

Outcomes of Managing Separated Endodontic Instruments at Various Anatomical Sites: A Retrospective Study

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Abstract: *Instrument separation is recognised as a frequent and challenging complication in endodontic practice. Rotary instruments, while highly efficient, are more prone to fracture compared with manual files, primarily due to cyclic fatigue and torsional stress. Such events can compromise canal preparation and negatively influence the prognosis of the treated tooth. This paper aimed to review the principal strategies for managing separated instruments during root canal treatment and to highlight the clinical considerations that guide the selection of appropriate interventions. Management approaches are generally classified into conservative and surgical modalities. Conservative treatment encompasses three principal options: bypassing the fragment, retrieving the fragment, or preparing and obturating the canal coronal to the obstruction. Retrieval is the most technically demanding procedure, requiring advanced endodontic equipment such as ultrasonic devices and a dental operating microscope, together with a high level of operator expertise. The present study demonstrated an overall success rate of 92.78% (95% CI = 89.0–96.5%) for the removal of separated endodontic instruments, significantly exceeding the expected benchmark of 80% ($p < 0.001$). Despite the inherent risks of dentine loss and potential root perforation, conservative retrieval remains a predictable and biologically respectful option. Careful case selection, advanced magnification, and evidence-based decision-making are crucial for achieving optimal, functionally stable outcomes.*

Keywords: broken instrument, endodontics, fractured instrument, separated instrument, management of separated instruments, prognosis

1. Introduction

Introduction

Separation of an endodontic instrument is a complication that may occur during root canal therapy and can have an impact on the treatment's success. Endodontic instruments, especially NiTi, rarely show visible evidence of deterioration and separation without warning. Several variables contribute to NiTi instrument separation, including an insufficient access cavity, canal curvature, numerous uses of the same endodontic tool, and operator expertise. These factors highlight the complexity of endodontic procedures, where both biological and technical elements converge to influence clinical outcomes. The occurrence of instrument separation not only compromises effective cleaning and shaping of the root canal system but may also lead to persistent periapical infection, ultimately threatening the prognosis of the tooth.

The safest and most generally utilised way for retrieving a detached endodontic tool is to employ ultrasonic tips under magnification with a dental operating microscope [1]. This approach has become standard in specialist endodontic practice because it allows clinicians to visualise the root canal system with enhanced precision, thereby minimising iatrogenic damage during retrieval. The ultrasonic tip has an 80% success rate in removing dissociated endodontic tools [2]. Such high reported success rates provide significant reassurance; however, they also underscore the need for advanced equipment, clinical training, and operator dexterity.

The ultrasonic method and bypass approach were employed in

this investigation to attempt removal of the detached instrument in this study. The method for removing a fractured instrument is a rather complex clinical manipulation. The manipulation depends mostly on the kind of separation instrument used and its location inside the root canal relative to the apical area. This complexity is compounded by anatomical variations such as severe curvatures, calcifications, or narrow canals, which significantly reduce visibility and accessibility. In addition, the decision-making process involves weighing the potential benefits of retrieval against the risks of further canal damage, perforation, or excessive dentine removal. Therefore, the clinician must evaluate each case individually, balancing the preservation of root structure with the goal of maintaining endodontic integrity and treatment success.

According to scientific studies, the overall endodontic instrument separation rate (rotary or hand files) ranges from 1.83% to 8.2% [3–5]. These data suggest that although the complication is relatively uncommon, it remains clinically significant and warrants considerable concern. Separation of rotary instruments affects approximately 0.13% to 10% of cases [4, 6–13] and involves several types of instruments. These figures reflect the variability of study populations, operator skill, and the diverse range of instruments on the market, many of which differ in metallurgical properties, design, and flexibility. The frequency of manual instrument separation is 0.25% to 6% of the endodontic cases [4, 9, 14]. Although manual instruments are generally associated with lower fracture rates than rotary NiTi files, their failure can still

pose significant challenges, particularly in anatomically complex or highly curved canals.

The clinical manipulation of removing a separated fragment is associated with alteration to the root canal walls. Instrument removal led to a significant change in the root canal's shape. The frequency and degree of modification of the morphology differed depending on where the fragment was located in reference to the curvature: 10% before the block curvature, 55% inside the curvature, and 100% following the curvature [15]. These findings demonstrate that the anatomical position of the separated fragment is a decisive factor in determining both the likelihood of successful removal and the extent of structural alteration to the canal, as demonstrated by Portigliatti et al., who reported longer clinical times and retrieval challenges when fragments were located in more apically positioned thirds of the canal [16]. Consequently, clinicians must consider not only the feasibility of retrieval but also the tooth's long-term biomechanical stability. Excessive dentine removal may predispose the root to vertical fracture, jeopardising the tooth's survival despite successful fragment removal.

Taken together, the literature indicates that instrument separation is a multifactorial problem that requires careful diagnostic assessment, advanced technical skill, and evidence-based decision-making. A clear understanding of the incidence, risk factors, retrieval techniques, and potential consequences is essential for both the prevention and effective management of this complication. This is further substantiated by Dioguardi et al., whose meta-analysis highlighted significantly higher failure rates for instrument removal in apical thirds [17], and by Natanasabapathy et al., who identified fragment location and retrieval technique as key prognostic variables in a ten-year retrospective cohort [18].

2. Materials and Methods

A total of 180 teeth ($n=180$) treated by one endodontist (A.G.) were studied retrospectively concerning the dental records, ensuring procedural consistency across the sample. The 180 teeth were randomly selected from all patients who had returned for recall (170 patients; 113 women and 57 men). For statistical purposes, the teeth were placed into three main groups according to the initial situation of the level of the instrument separation: *Group I* ($n=60$) - the instrument was separated on the coronal third or is visible at the coronal third; *Group II* ($n=60$) - the instrument was located at the middle third of the root and *Group III* ($n=60$) - the instrument was located at the apical zone of the root. Based on the method used for removal of the instrument and the success of the manipulation, the cases were grouped into three subgroups: *Subgroup A* - removed completely with ultrasound; *Subgroup B* - bypassed to the apical constriction; and *Subgroup C* - the separated instrument couldn't be removed or bypassed. All teeth were treated under isolation with a rubber dam.

3. Results

For statistical analysis, the teeth ($n = 180$) were stratified according to the location of the separated instrument within

the root canal system. Group I comprised 60 cases, where the fragment was situated in the coronal third; Group II comprised 60 cases, where the fragment was in the middle third; and Group III comprised 60 cases, with separation occurring in the apical zone. Regarding treatment outcomes, three subgroups were established based on the management approach and the procedure's success. In Subgroup A (complete removal with ultrasound, microtube technique or BTRPen/*Cercamed*/), 167 cases (92.78%) were successfully retrieved. The majority of these were in the coronal and middle third, which demonstrated a statistically significant association with higher removal success rates (92.78 % ($\hat{p} = 0.9278$); 95 % CI = 89.0–96.5 %). In Subgroup B (bypassed to the apical constriction), 10 cases (5.56%) were managed successfully. This subgroup was most frequently associated with instruments separated in the apical region. In Subgroup C (fragment could not be removed or bypassed), 3 cases (1.66%) were recorded, with the highest incidence in the apical third. When compared with an expected success rate of 80 %, the result was statistically significant ($z = 4.29$, $p < 0.001$).

We examined the distribution of teeth by instrument location and subsequent treatment outcome, summarising categorical variables as counts and percentages. The primary endpoint was dichotomous (treatment success versus failure at follow-up). Group comparisons for categorical factors—principally instrument location within the root canal system—were undertaken using Pearson's chi-square test; when an expected cell frequency was less than 5

Fisher's exact test was applied to ensure valid inference. For instrument location specified as ordered thirds (coronal, middle, apical), we additionally tested for a linear trend in proportions using the Cochran–Armitage approach.

The overall success rate, defined as either complete removal (Subgroup A) or successful bypass (Subgroup B), was 177 cases (98.34%). Conversely, the overall failure rate, represented by Subgroup C, was 3 (1.6%). When comparing groups according to the location of separation, success was highest in Groups I and II and lowest in Group III. Statistical analysis revealed significant differences among the coronal, middle, and apical groups ($p < 0.001$), with the apical third showing a markedly lower retrieval success rate (78.3%) than the coronal and middle thirds (100%).

In addition to fragment location, several factors were found to influence the likelihood of successful retrieval. These included canal curvature, fragment length, and initial visibility under magnification. Teeth exhibiting moderate to severe canal curvature demonstrated a lower success rate of 86.7%, compared with 97.2% in canals with minimal curvature. Similarly, fragments longer than 4 mm were successfully removed in 85.4% of cases, whereas shorter fragments (< 4 mm) showed a notably higher success rate of 96.1%. Improved visual access under magnification was strongly associated with predictable outcomes, reinforcing the importance of optimal visibility and conservative canal enlargement during retrieval procedures in different locations (Figure 1).

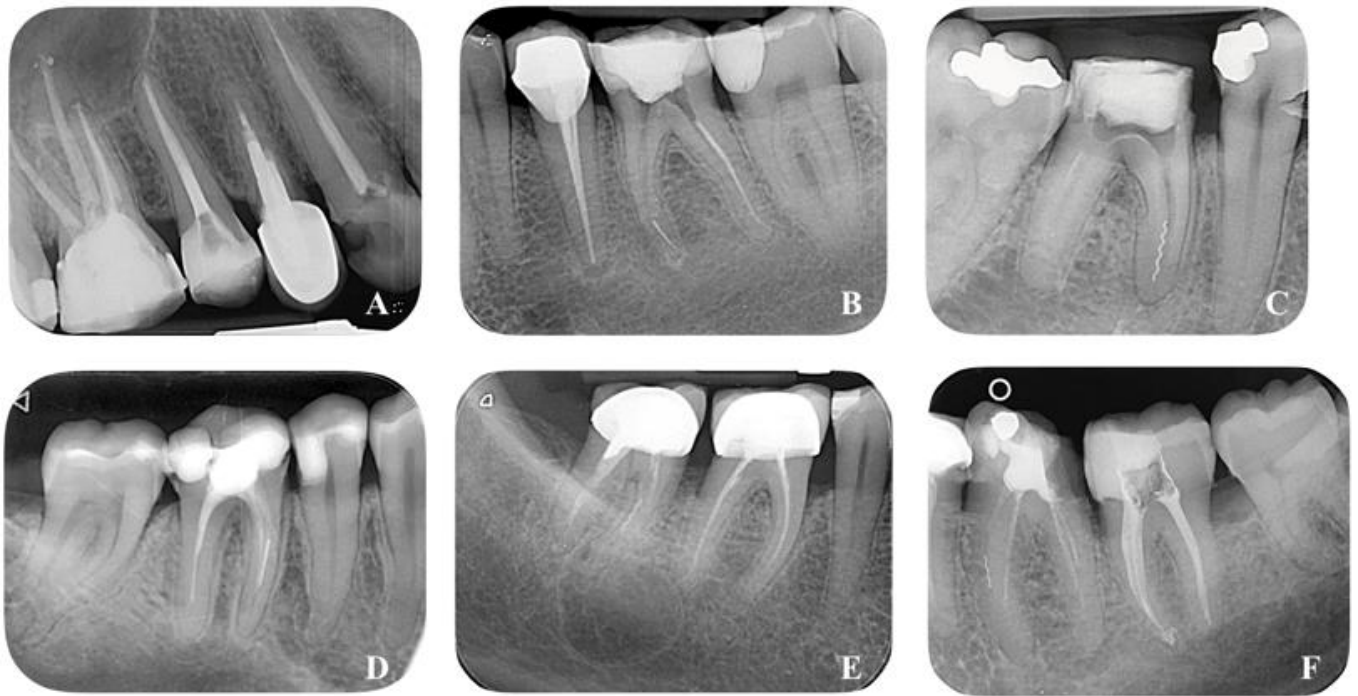


Figure 1 Different localization of separated endodontic instruments.

Table 1: Distribution of Teeth According to Instrument Location and Treatment Outcome

Group (Instrument Location)	Number of Teeth (n)	Subgroup A (Removed completely)	Subgroup B (Bypassed to apical constriction)	Subgroup C (Couldn't be removed or bypassed)
I (coronal third)	n=60	n=60	n=0	n=0
II (middle third)	n=60	n=60	n=0	n=0
III (apical third)	n=60	n=47	n=10	n=3
Total	n=180	n=167	n=10	n=3

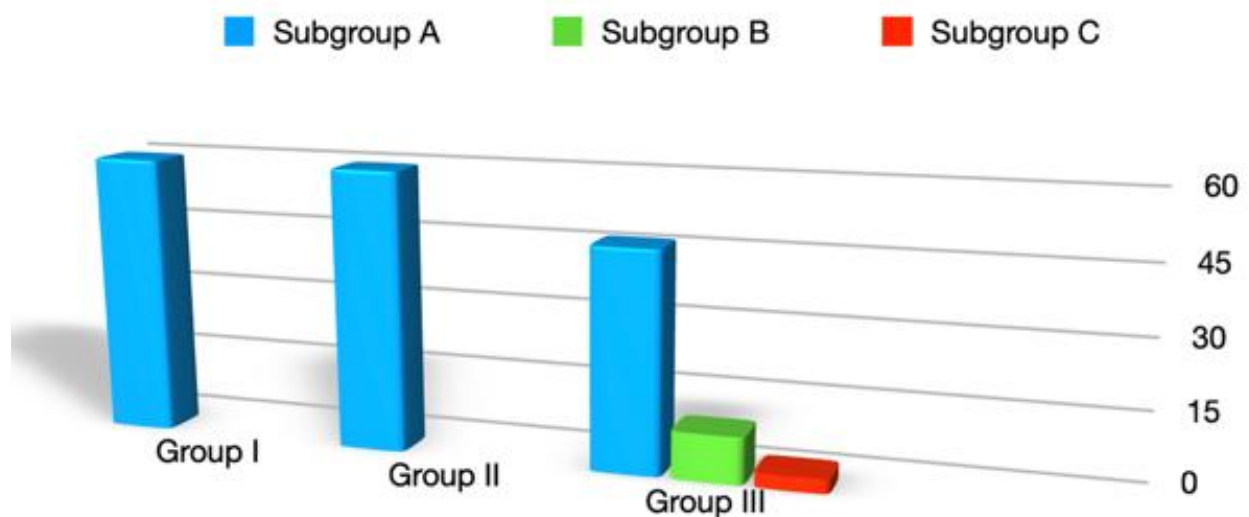


Figure 2 Graphical representation of the distribution of clinical cases (n=180) into three Groups (I-III) and three Subgroups (A, B, C) for each group.

No cases of adverse complications such as root perforation, instrument extrusion beyond the apex, or iatrogenic fracture were reported in this series. However, minor canal wall alterations were observed in 7.22 % of cases, predominantly in attempts at ultrasonic retrieval within curved canals.

Overall, these findings demonstrate that the success of instrument management is strongly dependent on the anatomical location of the fragment. Retrieval with ultrasound under magnification proved highly effective in the coronal and middle thirds, while bypassing was more often employed in apical cases. Nevertheless, fragments located in the apical third remained the most challenging to manage, with a significantly higher proportion of failures compared to other locations.



Figure 2 Removal of the instrument from the tooth classified in Group I, *Subgroup A*. Pre- and postoperative radiograph on tooth #13.



Figure 3 Removal of the instrument from tooth (*separated instrument into the MB canal*) classified in Group II, *Subgroup A*. Pre-, postoperative and monitoring radiographs on tooth #36.



Figure 4 Removal of the instrument from tooth (*separated instrument into the ML canal*) classified in Group III, *Subgroup A*. Pre- and postoperative radiographs on tooth #46.

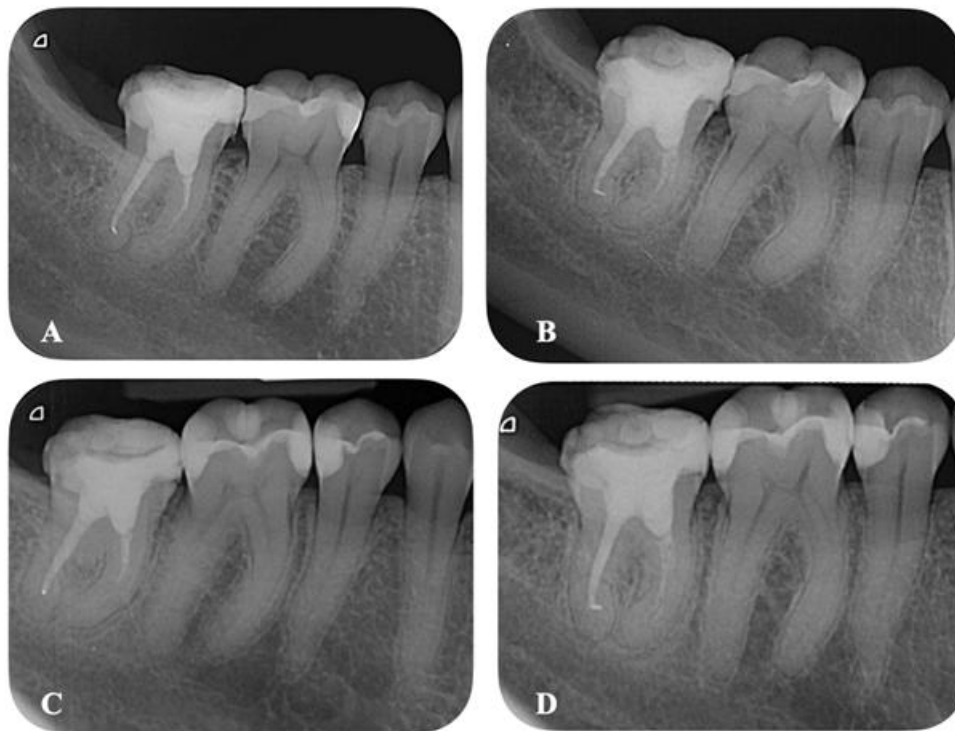


Figure 5. A clinical case from Group III, Subgroup C (Couldn't be removed or bypassed): **A/** Postoperative radiography - after the separation of the endodontic NiTi endodontic instrument into the distal canal; **B/** Control radiography - after 2 years; **C/** 5 years follow-up; **D/** 8 years follow-up.

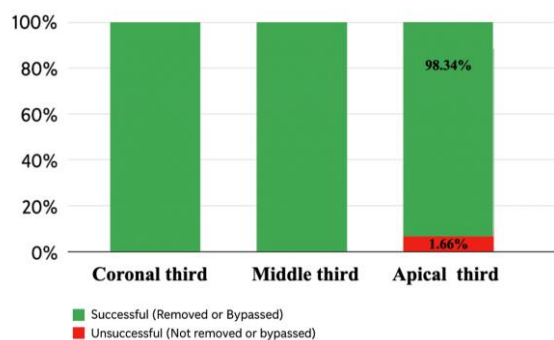


Figure 6 Clinical outcomes in relation to the position of separated instruments.

The distribution of treatment outcomes according to the location of the fractured instrument is presented in Figure 6. When the fragment was situated in the coronal or middle third of the root canal, complete removal with ultrasonics was achieved in all cases, resulting in a success rate of 100%. In contrast, when the fragment was located in the apical third, the procedure proved more challenging. Although a considerable proportion of fragments were successfully removed in 92.78%, an additional 5.56% could only be bypassed to the apical constriction. As both removal and bypassing provide adequate canal patency and enable subsequent disinfection and obturation, these cases should also be regarded as successful. Only a small minority (1.66%) of fragments located in the apical third could neither be removed nor bypassed, representing true treatment failures (Table 1).

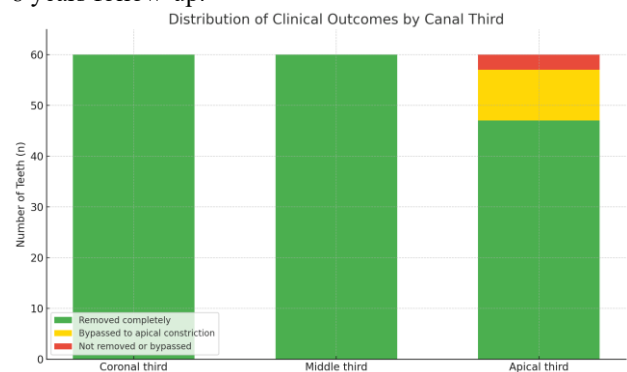


Figure 7 Stacked bar chart showing the distribution of clinical outcomes according to the third canal.

Green bars represent cases in which the separated instrument was completely removed (Subgroup A), yellow bars correspond to bypassed instruments (Subgroup B), and red bars represent cases in which the fragment could not be removed or bypassed (Subgroup C). The success rate decreases in the apical third, where removal becomes more technically challenging.

4. Discussion

Dental malpractice is the negligent or unintentional act of a dental professional who fails to meet established standards of care, thereby causing harm to the patient [19]. Endodontic malpractice constitutes approximately 14–17% of all reported cases [20, 21]. Despite the introduction of advanced techniques and novel technologies intended to improve the quality and success of endodontic treatment, the number of negligence claims in this field has been rising in recent years [22]. The most frequently reported errors include root canal perforation and separation of endodontic instruments [23]. Establishing a safe and reliable relationship with patients requires strict adherence to the core legal and ethical

principles of dental practice. Professional ethics should provide the guiding framework in the event of complications, such as instrument separation. Thorough pre-treatment communication, particularly the provision of appropriate informed consent, can help safeguard both the patient and the dentist from future conflict [24]. The prognosis of a tooth with a separated instrument depends on a number of factors, like the presence of a periapical lesion, the microbial contamination of the root canal at the time of instrument separation and last but not least, the quality of the obturation. The tooth prognosis is compromised when instrument separation is combined with a lesion, only when proper root canal disinfection is impossible to achieve.

In their study, Ungerechts C et al. observed 30 clinical cases of separated instruments that were either removed, bypassed or retained in the root canal, and followed up. The follow-up period of time was at least 12 months, and the absence of clinical symptoms and radiographic findings was set as an index of success. Overall, a 60% success rate was observed, regardless of instrument removal or retention and irrespective of the initial diagnosis. In cases of instrument removal, the success rate was 71.4%; in those of instrument bypass, it was 40%, and 64.7% in those cases that were obturated coronally to the fragment [14].

The retrieval of separated endodontic instruments remains one of the most technically demanding yet essential procedures in contemporary endodontic practice. Instrument fracture may compromise proper canal cleaning and shaping, obstruct access to the apical third, and consequently influence the long-term prognosis of root canal therapy. Hence, the ability to remove fractured fragments safely and predictably is a critical factor in achieving successful treatment outcomes. According to recent systematic reviews and experimental studies, the reported success rates of instrument retrieval vary substantially, depending on both the fragment's location within the root canal and the technique employed. Overall success has been reported to average around 83%, with significantly higher success for fragments located in the coronal and middle thirds (approximately 91–92%), and notably lower for fragments retained in the apical third (around 79–80%) [25]. The use of contemporary magnification, ultrasonics, and microtube systems has markedly enhanced removal outcomes, with some studies reporting success rates up to 92.5% under controlled clinical conditions [26]. Nevertheless, instrument retrieval remains a procedure requiring considerable skill and clinical judgement, as the removal process inevitably carries a risk of perforation, canal transportation, or unnecessary dentine removal. Current research continues to explore the optimisation of retrieval techniques through digital simulation, finite element analysis, and minimally invasive strategies to preserve root structure [26,27]. The establishment of predictable, biologically respectful, and conservative protocols is essential to ensure long-term success and maintain the structural integrity of the treated tooth [25–27].

Successful removal of fractured instruments may risk the long-term outcome of the tooth by sacrificing sound pericervical dentin, which may lead to perforations and predispose the tooth to vertical root fracture. The clinician should

consider the microbiological and biomechanical aspects during clinical decision-making [28].

When success is defined as either complete removal or effective bypassing, the overall success rate across all canal thirds was 98.3% (177 of 180 cases). These findings underline the predictability of fragment management in the coronal and middle thirds and highlight the clinical difficulties associated with fragments lodged in the apical third (Figure 6). Nevertheless, even in this region, a high rate of successful management was achieved, confirming the effectiveness of contemporary ultrasonic techniques and bypassing strategies.

The results from this investigation demonstrate that the management of fractured instruments is highly predictable when the fragment is located in the coronal or middle third of the root canal, with consistently favourable outcomes. Cujé et al. showed 100% removal success in these regions, confirming the predictability of management in the coronal and middle thirds [29]. Gencoglu and Helvacioğlu similarly reported excellent outcomes with ultrasonics, achieving >95% success in straight canals [30].

The overall success rate for the removal of separated endodontic instruments in the present study was 92.78% (167/180 cases), demonstrating a high level of clinical predictability. When this outcome was compared with an expected success rate of 80% derived from previously reported averages in the literature for similar procedures, the difference was statistically significant ($z = 4.29$, $p < 0.001$). This indicates that the success rate observed in the current investigation exceeds the generally accepted clinical benchmark for instrument retrieval and reflects the efficacy of the applied technique and operative protocol (Figure 8).

The calculated 95% confidence interval (CI) for the true population success rate ranged between 89.0% and 96.5%, suggesting that even at the lower limit of the interval, the expected performance remains well above the conventional 80% reference value. This narrow CI further confirms the consistency and reliability of the applied method, indicating low variability within the dataset. The upper limit of the confidence interval, approaching 97%, supports the assumption that under optimal clinical conditions, the success rate may reach values comparable to those reported in high-performing centres utilising magnification and ultrasonic systems.

From a clinical standpoint, these results validate the technique as a predictable and minimally invasive method for managing fractured instruments, particularly when supported by appropriate magnification and conservative canal enlargement. Statistically, the significant deviation from the hypothesised 80% success level substantiates the advantage of the current protocol.

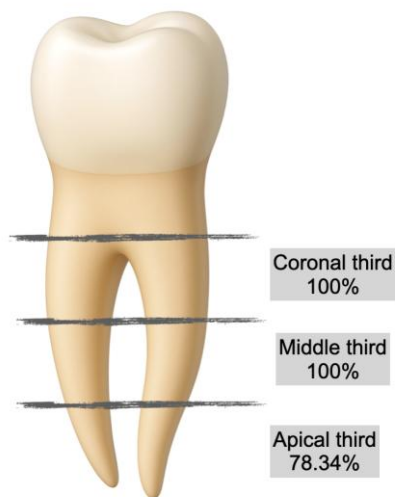


Figure 8 Three-dimensional schematic of a molar illustrating the distribution of success rates by root canal third.

Overall, the combination of a high mean success rate, statistical significance, and a tight 95% confidence range underlines the reproducibility and clinical robustness of the procedure for the retrieval of separated endodontic instruments.

Even in the apical third, where the technical challenges are greater, success was achieved in the vast majority of cases. Nevares et al. demonstrated that, although overall success was 70.5%, when fragments were visible under the microscope, success increased to 85.3%, supporting the high potential for favourable outcomes in this region [31]. However, other studies have reported considerably lower success rates. Souter and Messer found only 33% success when fragments were located in the apical third [32], while Tzanetakis et al. reported just 37.5%, highlighting the increased technical difficulty and reduced predictability in this region [33]. This underlines the importance of contemporary ultrasonic techniques and bypassing strategies as reliable approaches for maintaining canal patency and ensuring long-term treatment success. The collective evidence suggests that while coronal and middle thirds offer predictable success, outcomes in the apical third remain technique-sensitive and highly dependent on visibility, operator skill, and canal anatomy.

Fan et al. concluded that strict adherence to standardized protocols is indispensable in clinical practice for minimizing the risk of instrument separation. Particular caution should be exercised when reusing NiTi instruments. NiTi instruments are especially susceptible to fatigue and fracture in calcified or curved root canals, where increased stress is applied during instrumentation. To minimize the risk of instrument separation, instruments should be promptly replaced when encountering complex root canal anatomy or signs of wear. Considering single-use options can also further enhance the safety and efficacy of treatment. In cases of instrument separation, a thorough preoperative assessment is essential. Management strategies should be guided by a comprehensive evaluation of all relevant factors, including the characteristics of the separated instrument, root canal anatomy, and the patient's overall prognosis. When attempting retrieval, the likelihood of success must be carefully weighed against the

risk of complications. Case selection and adherence to strict procedural protocols are critical to achieving favourable clinical outcomes. Prioritizing instrument retrieval at the expense of ignoring potential complications is strongly discouraged. The primary goal remains the successful completion of nonsurgical root canal treatment. If high-quality nonsurgical therapy fails to resolve clinical symptoms, endodontic microsurgery may be considered as an alternative to optimize outcomes and preserve the tooth [34].

5. Clinical relevance and Final Considerations

The findings of the present investigation highlight the clinical relevance of adopting a precise, minimally invasive strategy for the retrieval of separated endodontic instruments. The statistically significant difference from the expected 80% success rate, together with the narrow 95% confidence interval, reinforces the reliability and reproducibility of the applied protocol. Such outcomes support the view that the use of magnification, controlled ultrasonic techniques, and careful canal design optimisation can markedly enhance procedural safety and effectiveness.

From a biological perspective, preserving pericervical dentine and maintaining the original canal anatomy are critical to sustaining the long-term structural integrity of the treated tooth. The conservative approach demonstrated in this study aligns with the principles of contemporary adhesive and biomimetic dentistry, where procedural efficiency is balanced with tissue preservation. Furthermore, the consistency of the results suggests that the protocol can be successfully integrated into routine clinical practice, providing a predictable method for managing fractured instruments without compromising tooth structure.

Overall, the evidence from this study contributes to the ongoing discussion on refining endodontic techniques through the integration of magnification, advanced instrumentation, and evidence-based decision-making, all aimed at achieving safer, more conservative, and biologically respectful endodontic outcomes.

6. Conclusion

Within the limitations of this study, the applied protocol for the retrieval of separated endodontic instruments demonstrated a high overall success rate of 92.78% (95% CI = 89.0–96.5%), which was significantly greater than the expected benchmark of 80% ($p < 0.001$). These findings confirm the reliability and clinical predictability of the proposed technique. The integration of magnification and controlled ultrasonic activation, combined with a conservative preparation design, contributed to effective instrument removal while minimising the risk of iatrogenic damage. The results underscore the importance of a minimally invasive philosophy that prioritises dentine preservation and structural integrity. Consequently, the described protocol may serve as a clinically valuable and biologically respectful approach for managing fractured instruments in endodontic practice, aligning with the principles of modern adhesive and biomimetic dentistry.

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