Restor Dent Endod. 2024 Nov;49(4):e35
https://doi.org/10.5395/rde.2024.49.e35
eISSN 2234-7666

Restorative Dentistry & Endodontics RDE

Research Article

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Predictive factors in the retrieval of endodontic instruments: the relationship between the fragment length and location

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OPEN ACCESS

Received: Apr 25, 2024
Revised: Jun 23, 2024
Accepted: Jun 27, 2024
Published online: Sep 9, 2024

Citation
Portigliatti R, Consoli Lizzi EP, Rodríguez PA. Predictive factors in the retrieval of endodontic instruments: the relationship between the fragment length and location. Restor Dent Endod 2024;49(4):e35.

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Conflict of Interest
No potential conflict of interest relevant to this article was reported.

Author Contributions
Conceptualization: Portigliatti R; Data curation: Portigliatti R; Formal analysis: Portigliatti R; Investigation: Portigliatti R, Consoli Lizzi

ABSTRACT

Objectives: This study aimed to relate the file fragment length and location in the root canal to the retrieval chances, the clinical time required and the occurrence of secondary fractures.
Materials and Methods: Sixty clinical cases of fractured instruments were included in this study. They were classified according to the instrument length and the location of the root canal. In each group, the success rate in the instrument retrieval, the clinical time required and the occurrence of secondary fractures were evaluated. The collected data were analyzed using the Kruskal-Wallis test on the basis of a 0.05 significance level.
Results: The fragment length showed no significant influence on the assessed variables ($p > 0.05$). The root third where the instrument was located resulted in an increased clinical time, with statistically significant differences ($p < 0.05$). However, the procedure success rate and the occurrence of secondary fractures showed no association with these variables.
Conclusions: In accordance with the findings of this study, the fractured fragment length did not influence any of the variables assessed, but it is suggested to focus on the fragment location inside the root canal to decide the retrieval of a fractured instrument.

Keywords: Fracture; Instrument; Nickel-Titanium; Retrieval

INTRODUCTION

During the root canal preparation, fractures of the endodontic instrument can occur, affecting the prognosis of the treated tooth. Attempting fragment retrieval, lateral bypassing, treating the root canal up to the level of the fragment, or a surgical procedure can be the treatment options to perform when instruments are broken [1]. The decision depends on the operator's expertise in performing the retrieval, magnification management, and the availability of extraction systems for fractured fragments [2,3]. In the case of attempting the retrieval, it becomes challenging to predict the success rate as well as the occurrence of procedural accidents and the clinical time required [4]. Currently, scientific progress is focused on the study of the causes of instrument fractures in order to prevent this type of accident [5]. However, file fracture remains a problem even today in clinical practice [6].

EP, Rodríguez PA; Methodology: Portigliatti R; Project administration: Rodríguez PA; Resources: Portigliatti R; Software: Portigliatti R; Supervision: Portigliatti R; Validation: Portigliatti R; Visualization: Portigliatti R; Writing - original draft: Portigliatti R, Consoli Lizzi EP, Rodríguez PA; Writing - review & editing: Portigliatti R, Consoli Lizzi EP, Rodríguez PA.

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The main causes of the file fracture are cyclic flexural fatigue and torsional stress [7]. The flexural cyclic fatigue occurs when a wire is bent over and over again at the same point and, for this reason, this event is referred to as cyclic fatigue. This occurs both in instruments with rotatory and reciprocating kinematics [8-11]. The resistance of an instrument to the CF is inversely related to its size. So, the larger the diameter of the wire subjected to flexion, the lower the resistance to cyclic fatigue [12]. As regards the metallography, the predominance of the martensitic phase favors the resistance when compared to the instruments with higher austenitic expression [13]. On the other hand, the torsional stress arises from the mechanical locking of the instrument within the root canal, usually in a location close to the tip. This friction hinders the instrument movement, either engine-driven or handled by the operator [14]. When the rotational force applied exceeds the resistance limit, plastic deformations occur in the shank of the file, leading to separation [7]. The resistance to torsional stress increases with the increase in the size of the file. Since the tip of the file is its thinnest part, this is the site of the instrument most sensitive to torsional fracture [15,16]. Furthermore, the files with austenitic configuration show higher resistance to torsional fracture than those with martensitic configuration [17].

The intracanal location and the length of the fragment are other factors affecting the removal procedures [12,18,19]. If the choice is to remove the fragment, the procedure protocol includes the use of magnification, specific ultrasonic tips, and removal systems such as micro-tweezers, microloops, and microtube devices [4,20,21]. Procedural risks involved in all these techniques are the root weakening in particular, or the occurrence of a secondary fracture, that is, the separation of the fragment while trying to dislodge it [22,23].

This clinical study was designed to take into account the risks of the procedures and those variables affecting the prognosis and the final success predictability. The objective of this study is to establish a relation between the fragment length and location with the retrieval possibility, the clinical time required and the occurrence of secondary fractures.

MATERIALS AND METHODS

The present study protocol was reviewed and approved by the Institutional Review Board of the Ethics Committee of the School of Dentistry of the University of Buenos Aires (approval No. 006/2020), and the informed consent was submitted by all participants. Sixty clinical cases of fractured instruments in patients attending the Postgraduate Program of Endodontics, University of Buenos Aires, Argentina, were included in this study. Inclusion criteria comprised teeth that required endodontic treatment and exhibited fragments of endodontic instruments. The exclusion criteria ruled out teeth in which the straight line access from the pulp chamber to the cervical portion of the fragment could lead to a root perforation. The broken instruments were classified according to the fragment length and the fragment location in the root.

- The fragment length: the subcategories were short (shorter than 3 mm), medium (3 to 4.5 mm), and long (larger than 4.5 mm) (**Figure 1A-1C**).
- The fragment location: The cervical, middle, and apical thirds were considered, according to the location of the top coronal part of the fragment (**Figure 1D-1F**).

All the patients were treated by the same operator, with technical resources available in the university clinic, such as specific ultrasonic tips (E18, E5 Helse Ultrasonic, Brazil; E6, E7

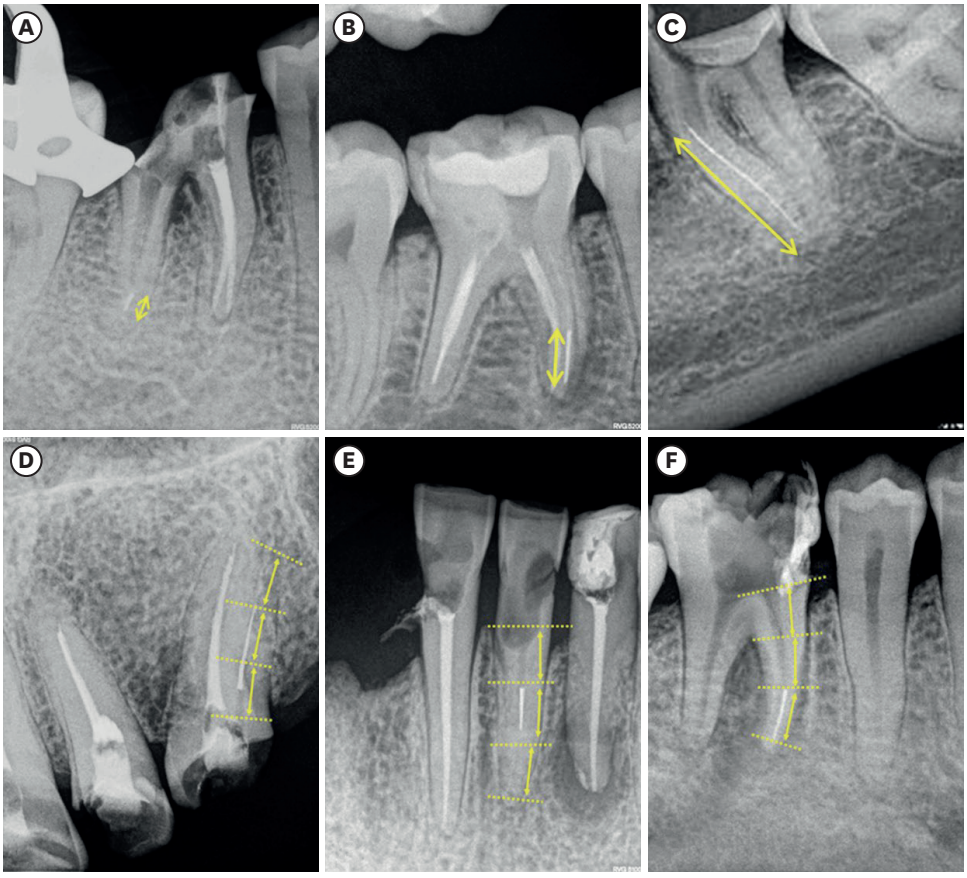

Figure 1. Upper row, fragments length: (A) short, 1.5 mm³; (B) medium, 3.5 mm; (C) long, 11 mm. Lower row, location of the fragment by thirds: (D) cervical; (E) middle; (F) apical.

Guilin Woodpecker Med Co., Guilin, China), micro-tweezers (Zumax Medical Co., Suzhou, China), loops system (BTR pen, Cerkamed, Stalowa Wola, Poland), and handmade tube systems (**Figure 2**). Once the removal procedure was performed, all the groups were related according to the following variables:

- Removal success rate.
- Time required from the tooth isolation and the removal of the dental filling until the fragment extraction or the cancellation of the removal attempt.
- Occurrence of a secondary fracture of the fragment to be retrieved.

The information was collected in spreadsheets. The 2 independent variables (length and location of the fragment) were analyzed separately from the dependent variables (success rate, working time and occurrence of secondary fracture). The statistical software R-medic was used [24]. The statistical assessment was analyzed using the Kruskal-Wallis test on the basis of a $p < 0.05$ significance level.

RESULTS

In this study, the cases of patients who presented with fractured instruments during the 2023 academic year in the Endodontic Program at the Faculty of Dentistry, University of Buenos

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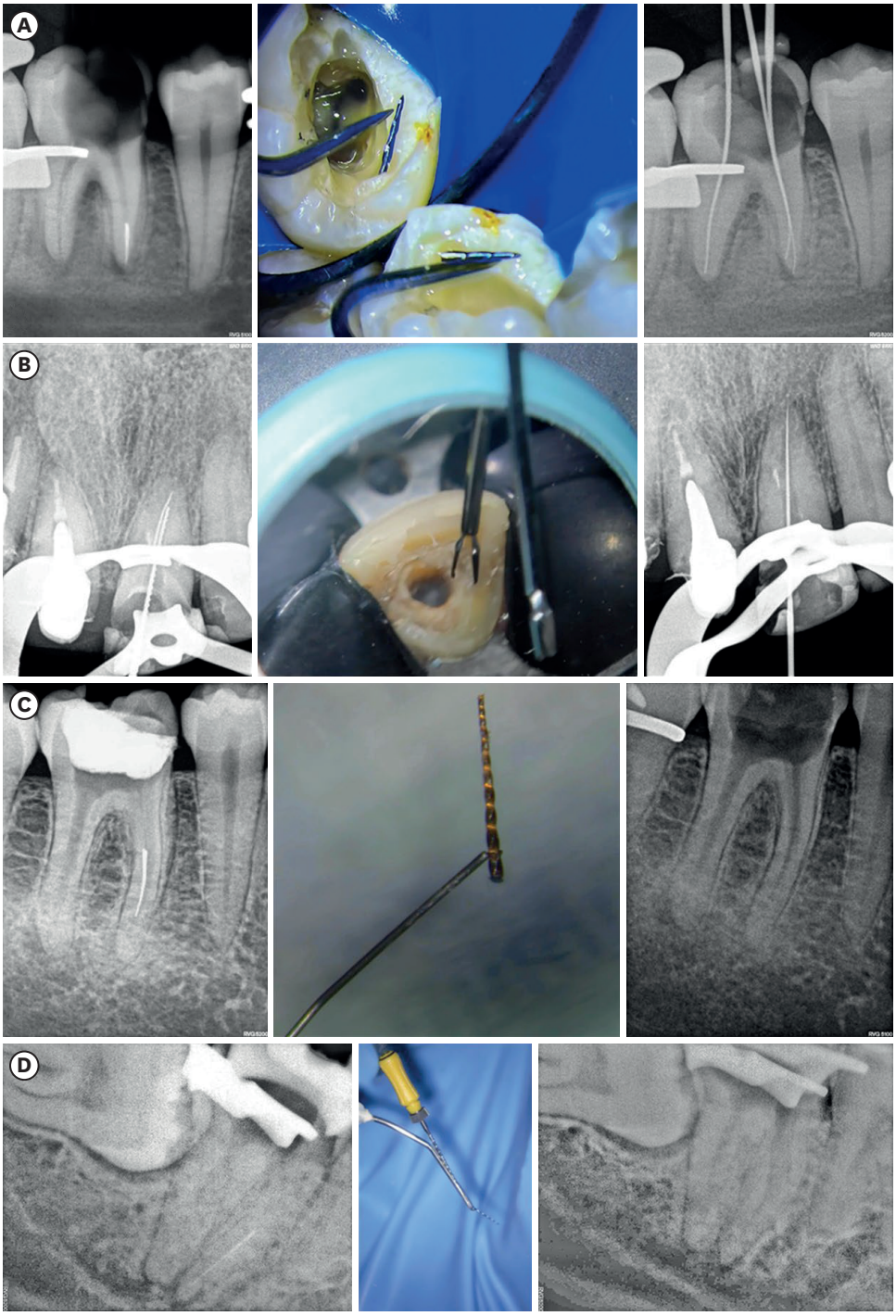

Figure 2. Removal system of fragments. (A) Ultrasonic tips; (B) micro-tweezer; (C) loop; (D) tube system.

Aires, were analyzed, and out of the 60 fragments intended for removal, 59 were successfully retrieved. In 3 of the cases, secondary fractures were reported. In one of them, the attempt to remove was abandoned as the reduced fragment did not allow access without a risk of perforation. The removal system used in each case can be seen in **Table 1**. The fragment location in the cervical, middle, or apical thirds was a significant influence on the retrieval time as the statistics show. Less removal time was required for those fragments accessible in

https://doi.org/10.5395/rde.2024.49.e35

Table 1. Retrieval technique used

Technique	Location			Length			No.
	Coronal	Medium	Apical	Long	Medium	Short	
US tips	7	15	9	5	11	16	31
Tubes	3	14	1	13	2	3	18
Loops	4	3	0	6	1	0	7
Micro-tweezers	1	2	0	3	0	0	3
Attempt abandoned	0	0	1	0	1	0	1
Total	15	34	11	27	15	19	60

Table 2. Time in minutes required to retrieve broken files according to location

Location of the fragment	Minimum	Mean	Median	Maximum	Standard deviation	No.
Coronal third	10.00	20.20	18.00	40.00	8.48	15
Middle third	10.00	33.38	33.00	55.00	11.21	34
Apical third	25.00	39.55	45.00	55.00	10.59	11

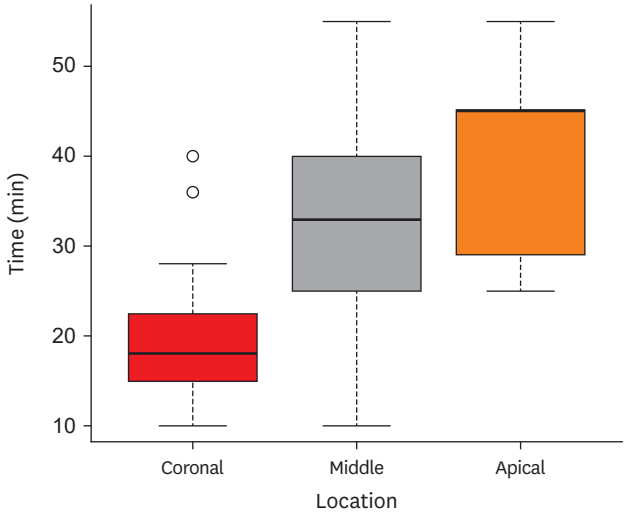

Figure 3. Box plot relating the location of the fragment and the removal time.

the root canal cervical third (**Figure 3**, **Table 2**). Regarding the fragment length and the time required, the results did not show statistically significant differences with any of the assessed variables (**Figure 4**, **Table 3**). Regarding the success rate and the secondary fractures, none of the studied groups showed significant differences.

DISCUSSION

The removal of a fractured instrument fragment in the root canal involves different degree variables of complication, making the prediction of the outcome difficult. These difficulties determine the clinical decision-making and occasionally lead to dismissing the attempt [1,21]. Therefore, the search for more and better tools to improve the procedure predictability could be very helpful to the endodontic community. In this work, the release of the fragment began with the use of ultrasonic tips. When the fragment was short, this action was sufficient to detach it and let it flow with irrigation. However, when the fragment was long, the space created with the ultrasonic tips was used to capture the fragment with systems such as tubes, loops, or micro-tweezers. Additionally, when the mechanical retention was very high, tube

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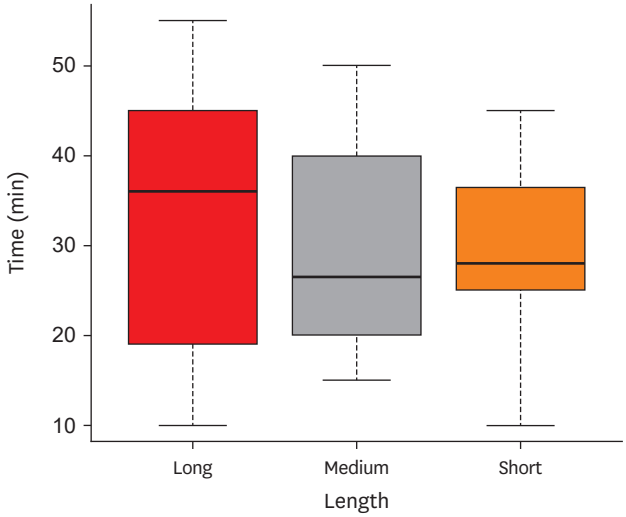

Figure 4. Box plot relating the length of the fragment and the removal time.

Table 3. Time in minutes required to retrieve broken files according to length

Length of the fragment	Minimum	Mean	Median	Maximum	Standard deviation	No.
Long	10.00	33.52	36.00	55.00	14.20	27
Medium	15.00	29.21	26.50	50.00	11.54	14
Short	10.00	29.42	28.00	45.00	9.95	19

systems were selected; for intermediate retention, loop systems were used; and in cases of minimal retention, micro-tweezers were employed.

The original protocols previously published by Madarati *et al.* [2] and Parashos and Messer [3] suggested avoiding removal attempts when the intracanal fragment is located in the apical third. However, in this study, the apical location of the fractured files showed no influence on the procedure success rate, although the removal time required was increased. This may be due to better visualization and handling of the fragment when it is closer to the dental pulp chamber.

Clinical cases were classified based on the cervical position of the fragment. Therefore, when the fragment was long, occupying the entire canal, and accessible in the cervical third, it was considered to be in a cervical location. This factor can explain why the time required varied greatly among different clinical cases. Regarding the length of the fragment, Terauchi claims that those longer require more removal time [4]. Furthermore, in the present study, no differences were observed in the time required by short, medium, and long fragments. However, a wide data dispersion was observed for this variable. This suggests that the difficulty related to the length depends on other associated factors, such as the cause of the fracture. Moreover, in this study, when the short fragments were easily accessible, allowed a quick removal, because they were easily dragged by the irrigation turbulence along with the removed dentin released from the surroundings of the first threads. However, when they were located in the apical third, they exhibited a greater visualization and access difficulty, as well as a higher risk of perforation because of the diminished thickness of the surrounding dentin.

The literature mentions the different accidents that can occur because of the removal procedure of fractured fragments. In this study, the secondary fractures were only considered. The introduction of a variable such as the weakening of the root housing

the fragment, that can later lead to a fracture, can be introduced in *in vitro* studies [18]. However, in this clinical study, the measurement of this factor is hindered by the lack of standardization of cases and the anatomic variables. On the other hand, certain treated teeth exhibited weakened roots before their inclusion in the protocol because of the removal attempts previously made by other dental care professionals. In the present research, the occurrence of secondary fractures increased the working time twice, with no effect on the final outcome. However, in another clinical case, it was necessary to stop the removal attempt because the access to the fragment might have led to a perforation.

Terauchi *et al.* [19] concluded that the long fragments have to be removed by means of retrieval systems and not only by using ultrasonic tips. Nevertheless, according to the experience of the current report, when the long fragment did not exhibit mechanical retention, it was easily retrieved with micro-tweezers, without exerting any force in the retrieval. But when there was mechanical locking, it became necessary to exert retrieving force, so the loop and tube devices appeared to be more effective.

CONCLUSIONS

Within the limitations of this clinical report, none of the assessed variables influenced either the success rate or the generation of secondary fractures. Moreover, the fractured fragment length did not influence any of the variables assessed. However, the location of the fragment influenced the removal time. For this reason, it is suggested to consider this parameter when making the decision to remove a fractured file.

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