND METHODS

This was a comparative in vitro study that was conducted on forty mandibular first molar teeth that were collected from the oral and maxillofacial department at Pharos University.

Specimens Selection and Preparation

Teeth that had closed apices, mesial roots with a root canal configuration of type IV according to the Vertucci classification,[12] and mesiobuccal canals with an angle of curvature ranging from 25° to 45° measured according to Schneider's technique[13] were included. A conventional endodontic access cavity was done. A stainless-steel K-file #10 (M access, Dentsply Mailliefer, Ballaigues, Switzerland) was inserted into the mesiobuccal canal until the tip was visible through the apical foramen to ensure apical patency then one mm was deducted for working length establishment. Specimens were mounted in acrylic resin blocks and a glide path was established using a stainless-steel hand #10 and #15 in the mesiobuccal canal. The mesiobuccal canal was instrumented to the full working length by ProTaper Next X1 rotary file (Dentsply Sirona, USA). Between each file and the subsequent, copious irrigation of 5ml of 6% sodium hypochlorite was accomplished using a 30-gauge side-vented closed-end irrigation needle placed one mm shorter than the working length and the final irrigation was performed using EDTA solution.

Instrument separation inside the root canal

The ProTaper Next X2 rotary file was partially notched to half of the instrument thickness with a diamond disc mounted on a low-speed handpiece, as per Faus-Matoses et al. [14], at 5mm 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 until separation at a depth of three mm apical to the canal orifice to be visible under the DOM.

Post-instrument fracture imaging (CBCT scan I)

Before taking CBCT scans, the specimens were inserted into custom-made rubber base blocks to provide repetitive placement of the samples thus facilitating the reproducibility of pre- and post-retrieval CBCT scans. The CBCT images were acquired with J Morita Veraview X800 imaging device. The scan was done with a field of view of width 80mm X height 80mm. The volume was reconstructed with 0.2m voxel size. The tube voltage was 75 KVP and 7 mA with an exposure time of 17 seconds. The CBCT images were exported as Digital Imaging and Communications in Medicine (DICOM) files. Consequently, they were imported into Materialise Mimics software to perform volumetric analysis of the mesiobuccal canals.

Grouping

Samples containing the separated files were randomly divided into two experimental groups of 20 each according to the retrieval method as follows: Group A in which separated files were retrieved by BTR-Pen system (Cerkamed, Stalowa Wola, Polska) and Group B in which separated instruments were retrieved by zumax kit (Zumax Medical Co., Ltd., Jiangsu, China).

Retrieval of the separated files

The procedure of retrieval was carried out under a dental operating microscope (Carl-Zeiss Meditec, Jena- Germany) at a magnification of 17X. Using a stop-watch timer, the time needed to complete the entire procedure was recorded, starting from the staging platform step until the retrieval was completed, and the allotted time limit was 45 minutes. The trial was considered unsuccessful if the separated fragment wasn't removed within 45 minutes.

Group A

The assembly of the BTR pen was done according to the manufacturer instructions (Figure 1). A circumferential staging platform was created by modified Gates Glidden drills #2, #3, and #4 (Mani Inc, Tachigiken, Japan) to establish straight line access and increase the visibility of the broken instrument[15]. A Terauchi straight ultrasonic tip (TERAUCHI CO, LTD, Osaka, Japan) was used to trough the dentin circumferentially in counterclockwise direction around the fragment for approximately three mm. All ultrasonic work inside the root canal was conducted in a dry environment[16]. To blow away dentinal dust, the canal was filled with EDTA solution and Stropko irrigator (DCI, International, Newberg, OR) was used for a direct stream of air for clear microscopic vision. Working tips of 0.5mm diameter with a 0.1mm diameter nitinol loop were used. The loop was placed and squeezed over the exposed coronal aspect of the broken file. After tightly grasping the separated file, it was loosened by making side moves with the BTR pen and it was removed from the canal by pulling the BTR pen (Figure 2).

Group B

Modified Gates Glidden drills were used to create a staging platform. Afterward, Terauchi straight ultrasonic tip was used to trough the dentin around the head of the separated file for approximately one mm. A one mm trephine bur was used first manually in a counterclockwise direction to secure a grip. Subsequently, it was operated on endodontic motor and rotated in a counterclockwise direction at a speed of 1000 rpm, according to the manufacturer's instructions, to remove the dentine around the fractured segment, exposing the coronal aspect of the fragment for approximately three mm. The one mm extractor was attached to the handle, placed above the exposed coronal part of the file, and the fragment was clamped by mechanically locking the instruments in the lumen of the extractor with a metal wedge then the handle and the extractor were pulled together until the file was retrieved (Figure 3).

Fig. (1) Setup of the btr pen

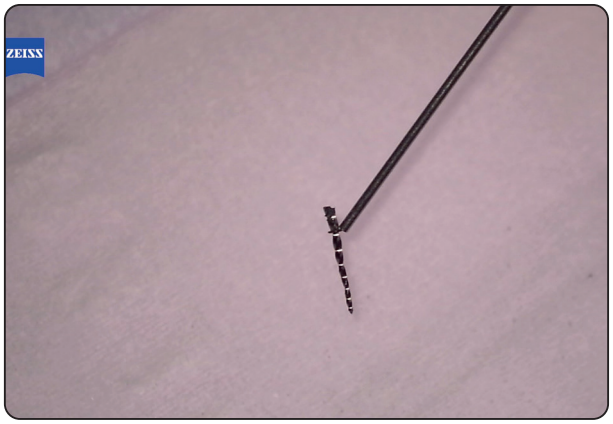

Fig. (2) Retrieval of the separated file by BTR Pen

Fig. (3) The separated file wedged inside the extractor

Post-retrieval CBCT scan (CBCT II)

The post-retrieval CBCT was carried out using the same technique and parameters as the preoperative CBCT scan and by using the Materialise Mimics software, volumetric analysis of the samples was established.

Methods of evaluation

a) Success rate

The success rate was calculated as follows: The number of successful trials in each group divided by the number of teeth in the same group was multiplied by 100 to determine the success percentage.

b) Root canal volume changes

The tooth structure that was removed in 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).

c) Retrieval time

A stopwatch timer was used to record the duration of the retrieval procedure, starting from the staging platform preparation until the time the instrument was successfully retrieved, with a maximum time of 45 minutes. The procedure was deemed unsuccessful if it exceeded a duration of 45 minutes.

Statistical analysis

Values were analyzed using Statistical Package for Social Sciences (SPSS) (IBM SPSS, IBM Corp., Armonk, N.Y., USA) version 24.0. The Shapiro–Wilk test was used to test of normality of data, the data of Fracture resistance was parametric data, the Kolmogorov-Smirnov and Shapiro–Wilk had p-value>0.05. Quantitative data were described using mean and standard deviation for normally distributed data. Qualitative data were described using number and percentage. Comparison between different groups regarding categorical variables was tested using Chi-square (X^2) test. For normally distributed data, comparison between two independent populations was done using independent t-test. Significance test results are quoted as two-tailed probabilities. The significance of the obtained results was judged at the 5% level.

RESULTS

The success rate in zumax group (n=18, 90%) was higher than the BTR group (n=16, 80%). However, there was no significant difference (P=0.31) between the two groups (Table 1).

TABLE (1) Comparison between the two studied groups regarding success rate.

Success rate	BTR group		Zumax group	
	No.	%	No.	%
Success	16	80.0	18	90.0
Failed	4	20.0	2	10.0
X^2 -test	1.58			
p-value	0.314 N.S.			

Increase in the root canal space during retrieval procedure was measured in cubic millimeter 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 similar trend was also observed in Group B (Zumax group), in which the root canal volume post-retrieval was significantly 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.

In addition, the difference in means in pre- and post-retrieval was calculated and was 1.526±0.29 versus 3.098±0.789 in the BTR group and Zumax group, respectively. The cross-comparison of the difference in means was statistically significant

(P=0.0051). The effect difference in the BTR group was lower than in the Zumax group (40.62% and 81.62%), respectively (Table 2).

The mean retrieval time ± S.D in group A (BTR group) was 29.56±3.69 while in group B (Zumax group), the meantime ± S.D was 22.88±7.15, with significant difference between the two groups (P=0.001) (Table 3).

TABLE (2) 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 (3) Comparison between the two studied groups regarding the time (min.) for retrieval.

Time for retrieval (min.)	**BTR group**	**Zumax group**
Min.-Max.	25.17-37.28	16.2-35.67
Mean±S.D.	29.56±3.69	22.89±7.15
Median (IQR)	31.216 (6.53)	20.233 (14.39)
95% CI	27.833-31.294	19.537 26.232
t-test	3.71	
p-value	0.001*	

DISCUSSION

Instrument separation during root canal therapy prevents the root canal from being cleaned and shaped effectively, which might reduce the success rate of endodontic treatment. When this condition exists, removing the separated instrument followed by optimal cleaning and shaping is regarded as a more favorable course of action compared to leaving it within the canal. The growing use of rotary instruments for root canal preparation has led to an increase in the risk of instrument fracture in recent years as reported by numerous investigators.

However, in situations where the file is firmly lodged within the canal and ultrasonic tips are ineffective in dislodging it, alternative methodologies can be employed to remove the fragment such as a loop device or microtube with a screw wedge. Recent loop techniques have been introduced to the market, namely BTR Pen, and Yoshi Loop which can be used to engage and remove fractured instruments through forces directed more coronally.[17]

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. It comes with three color-coded working tips corresponding to 0.3mm, 0.4mm, and 0.5mm. Each color indicates the diameter and strength of the wire. The system also has a calibrator that modifies the loop's size to fit the size of the separated instruments. According to Dulundu and Helvacioglu-Yigit[7] excessive enlargement of the canal is unnecessary due to its shape memory, which facilitates its placement within narrow and curved root canals. In our study, working tips with a 0.5 mm diameter containing a wire of 0.1mm were used in order to gain the most strength possible.

The Zumax kit retrieval system was used in the present study. It 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 chosen because its maximum cross-sectional diameter was slightly larger than the visible coronal aspect of the fractured instrument. However, we have made a modification to this technique by employing an ultrasonic tip to produce a space around the separated fragment, to facilitate safe insertion of the trephine bur around the head of the separated file without deviation or encompassing a shelf of dentin around the file. The subsequent phase in the Zumax removal system entails removing the instrument using an extractor, which was carefully inserted into the pathway that was previously created using the trephine bur. One drawback associated with this technique is its inability to remove a broken instrument placed after a root canal curvature.

The process of gaining access to the fractured instrument and removing it requires the sacrifice of dentin, which may lead to a significant decrease in root fracture resistance.[4] This might result in the extraction of single-rooted teeth and the amputation or hemisection of multi-rooted teeth.[11] Accordingly, the removal of dentin during the retrieval procedure is a critical factor that must be carefully assessed, as it significantly increases the likelihood of tooth fracture. This was in line with Lim and Stock,[18] who reported that a dentin thickness of 200–300 μm should be retained after preparation to withstand forces during obturation and to prevent fracture. Consequently, volumetric analysis of the canal space before and after fractured instrument removal was necessary to evaluate the dentin loss and the potential hazards of the file removal procedure.

It was acknowledged in the literature that the superior methods that were used to assess the amount of removed dentin were micro-CT and CBCT. However, Xu et al[19] found that the evaluation of dentin removal using CBCT images was accurate and practical when compared to micro-CT, which couldn't be used due to its unavailability among any of the governmental research associations in Egypt or the private sector. In consequence, in the present study, CBCT was used to assess changes in the root canal space following the removal of broken instruments.

Based on previous studies,[20,21] files were chosen to be separated in the mesiobuccal root canals of extracted human mandibular first molars. These canals are often narrow and curved in three dimensions, with a significant likelihood of instrument separation.[22]

Regarding the curvature of the canal, the success rate is negatively and positively correlated with the location of the separated instrument in relation to the curvature of the canal and the degree of curvature. This came in agreement with Hülsmann and Schinkel[23] who reported a success rate of 100% for fragments located before the canal curvature. However, according to Shen et al[24], the success rate dropped to 60% and 31% when fragments were located at and beyond the curvature, respectively. In our study, the angle of curvature was selected to range from 25 to 45 degrees which is classified as severely curved canals and was measured according to Schneider's method. This was similar to what was stated by Hülsmann and Schinkel[23] who reported that the degree of root canal curvature is a critical factor that significantly impacts the effective management of separated instruments. Furthermore, Lin et al[25] reported that as the root canal curvature increased, the retrieval rate of separated instruments gradually decreased. These findings align with a study done by Shen et al[24] who documented success rates of 100%, 83%, and 43%, respectively, for canals exhibiting slight (≤5 degrees), moderate (>5 ≤20 degrees), and severe curvature (>20 degrees). On the contrary, Eid and Seyam[20] showed no significant influence of severity of curvature on the overall success. This difference in findings may be due to the use of different retrieval techniques.

In the present study, a five mm of ProTaper Next X2 file was separated at a level of three mm apical to the canal orifice. This was in agreement with

Khalil and Alghamdi[26] who stated that ProTaper Next files were more likely to fracture than to deform. Additionally, this was compatible with a recent review by Terauchi et al[27] which showed that most fractured instruments <4.6mm can be solely removed using ultrasonics. Furthermore, they also stated that fractured instrument length is positively correlated with the preparation and retrieval times.

Using the dental operating microscope (DOM) during instrument retrieval was crucial in our study and played a key role in the retrieval procedure. This came in agreement with Nevares et al[28] and Abdeen et al[29] who reported that the utilization of DOM is a prerequisite for successful removal of fractured instruments. In the present study, the entire procedure was carried out at 17X magnification to increase illumination, provide direct vision inside the root canal, avoid excessive removal of the remaining dentin and further weakening of the root, and allow the ultrasonic to work safely. Furthermore, Ruddle[15] stressed that ultrasonic tips should be used to trephine dentin around the head of the fragment only when the fractured instrument is visible under DOM to avoid direct contact of the ultrasonic tip to the instrument fragments, as such occurrences may lead to secondary instrument fracture and push the fragment apically.

However, while using the trephine bur, the shaft of the bur blocked the vision. Therefore, the DOM worked only as a monitor during the trephine procedure after establishing the staging platform and was used to confirm that the head of the fractured instrument was in the center of the platform and the center of the trephine bur. This was supported by Meng et al[30] and Yang et al[31] who reported that the use of a trephine and extractor provides less visibility when compared with ultrasonics.

The maximum time for retrieving the separated instruments was 45 minutes. This was in accordance with Suter et al[32] who recommended a retrieval time of 45 to 60 minutes due to the possibility of operator fatigue, or excessive dentin removal, which in turn may lead to higher risks of perforation.

To the best of our knowledge, the current study was the first of its nature to compare the BTR pen and Zumax kit. An extensive literature search using PubMed as well as Google Scholar was conducted and included years from 2015 until 2023. The search terms used were: BTR pen, Zumax broken instrument removal kit, tube technique versus loop technique, and retrieval of broken rotary instruments. The literature search did not yield any results for a comparative study similar to this current work. Therefore, it should be kept in mind that a direct comparison between the results of the current study among the previous studies was difficult since no comparison has been made between the two mentioned techniques.

The results of the current study revealed that in group A, which used the BTR pen, a total of 16 fragments were removed, resulting in a success rate of 80%. Similarly, in group B, where the Zumax kit was employed, a total of 18 fragments were successfully removed, yielding a success rate of 90%. The high success rate in both groups might be attributed to the fact that the fragments were visible under the dental operating microscope. Even though both the BTR pen and the Zumax kit had a tolerable success rate in the retrieval of fractured instruments, it must be noted that, unlike an actual clinical situation where space and vision are restricted, experimental conditions allow for easier removal of fractured files. However, it is recommended to conduct further clinical studies to assess the efficiency of the BTR-Pen and Zumax kit.

According to the results of the present study, when compared to group A, group B yielded a higher success rate. However, there was no significant difference between the two groups when comparing their respective success rates. This could be because the pulling force of the extractor, which is contingent on the entire hand, is higher than that of the BTR pen, which is dependent only on the fingers. The occurrence of failure in group A was observed in four fragments, while group B experienced failure in two fragments. The unsuccessful cases might

be attributed to the difference between samples in dentin hardness and modulus of elasticity. Therefore, it necessitated a longer preparation time to trephine the dentin around the separated fragment in some samples as the dentin hardness and modulus of elasticity increase with age.[33] however, failure to retrieve separated instruments in the current study might not be considered total failure, since retrieval might have been successful if extra time was given. This could be considered clinically since factors like operator and patient fatigue might play a role. The results of the current study revealed that there was no difference between both groups in terms of the success rate, and therefore the Null Hypothesis was retained.

In the current study, volumetric analysis of the root canal space demonstrated that there was a significant difference in the changes in the volume of the root canal space before and after instrument retrieval in the BTR and the Zumax groups. A possible explanation of these findings is that to firmly grip the instrument fragment during the removal process, it was necessary to expose approximately three mm of the coronal end of the fragment.

It is worth noting that the utilization of the BTR pen resulted in a significantly smaller increase in the overall root canal volume with a mean of 1.53 mm^3 compared to Group B, which had a mean of 3.1 mm^3. The observed results can be attributed to the difference in dimensions between the ultrasonic tip utilized in Group A, which had a length of 30 mm and a tip diameter of 0.2 mm, and the trephine bur that was employed in Group B, which had a diameter of one mm. Therefore, it is advisable to perform a thorough preoperative evaluation of the root canal morphology before attempting a retrieval. The results of the present study have also shown that there was an increase in the root canal space subsequent to the retrieval of separated instruments within the two groups. However, the observed increase was lesser in Group A as compared to Group B. Therefore, the Null Hypothesis was rejected.

Regarding the time elapsed until successful retrieval, the results of the present study revealed that there was a significant difference between group A and group B. The mean time in group A was 29.56 minutes, while in group B, the mean time was 22.89 minutes. A possible explanation for the increase in retrieval time among the BTR group could be attributed to the requirement of loosening the file with the BTR pen before being retrieved, in contrast to the extractor employed by group B, which did not necessitate such loosening. The results of the present study have revealed that there was a difference between the two groups in terms of the mean retrieval time that each group had, with Group A having a longer average time as compared to Group B. Therefore, the Null Hypothesis was rejected.

CONCLUSION

The BTR pen system and Zumax kit are both successful in the retrieval of separated rotary files. There is a significant increase in root canal volume after retrieval in both groups. The BTR-Pen system is more conservative than the Zumax kit. The BTR pen system required a significantly longer retrieval time than the Zumax kit.

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