



Comprehensive Analysis of the Use of Individual Instrumentation in Endodontic Practice

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Article History	Abstract
Received: 06 June 2023 Revised: 05 Sept 2023 Accepted: 11 Sept 2023	<i>Despite advances in endodontic instruments, such as the use of nickel and titanium, avoiding instrument separation during root canal shaping and cleaning remains a challenge for endodontists due to cyclic fatigue and torsional stress. Therefore, it is necessary to carry out a comprehensive search for original articles related to the handling of separated instruments in endodontic practice between 2018 and 2022. The objective is to obtain knowledge on how to approach situations with fractured instruments during endodontic procedures. Twenty articles were analyzed using a documentary methodology and a content matrix. The occurrence of instrument fractures can affect the prognosis of treatment and the endodontic triad. However, it was concluded that there are several successful techniques to address this problem, both surgical and non-surgical, and the use of magnification and CT is also relevant to achieve successful long-term treatments.</i>
CC License CC-BY-NC-SA 4.0	Keywords: Endodontic instruments, Root canal, Endodontics, Procedures.

1. Introduction

The treatment of root canals has as final objectives to destroy microorganisms within the root canal system, eliminate necrotic pulp tissue and finally achieve an acceptable filling and sealing of all root canal spaces ⁽¹⁻²⁻²¹⁾, despite the technological advances that have been incorporated into the methodology of endodontic treatment, one of the drawbacks that can occur is the separation of the endodontic instruments during the shaping and cleaning of the complex root canal system that exists, creating a very unpleasant situation ⁽³⁻⁴⁻⁵⁻⁶⁻²²⁾ and very frequent especially when using NiTi rotary files despite the fact that these files are flexible and retain the configuration of the root canal during its preparation ⁽⁷⁻⁸⁻⁹⁻¹⁰⁻²³⁾.

There are several factors that increase the risk of separation of endodontic instruments during use, preventing access to the most important portion of the root canal ie the apical portion, these factors range from the manufacturing process of the instrument, multiple uses of the same instrument, the inappropriate access cavity, the anatomy of the root canal i.e. curved or C-shaped ducts, Insertion of inadequate files, how to use inside the duct, as well as the experience of the professional ⁽⁷⁻⁶⁻¹⁰⁻²⁴⁾

Villalpando et al ⁽⁶⁾ indicate that before taking an alternative treatment for these cases it is important to evaluate in which area of the duct the separation occurred since many times the fragment came out to the periapical tissues. It is also important to take into account the length and location of the fragment in the duct, the design of the cross-section of the instrument, the diameter and degree of

curvature of the root, as well as the presence or absence of apical periodontitis, a critical factor influencing the prognosis of treatment. ⁽³⁻⁷⁻¹¹⁻²⁵⁾

Richert et al ⁽¹²⁾, indicates that for the management of separate instruments it is important to have good magnification, solid skills and clinical judgments, especially in the evaluation of the difficulty of the cases that is necessary for various treatment approaches. For this reason, interest arose in conducting a bibliographic review in order to analyze the handling of separate instruments in the endodontic clinic. At present there are different techniques to treat the separation of endodontic instruments, being the first alternative non-surgical procedures and within these the best option is the use of ultrasound tips, however, its improper use can cause secondary fracture of the fragment of the separated file, transport, perforation and fracture of the root, Endodontic forceps, endodontic files and own systems can also be used to remove fragments. ⁽⁵⁻¹³⁻¹⁴⁾. There are surgical techniques such as apicoectomy when the use of conventional techniques is not possible, but there are occasions that due to the proximity to vital structures such as the maxillary sinus, the fragment is preserved for which radiographic controls must be carried out periodically ⁽³⁻¹³⁻¹⁰⁾.

2. Materials And Methods

This systematic literature review represents an exhaustive and rigorous analysis of the information from studies carried out and published during the period between 2018 and 2022. To carry out this research, a sample of 20 carefully selected original articles has been used, which directly address the issue of the management of separate instruments in endodontic practice.

The collection of these articles was carried out through a meticulous electronic search in various renowned databases in the scientific and dental field, such as Web of Science, Science Direct, PubMed and Journal Endodontic. This selection of databases guarantees the obtaining of specialized and quality literature to support the review.

The inclusion criteria applied for the selection of the 20 articles have been carefully established with the aim of ensuring the relevance and relevance of the information obtained. Among these criteria, the availability of the full text of the articles, the focus on the specific topic of the management of separate instruments in endodontics, as well as the timeliness of the publications within the established period were considered.

The qualitative analysis of the information from these studies will allow to obtain a deep and well-founded understanding of the various strategies, techniques and approaches used in the management of separate instruments in endodontic practice. Rigor and consistency in the review will ensure that the results are reliable and applicable in the clinical context.

The final purpose of this literature review is to offer a comprehensive and updated view of the state of the art regarding the handling of separate instruments in endodontic practice, which will serve as a valuable source of knowledge for endodontists, researchers and dental professionals in general. The findings obtained will contribute to the advancement and improvement of clinical practices in this specialty, always seeking to provide more effective and safe treatments for patients.

Inclusion criteria used in the search were:

- to. Articles with full text.
- b. Articles from the last 5 years.
- c. Articles broadly related to this research topic.
- b. Articles in English most

Exclusion criteria:

- to. Articles that could not be accessed in the full text.
- b. Articles that lacked interest or usefulness for the topic to be discussed.
- c. Articles that were not within the years established as a parameter.

In this way, 22 articles were selected, of which not all met the parameters indicated above, in such a way that only 20 original articles published in the year 2018-2022 were used and that are related to the aspects established in the objective of this bibliographic review and thus achieve an understanding of the handling of the separate instruments in practice.

3. Results and Discussion

Table 1. Description of the articles used for the research.

Author	Title	Data	Category
Azarpazhooh et al. ⁽⁸⁾	A Scoping Review of 4 Decades of Outcomes in Nonsurgical Root Canal Treatment, Nonsurgical Retreatment, and Apexification Studies—Part 1: Process and General Results	The methodology of endodontic treatment is continually evolving as new treatments are introduced. Molar retreatments are more frequent, compared to anterior and premolar pieces, due to procedural errors, difficult accessibility, root canal curvature and higher rates of lost canals, aggravating with age.	Technological advances Complex anatomy of the root canal system.
Kaddoura & Madarati, ⁽¹⁰⁾	Management of an over-extruded fragment in a C-shaped root canal configuration: A case report and literature review	The complex configuration of root canal systems is one of the most influential factors, not only during instrument separation, but also during handling. Separate intraduct instruments are one of the most difficult complications that prevent complete cleaning of root canals.	Complex anatomy of the root canal system. Endodontic failures
Sandhu M, ⁽¹⁴⁾	Techniques for removal of intracanal separated instruments (Part 2)	The two main causes of Ni-Ti rotary file breakage are cyclic fatigue and torsional stress. There are different methods for the extraction of separate intraduct instruments: mini-forceps, endodontic file tensioning technique, wire loop method, extractors, ultrasound, electrolytic techniques, laser irrigation among others.	Causes of breakage Extraction methods.
Alrahabi & Ghabbani) ⁽⁷⁾	Removal of a separated endodontic instrument by using the modified hollow tuve-based extractor system: A case report	In recent years, nickel-titanium (NiTi) rotary instruments have been widely used to clean and shape the complex root canal system. They are more susceptible to separation compared to stainless steel hand instruments. There are different techniques for the management of the separation of endodontic instruments, the most interesting being the use of ultrasound tips accompanied by the dental surgical microscope. The presence of apical periodontitis is a critical factor influencing the outcome of root canal treatment and instrument separation.	Susceptibility to fracture. Complex root anatomy Use of techniques, methods and devices for the removal of fragments Apical periodontitis
Cunha et al., ⁽¹⁾	Treatment outcome of young molars obstructed by fractured endodontic instruments: two case reports	Fragments such as ultrasound tips as well as endodontic files can hinder proper preparation of the root canal space and negatively affect the prognosis of endodontic treatment. The ultrasonic technique has been successfully used to remove fractured rotating files, although its improper use can lead to secondary fracture of separated file fragments. Several factors influence the decision to remove the instrument separately or keep it, however the success rate of endodontic treatment is related to the efficiency in disinfection.	Fragility of instruments. Ultrasound Disinfection of root canals.
Mantri S, ⁽³⁾	Management of fractured root canal treated mandibular molar with separated endodontic instrument extending in periapical region.	The separate segment of the instrument, together with bacteria and dentin debris, can act as a foreign body that prevents healing after endodontics as it prevents access to the apical part of the duct, compromising disinfection and filling. Factors such as periapical injury, canal infection, canal anatomy, fragment position, and type of fractured instrument can significantly influence prognosis and treatment approach.	Disinfection and filling Associated factors

Yadav et al., (17)	Nonsurgical Management of a Large Periapical Lesion Following Instrument Retrieval From the Apical Third: A Case Report With a Three-Year Follow-Up	Despite technological advances especially in the metallurgy of rotary instruments, the separation of these instruments from NiTi is 1.3 to 10% compared to stainless steel. Several techniques and kits have been designed for the recovery of fractured instruments, of which ultrasound is quite effective. The separate instrument can potentially reduce the success rate of endodontic therapy, particularly when the tooth is associated with a periapical injury.	Probability of separation Ultrasound efficiency Success rate
Al- Shehadat et al., (20)	Retrieval of over-extending separated Endodontic instrument: a review of methods and case report	The advent of nickel-titanium alloys (NiTi) has not resulted in a lower incidence of instrument fractures blocking access to the apical third compromising	Anatomy of the ducts
Richert et al., (12)	Decision Support for Removing Fractured Endodontic Instruments: A Patient-Specific Approach	Instrumental fracture is a common endodontic complication (0.25 to 7.41%) especially in the apical third of the root. There are many factors that contribute to this event, being torsional stress or flexural fatigue the most frequent causes. There are digital tools that help Decide between surgical (apicectomy) and non-surgical (use of ultrasound tips) strategies in a clinical situation of a fractured instrument.	Place of fracture. Torsional stress or bending fatigue. Solution criterion
Šošić et al., (15)	Assessment of Damage of Endodontic Instruments with Naked Eye and Optical Instruments	Advances in material technology and operational techniques have allowed the use of nickel titanium rotary instruments being very flexible and with better cutting capacity, compared to manual steel instruments. Endodontic instruments are subject to fatigue, which occurs with repeated loading, thus creating microcracks, specifically when used in curved root canals. The removal of a broken instrument is extremely demanding, which makes the favorable result of endodontic treatment more difficult to achieve, for which it is suggested to evaluate if there are microcracks in the endodontic file before being used either with the naked eye with a magnifying glass or microscope	Cutting capacity and flexibility of rotating instruments. Instrument fatigue in curved ducts Complex treatment. Evaluation of Microfractures in the endodontic file.
Liao et al., (11)	Management of Separated Instruments Extruded into the Maxillary Sinus and Soft Tissue: a Case Series	The separation rate of NiTi rotary instruments is 1.3 to 10%, with several techniques for the extraction of separate instruments being the ultrasound technique the safest and most successful. Extrusion of separate instruments is a serious complication that is difficult to manage, especially when fragments are extruded into the maxillary sinus.	Separation rate. Ultrasound technique Location of the fractured segment.
Lemos et al., (18)	Different techniques to remove a fractured endodontic instrument in an upper first molar: case report	Fractured instrument hinders the correct conformation and cleaning of the duct system even more when there are infections. Magnification in combination with ultrasound dramatically improves efficiency and safety in the removal of fractured instruments. The success rate of fracture instrument removal ranges from 68% to 87%, however it depends on several factors to achieve such an event.	Associated injuries Magnification and ultrasound. Success rate.
Souha et al., (5)	Conservative Approach for Management of Separated Endodontic Instruments: Case Reports	The presence of a foreign instrument in the root canal system blocks access to the apical third of the root and thus compromises the effectiveness of cleaning and shaping procedures. The conservative procedure should be the first attempt, since the extraction of a fractured file is associated with considerable risk, the selection of the technique should be discussed based on the selection of the case and the consent of the patient.	Root canal blockage. Selection of cases.

Da Silva et al., (13)	Methods for Removing Fractured Endodontic Instruments in Root Canal: A Brief Systematic Review	The separation of instruments inhibits the optimal cleaning and filling of the root canals, resulting in a less favorable prognosis for the tooth especially when apical periodontitis is present. There are several techniques available to extract fractured instruments and with the help of the surgical microscope a success of 77.3% is achieved however, the substance of the healthy tooth often must be destroyed in the process. It is important to perform a radiographic control either with periapical radiographs or CBCT	Prognosis. Success rate
Abu-Tahunet et al., (16)	Microscopic Features of Fractured Fragment of Nickel-Titanium Endodontic Instruments by Two Different Modes of Torsional Loading	By using NiTi instruments, clinicians can predictably shape curved, well-centered root canals, with a lower risk of transport, protrusions and perforation compared to stainless steel instruments. NiTi rotary instruments have Two basic mechanisms of fracture, by cyclic fatigue and by torsion.	Benefits of rotating instruments. Fracture mechanism
Van der Vyver et al., (2)	Modern considerations when approaching fractured endodontic instruments - Part 2: A review of the literature and clinical techniques	In recent years, several new techniques and devices used in the extraction of separate instruments have been introduced to the market. Instrument failures are attributed to several factors. One of them is the incorrect use of instruments; Traders may ignore techniques recommended by manufacturers or operate instruments that are already fatigued from repeated use. The following options may be considered once the decision is made to continue treatment: leave the fragment, omit the fragment, remove the instrument by means of various techniques.	Extraction mechanisms. Failure factors. Solution criterion.
Vouzara & Lyroudia, (19)	Separated Instrument in Endodontics: Frequency, Treatment and Prognosis	An immediate periapical x-ray is recommended to confirm separation of the instrument, locate the instrument in the root canal, evaluate the anatomy of the root canal and measure the length of the fragment. The handling of a separate instrument can be conservative and/or surgical, with three approaches to conservative treatment: a) derivation of the separate instrument, b) removal of the separate instrument, c) instrumentation and filling of the root canal coronally to the fragment	Radiographic diagnosis. Treatment approaches.
Dulundu & Helvacioğlu-Yigit, (9)	The Efficiency of the BTR-Pen System in Removing Different Types of Broken Instruments from Root Canals and Its Effect on the Fracture Resistance of Roots	Separation of instruments during root canal treatment prevents effective root canal cleaning and conformation, this can reduce the success rate of root canal treatment Successful removal of broken instruments depends on the type of material, location and length of the instrument.	Biomechanical disinfection. Criteria for success.
Quispe et al., (4)	Strategies for removing fractured instruments in endodontic practice: literature review	There are technological advances that make it possible to access and remove fractured instruments, such as the dental surgical microscope, ultrasound and special systems that improve the visualization and handling of the separated fragments inside the root canal. The initial endodontic diagnosis is important to determine the degree of contamination of the root canal, as well as the anatomy of the root canal, the position and type of fractured instrument as well as the degree of wear that would be caused to the remaining tooth structure. Techniques have been developed that exceed the effectiveness of the ultrasonic system in variables of anatomical complexities, time and dentin conservation, as is the case of the Microtube extraction system, or Laser techniques such as Nd:	Technological advances Degree of contamination and anatomy. New extraction methods.

		YAG5, which claims to eliminate minimal amounts of dentin by eliminating fragments in relatively shorter times.	
Villalpando et al., ⁽⁶⁾	Instrument extrusion to periapical tissues and Resolution by surgery periapical: a case report	Detachment of an instrument into the duct is common but does not always lead to treatment failure. When there is a separation of manual or rotary instruments, especially in those cases in which it is impossible to remove them and it has been extruded to periapical tissues, it is necessary to perform periapical surgery using biocompatible materials.	Evaluation of the fragment. Surgical removal of instruments.

Studies by Alrahabi & Ghabbani (7), Yadav et al. (17) and Sosic et al. (15) have highlighted that technological advances have driven the evolution of endodontic treatments, allowing the incorporation of new materials and methodologies, such as the use of nickel-titanium (NiTi) rotary files, which have significantly improved the conformation of the root canal system. These observations are consistent with the criteria established by Azarpazhooh et al. (8) and Abu-Tahun et al. (16).

The root canal system of the teeth, especially in the posterior and apical portion, presents a highly complex internal configuration (4, 9, 10, 20), which makes the separation and fracture of instruments a common and recurrent phenomenon (5, 11, 12, 14, 18). Cyclic fatigue and torsional stress are identified as the main factors that predispose to the occurrence of these events (2, 3, 10, 16, 20), representing a significant challenge for the endodontist due to the complications that can arise in the conformation, cleaning and filling of the duct system (1, 3, 5, 9, 13).

Faced with the separation of endodontic instruments, various techniques have been developed for their management, which can be classified as non-surgical and surgical (12, 13, 17, 19). However, the choice of the appropriate approach depends on several crucial aspects, such as the presence of an apical lesion, the existence of infection in the canal, the anatomy of the root canal, the location of the fragment and the type of instrument involved (2, 4, 5, 6, 9, 11, 16). In most cases, a non-surgical conservative approach is preferred on the first attempt, with the ultrasonic technique being the most commonly used for the removal of separate fragments of rotating and manual files. The combination of this technique with the use of adequate magnification provides safety and efficiency in the procedure. However, it is essential that the professional has solid knowledge, patience and skills to carry out this procedure successfully and avoid further complications, thus ensuring the success of endodontic therapy (1, 5, 13, 17, 18).

The separation of endodontic instruments represents a significant challenge in clinical practice and requires precise and careful approaches to its management. Technological advances and current techniques provide effective tools to address this problem, which contributes to improving the outcome of endodontic treatments and ensures the preservation of patients' oral health.

In dental practice, one of the treatments that is frequently performed is endodontics, which is responsible for the study of the pathological processes of the dental pulp and its consequences on the tooth and surrounding tissues⁽⁹⁾. To perform the conformation and cleaning of the root canal system, ultrasound files and tips are used, instruments that are very often susceptible to fracture during the execution of these procedures.

Thanks to technological advances, NiTi rotary files are introduced to the market, which, being flexible and having a better cutting capacity^(7,15), it was considered that it could work safely especially in those curved ducts having a lower risk of transport, protrusions or perforations (16,7) Since at the beginning there were only manual stainless steel files, but having a very complex root anatomy during the preparation of the root canals another inconvenience arose, the fracture or intraduct separation of the instruments.^(7,10) especially in the apical portion, but not in the coronal and middle third of the duct; Yadav et al (17) and Liao et al (11) indicate that the percentage of fracture is 1.3 to 10%, which hinders the cleaning, conformation and filling of the ducts^(18,5) often causing treatment failure and possibly the loss of the tooth⁽¹⁷⁾

It is important to make a correct initial diagnosis ⁽⁴⁾, since this way it can be determined if there is the presence of an infected duct or a lesion at the periapical level aspects that must be taken into account when this inconvenience occurs that not only bothers the professional but also the patient who must have all the information about the fracture of the instrument inside the duct, as well as the protocol to follow to try to extract the separated fragment ⁽⁸⁾.

Currently, there is a large number of methods or systems ⁽²⁾, which allow to remove the fragment of the separated instrument that occurred especially during the formation of the duct system and as Van der Vyver et al ⁽⁶⁾ states this event can be caused either by the incorrect use of the instruments, inadequate access cavity, duct curvature, lack of training on the part of the operator as he ignores the techniques recommended by the manufacturers or uses instruments that are already fatigued by repeated use, as Abu-Tahunet et al ⁽¹⁶⁾ indicates that the basic mechanisms for NiTi rotary instruments to fracture are cyclic fatigue and torsion.

Cunha et al ⁽¹⁾ considers that several factors must be taken into account before deciding which method is the best way to take to remove the fragment, aspects that may be, periapical injury, infection of the canal, anatomy of the duct, type and location of the separated fragment inside the duct; however, today the following options can be considered once the separation of the endodontic instrument has been presented and It is decided to continue with the treatment: omit the fragment, leave the fragment or remove it ⁽²⁾

Vouzara & Lyroudia ⁽¹⁹⁾, Dulundu & Helvacioğlu-Yigit ⁽⁹⁾ consider that the best option is to remove the instrument for which there are non-surgical and surgical procedures ⁽¹²⁾, depending on the case, however, you should first opt for non-surgical procedures being the safest and most successful technique that enables the access and extraction of fractured instruments the use of ultrasound tips with magnification aid i.e. a surgical microscope achieving an instrument extraction success rate of 77.3% as stated by Da Silva et al ⁽¹³⁾, Lemos et al ⁽¹⁸⁾, Liao et al. ⁽¹¹⁾, Quispe et al ⁽⁴⁾; but the professional must have sufficient knowledge, patience and skill since it can cause new complications such as secondary fracture of the instrument, increase in temperature on the external surface of the root, damage to periodontal tissues, excessive removal of dentin, among others.

Villalpando et al ⁽⁶⁾ and Al-Shehadat et al ⁽²⁰⁾ consider that when there is separation of the intraduct instrument together with apical periodontitis or when the instrument has been extravasated and is in the periapical tissues, the best option to remove the instrument is a surgical approach, that is, an apicoectomy using biocompatible materials such as MTA, root amputation or intentional reimplantation is also chosen, but there are times when this procedure cannot be performed due to the difficulty of access to the site, the lack of visibility of the surgical site and its proximity to important anatomical regions, such as the mandibular canal, maxillary sinus or nostrils as indicated by Mantri S. ⁽³⁾ and Sandhu M ⁽¹⁴⁾ decreasing the success of endodontic treatment.

4. Conclusion

From the careful review of the different selected articles, important conclusions have been obtained that shed light on the management of the separation of instruments in the conformation of the root canal, especially in teeth such as molars, which present a highly complex root anatomy, particularly in its apical third.

Despite advances in the use of nickel-titanium (NiTi) files, instrument separation remains a recurring challenge in endodontic practice. However, it is highlighted that thanks to continuous technological development, a wide variety of methods are now available to successfully extract the separated fragments. The implementation of ultrasound tips and the use of magnification techniques have been revealed as fundamental tools for the effective removal of these fragments, which allows to comply with the essential principles of the endodontic triad (conformation, disinfection and filling of the root canal system).

When instrument separation occurs in combination with the presence of apical periodontitis, an accurate and timely diagnosis becomes essential. In such situations, a surgical approach should be considered by performing an apicoectomy, which involves removing the tip of the affected root.

Importantly, in these cases, the use of biocompatible materials plays a crucial role in the success of the surgical procedure.

The search for effective solutions to the separation of instruments is essential to ensure the success of endodontic treatment and the preservation of the patient's oral health. Through this review, the importance of the continuous training of the endodontist in advanced techniques and the appropriate use of modern technologies has been reinforced, which will allow to face with greater efficiency and confidence the challenges that may arise during the procedures of shaping and cleaning the root canal system in complex teeth such as molars. These conclusions will serve as a valuable guide for clinical practice and decision-making in the management of clinical cases of this nature.

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