OPEN ACCESS

**Saudi Journal of Oral and Dental Research**
Abbreviated Key Title: Saudi J Oral Dent Res
ISSN 2518-1300 (Print) | ISSN 2518-1297 (Online)
Scholars Middle East Publishers, Dubai, United Arab Emirates
Journal homepage: https://saudijournals.com

**Review Article** **Dentistry**

# Management of Separated Instruments in Endodontics – A Comprehensive Review

Dr. Akanksha Kumari[1]* Dr. Ajay Kumar Nagpal[1], Dr. Mohammad Mutiur Rahman[1], Dr. Juhi Dubey[1], Dr. Seemran Panda[1], Dr. Arunima Jana[1]

[1]K.D. Dental College and Hospital, Mathura, UP, India

**DOI:** https://doi.org/10.36348/sjodr.2026.v11i06.004 | **Received:** 15.04.2026 | **Accepted:** 10.06.2026 | **Published:** 20.06.2026

***Corresponding author:** Dr. Akanksha Kumari
K.D. Dental College and Hospital, Mathura, UP, India

## Abstract

The fracture of endodontic instruments within root canals remains one of the most challenging and anxiety-provoking complications in clinical endodontic practice. With reported separation rates ranging from 0.25% to 10%, the occurrence of broken instruments demands a systematic, evidence-based approach to management. This review comprehensively examines the etiology and mechanisms of instrument fracture, clinical classification, preoperative assessment strategies. non-surgical and surgical retrieval techniques, risk factors influencing outcomes, complications, and future directions. Drawing from published review articles, systematic reviews, and meta-analyses, the article aims to provide clinicians with a structured decision-making framework to optimize treatment outcomes and preserve natural dentition.
**Keywords:** Endodontic instrument fracture, Instrument separation, Root canal treatment, Instrument retrieval, Endodontic complications, Surgical retrieval.



## 1. INTRODUCTION

Instrument separation during root canal therapy [RCT] is a significant iatrogenic complication that disrupts the standard workflow of cleaning, shaping, and obturation. The prevalence of this mishap is well-documented, with separation rates ranging from 0.25% to 10.0%, depending on the type of instrument and clinical setting [1]. Specifically, the incidence of fractured stainless-steel instruments varies between 0.25% and 6%, while for nickel-titanium [NiTi] instruments, the rate ranges from 1.3% to 10%. A retrospective study identified 108 cases of separated instruments out of 3150 treated teeth, with molars accounting for 96% of cases [2]. The incidence of fracture in molars compared to premolars is approximately 2.9 times higher, underscoring the particular vulnerability of posterior teeth [2]. When instrument separation occurs, it can hinder thorough cleaning, shaping, and obturation of the root canal, posing significant challenges to successful treatment outcomes. The presence of a fractured segment may prevent debridement of the apical root canal, particularly in teeth with periapical lesions, where the requirement for disinfection is greatest. Beyond its clinical implications, instrument separation often leads to frustration for both patients and clinicians, and in some cases may precipitate medico-legal concerns. Effective management requires a thorough understanding of causative factors, meticulous preoperative assessment, selection of appropriate retrieval techniques, and careful anticipation of potential complications. This review synthesizes the current literature to provide a comprehensive and up-to-date reference for the management of broken endodontic instruments.

### 2. Etiology and Mechanisms of Instrument Fracture

The etiology of instrument separation is multifactorial, involving the intricate complexity of root canal anatomy, the mechanical properties of endodontic instruments, the techniques employed during instrumentation, and the sterilization procedures used in clinical practice. Understanding these contributing factors is essential for both preventing fractures and designing effective retrieval strategies.

### Anatomy of the Root Canal System:

The anatomical diversity and complexity of the root canal system constitute critical contributing factors to instrument separation [1]. Molars, particularly the mesiobuccal canal of the maxillary first molar and the mesial canal of the mandibular first molar, often exhibit complex morphology, including curvatures and multiple canals, thereby increasing the risk of separation [1]. Instrument separation is more prone to occur in narrow and curved canals, and failure of rotary NiTi instruments appears more often in molars. Root canals with acute curvature, Type V root canals, and irregular shapes with multiple ramifications are also more susceptible to instrument separation [1]. The curvature of a root canal is defined by both its angle and radius; NiTi instruments are more likely to fracture when root canal curvature exceeds 30°, typically in the middle or apical portions with aging, continuous dentin deposition along the inner walls gradually narrows or calcifies canals, complicating the use of endodontic instruments and increasing separation risk [1].

**Instrument-Related Factors:**

Fracture of stainless-steel hand files typically occurs after visible deformation, whereas NiTi instruments may exhibit no visible signs of fatigue, making unexpected breakage more likely during reuse [1]. NiTi rotary instruments are susceptible to two main types of fatigue: cyclic fatigue and torsional fatigue [1]. Cyclic fatigue results from repeated tensile and compressive stresses as the instrument rotates within curved canals, while torsional fatigue occurs when the instrument becomes locked within the canal while continuing to rotate Most NiTi instruments are manufactured through a milling process rather than twisting, which can introduce surface imperfections such as pits, grooves, and cracks that act as stress concentration points, promoting crack initiation and propagation. There is no definitive number of uses before fracture, though some studies advocate single use in anatomically complex canals, while others suggest reuse up to 3-5 times with careful inspection [1].

**Operator and Technique-Related Factors**:

Inadequate access cavity preparation, excessive force, high rotational speed, and skipping file sizes during instrumentation all significantly increase fracture risk [1]. Repeated use of NiTi files exhibiting visible defects such as uneven flute spacing, unwinding, or signs of corrosion substantially increases the risk of separation [1]. Preventive techniques, such as the crown-down approach, are recommended to reduce friction and minimize fracture [1]. Establishing a continuous glide path of at least size #15 prior to rotary NiTi instrumentation is another crucial preventive step [1]. The use of torque-control electric motors has significantly reduced the risk of fracture, particularly among less experienced clinicians. Instrument separation rates tend to decline with increased clinical experience as experienced endodontists are more proficient at identifying fracture risks and applying advanced techniques [1].

**Effect of Sterilization and Irrigants**:

Repeated autoclave sterilization cycles may lead to surface alterations in NiTi instruments, including corrosion and increased surface roughness, although no definitive correlation has been established between these surface changes and clinical instrument separation [1]. Prolonged exposure of NiTi instruments to high-concentration sodium hypochlorite, particularly at elevated temperatures, has been shown to induce corrosion and create microscopic surface defects that reduce cyclic fatigue resistance [1]. Extended exposure or high-temperature irrigant treatment can intensify corrosion and fatigue damage, further increasing fracture risk [1].

**3. Broken instruments may be categorized according to several parameters, each with direct clinical implications.**

**Location Within the Root Canal:**

Separation can occur in the coronal, middle, or apical third of the root canal. In curved root canals. [1] it is also crucial to determine whether separation occurred at the upper or lower segment of the curvature, as most NiTi instrument separations in molar canals occur at the curvature within the apical third. [1] Instruments separated in the coronal third are generally easier to retrieve, especially if located in straight canals or near the root canal orifice. .[1] Retrieving separated instruments from the apical region of a curved canal is considerably more challenging, and establishing a safe retrieval channel is difficult due to anatomical constraints. .[1]

**Instrument Type and Length**:

Stainless steel K-files are generally easier to retrieve than NiTi rotary instruments due to differences in taper, cross-sectional design, and mechanics. [1] NiTi instruments, owing to their rotational motion, are prone to become lodged in canal walls, frequently occluding the entire root canal. [1] NiTi instruments are brittle and often disintegrate into fragments when exposed to direct ultrasonic energy during retrieval. .[1] Longer fragments are generally easier to retrieve due to better accessibility of their coronal portion; most separated NiTi instruments have an average length of approximately 3 mm. [1] For each additional millimeter of instrument length, the duration of retrieval attempts tends to increase.

**Type of Fracture Mechanism**:

Endodontic instrument fractures are attributed primarily to two mechanisms: cyclic fatigue and torsional fatigue [4] Modern NiTi instruments show a higher incidence of fracture compared to stainless steel instruments despite their greater inherent flexibility, partly because stainless steel instruments often display clinically visible distortions before breaking, prompting clinicians to discard them[4] In contrast, NiTi instruments, both manual and rotary, may exhibit no visible signs of torsional or cyclic fatigue [4]

**4. Preoperative Assessment**: A thorough preoperative assessment is fundamental to developing an appropriate management strategy for a separated instrument [SI]. This evaluation must consider the tooth's restorability, root canal anatomy, infection status, and characteristics of the SI itself.

- **Tooth Assessment**: Evaluating the tooth's retention value and restorability is essential. Teeth with root fractures, advanced periodontal disease, or no potential for restoration are generally recommended for extraction. [1] Root morphology, including dentin thickness and depth of external concavities, must be examined, as retrieving an SI often requires dentin removal, and excessive removal can weaken the root structure, increasing perforation or fracture risk.[1] For teeth featuring thin canal walls or deep root concavities, bypassing the S1 or instrumenting and obturating the root up to the fragment might represent safer alternatives. [1]
- **Assessment of Root Canal Anatomy**: The length, diameter, and curvature of the root canal significantly impact instrument retrieval feasibility [1] Retrieval success rates decrease from 83% to 43% when the curvature exceeds 20°, with smaller radii further lowering success. [1] Curvatures exceeding 30º not only require more time but also significantly reduce the chances of successful retrieval in such cases, ultrasonic techniques alone may be insufficient, necessitating adjunctive techniques. [1]
- **Assessment of Periapical Infection**: The infection status of the root canal is a key determinant of prognosis. In vital teeth with intact root canal systems and absent microbial contamination, the long-term prognosis is generally favorable even if the SI remains in the canal. [1] Conversely, early separation during initial instrumentation in infected canals can obstruct cleaning and compromise treatment outcomes. [1] Teeth with periapical lesions have an 85.4% healing rate following root canal therapy, compared to 94.6% for teeth without lesions; the additional presence of a fractured instrument further reduces the success rate. ·[1]
- **Radiographic Evaluation**: Radiographic evaluation is crucial for diagnosing and managing Si in root canals. [1] Periapical radiographs, though widely used, have limitations due to their two-dimensional nature, including image overlap and lack of structural detail.[1] Cone-bcam computed tomography [CBCT] offers high-resolution, three-dimensional imaging, providing significant advantages for preoperative evaluation of dentin thickness, instrument localization, canal curvature, and spatial relationship with surrounding anatomical structures. Both periapical radiographs and CBCT scans are recommended during preoperative planning, with CBCT being particularly valuable in complex root canal systems. [1] Radiographic evaluation also plays an essential role in postoperative follow-up to confirm complete retrieval and assess the integrity of root canal treatment. .[1]

**5. Decision-Making Framework**

The decision to retrieve, bypass, or retain a separated instrument requires a balanced, case-specific approach [6] The primary goal in managing instrument separation is to restore the canal's cleaning and filling pathway, ensuring treatment success [1]

According to the review by Madarati and colleagues, decisions on management should consider: the constraints of the root canal accommodating the fragment; the stage of root canal preparation at which the instrument separated, the expertise of the clinician; the armamentaria available, the potential complications of the treatment approach adopted; and the strategic importance of the tooth involved along with the presence or absence of periapical pathosis McGuigan *et al.,* emphasize that the presence of a fractured instrument need not reduce prognosis if the case is well treated and there is no evidence of apical disease [6] Therefore, in cases without apical disease, removal may not be necessary and retention or bypass should be considered [6] If apical disease is present, file fracture significantly reduces prognosis, indicating a greater need to attempt file removal or bypass [6] In non-infected canals or cases with adequate preparation, the absence of retrieval does not necessarily increase the risk of treatment failure. If retrieval is deemed beneficial and associated risks are manageable, it is generally recommended to retrieve the instrument to avoid compromising subsequent canal disinfection, If retrieval is not feasible or poses excessive risk, bypassing the instrument or encapsulating it in filling material is a viable alternative to preserve the integrity of root canal treatment If neither option is viable, the endodontist should focus on cleaning and shaping the canal above the SI, ensuring thorough preparation and filling.

**6.Non-Surgical Retrieval Techniques**

Numerous non-surgical techniques have been developed for the retrieval of separated instruments from root canals. The most reliable and safe approach involves a combination of the dental operating microscope, ultrasonics, trephine burs, and micro-tube and loop techniques]. The initial step in any retrieval procedure is to establish straight-line access to the coronal end of the SI. .[1]

**Establishing Straight-Line Access and Staging Platform**:

The recommended method involves using hand files to progress from the canal orifice toward the coronal end of the SI, starting with smaller files and gradually increasing to larger ones to enlarge the canal methodically. [1] Gates Glidden [GG] drills should only be used in the root canal's relatively straight portions, employing a gentle brushing motion directed away from the furcation to preserve tooth structure! If insufficient space exists around the instrument for the effective use of a fine ultrasonic tip, a staging platform must be prepared. [1]

**Ultrasonic Technique**:

Ultrasonics, in combination with the dental operating microscope constitute the most effective and reliable tools for removing a separated endodontic instrument from a root canal.[7] The technique involves operating the ultrasonic tip at a lower power setting to reduce the amplitude of movement; after creating a staging platform, the tip is applied in a semi-circular motion on one side of the SI's coronal end to remove surrounding dentin gently.[1] The next step involves carefully wedging the ultrasonic tip between the SI and the root canal wall to loosen the fragment, eventually allowing it to emerge from the canal orifice. If localized ultrasonic movement fails to loosen the instrument, the tip is maneuvered in a counterclockwise circular motion to incrementally expose the coronal end. In a landmark specialist practice study using a micro endodontic technique with ultrasonic tips and an operating microscope, 162 out of 170 fractured instruments were successfully removed, corresponding to a success rate of 95%, with root wall perforation occurring in only one case. [8]

A major advantage of ultrasonic technique is the ability to perform asymmetrical dentin removal under direct microscopic visualization, preserving dentin on the thinner root canal wall.[1] However, the procedure must be performed without water irrigation for optimal visibility, which can increase the risk of heat generation in periodontal tissues, requiring intermittent activation and frequent irrigation to dissipate heat.[1] This technique demands both advanced theoretical knowledge and considerable practical experience from the practitioner. .[1]

**Trephine Bur Technique**:

The trephine bur technique utilizes a hollow, tube-shaped trephine with a cutting edge at its tip to remove dentin layer by layer around the S1 The hollow, tubular design allows the trephine bur to use the SI as a guide, reducing the risk of slippage, deviation, and lateral perforation. .[1] The trephine bur is positioned to encircle the SI and gradually advanced along its long axis, steadily removing surrounding dentin. During the procedure, the fragment may become trapped within the trephine bur by dentin debris, allowing for its removal If the trephine fails after creating a sufficiently deep groove, additional tools such as micro-tube or loop techniques may be required [1]

**Micro-Tube and Loop Technique**:

The micro-tube and loop technique is an auxiliary method employed to retrieve SI lodged within the root canal. .[1] This approach involves either wedging a micro-tube or core pin around the fractured instrument or using a loop to secure its end. .[1] NiTi instruments often lodge against the outer wall of the root canal due to their shape-memory properties; even when loosened, the angle between the coronal aspect and the top of the SI may prevent its retrieval, making this technique the most effective or sometimes the only viable method in curved canals. The bevel of the micro-tube is inserted between the SI and the canal wall to guide the instrument into the tube, after which a corresponding wedge is inserted to secure the fragment. .[1]

**Masserann Technique**:

The Masserann technique, one of the earlier established methods for broken instrument retrieval, utilizes a trepan to cut the surrounding dentine and an extractor tube to retrieve the obstruction. [9] The Masserann kit provides a mechanical solution for the orthograde removal of intracanal metallic obstructions and has been reported as successful even in posterior teeth where its application was initially considered limited. The Instrument Removal System represents a similar mechanical device designed for orthograde removal of intracanal metallic obstructions, described in multiple case reports as effective for retrieval in posterior teeth. .[10]

**Bypass Technique**:

Bypass is generally performed with small-sized manual steel endodontic files and is highly operator-dependent, relying on the tactile sensitivity and perseverance of the endodontist. [2] This technique does not require direct visualization of the fragment and may be particularly suitable when the fragment is located beyond a curve in the root canal .[2]A small pre-curved hand file [#8 or #10] is gently guided alongside the instrument with minimal pressure; if successful, progressively larger hand files create a path toward the apex, allowing complete canal instrumentation and obturation with the fragment incorporated in situ. [1] This technique may lead to complications such as ledges, perforations, and canal transportation if not performed carefully [2]

**Laser-Assisted Retrieval**:

Laser technology employs photothermal effects to interact with the SI or root canal dentin, offering potential utility in complex or narrow root canals. [1] Erbium-doped yttrium aluminum garnet [Er:YAG] lasers are particularly effective for removing SI, through several approaches including melting the surrounding dentin, directly melting the Sl, or using the laser to join a copper tube to the exposed coronal end of the SI via solder. [1] The use of Nd:YAG laser-mediated connection of a brass tube to a fractured endodontic instrument has also been reported as a feasible and tissue-conserving removal approach when more than 1.5 mm of the instrument is accessible. [1] However, laser application in root canals carries risks including temperature increases in dentin and periodontal tissues, which may lead to carbonization, melting. or perforation, necessitating careful operation.[1]

**Cyanoacrylate and Modified Needle Technique**:

Alternative low-cost techniques have been described, such as the use of a modified hypodermic needle and cyanoacrylate adhesive [12] This technique involves inserting a hypodermic needle in the root canal with a handling file adapted in the needle lumen to fix and remove the fragment, representing a simple and cost-effective method for removal of fractured instruments using items already present in the endodontic arsenal [13]

**7. Surgical Management**

When non-surgical approaches have been exhausted or are deemed impractical, surgical interventions provide a viable alternative for managing separated instruments Surgical approaches for removing separated endodontic instruments are a valid therapeutic option when non-surgical treatments are ineffective or not feasible. [4] A systematic review examining surgical endodontic approaches for separated instrument removal identified four main surgical strategies: apicoectomy, intentional replantation, surgical removal, and the "pushed" technique [4]

**Surgical Removal**:

Direct surgical removal does not involve resection of the apical root but typically requires creation of a surgical flap followed by an osteotomy to access and remove the fractured instrument.[4] Understanding the precise location of the fractured endodontic instrument is critical and requires supplementation with 3D CBCT imaging, which provides information about the extent of periapical lesions, the position of the instrument, and its spatial relationship with critical anatomical landmarks .[4] Recovering a fractured fragment from the apical root of maxillary molars can be particularly challenging due to proximity to the maxillary sinus, while the proximity to the mandibular canal in posterior mandibular teeth poses additional surgical risks. [4] Guided endodontic surgery in conjunction with CBCT-derived surgical guides can be utilized for retrieving separated instruments beyond the apex, minimizing risk of damage to vital surrounding structures [4]

**Apicoectomy**:

Apicoectomy is indicated in cases where the fragment is retained in the apical third and cannot be removed using microsurgical instruments. [4] Site preparation should include a minimal osteotomy [3-4 mm] to ensure better postoperative healing, and apical resection can be performed using rotary diamond burs or ultrasonic inserts. [4] The retrograde seal after apical resection is commonly completed using Mineral Trioxide Aggregate [MTA], which offers good biocompatibility and bio-inductive properties. [4] In reported case series, radiographic follow-ups have demonstrated complete healing of periapical lesions within 12-18 months with no signs of recurrence or residual inflammation. [4] The use of a surgical microscope and CBCT combined with 3D-printed virtual surgical models represents the current standard of care for apicoectomy in complex cases.[4]

**Intentional Replantation**:

Intentional replantation may be considered when apicoectomy is limited by proximity to critical anatomical structures such as the maxillary sinus or the mandibular nerve. [4] The procedure must be swift, typically lasting no more than 10-15 minutes, and performed under sterile conditions; the tooth should be kept moist with saline-soaked gauze during the extra-oral period [4] After extraction, the apices and separated fragment are removed, a retrograde cavity is prepared using ultrasonics and filled with MTA, and the tooth is replanted and splinted. [4] Failures manifest most commonly within the first year, warranting a minimum follow-up of three years, and may include root resorption, ankylosis, or replacement resorption. The average retention time for reimplanted teeth is reported to range from 3 to 5 years, and replantation is considered simpler, less invasive, and less expensive compared to apicoectomy.[4]

**Pushed Technique**:

The pushed technique involves displacing the separated instrument from the periapical region back into the root canal through a minimally invasive surgical or fistulous pathway. [4] This technique reduces the need for extensive surgical interventions, minimizes invasiveness, and preserves surrounding tissues. [4] The use of three-dimensional navigation systems for precise localization of the fragment and creation of a bone window represents an advanced refinement of this approach. [4] Disadvantages include a steeper learning curve, longer preparation times, and the risk of fragment repositioning complications [4]

**8. Factors Affecting Retrieval Success**

The success rate of fractured instrument retrieval varies considerably and depends on several interrelated factors.[14] Meta-analytic evidence demonstrates that the failure rate for retreating teeth with a fractured instrument in the canal is approximately 17%, with 172 failures out of 1012 retreated teeth in a recent systematic review. [2] When the instrument is located in the apical third, the failure rate increases to 21%, compared to only 8.8% in the middle and coronal thirds [2]

**Location of the Instrument**:

The anatomy of root canals, particularly the location of the separated instrument, significantly influences success rates.[2] The odds ratio for failure is 0.33 for instruments located in the middle/coronal thirds compared to the apical third, clearly demonstrating the advantage of a more coronal location [2] In clinical studies, removal was successful in all cases where the separated instrument fragment was located in the coronal or middle thirds, while success was achieved in only 9 of 27 cases in the apical third with an additional 7 resulting in perforations [2]

**Canal Curvature**:

The angle of root canal curvature is a decisive negative factor, the lowest success rates are found in canals with curvature angles between 21° and 50°, Retrieval success rates decrease significantly as curvature increases beyond 20°, with smaller curvature radii further lowering success rates and increasing procedural risks [1]

**Fragment Length**:

When fragment length is less than 5 mm, the success rate is 97%, for separated fragments of 5-10 mm in length, the success rate drops to 76% [2] Longer fragments [greater than 3.1 mm] in highly curved canals have greater contact area with the canal wall, which complicates retrieval and prolongs the retrieval process [1]

**Instrument Material**:

Stainless steel instruments are generally easier to retrieve than NiTi instruments due to differences in taper, cross-sectional design, and mechanical behavior NiTi instruments, due to their shape-memory properties, press against the outer wall of curved canals rather than staying centered, hindering access and retrieval. [1]

**Retrieval Time**:

The time taken to remove the separated instrument appears to be statistically associated with the success rate, the failure rate increases when removal time exceeds 45-60 minutes Experienced endodontists are better equipped to minimize dentin loss and reduce retrieval time, thereby improving the safety and success of the procedure.

**Visibility and Magnification:**

The dental operating microscope provides a significant improvement in vision of the operative field, offering better quality procedures and a higher success rate in instrument removal The position of the instrument within the canal in relation to the curvature specifically whether the coronal end remains visible under the microscope-is a decisive factor in determining the likelihood of successful retrieval [14]

**9. Complications of Retrieval**

Instrument retrieval is associated with several well-documented complications that must be carefully managed. [11]

**Root Perforation:**

Root perforation is a major complication when managing SI, with damage to root canal wall integrity severely affecting tooth prognosis.[1] The risk of perforation increases when the SI is closer to the apex, and perforations often occur on the inner wall of the canal curvature during bypass attempts. A meta-analysis reported a perforation rate of 6.5%, with 55 perforations occurring out of 839 retreatments. [2] Importantly, root perforation does not necessarily result in treatment failure, as some perforations have been associated with favorable healing outcomes.[2]

**Excessive Removal of Tooth Structure**:

Excessive dentin removal is a common complication during SI retrieval attempts, and while removing more dentin may improve the success of loosening the fragment, it compromises the tooth's structural integrify.[1] Research demonstrates that retrieving SI from the coronal one-third does not impact fracture resistance, while retrieval from deeper locations can jeopardize root resistance to vertical fracture. [1] Minimally invasive techniques, high magnification, and small ultrasonic tips should be prioritized to control dentin removal. [1]

**Thermal Injury**:

The use of ultrasonic instruments without adequate cooling can lead to excessive heat generation on the external root surface, potentially damaging periodontal ligaments and alveolar bone. [1] Temperature rise is influenced by root canal wall thickness, ultrasonic tip type, power setting, and duration of application; friction of the oscillating ultrasonic tip against the SI generates greater temperature rise than friction against dentin. To prevent excessive temperature rise, endodontists should lower ultrasonic power settings, use smaller tips in an intermittent mode, and irrigate frequently [1]

**Secondary Instrument Fracture:**

When attempting to bypass a fragment, a second instrument may become engaged between the SI and dentin, causing stress exceeding its fracture limit and leading to an additional fracture[1] NiTi rotating instruments are particularly unsuitable for bypassing techniques due to their higher susceptibility to stress-related fracture High-energy ultrasonic operations may cause secondary separation of the original NiTi fragment; using low power settings for NiTi instruments and employing micro-tube techniques are recommended mitigations. [1]

**Apical Transportation of the SI**:

Applying ultrasonic energy to a relatively loose SI, especially when the tip is placed directly on the coronal end rather than beside the fragment, may inadvertently push it deeper into the root canal or even extrude it through the apical foramen into periapical tissues. [1] This risk is particularly significant in the apical third, and apical pressure must be strictly avoided. [1] When instruments inadvertently enter adjacent anatomical structures such as the maxillary sinus or mandibular nerve canal, complex interdisciplinary management involving endodontists, oral surgeons, and otolaryngologists may be required. [1]

**10. Prognosis of Teeth with Retained Instruments**

The overall prognosis of endodontically treated teeth with retained broken instruments has been the subject of considerable research. Within the confines of the available literature, retained fractured instruments do not appear to reduce the prognosis of endodontically treated teeth when apical periodontitis is absent [3] However, if periapical disease is present, instrument fracture significantly reduces prognosis, and healing is substantially compromised[3] The overall success-survivor rate for retreatment of teeth with a fractured instrument is approximately 83%, underscoring that favorable outcomes remain achievable in the majority of cases with appropriate management [2] The prognosis for a tooth retaining a separated instrument also depends on the microbial load of the root canal at the time of separation and the quality of the obturation[7] Early separation during the initial stages of instrumentation in infected canals significantly compromises the prognosis, whereas separation near the apex following thorough cleaning suggests a more favorable outcome[1] It is logical to distinguish between teeth treated before the development of periapical lesions and those treated during active infection, as teeth with periapical lesions have an 85.4% healing rate compared to 94.6% for unaffected teeth [2]

11. **Patient Communication and Medico-Legal Considerations**:

It is imperative that the patient is informed if instrument fracture occurs during treatment or if a fractured file is discovered during a routine radiographic examination. [6] Patients may be concerned about the potential health implications of a fractured instrument remaining in situ, especially if they are unaware of its possible consequences Patients must be informed about potential complications and considerations related to treatment duration, cost, and psychological impact prior to obtaining informed consent[1] For endodontists, instrument separation often represents an unsatisfactory outcome that may lead to patient complaints or medico-legal issues if not communicated and documented appropriately[1] Thorough documentation including clinical notes, radiographs, and a clear record of the circumstances of separation and the management plan adopted constitutes best practice in such situations [6]

**12. Prevention of Instrument Fracture**:

Prevention remains the most effective strategy for minimizing the occurrence of instrument separation. [1] Strict adherence to standardized protocols is indispensable in clinical practice for minimizing fracture risk, with particular caution required when reusing NiTi instruments in calcified or curved canals. [1] Instruments should be promptly replaced when encountering complex root canal anatomy or signs of wear, and single-use options considered to further enhance safety and efficacy [1] The crown-down technique is recommended for the vast majority of rotary NiTi instruments to reduce friction and minimize fracture risk. [1] Preoperative radiographic imaging to anticipate anatomical challenges, ensuring adequate access cavity preparation, and avoiding skipping of file sizes are fundamental preventive steps. [1] Regular examination of the cutting edges for signs of wear, deformation, unwinding, dulling of flutes, or loss of luster should prompt immediate instrument disposal Maintaining detailed records of each instrument's usage history, including the number of uses and the type of canals treated, assists in better evaluating fracture risk [1]

**13. Future Directions**: Emerging technologies are revolutionizing endodontic practice, offering novel strategies to prevent and manage instrument separation with greater accuracy and predictability. [1]

**Artificial Intelligence**:

Artificial intelligence [AI] has been applied in dental clinics, assisting endodontists by improving preoperative assessment through advanced imaging analysis and aiding in precise localization of SI within complex root canal systems[1] Al-powered diagnostic tools integrated with CBCT can provide real-time, high-resolution visualization, facilitating accurate decision-making regarding retrieval strategies[1] Machine learning models trained on large datasets can predict the risk of instrument separation based on instrument type, canal curvature, and patient-specific anatomical factors. [1]

**Bioengineering and Nanotechnology**:

Advancements in nanotechnology include the development of nanoparticle-based coatings on NiTi instruments shown to reduce surface friction, improve fatigue resistance, and reduce the incidence of instrument separation. [1] Smart, minimally invasive retrieval devices designed through computational modeling are enabling more conservative and efficient retrieval procedures.[1] Recent advances in microrobotics in endodontics have the potential to improve root canal disinfection and biofilm eradication in anatomically challenging regions where St management is most difficult. [1]

**Digital Guided Endodontics**:

CBCT combined with 3D-printed virtual surgical models and guided navigation systems provides unprecedented precision in surgical planning and execution for complex cases involving separated instruments [4] Computer-aided navigation systems and robot-assisted endodontic microsurgery may further enhance procedural precision, minimizing excessive dentin removal and complications in future clinical practice. [1] Future directions of fractured instrument retrieval should particularly focus on the management of nonvisible fractured instruments, since removal of those beyond the root curvature remains unpredictable with current techniques [14]

## 14. CONCLUSIONS

Broken instrument removal in endodontics represents a complex, multifaceted clinical challenge requiring systematic assessment and individualized treatment planning. The management approach must be guided by a comprehensive evaluation of the tooth's condition, root canal anatomy, infection status, instrument characteristics, and the clinician's level of expertise and available armamentaria. [1] non-surgical retrieval using ultrasonic techniques combined with the dental operating microscope remains the gold standard for visible instruments, with high success rates reported in specialist settings [8] When non-surgical retrieval is not feasible, surgical options including apicoectomy, intentional replantation, direct surgical removal, and the pushed technique provide viable alternatives with favorable reported outcomes. [4] The overall success rate for endodontic retreatment in teeth with separated instruments is approximately 83%, with location within the apical third representing the most significant determinant of difficulty and failure. [2] Prevention through adherence to best instrumentation practices, single-use protocols for high-risk canals, and preoperative CBCT assessment remains the most effective strategy for managing this complication.[1] Emerging technologies including Al-assisted diagnosis. nanotechnology-enhanced instruments, and guided surgical navigation promise to further improve outcomes in this demanding area of clinical endodontics. [1]

## REFERENCES


1. Fan Y, Gao Y, Wang X, Fan B, Chen Z. Expert consensus on management of instrument separation in root canal therapy. Int J Oral Sci. 2025.
2. Dioguardi M, Dello Russo C, Scarano F, Esperouz F, Ballini A. Analysis of Endodontie Successes and Failures in the Removal of Fractured Endodontic Instruments during Retreatment: A Systematic Review, Meta-Analysis, and Trial Sequential Analysis. Healthcare. 2024;12[14]:1390.
3. McGuigan MB, Louca C, Duncan HF. The impact of fractured endodontic instruments on treatment outcome. Br Dent J. 2013;214[6]:285-289.
4. Dioguardi M, Guerra C, Quarta C, *et al.,* Endodontic Surgery for Separated Instrument Removal: Success Rates and Techniques in a Systematic Review. Dent J. 2025;13[10]:449.
5. Madarati AA, Hunter MJ, Dummier PM. Management of intracanal separated instruments JEmbol 2013,39[5]:569-581.
6. McGuigan MB, Lonca C. Doncan IIF. Clinical decision-making after endodontic instrument fracture. Br Dent J. 2013;214[8]:395-400.
7. Vouzara T, Lyroudia K. Separated instrument in endodontics: Frequency, treatment and prognosis. Balk J Dent Med. 2018,22[3]:123-130.
8. Cuje J. Bargholz C. Hülsmann M. The outcome of retained instrument removal in a specialist practice. Int Endod J. 2010;43[7]:545-554.
9. Pai AV, Gautam S, Bhatt P. Retrieval of metallic foreign body from the root canal using the Masserann technique: A case report. Contemp Clin Dent. 2013;4[3]:396-398.
10. Kunhappan S, Agarwala V, Kunhappan N. Patil S. Retrieval of a separated instrument using the Instrument Retrieval System [IRS]: A case report. J Int Clin Dent Res Organ. 2012;4[2]:93-96.
11. Holly M. Doyle SL, Caputo AA, *et al.,* Removal of fractured endodontic instruments using Nd:YAG laser: a case report. J Laser Dent. 2016;24[1]:12-17.
12. Aguiar BA, Câmara AC, Furtado-Junior SA, Frota LMA, Figueiredo JAP. Removal of Separated Endodontic K-File Using a Modified Hypodermic Needle and Cyanoacrylate: A Case Report. Case Rep Dent. 2016; 2016:7212067. doi:10.1155/2016/7212067
13. Plazza FA, Moreira MFS, Bueno CEDS, *et al.,* Removal of Fractured Endodontic NiTi File in Apical Third: A Case Report. Res Soc Dev. 2021;10[6]: e1210615259.
14. Terauchi Y, Ali WT, Abielhassan MM. Present status and future directions: Removal of fractured instruments. Int Endod J. 2022;55[Suppl 3]:685-717.
15. Travassos RMC, Gomes BP, Ferraz CCR, *et al.,* Operating microscope in endodontics: a systematic review. Open J Stomatol. 2013; 3:75-81.