Review Article

# The Retrieval of Separated Instruments

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## Abstract

The fracture of endodontic instruments is a procedural problem creating a major obstacle to normal routine therapy. The separated instrument, particularly a broken file, leads to metallic obstruction in the root canal and impedes efficient cleaning and shaping. When an attempt to bypass such a fragment becomes difficult, it should be retrieved. The purposes of this narrative review of separated instruments were to review the literature regarding treatment options, influencing factors and suggest a process for their management.

**Keywords:** BTR, Instrument retrieval, Instrument separation, Retrieval.

## Introduction

One of the obstacles in the completion of a routine endodontic therapy is the fracture of endodontic instrument in the root canal. Removal of a fractured instrument from the root canal is often a very difficult procedure. The difficulty is more when the instrument is fractured in the apical third of the root canal.[1]

There are various instruments that have been reported to fracture inside a root canal which include Gates-Glidden burs, carbon steel or stainless steel (SS) endodontic files (K-files, Hedström files, barbed broaches, and reamers), nickel-titanium (NiTi) rotary instruments, lateral spreaders, peeso reamers, spiral fillers, and irrigation needles.[2]

SS hand files show a distortion or a deformation before fracture whereas NiTi rotary instruments fracture without any visible change or warning for the operator.[3]

In recent years, the incidence of fracture of NiTi instruments has risen.[4]

Tzanetakis *et al*. reported that the prevalence of instruments fractured in the apical third (52.5%) was significantly higher when compared with the middle (27.5%) and coronal (12.5%) thirds of the canals. Instrument fracture occurred significantly more often in molars and in teeth rated as difficult preoperatively.[3]

Di Fiore *et al*. found that instruments fractured in anterior teeth were 0.28%, in premolars 1.56%, and in molars 2.74%, which appeared to be related to the increasingly complexity of canal morphology.[5]

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Some 39.5% of fractured instruments were located in the mesiobuccal canals of molars and 76.5% of the fragments were located apically, while a significantly high percentage of instruments of small apical diameters (sizes 006-015) fractured in relatively straight root canals.[6]

There are various factors that may result in intracanal fracture of an endodontic instrument.

Operator experience is a commonly reported factor in relation to the occurrence of clinical instrument fracture. Instrument fracture was found to be less in case of an experienced operator as compared to an untrained operator.[7,8]

The fracture occurs at the point of maximum flexure which corresponds with the point of greatest curvature.

Various tests have shown that the number of cycles required for fracture is directly proportional to the angle of curvature and inversely proportional to the radius of curvature.[9]

There are various instrument-related factors that may lead to instrument fracture.

Torque-controlled motors, which work below the elastic limit of the file, decrease instrument fracture that occurs due to torsional overload.[10]

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However, clinical studies did not demonstrate any significant difference in failure of ProFile NiTi instruments used with high or low torque motors.[11]

There are also studies that question the use of torque control. They suggest that rotary NiTi instruments function better at higher torque and that frequent engagement of the auto-reverse function carries a risk of torsional fatigue and failure.[12]

Higher rotational speed generates more heat than lower speed and thus increases the temperature faster which leads to increase in the tension on the surface making the fatigue fracture occur sooner.[13]

A crown-down instrumentation and creating a manual glide path have been suggested to decrease the frequency of instrument fracture.[14,15] These techniques aid in reducing instrument "taper lock" or "instrument jamming" which is related to torsional fracture. Crown-down instrumentation reduces torsional stresses generated, particularly in the smaller instruments,[16] and a glide path limits the level of torque on the instrument, thereby protecting against shear fracture.[14]

Irrigation also plays an important role in instrument fracture. Irrigating solutions dissipate heat produced because it acts as an efficient heat absorber. Thus, decreasing the chances of fracture. In contrast, when the rotary instrument is rotated in a non-irrigated environment, heat dissipation is reduced and thus decreases the number of rotations, leading to fracture.[17]

Although a spread of techniques and devices are described and used, no standardized procedure for the safe, successful, and consistent retrieval of instrument fragments within the passage exists. The decisive factor for a successful intervention in the vast majority of proposed techniques is the preparation of a straight-line access to the fragment. Surgical operating microscopes and powerful piezoelectric ultrasonic units along with refined ultrasonic instruments are among the technological advances that have considerably increased the potential for retrieval of instrument fragments. Some of them are mentioned below:

- Ultrasonics
- Tube techniques
- Loop techniques
- Canal finder system
- Laser techniques
- Electrochemical dissolution techniques
- Chemicals
- Magnets
- Multisonic Ultracleaning system
- Softened gutta-percha
- File removal system
- Bypassing.[18]

## Factors Affecting Intracanal Instrument Fracture

Root canal treatment (RCT) may require the use of a variety of instruments including files and reamers, ultrasonic tips, explorers, irrigation needles, Lentulo spirals, spreaders and pluggers, heat-conducting tips, and filling material injection tips; any of those instruments may fracture inside the basis canal during use, but the fracture of files and reamers is taken into account to be a more frequent problem. Several factors are implicated within the failure of passage instruments, and lots of studies have attempted to elucidate their individual contributions. To facilitate the outline and analysis of the relevant factors, they need been grouped together in four main categories, namely, operator related, anatomy related, instrument related, and technique/use related. However, it is likely that some of these factors may actually fit in more than one category.[18]

## Operator-Related Factors

Operator experience is a consistently reported factor in relation to the incidence of clinical instrument fracture.[7,8] When other factors (instrument speed and sequence, canal morphology) remain constant, the operator experience is the key factor in instrument failure.[19]

Finally, the operator has to develop his/her judgment to discard an instrument that shows a dubious defect or that has been used in a difficult-to-prepare root canal.[18]

## Anatomy-Related Factors

### Access cavity design

A completed access cavity should still allow unobstructed visual access to all or any root canals and act as a funnel to guide the instruments into the canal, straight to the apex, or to the point of first curvature. Interference by the cavity walls or by unremoved dentin shoulders can increase the stress imposed on the instruments during preparation by increasing the number and severity of curvatures that must be negotiated; this could lead to instrument failure.

Expanding the access cavity beyond the confines of the pulp chamber could also hinder the entrance of files into the root canals and lead to accidental bending of the tips.[18]

### Root canal anatomy

The risk of instrument failure seems to increase in cases with complex root canal anatomy. Fractures appear more often in molars than premolars or anterior teeth and also in the mesiobuccal root canal of maxillary and mandibular than in other root canals. The curvature of a root canal is described by its angle and radius the wider the angle and the smaller the radius, the more abrupt the curvature.[18]

Various tests have shown that as the angle of curvature increases and the radius of curvature decreases, there is a reduced number of cycles to file fracture which means that there are more chances of a file to fracture.[9,20,21] It appears that the radius has a more pronounced effect on this process.[18]

## Instrument-Related Factors

Raw materials, design, and manufacturing process can have a big impact on instrument fracture.

In many instruments such as Ni-Ti files, manufacturing imperfections such as milling grooves, cracks, pits, and regions of metal rollover may render the instruments more prone to fracture because they could act as stress concentration points.[18]

The cross-sectional area of the instrument also plays an important role. It has been demonstrated that increasing the diameter and cross-section of a file increased resistance to torsional failure[22,23] but conversely reduces resistance to flexural fatigue failure.[21]

## Technique-/Use-Related Factors

### Motors operating parameters

Nowadays, electric motors are almost unanimously recommended over air-driven motors for rotary instrumentation mainly because they will maintain a continuing rotational speed and also limit the utmost torque applied to the instruments. Torque-controlled motors, which perform below the elastic limit of the file, reduce instrument fracture due to torsional overload.[18]

### Rotational speed

The effect of rotational speed on fracture is not clear with some studies reporting rotational speed to have no influence on fracture incidence[7,21] while others reported the opposite.[24,25]

### Torque

Torque is a measure of the turning force applied to the instrument for the instrument to overcome friction and continue rotating. Since electric motors strive to take care of a continuing rotational speed, the torque applied to the instrument can vary continuously counting on friction, which is, in turn, determined by the contact area between the instrument blades and dentin and therefore the handling of the instrument.

The maximum torque which will be applied is restricted by the instrument's ability to face up to the applied stress without undergoing plastic deformation or fracture. Obviously, different torque limits should be used for each instrument, according to the manufacturer's recommendations.[18]

### Instrumentation technique

A crown-down instrumentation technique and creation of a manual glide path has been proposed to reduce the frequency of instrument fracture.[14,15] Crown-down instrumentation reduces torsional stresses generated, particularly in the smaller instruments,[16] and a glide path limits the level of torque on the instrument, thereby protecting against shear fracture.[14]

### Effect of reuse and sterilization

According to studies, that subsequent to multiple sterilization/autoclave cycles, NiTi instruments exhibit evidence of crack initiation and propagation and an increase in depth of surface irregularities, furthermore, a decrease in cutting efficiency has been demonstrated.[26,27]

### Role of irrigation

Total immersion of the instruments in hypochlorite, which can occur during post-use cleaning before sterilization, seems to possess a more pronounced effect, but there's a substantial discrepancy among studies.[18]

## Mechanisms Of Instrument Failure

### H-files

The analysis of fractured H-files provided substantial information on the fracture mechanisms. SEM analysis of clinically fractured files revealed the presence of striations, which is characteristically seen in fatigue fracture. A crack originated from the cutting surface propagates during clinical use and causes final fracture.[18]

It seems that this acts as a stress concentration factor facilitating the initiation of surface cracks and their propagation perpendicularly to the long axis of the instrument.[28,29]

### K-files

K-files are more resistant to torsion and demonstrate higher angular deflection with higher twist angles before fracture.[30] Testing the K-files under simulated conditions, it was concluded that fatigue cracks originating in the corners of the cross-section decrease the bearing area, leading to the catastrophic fracture of K-files.[31]

### NiTi files

The fracture of NiTi files has been grouped into two categories commonly known as torsional fracture and flexural fatigue.[2,32] If the fractured instrument shows extensive plastic deformation around the fracture point (mainly unscrewing or over screwing of the flutes), it is classified as a torsional fracture, and if the plastic deformation is absent, it is called flexural fatigue. However, the absence or presence of plastic deformation is not an evidence of fatigue fracture as other conditions like high strain rates can eliminate the plastic deformation of ductile metals as well.[18]

## Parameters Influencing the Removal of Fractured Instruments

The chances of successful management of fractured instruments range greatly.[18] It has been reported in various studies that the longer the time needed to manage a fractured instrument, the greater the chances for complications and the lower the success rate.[33,34] There are varieties of factors influencing the possibility of their retrieval.

These factors can be grouped into:
- Tooth factors
- Localization of the fragment
- Fractured instrument factors
- Operator factors
- The technique chosen
- Patient factors.[18]

### Tooth factors
These include the type of tooth, the root canal morphology and particularly its cross-sectional shape and diameter, the thickness of the dentin, the depth of the external root concavities, the presence of root canal curvature, and the radius and degree of the root canal.[18]

### Localization of the fragment
Fragments in the coronal third are managed more easily and with a higher success rate compared to the corresponding rates for fragments in the middle or apical third.[3,35-37]

### Fractured instrument factors
The retrieval of a fragment also depends on the material it is made of. Fragments of rotary NiTi endodontic instruments are more difficult to remove in the vast majority of cases compared to SS instrument.[18]

Due to their rotational motion, they tend to be wound in and impacted in the canal walls, occluding the entire canal.[33]

SS fragments absorb the ultrasonic energy bodily during retrieval efforts and thus move early on in contrast to NiTi fragments which absorb the energy at and/or near the point of contact with the tip.[38]

### Operator factors
The knowledge, skill, experience, creativity, and patience of the operator are crucial for the management of fractured instruments.[39,40]

### The technique chosen
The technique chosen can act as a leading factor in the successful retrieval of an instrument fragment from a root canal. It may not be as important as anatomical factors.[18]

### Patient factors
The extent of mouth opening and troubles in accessing the canal with the fragment are the two main anatomical factors to be carefully checked before commencing any attempt. The patient's anxiety and agony level as well as his/her attitude toward dentistry and in particular toward retention of the tooth in question might also influence the operator's manipulations and efforts.[18]

## Retrieval of the Fragment

Various techniques and equipment, which quite frequently have to be used in combination, have been recommended for retrieving fragments. Technological advancements in vision and particularly the dental operating microscope prove to be a key factor in a successful.[18]

### Chemical means
The aim of using chemical means is:

- Decalcification of root canal wall dentin in the vicinity of the fractured instrument with a weak acid (usually EDTA) to facilitate successive removal or bypass of the fragment with mechanical means
- Corrosion of the metallic fragment and its "dissolution" or reduction of its cross-section (with iodine compounds) to facilitate its removal or bypass with mechanical means.[18]

Historically, potassium iodine (Lugol's), crystalline iodine, iodine trichloride, crystals of iodine, iron chloride solution, and nitrohydrochloric acid have been some of the chemical proposed and most frequently used to intentionally corrode metallic objects in the root canal.[41,42]

### Ultrasonics
Fragments of instruments, silver cones, or intraradicular posts[3,43-45] can be loosened by ultrasonics and then removed.

Initially hand files or spreaders were activated by ultrasonic devices to manage fractured instruments.[43,45,46]

Nowadays, a selection of specially designed ultrasonic tips is available.[18]

The ultrasonic units presently available in dentistry are of two basic types with different action mechanisms.

### Magnetostrictive
Magnetostriction converts electromagnetic energy into mechanical energy.[18]

### Piezoelectric
These are based on the piezoelectric principle, in which a crystal is used that changes dimension when an electrical charge is applied.[47] Deformation of this crystal is converted into mechanical oscillation without producing heat.[48]

### Endosonic filing
In this method, an endosonic file #15 or #20, attached to the handpiece and monitored under the dental operating microscope, is inserted into the root canal up to the coronal part of the fragment and energized ultrasonically to make a trough around this end of the fragment.

A small K-file, pre-curved at its tip, is then considerately pushed down to bypass the fragment.

When the fragment can be bypassed at least to its midpoint, it may be removed by contemporaneous irrigation and agitation with the endosonic file. A low-power setting is used initially, but this can be adjusted upward depending on the fragment.[45,49]

### The Masserann technique
The Masserann technique, being used for the removal of fractured instruments, has also been used for the retrieval

from the root canal of metallic objects such as silver cones and posts.[50,51]

The available Masserann kit consists of:

- An assorted 14 color-coded, end-cutting, tubular trepan burs of increasing size
- Two sizes of tubular extractors (1.2 and 1.5 mm)
- A gauge that helps in predicting the size of the bur and the extractor that is to be used.

The trepan burs are hollow tubes with edges designed to cut dentin peripherally to the fragment. They are supposed to be used with an anticlockwise rotation. During the apical movement of the drill, the coronal end of the fragment is engulfed in the tubular portion. The extractor is tube-like with a plunger rod (stylet) which, when screwed inside the extractor, locks the exposed coronal end of the fragment against an internal embossment just short of the end of the extractor.[18]

## Tube technique

With this technique, the coronal segment of the fragment is exposed and positioned in the center of the root canal, and then, a hollow tube device with an adhesive is slid into it. In most of the proposed tube techniques, cyanoacrylate is used as an adhesive. The alternative to cyanoacrylate is resin.[18]

The most characteristic and well-known systems for this technique are:

1. The endo extractor
2. The Cancellier extractor kit
3. Hypodermic surgical needles
4. The separated instrument removal system
5. The microretrieve and repair system.[18]

## Canal finder system

The Canal Finder System consists of:

- A special handpiece. The system produces an up-and-down pecking motion and a quarter of a turn rotation that guides the instrument into the path of the root canal
- Exclusively designed for the system engine-driven instruments.[18]

The system has been used effectively in the removal of fractured instruments and silver cones.[52,53]

In this technique, starting with a size #8 and size #10 path finding file, an attempt is made to work along the obstruction and to loosen the fragment by circumferential filing under copious irrigation. The files are initially moved at an amplitude of 1–2 mm and subsequently at a smaller amplitude with a higher speed. The flutes of the files are mechanically engaged with the fragment, and through the vertical vibration of the file, the fragment is loosened and eventually retrieved in the majority of cases.[18]

## File retrieval system

This system, that was developed in 2006, has been found productive in laboratory studies and in clinical cases of instruments broken at the apical third of the canal in a moderately short retrieval time with the removal of a minimal amount of root dentin.[4,54,55]

The Terauchi File Retrieval Kit in its autoclavable cassette contains:

A modified Gates-Glidden #3 bur, a microtrephine bur, a microexplorer instrument, a loop device, gutta-percha removal instrument, four customized ultrasonic tips that can be bent to accommodate canal curvature, a tooth replica with three broken files for practice.[18]

## The wire loop technique

This technique aims at removing the segment by circling it with a wire loop. It employs a disposable 25-gauge dental injection needle with an external diameter of 0.46 mm; a 12–15 cm piece of steel wire, 0.14 mm in diameter; and a small hemostatic forceps.[56]

Steps:

– Root canal instrumentation up to the fragment
– Exposure of the coronal 1.5–2 mm of the fragment
– Radiographic control to confirm that the loop surrounds the instrument. This is required only in cases of difficulty or doubt
– Tightening of the loop around the exposed portion of the fragment with the help of hemostatic forceps. By pulling the complete assembly out of the canal in various directions to dislocate the fragment from the dentine walls, the fragment is retrieved.[18]

## Electrolytic technique

The electrolytic technique aims to partially or even totally dissolve the fragment through electrolysis, thus enabling the recovery of the original canal path to the apex. For this purpose, a system of electrodes is inserted into the root canal so that the anode comes into contact with the fragment of the instrument.[18]

Electrolytes used with the technique include normal saline, sodium hypochlorite in various concentrations, and saline with 0.1 N hydrochloric acid.[18]

## Laser irradiation (Laser-assisted removal of fractured instruments)

The neodymium-doped yttrium aluminum garnet lasers (Nd: YAG lasers) tested in laboratory studies have been claimed to successfully manage instrument fragments in <5 min. There are four ways to do this, all correlated to temperature effects:

1. The laser melts the dentin around the fragment, and then, H-files are used to bypass and retrieve it
2. The laser melts the fragment
3. Laser energy melts the solder, connecting the fractured instrument with the brass tube charged with solder and placed at the exposed coronal end of the fragment
4. The laser welds the file fragment positioned within the metal hollow tube.[57-59]

## Summary and Conclusion

Instrument fracture is an unwanted and bothersome incident during RCT that frustrates both practitioners and patients. It can happen even to experienced clinicians following the most proper preventive measures.

The incidence of endodontic tool fracture is still an area of uncertainty, first because many studies that have assessed this phenomenon offer varying and sometimes conflicting results and, second and most importantly, because incidence rates result from studies with many non-comparable methodologies.

Several non-surgical and surgical techniques have been proposed and clinically applied for the management of separated instrument fragments. These management attempts can be considered as uncertain and may include the possibility of further iatrogenic complications. Thus, clinicians must consistently take all necessary precautions during RCT or retreatment procedures to prevent instrument fracture.[18]

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