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Separated Instrument Management as a Procedural Accident in Endodontics Using the EDTA ($C_{10}H_{16}N_2O_8$) Aided Bypassing Technique and the Ultrasonic Removal Method. An *in vitro* Study

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***Abstract**: Fracture of endodontic files can be considered a real concern during root canal treatment. This procedural accident is caused both by overusing instruments due to economic reasons and using an incorrect technique in root canals with difficult anatomy. A broken endodontic file does not always regard the treatment as a failure. Frequently the broken fragment can be bypassed, and the root canal treatment completed. In other cases, when the file is separated in a tooth with associated apical disease, its retrieval using ultrasonic tips is advised. Separation of a file usually occurs in molars, mainly in the mesiobuccal canal due to major curvature, poor access or small diameter. Our research was conducted to determine the in vitro efficiency of the ultrasonic removal method and the bypass technique by using 40 extracted molars with moderately curved roots. #25 K-files were deliberately broken in the middle third of mesiobuccal root canals after making a small excavation in the apical third of their active part. The results showed a significantly higher success rate of the ethylenediaminetetraacetic acid (EDTA) aided bypassing technique compared to the ultrasonic removal method.*

***Keywords**: separated instrument, ultrasonic, bypass, EDTA, endodontic treatment*

1.Introduction

Instrument separation during endodontic treatment can occur sometimes, obstructing the canal and making cleaning, shaping and filling difficult or even impossible. Instruments which separate most frequently are K-files, rotary files, Gates-Glidden burrs and Lentulo spiral fillers. The first Ni-Ti file was introduced to the market in1991. Super elasticity and shape memory are the properties that make NiTi files very flexible. The shape memory property allows this metal to "remember" its original shape and retain it when heated above its transformation-temperature. It happens due to the different crystal structures of nickel and titanium. This pseudo-elastic metal also shows incredible elasticity which is approx. 10 to 30 times more than that of any ordinary metal. The high flexibility of NiTi files makes them superior to stainless steel files for the purpose of rotary root canal preparation. The use of NiTi rotary files in dentistry is a common practice. Some physico-mechanical properties of Ni-Ti alloys are presented in Table 1. X-ray imaging is extremely helpful in the assessment of this complication. Regardless of the alloy from which the instrument is made (stainless steel, nickel-titanium) and their use (manual, rotary), the risk of fracture still exists. The incidence of separated files in literature varies from 0.25% [1] in hand files and 1.68% [2] in rotary files. The most common causes of instrument separation are improper techniques, inadequate access, difficult endodontic anatomy, manufacturing flaws and torsion stress [3]. Although all of the above are equally important, the one that can be closely controlled by physicians is the number of uses of each endodontic file. The following aspects should be considered when deciding not to use an instrument, but to discard it: [4] flaws of the flutes, excessive bending, most commonly noticed in small sized hand files, exaggerated curving or existing corrosion on the instrument's active part [5].

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Table 1. Physico-mechanical properties of Ni-Ti alloys

DENSITY	6.45 g/cm^3
MELTING POINT	1310 ^{o}C
TYPICAL ELONGATION TO FRACTURE	15.5 %
ELASTIC MODULUS	75 GPa in high temperature 28 GPa in low temperature

Alongside the most common causes of instrument separation there is also the excessively applied apical pressure to nickel-titanium (Ni-Ti) rotary files which can cause deformation of the instrument in the root canal or friction increase between the canal walls and the instrument, eventually leading to overloading the metal and separation of the file. This is the reason why continuous lubrication of the root canal is essential, since it reduces friction but increases the file's efficiency. Access cavity preparation is another crucial step into avoiding file separation. The cavity walls must allow straight line access to the apical third of the canal to all types of files and burrs; otherwise the file will break due to excessive torsion stress [6].

File separation does not compromise the endodontic treatment. As a matter of fact, the long-term prognosis of the tooth can be favorable depending on some aspects such as the phase of the treatment during which the file broke, associated apical disease, the position, length of the fragment and direct visibility [7].

Separated instrument as a procedural accident can be managed non-surgically in three ways: removal of the fragment using ultrasonic instruments or retrieval kits, bypassing with small hand files aided by copious irrigation and shaping, cleaning and filling the root canals up to the coronal level of the broken instrument [8].

The optimal treatment method is retrieval of the instrument as in cleaning the root canal and eliminating microorganisms can then be accomplished adequately. None the less, this method requires special skills, training, experience and the special aid of the operating microscope. Furthermore, this technique also implies excessive dentin removal coronal to the fractured segment in order to be reached by the ultrasonic tips, which may predispose to perforation or root fracture. Altogether, the ultrasonic method can be beneficial but also dangerous in severely curves canals, and its true indication is in teeth with associated apical infection, where the most important aspect is eliminating the infected tissue from the root canal and in which the presence of a separated file even bypassed can maintain apical inflammation [9].

Another successful treatment option is bypassing the separated fragment especially when there is no sign of apical infection. Leaving the segment in situ and bypassing it is a more conservative method which eliminates the complications that removing the broken file with ultrasonic tips could presume and it is indicated when the fragment is beyond the root's curvature. Bypass is done by inserting a small sized hand file between the broken fragment and the canal walls and obtaining apical patency. If used incorrectly, the small sized files could create a false canal and lead to perforation [10]. The 17% EDTA gel or solution used during the bypass attempt, acts as a chelating agent by reacting with the calcium ions from the dentin walls and forming calcium chelators, significantly reducing the smear layer [11].

Although there is no universal guideline into the management of separated files, practitioners should choose the technique based on where the fragment is situated, presence of apical infection, root curvature and potential complications of the technique adopted [11].

The aim of our in vitro study was to determine the success rate of ultrasonic method compared to the EDTA aided bypassing technique in the management of separated files from the middle third of root canals.

2.Materials and methods

This study was conducted on the mesiobuccal canals of 40 extracted upper first molars with moderately curved mesiobuccal roots (less than 25 degrees), without prior endodontic treatment. Before we commenced the experimental part, the teeth were fixed in 2.5% sodium hypochlorite solution. Also,

the teeth were cleaned of tartar, carious dentin, and granulation tissue with ultrasonic scalers, diamond burrs, scalpels and curettes. The access cavity was performed with turbine diamond burrs and flaring was also achieved using Gates-Glidden burrs on the low-speed hand piece. After removing the radicular pulp tissue residues, the root canals were cleaned and shaped with hand K-files starting from file #10 up to #20 paying attention to copiously irrigating the canal with 5.25% sodium hypochlorite solution throughout the instrumentation procedures.17% EDTA($C_{10}H_{16}N_2O_8$) solution was used after wise in furtherance of disposing the smear layer (Figure 1). The use of EDTA solutions in endodontics is to remove inorganic debris (smear layer) and lubricate the root canals. This procedure helps prepare root canals for filling. Furthermore, EDTA solutions with the addition of surfactant loosen up calcifications inside a root canal and allow instrumentation (canal shaping) and facilitate apical advancement of a file in a tight or calcified root canal towards the apex. The chemical structure of EDTA is presented in Figure 2.

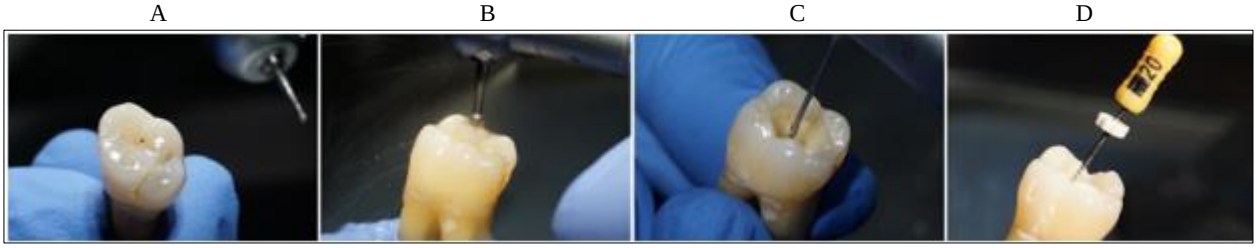

Figure 1A). Occlusal surface of tooth; B) performing the access cavity; C) flaring; D) Shaping with a #20 K-file

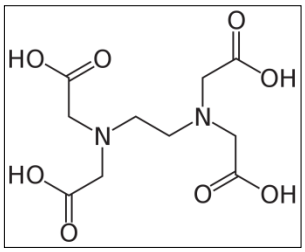

Figure 2. Chemical structure of EDTA

Because the apical patency was established with file #20, the instrument to be deliberately broken into the endodontic system had to be at least one size larger, therefore, size #25 K-files were prepped by making a small groove using diamond burr on the high-speed handpiece. The #25 files were then introduced 15 mm into the mesiobuccal canals as the working length of this canal is usually 19 mm and with rotational movements, they were broken into the canal's middle third (Figure 3). X-ray imaging was then performed.

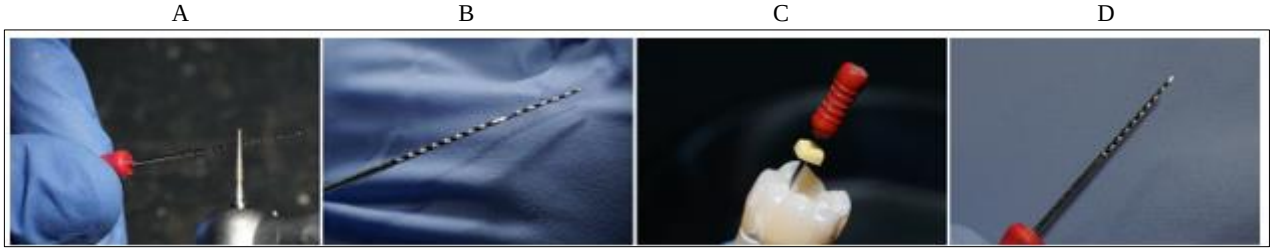

Figure 3A) B). Making a small groove on a #25 file; C) Forcing the #25 file into the canal; D) #25 file after the tip broke

The teeth were then randomly divided into two groups: the separated files from group A underwent the ultrasonic retrieval method. On the broken files from group B the bypassing method was attempted. The ultrasonic method was commenced by creating a staging platform around the coronal end of the broken file using modified Gates-Glidden drills on which the ultrasonic tips (Endotips E4, E5, ES2:

Woodpecker) were vibrated around the segment using a counterclockwise motion. This unscrewing force applied to the separated fragments forced them to suddenly exit out of the canals in which situation, the objective of the study was reached (Figure 4).

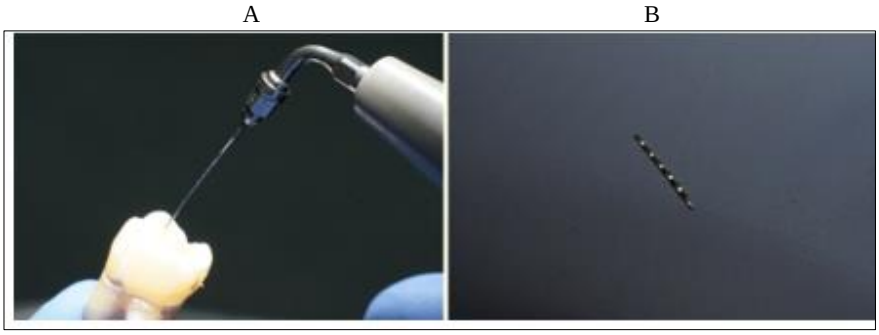

Figure 4A). Attempting to remove the separated fragment with ultrasonic tips; B) Fragment retrieved

The time taken to remove the segments was measured in minutes. We allocated 50 min of ultrasonic activation for each fragment and if by that time the fragment would not eject from the endodontic system, we stopped and considered the treatment a failure, as the risk of perforations increases after 50 min of attempted retrieval. The bypassing technique was initiated by using a 15% EDTA ($C_{10}H_{16}N_2O_8$) file prep root canal conditioner (Glyde, Dentsply Maillefer) and #08 hand files with which we tried obtaining apical patency inserting them around the obstacle using in-and-out movements. Abundant irrigation with 5.25% sodium hypochlorite was used. When the small hand file appeared at the apex of the root canal, the fragment was bypassed, and the treatment was considered a success. Likewise, the time for successful bypass was recorded and after 50 min, the attempt was stopped if we could not go around the fragment by that time. The statistical analysis was performed using GraphPad Prism 7 for Windows (GraphPad Software, California, USA). The level of statistical significance was set at $p< 0.05$.

3.Results and discussions

The results of the study concluded that in group A, only 5 out of 20 separated files could be removed using ultrasonic tips. In group B there was a higher success rate, 13 out of 20 instruments were bypassed. X-ray imaging was performed on both groups to show if the separated files were removed, bypassed or irreclaimable. (Figure 5) The statistical analysis, summarized in Table 2, was determined using Fisher's Exact Test and showed a 0.1795 Odds-Ratio (O.R.) and a statistically significant difference between the two methods (p=0.0248).

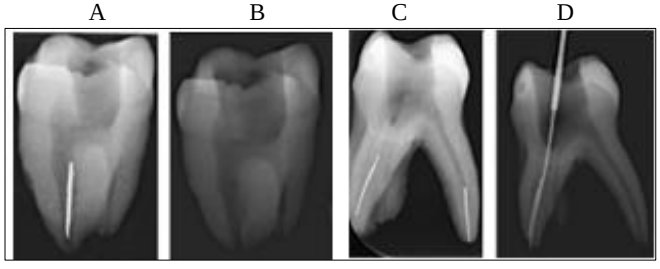

Figure 5.X-ray imaging before and after treatment; A) B) Ultrasonic method; C) D) Bypass technique

Table 2. The results of the ultrasonic (Group A) and bypass (Group B) methods

Study Group/ Treatment outcome	Success Nr. (%)	Failure Nr. (%)	Total Nr. (%)
Group A	5 (13%)	15 (38%)	20 (50%)
Group B	13 (33%)	7 (18%)	20 (50%)
Total	18	22	40

*Statistically significant differences, with p= 0.0248 (p<0.05)

The evaluation of time intervals used for both methods is presented in Table 3, as mean and Standard Deviation using the unpaired t test with Welch correction. The average time required for removing the separated fragments with the ultrasonic technique from group A was 42.2 min, with a minimum of 35 and maximum of 48. The minimum time taken for the bypassing method in group B was 23 min, while the maximum was 43, the average time being 33.9 min. The comparison among the two groups showed statistically significant differences (p=0.0157), the time required for the ultrasonic technique being considerably higher.

Table 3. The values of maximum, minimum of time (min), mean and SD for both methods

Study Group	Minimum Time (min)	Maximum Time (min)	Mean	Standard Deviation
A	35	48	42.2	5.805
B	23	43	33.923	6.601

*Statistically significant differences, with p= 0.0157 (p<0.05)

Various studies reviewed the ultrasonic and/or bypassing techniques as successful managing procedures of both manual and rotary broken endodontic instruments. According to these, the retrieval or bypassing of the instrument revolve around such factors as the level of separation (apical, middle, coronal third), the depth of the file location in relation with the root canal curvature, the length and type of instrument and the location of the tooth.

According to in vivo and in vitro studies, these days, with the instrumentality of new materials and treatment systems, the successful outcomes of broken endodontic files fluctuates between 66.6% and 93.3%, for both ultrasonic and bypass techniques (Suter et al) [12]. The different success rates among in vitro and clinical studies may be related to the fact that they were carried out under different and incomparable circumstances as the technique used and most importantly, the physician's competence and sense of touch which can only be developed by prolonged practice. Most studies indicate that the treatment's outcome after removing or bypassing the fragment is favorable in roughly 75% of the cases, with a slightly higher rate for when the instrument could be eliminated, therefore if this mishap occurs, increasing the difficulty of the treatment, several conservative solutions are available. Moreover, if both attempts of either removing the fragment or bypassing it fail, there is always the possibility of a surgical treatment [12].

The results of our in vitro study showed a significantly big difference between the two techniques in favor of the bypassing approach. Ultrasonic instruments had a success rate of only 26% which is considerably lower than what international literature reports. This is related to considerably wider knowledge and experience of specialists as well as the superiority of materials and instruments used by them in attempt to recover the fractured instruments from the root canals. According to Gencoglu et at, the higher success rate in removing fractured instruments from the middle third of curved root canals (80%) described in their study was definitely attributed to using the dental microscope and the help of experienced endodontist [13].

Also, as reported by Hulsman et al, success rate decreases when the fragment is located beyond the root canal's curvature (52-58%) [14]. For the same location Shen et al reported 31% success rate in removing separated fragments, results comparable with our study's outcome [15]. A very similar study was conducted in the postgraduate endodontic program at the Dental School of Athens where the similar experienced doctors found a success rate of 45.4% for removing the broken files from the middle third of slightly straight root canals [16, 17]. This result was surely related to the degree of curvature of the root canal, which was superior in our study, hence the mildly lower success rates in completely removing the fragments.

As our results of retrieving the separated fragments were rather low, the bypassing technique could potentially compensate this issue when it comes to clinical cases. Given that the successful outcome of a root canal treatment and apical healing depends on thoroughly disinfecting the endodontic system,

this aspect can be achieved even if the root canal is obstructed by a broken file. By going around the segment with small hand files and copiously irrigating and activating the canal containing the separated instrument, the condition of a tight apical seal can be reached. Furthermore, numerous studies prove that root canal fillings containing broken endodontic instruments have no effect on the long-term prognosis. (Crump et al) [17] Saunder's study on bacterial penetration of filled root canals also showed that there was no significant difference between the group of sealed canals containing separated files and those without broken files [18].

The noticeable successful outcome found in teeth from group B (66%) is similar to those found by Nevares et al. (567%), Ward et al. (67%) and Messer (70%) [15]. This technique is simple and less invasive and should be used when there is no sign of apical infection since its risks of perforations are far less low than the ultrasonic methods are.

Analyzing the necessary time for each method's successful outcome, the bypassing method was by far the quickest of the two, with a significant difference (p=0.0157), of 33.9 min, result similar to those highlighted in international literature. Khalid et al observed an average of 40 min necessary for removing broken files using ultrasonic instruments, finding comparable to our result of 42.2 min [19].

4. Conclusions

Although the best management method towards separated instruments is prevention, if the incident occurs, there are several applicable techniques that will not affect long term prognosis of the tooth. The ultrasonic method should be taken into consideration when the tooth presents infectious apical disease even though this study's outcome revealed a lower percentage of success using this method.

Analyzing the potential complications of what retrieving separated instruments presume, bypassing the segment is also a successful approach. Within the limitations of our study, we found a statistically significant difference between the rate of success by using the bypassing method and including the separated file into the root canal filling and removing the fragment with ultrasonic instruments. Furthermore, a considerable difference was also found in the needed time for each method's favorable outcome, the bypassing technique being the one which required the least time. For the most part, this bypassing procedure fulfills the purpose of an appropriate root canal treatment which is proper shaping and an adequately sealed filling.

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