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Endodontic File Retrieval: Techniques, Systems, and Clinical Perspectives

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Abstract

Instrument separation during root canal treatment remains one of the most challenging procedural complications in endodontics. The fracture of endodontic instruments may obstruct adequate cleaning and shaping of the root canal system, thereby compromising treatment outcomes and long-term prognosis. The increasing use of nickel–titanium rotary instruments has significantly improved canal preparation efficiency; however, their susceptibility to cyclic fatigue and torsional stress has contributed to a rise in the incidence of separated instruments. Over the years, numerous techniques and systems have been developed for the management of fractured instruments, ranging from conservative bypass procedures to advanced ultrasonic retrieval systems and surgical interventions. The prognosis of teeth with retained separated instruments depends on multiple factors, including the stage of canal disinfection at the time of fracture, canal anatomy, fragment location, and the presence of periapical pathology. Contemporary endodontics emphasizes minimally invasive retrieval strategies that preserve radicular dentin while maximizing retrieval success. The integration of dental operating microscopes, cone-beam computed tomography, ultrasonic devices, and heat-treated nickel–titanium alloys has significantly improved the management of intracanal separated instruments. This review aims to comprehensively discuss the etiology, incidence, mechanical behavior, retrieval systems, bypass techniques, prognosis, complications, and future perspectives related to endodontic file retrieval. The article further highlights evidence-based approaches for preventing instrument separation and outlines contemporary clinical protocols that improve treatment outcomes while maintaining tooth structure.

Keywords: *Root canal treatment, Nickel–titanium rotary files, Separated instruments, Endodontic file retrieval, Ultrasonic retrieval technique*

I. Introduction

Root canal treatment (RCT) is a fundamental procedure in modern dentistry aimed at eliminating infection from the root canal system thus , preserving the natural tooth. The primary goals of endodontic therapy include complete debridement of infected pulp tissue, prevention of reinfection, and maintenance of tooth function and structural integrity [1]. Successful treatment outcomes rely heavily on effective cleaning, shaping, disinfection, and obturation of the complex root canal system. However, the intricate anatomy of root canals, including curvatures, lateral canals, fins, and isthmuses, poses significant challenges during instrumentation and may compromise treatment success if not adequately managed [2,3].

The success of RCT is influenced by several interrelated biological, anatomical, procedural, and restorative factors.. Proper instrumentation and irrigation are critical for successful endodontic therapy , as inadequate cleaning and shaping can leave infected tissue and bacteria withing the canal system , leading to infection and eventually treatment failure . [4,5]. In complex root canal anatomy especially in molars with curved mesial canals,this becomes even more important to achieve .Furthermore in these teeth it increases the risk of procedural errors such as ledging , transportation , perforation , and instrument fracture .This negatively affect tooth prognosis . Strindberg et al. (2002) reported reduced periapical healing rates in teeth containing retained fractured instruments because of persistent infection and incomplete canal disinfection [6]

The advent of NiTi instruments revolutionized endodontic practice by improving canal shaping efficiency increasing flexibility and facilitating preservation of canal anatomy . [7]

Rotary Ni-Ti instruments were introduced first , to overcome stainless hand files due to their limitations . Their continuous 360 ˚ rotation allows efficient canal shaping . However continuous rotation subjects the instrument to cyclic fatigue and torsional stress , increasing the risk of instrument separation . [8,9] To overcome these drawbacks , reciprocating instruments were introduced .

The challenges of reciprocating instruments include possible increased debris extrusion and different shaping characterstic compared to rotary instruments . Reciprocating instruments work through alternating clockwise and counterclockwise. Typically, the instrument rotates in a larger angle in the cutting direction followed by a smaller reverse angle, producing a repeated cutting-and-release motion. This mechanism allows the file to disengage periodically from the dentinal walls, thereby reducing taper lock and excessive stress accumulation within the instrument.[10]

Heat treated Niti instruments represent a major advancement in NiTi metallurgy . The heat treatment increases the proportion of martensitic phase in the alloy , resulting in greater flexibility enhanced cyclic fatigue resistance , improved canal centering ability and better adaptation to curved canals such as ProTaper Gold (Dentsply Sirona) , HyFlex EDM (Colténe) and Waveone (Dentsply Sirona) are few examples of heat treated NiTi instruments .[11]

ETIOLOGY OF FILE SEPARATION

The etiology of instrument separation is multifactorial . It can occur because of inexperienced operator , excessive torsional stress , cyclic fatigue , improper instrumentation technique , inadequate irrigation and lubrication or repeated use of instruments . [12] Canal curvature and narrow root canal anatomy significantly increase stress concentration within endodontic files, making fracture more likely to occur .[13]

Torsional stress has been reported to account for approximately 55.7% of fractures, while cyclic fatigue contributes to nearly 44.3% of cases [14]. Cyclic fatigue results from repeated compressive and tensile stresses during rotation in curved canals, whereas torsional failure occurs when the instrument tip binds within dentin while the shank continues to rotate [15].

Establishing a proper glide path, avoiding excessive apical pressure, maintaining adequate lubrication, and adhering to manufacturer guidelines are essential preventive strategies .

Thus , we can say that reciprocation and heat treated metallurgy combination can provide highest fracture resistance .

II. Review

Historical Evolution of File Retrieval

The concept of managing separated endodontic instruments has evolved considerably over the past century. During the early era of endodontics, fractured instruments were often left within the canal because retrieval techniques were limited and unpredictable . Carbon steel files used during the early twentieth century were rigid and highly susceptible to fracture. In many cases, extraction was considered the only treatment option when symptoms persisted.

The introduction of stainless steel instruments during the 1950s and 1960s improved flexibility and corrosion resistance. Clinicians gradually began attempting bypass procedures using small K-files and Hedström file.[16]

By the 1980s, retrieval procedures became more sophisticated with the introduction of ultrasonic instrumentation and the dental operating microscope [17].

The widespread use of nickel–titanium rotary systems in the 1990s significantly improved shaping efficiency but increased the frequency of unexpected instrument fracture . This led to the development of dedicated retrieval systems including the Masserann kit, microtube systems, and ultrasonic retrieval techniques . Contemporary endodontics now integrates CBCT imaging, advanced ultrasonics, and minimally invasive protocols for predictable instrument retrieval.[18]

Incidence and Distribution of Instrument Separation

The reported incidence of instrument fracture varies widely from 0.4% to 23% depending on study design, instrument type, and operator experience [19]. Rotary NiTi instruments demonstrate higher fracture incidence than stainless steel hand files.[20]

Ungerechts C et.al (2014) concluded in his study that instrument separation occurs more frequently in molars than in anterior teeth [21]. Accoring to a study by Madarati AA (2008), mandibular molars, especially mesial canals, show the highest prevalence due to abrupt canal curvatures and narrow anatomy[22].

Diagnosis and Assessment

Accurate diagnosis is essential before attempting retrieval. Conventional periapical radiographs provide initial information regarding fragment location and canal anatomy . However, two-dimensional imaging has limitations in assessing surrounding dentin thickness and spatial orientation.[23]

Cone-beam computed tomography provides three-dimensional visualization of:

- Degree of Canal curvature
- Surrounding dentin thickness
- Fragment location
- Presence or absence of perforation
- Periapical lesions (exact dimensions)

Clinical examination under magnification using a dental operating microscope is also indispensable. Magnification improves visualization and enables conservative dentin removal around the fragment [24].

Principles of Instrument Retrieval

Successful retrieval depends on several principles:

1. Straight-line access
2. Adequate visualization
3. Conservative dentin removal
4. Canal curvature
5. Armamentarium used for retrieval
6. Controlled retrieval forces
7. Length of fragment
8. Instrument type
9. Operator skill

Coronal fragments are easier to retrieve than apical fragments [25]. Fragments located beyond canal curvatures are particularly difficult because visibility and access are limited.

Ultrasonic Retrieval Technique

Ultrasonic retrieval is considered the gold standard for separated instrument management . The technique involves selective dentin removal around the coronal aspect of the fragment using ultrasonic tips under magnification.[26]

The procedure generally includes:

1. Establishing straight-line access
2. Creating a staging platform using modified Gates-Glidden drills
3. Troughing dentin around the fragment using ultrasonic tips
4. Removing dentin around 1-2 mm coronal to fragment
5. Loosening the fragment through vibration
6. Retrieval using microforceps or suction

Advantages include:

- Conservative dentin removal
- High success rates
- Better control

Disadvantages include:

- Heat generation
- Risk of secondary fracture
- Technique sensitivity
- Requirement for magnification

Studies have demonstrated retrieval success rates exceeding 90% with ultrasonic techniques in straight canals [27].

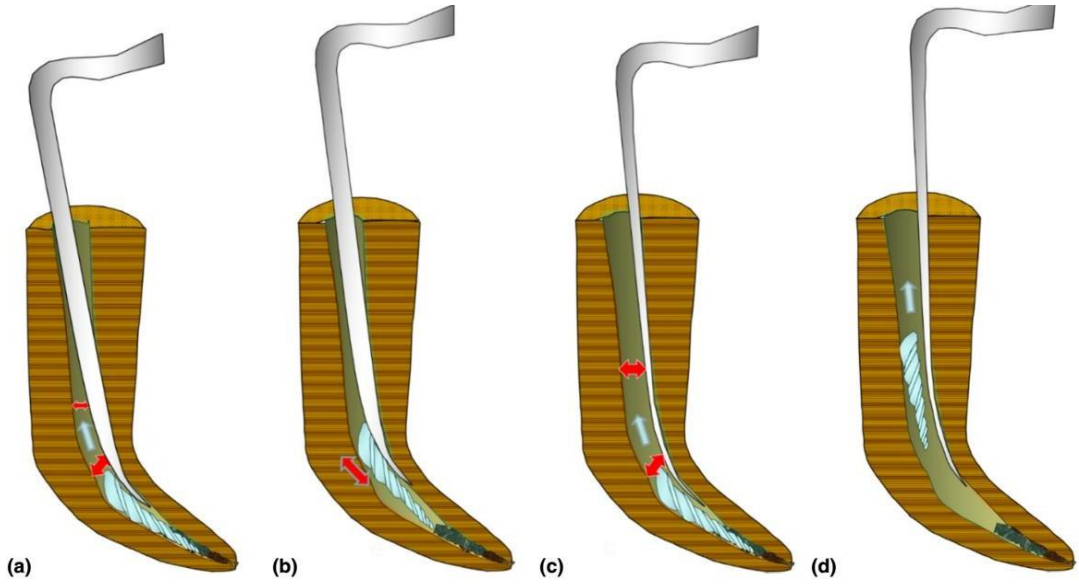

Fig.

Figure 1: Schematic Representation of retrieval using Ultrasonics

Masserann Kit

The Masserann kit is a mechanical retrieval system consisting of trepan burs and extractor tubes . The trepan bur removes dentin around the fragment, after which the extractor tube engages and removes the separated instrument.

Fig 2 . Masseran kit

Advantages:

- Effective in straight canals
- Useful for coronal fragments

Disadvantages:

- Excessive dentin removal
- Limited use in curved canals
- Increased risk of perforation
- Weakening of root structure

The system is now used less frequently because ultrasonic techniques provide more conservative alternatives [28].

Microtube and Loop Techniques

Microtube systems are widely used for fragments resistant to ultrasonic retrieval [29]. These systems involve engaging the fragment using adhesive materials, loops, or internal wedges.

Common systems include:

- Tube-and-loop devices
- Cyanoacrylate-assisted systems
- Internal shaft mechanisms
- Wire loop systems

These methods are particularly useful when sufficient coronal exposure of the fragment is available. Studies have shown favorable pull-out forces using cyanoacrylate glue and internal shaft systems [30].

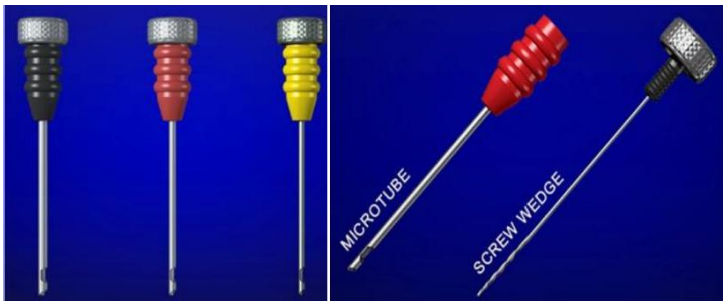

Fig 3: Colour Coded Microtubes with Corresponding Screw Wedges

Complications of Retrieval

Retrieval procedures may produce several complications:

- Excessive dentin removal
- Root perforation
- Vertical root fracture
- Secondary instrument fracture
- Heat-induced periodontal damage
- Canal transportation

Studies evaluating fracture resistance have shown that aggressive retrieval techniques significantly weaken root structure [31]. Therefore, minimally invasive approaches are strongly recommended.

Prognosis of Retained Instruments

The prognosis of teeth containing retained instruments depends largely on the microbial status of the canal at the time of separation [32]. If canal disinfection was adequate before fracture and no periapical lesion exists, prognosis may remain favorable.

However, when infection persists apical to the fragment, healing outcomes may be compromised.

A systematic review and meta-analysis by Piyanee Panitvisai and colleagues(2010) reported that retained instrument fragments did not significantly influence healing outcomes, with a weighted mean healing rate of 91% for teeth containing retained fragments. The authors concluded that the prognosis is primarily affected by the extent to which canal disinfection is compromised rather than by the presence of the fragment itself [33].

Surgical Management

When nonsurgical retrieval fails, surgical approaches may be considered. These include:

- Apicoectomy
- Root-end resection
- Intentional replantation
- Hemisection

Surgical intervention is indicated when persistent pathology exists and orthograde retrieval is not feasible [34]

Bypass Technique

In bypassing separated instrument isn't retrieved ,involves negotiating a small no. K file (8,10) hand file alongside the separated instrument to regain canal patency followed by adequate cleaning and shaping . The procedure is conservative and preserves dentin structure.[35]

Advantages:

- Conservative approach
- Reduced dentin removal
- Lower perforation risk
- Cost - effective

Disadvantages:

- Technically challenging

Time consuming

- Incomplete bypass possible

Bypass success rates range from 70% to 90% depending on fragment location and canal anatomy [36].

Recent Advances and Future Directions

Modern endodontics continues to evolve toward safer and more conservative retrieval procedures. Emerging technologies include:

1. The Canal Finder System is a specialized, automated endodontic handpiece system used in dentistry for the initial penetration, cleaning, shaping, and negotiation of root canals. Developed primarily to navigate highly curved or narrow root canals safely, it serves as an alternative or mechanical aid to traditional manual hand files.

Unlike conventional rotary endodontic systems that spin continuously, the Canal Finder System functions via a unique **partially mechanical, non-rotary movement**

- **Negotiating Complex Anatomies**: It excels at initial glide-path creation in tightly calcified, narrow canals .
- **Bypassing Obstructions**: Clinicians frequently employ the system to bypass steps, ledges, or old root-filling materials.
- **Automated Irrigation [37]**

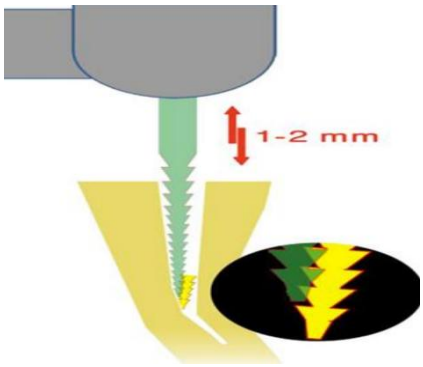

Fig 4: Canal Finder System

2. Dynamic Navigation Systems

Computer-assisted navigation may improve retrieval precision in the future [38].

4. Laser-Assisted Retrieval

Laser systems are being investigated for conservative fragment loosening [39].

5. Artificial Intelligence Integration

AI-assisted imaging analysis may help predict fracture risk and optimize retrieval strategies [40].

Separated endodontic instruments remain a significant challenge in contemporary endodontic practice. The increasing reliance on rotary nickel–titanium instrumentation has improved shaping efficiency but has simultaneously increased the incidence of procedural separation. The management of these fractured instruments requires careful clinical judgment because aggressive retrieval attempts may compromise the structural integrity of the tooth [13-17].

Current literature strongly supports the use of ultrasonic retrieval under dental operating microscope . Ultrasonic systems provide excellent visualization and selective dentin removal while minimizing unnecessary sacrifice of root structure. Nevertheless, the success of retrieval remains highly dependent on anatomical considerations such as canal curvature, root thickness, and fragment location.

Technological advances have significantly improved retrieval predictability. CBCT imaging allows accurate preoperative assessment of fragment location and dentin thickness, while heat-treated NiTi systems have reduced fracture incidence through improved cyclic fatigue resistance. Future developments involving artificial intelligence, dynamic navigation, and advanced metallurgy may further enhance prevention and retrieval outcomes [31-33].

Despite modern advances, prevention remains the most effective strategy. Proper glide path preparation, adherence to manufacturer recommendations, adequate irrigation, torque control, and timely replacement of fatigued instruments are essential components of safe endodontic practice. Clinicians must balance retrieval attempts against the long-term structural preservation of the tooth to ensure optimal treatment outcomes.

III. Conclusion

Instrument separation during root canal treatment represents one of the most significant procedural complications encountered in endodontics.

Over the years, substantial advancements in magnification, ultrasonic technology, CBCT imaging, and NiTi metallurgy have transformed the management of separated instruments into a more predictable and

conservative procedure. Ultrasonic retrieval under dental operating microscope visualization currently remains the gold standard technique because of its high success rate and minimally invasive nature.

Future innovations involving advanced imaging systems, heat-treated alloys, artificial intelligence, and minimally invasive retrieval devices are expected to further improve clinical outcomes. Nevertheless, prevention of instrument separation through proper instrumentation techniques, glide path preparation, adequate irrigation, and adherence to manufacturer recommendations remains the cornerstone of successful endodontic practice.

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