MedNEXT
Journal of Medical an Health Sciences

REVIEW ARTICLE

DOI: 10.54448/mdnt24S409

Major observations of root canal instrument fractures and techniques for treatment and removal of endodontic instrument fragments: a systematic review

Helena Favaro[1,2*], Halana Boni Condessa Linhares de Castro[1,2*], Fábio Pereira Linhares de Castro[1,2]

[1] UNORTE - University Center of Northern São Paulo, Dentistry Department, São José do Rio Preto, São Paulo, Brazil.
[2] UNIPOS - Post Graduate and Continuing Education, Dentistry Department, São José do Rio Preto, São Paulo, Brazil.

*Corresponding author: Helena Favaro.
Unorte/Unipos - University Center of Northern São Paulo, Dentistry Department, and Postgraduate and continuing education, Sao Jose do Rio Preto, Sao Paulo, Brazil.
E-mail: f.helenafavaro@gmail.com
DOI: https://doi.org/10.54448/mdnt24S409
Received: 08-26-2024; Revised: 10-30-2024; Accepted: 11-15-2024; Published: 11-25-2024; MedNEXT-id: e24S409

Editor: Dr. Vihan Moodi, MD, MHPE, DBA, Post-DBA.

Abstract

Introduction: In the context of root canal endodontic treatments, fracture of instruments in the root canal during canal shaping is reported as one of the most common reasons for a negative prognosis. Nickel-titanium (Ni-Ti) instruments stand out. However, Ni-Ti instruments can fracture, with a prevalence of approximately 1.6% (0.7-7.4%). Special techniques to retrieve obstructing objects, such as ultrasonic instruments, hollow tubes with cyanoacrylate adhesive, trepanation techniques using an ultrasonic tip or a trepan bur, endo-extractors and welding with neodymium: yttrium-aluminum-perovskite (Nd: YAG) laser, and surgical techniques have been proposed. **Objective:** It was to develop a systematic review of the endodontic literature to externalize and discuss the main observations of fractures of root canal instruments, as well as to show the main techniques for treatment and removal of fragments of endodontic instruments. **Methods:** The PRISMA Platform systematic review rules were followed. The search was carried out from June to August 2024 in the Scopus, PubMed, Science Direct, Scielo, and Google Scholar databases. The quality of the studies was based on the GRADE instrument and the risk of bias was analyzed according to the Cochrane instrument. **Results and Conclusion:** 93 articles were found, 34 articles were evaluated and 08 were included in this systematic review. Considering the Cochrane tool for risk of bias, the global assessment resulted in 32 studies with a high risk of bias and 27 studies that did not meet GRADE and AMSTAR-2. Most studies showed homogeneity in their results, with X^2 =89.5% >50%. It was concluded that comprehensive cleaning of the root canal system is often impossible in the presence of a broken instrument. No consensus has been reached on a safe technique with a high success rate for removing broken instruments. Fracture of nickel-titanium (Ni-Ti) instruments during root canal instrumentation leads to compromised results in endodontic treatments. Thus, irradiation for a clinical procedure involving the use of a Neodymium: Yttrium-Aluminum-Perovskite (Nd: YAP) laser has shown good performance for removing fractured nickel-titanium files. Thus, fractured instruments can be removed by a variety of methods, such as good ultrasonic tips, microtubule devices, and hemostatic pliers/forceps. These techniques require qualified use of the operating microscope. Removing a fractured file is associated with considerable risk, and therefore the fragment must be circumvented. Removing fractured instruments can be expensive in terms of time and equipment. Thus, a cost-benefit analysis of the treatment must be considered before selecting a definitive therapy for the patient.

Keywords: Endodontic treatment. Fractures. Instruments. Root canal. Techniques.

Introduction

In the context of root endodontic treatments, fracture of instruments in the root canal (RC) during

canal shaping is reported as one of the most common reasons for a negative prognosis [1,2]. Nickel-titanium (Ni-Ti) instruments, a versatile alloy with properties such as memory, super elasticity, corrosion resistance, torsional fracture resistance, and biocompatibility, stand out [3–8]. However, Ni-Ti instruments can fracture, with a prevalence of approximately 1.6% (0.7–7.4%) [9-12].

To address this complication, several studies have introduced special instruments and techniques to retrieve obstructing objects, such as ultrasonic instruments, hollow tubes with cyanoacrylate adhesive, trepanation techniques using an ultrasonic tip or a trepan bur, endo-extractors, and welding with a neodymium:yttrium-aluminumperovskite (Nd: YAG) laser. Surgical techniques for the removal of the instrument itself or the entire portion of the root surrounding the instrument have also been described [13-18].

In this sense, the success rate of fractured instrument retrieval varies because it depends mainly on several factors, including the visibility of the fractured instrument, the length of the fractured instrument to the canal curvature, and the techniques applied to each case. Future directions of fractured instrument retrieval should focus on the management of non-visible fractured instruments since the removal of these instruments is considered unpredictable with current techniques, while the removal of visible fractured instruments is considered predictable now. Another possible direction is that there may be no more instrument fracture due to possible significant changes in the root canal preparation technique, which may dispense with the use of rotary instruments [19].

Also, definitive management should be based on a thorough understanding of the success rates for each treatment option, balanced with the potential risks of file removal or retention. Although the integration of modern techniques with endodontic practice has improved the clinician's ability to remove fractured files, removal is not always possible or even desirable. Therefore, in cases without apical disease, removal of the file may not be necessary and retention or deviation should be considered. If there is an apical disease, the file fracture significantly reduces the prognosis, indicating a greater need for attempted removal of the file or deviation. The removal of a fractured file presents considerable risks, especially in the apical regions of the root canal, therefore, leaving the fragment in situ should be considered if a referral is not possible [20,21]. An example, Nd: YAG laser treatment is a method to remove fractured stainless steel instruments without destroying the substance of the healthy tooth. Fractured endodontic instruments can be successfully removed in 77.3% of cases [22].

Furthermore, there is an alternative method with the use of the SureFil SDR for photopolymerization (Dentsply, York, PA) to the use of cyanoacrylate for the removal of fractured endodontic instruments using the tube technique. In general, studies have shown that the use of photopolymerizable composites within the microtube is superior in comparison to the use of cyanoacrylate [23,24].

The success rate of standardized techniques with the aid of a surgical microscope to remove or bypass fractured instruments from root canals has been shown to considerably increase the visualization of the fractured instrument, up to a 2-fold increase, with a success rate of around 47.7% to 85.3% [25]. The ultrasonic technique can exhibit an 80% success rate in removing these fragments. Also, the success rate for roots with a file fracture before the curve was 11.5 times higher than in cases of file fracture beyond the curve. Studies have also shown that the average time required for the removal of lime fragments was 36.3 ± 7.15 minutes, which did not differ significantly in different lime locations within the canal [26].

Finally, as measures to track these instrument fractures in root canals, periapical radiographs, and cone-beam computed tomography (CBCT) stand out for dentists' decision-making in diagnosis and treatment. In general, CBCT observers decide to remove and circumvent the fractured fragment, while CR observers decide to leave the fragments in situ [27].

In view of this, the present study developed a systematic review of the endodontic literature to externalize and discuss the main observations of fractures of root canal instruments, as well as to show the main techniques for treatment and removal of fragments of endodontic instruments.

Methods

Study Design

The present study followed the international systematic review model, following the rules of PRISMA (preferred reporting items for systematic reviews and meta-analysis). Available at: http://www.prisma-statement.org/?AspxAutoDetectCookieSupport=1. Accessed on: 07/08/2024. The methodological quality standards of AMSTAR-2 (Assessing the methodological quality of systematic reviews) were also followed. Available at: https://amstar.ca/. Accessed on: 07/08/2024.

Research Strategy and Search Sources

The literary search process was carried out from June to August 2024 and was developed based on Scopus, PubMed, Science Direct, Scielo, and Google Scholar, covering scientific articles from various eras to the present. The Health Science Descriptors (DeCS /MeSH Terms) were used: *"Endodontic treatment.*

Fractures. Instruments. Root canal. Techniques", and using the Boolean "and" between the terms MeSH and "or" between historical discoveries.

Study Quality and Risk of Bias

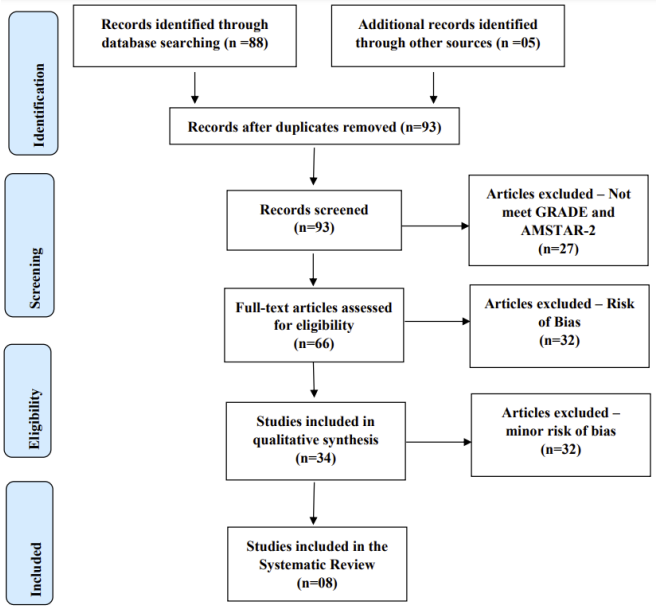
Quality was classified as high, moderate, low, or very low in terms of risk of bias, clarity of comparisons, precision, and consistency of analyses. The most evident emphasis was on systematic review articles or meta-analyses of randomized clinical trials, followed by randomized clinical trials. The low quality of evidence was attributed to case reports, editorials, and brief communications, according to the GRADE instrument. The risk of bias was analyzed according to the Cochrane instrument by analyzing the Funnel Plot graph (Sample size versus Effect size), using the Cohen test (d).

Results and Discussion

Summary of Findings

As a corollary of the literary search system, a total of 93 articles were found that were subjected to eligibility analysis and, subsequently, 08 of the 34 final studies were selected to compose the results of this systematic review. The studies listed were of medium to high quality (Figure 1), considering in the first instance the level of scientific evidence of studies such as meta-analysis, consensus, randomized clinical, prospective, and observational. The biases did not compromise the scientific basis of the studies. According to the GRADE instrument, most studies showed homogeneity in their results, with X^2=89.5%>50%. Considering the Cochrane tool for risk of bias, the overall assessment resulted in 32 studies with a high risk of bias and 27 studies that did not meet GRADE and AMSTAR-2.

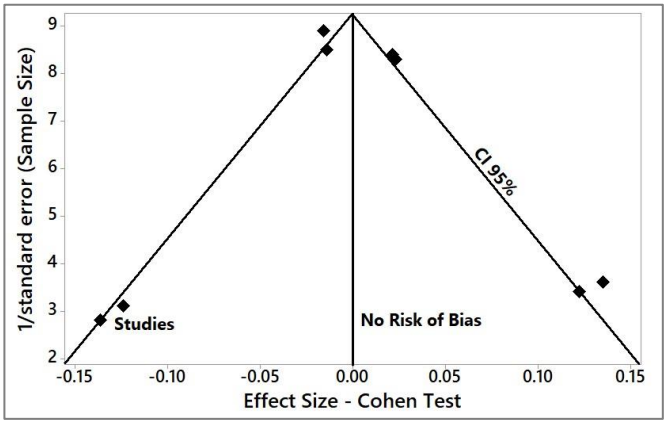
Figure 1. Flow Chart of Study Eligibility.



Source: Own Authorship

Figure 2 presents the results of the risk of bias of the studies using the Funnel Plot, showing the calculation of the Effect Size (Magnitude of the difference) using the Cohen Test (d). Precision (sample size) was determined indirectly by the inverse of the standard error (1/Standard Error). This graph had a symmetrical behavior, not suggesting a significant risk of bias, both between studies with a small sample size (lower precision) that are shown at the bottom of the graph and in studies with a large sample size that are presented at the top.

Figure 2. The symmetric funnel plot suggests no risk of bias among the small sample size studies that are shown at the bottom of the plot. High confidence and high recommendation studies are shown above the graph (n=08 studies).



Source: Own Authorship

Major Findings

After analyzing the selected articles, it became evident that instrument fracture in the root canal system is an incident that can occur during treatment and that must be removed. Comprehensive cleaning of the root canal system is often impossible in the presence of a broken instrument. Several methods have been proposed for the removal of broken instruments from the root canal system. However, no consensus has been reached on a safe technique with a high success rate for removing broken instruments. There are different methods, including ultrasonic, tube and glue, tube and wire, tube and internal rod, and forceps [28].

The advent of nickel-titanium (NiTi) rotary instruments in endodontics has expanded the applicability of rotary instruments to curved root canals. The effectiveness of root canal filling removal is represented by the cleanliness of the root canal after the removal procedure and the ability to remove the root canal filling without causing root canal complications, such as protrusions and perforations [1,2].

Efficiency is the ability to remove root canal filling using less time and fewer rotary files. The reported

efficacy and efficiency of each NiTi rotary system differs due to different methodologies among studies. Many studies evaluated root canal wall complications, NiTi rotary file complications, cleaning, and time consumption. Furthermore, most previous studies used NiTi rotary files more than once for retreatment procedures which may not show the true efficacy and efficiency of the file [1].

An experimental study compared the efficacy, efficiency, and complications of single-use NiTi rotary files using continuous rotation, reciprocating, and adaptive motions in removing root canal filling in curved root canals. Reciproc blue R25 was used with reciprocating motion (RB), VDW.ROTATE retreatment files with continuous rotation (VR), and ProTaper NEXT X2 with continuous rotation (PTNc) or adaptive motion (PTNa). A total of 40 mesial root canals of extracted mandibular first and second molars with a curvature angle between 20°-40° and a radius of curvature between 5 and 10 mm were collected. The specimens were instrumented and obturated with gutta-percha and AH Plus sealer using the continuous wave condensation technique. The specimens were randomly divided into 4 retreatment groups (n = 10), RB, VR, PTNc, and PTNa. The percentage of root canal filling removal in each group was analyzed using Micro Computed Tomography (µCT). The motor running time, total time, root canal complication, and instrument complication were recorded and analyzed statistically (pvalue < 0.05). The preoperative root canal curvature and root canal filling volume were comparable between the groups. The percentage of root canal filling removal from the entire canal in the PTNc, RB, PTNa, and VR groups was 98%, 96%, 95%, and 93%, respectively. A significant difference was observed between the PTNc and VR groups for the entire canal and the apical third portion. The motor running time and total time were significantly different between the groups. Instrument fracture was observed in 40% in the VR group and 20% in the PTNa group, but none in the RB and PTNc groups [29].

After a thorough analysis of these selected studies, it was found that the probability of successful removal of a fractured instrument is reported to range from 53 to 95%, with more than 80% of fractured instruments being removed by the use of ultrasound, but cementation techniques are useful in cases where ultrasonic techniques fail. Also, long fragments (0.4 mm) can adsorb ultrasonic energy and hinder its loosening. Nickel-titanium (NiTi) instruments with their pseudo-elasticity, especially the newly developed heat-treated NiTi instruments are more ductile and flexible compared to conventional NiTi2 [30,31].

Fracture of nickel-titanium (Ni-Ti) instruments during root canal instrumentation leads to compromised outcomes in endodontic treatments. Despite the significant impact of instrument fracture during root canal treatment, there is still no accepted method to address this complication. Several previous studies have demonstrated the ability of a Neodymium: Yttrium-Aluminum-Perovskite (Nd: YAP) laser to cut endodontic files. Thus, one analyzed the safe irradiation conditions for a clinical procedure involving the use of a Neodymium: Yttrium-Aluminum-Perovskite (Nd: YAP) laser to remove fractured nickel-titanium files in root canals. A total of 54 extracted permanent human teeth (n = 54) were used. This study involved nine distinct groups, each employing different irradiation conditions. The 1 s, 3 s, 5 s, 10 s, and 15 s groups simply consisted of irradiation for 1, 3, 5, 10, and 15 s, respectively. After identifying the longest and safest duration, four additional groups were proposed (labeled A, B, C, and D). Group A consisted of three series of 5 s irradiations each, separated by a 30 s rest time (L5s + 30 s RT). Group B consisted of three series of 5 s irradiations each, separated by a 60 s rest time (L5s + 60 s RT). Group C consisted of two series of irradiations of 5 s each, separated by a rest time of 30 s (L5s + 30 s RT), and group D consisted of two series of irradiations of 5 s each, separated by a rest time of 5 s (L5s + 5 s RT). In all groups, during the rest time, continuous irrigation with 2.5 mL of sodium hypochlorite (NaOCl 3%) was performed. The temperature variation during irradiation was recorded with a thermocouple during irradiation with different protocols. The mean and standard deviation of the temperature increase were noted. The temperature calculation was made as the Δ of the highest temperature recorded on the root surface minus (-) that was recorded at baseline (37°). In addition, scanning electron microscopy (SEM) was used after irradiation in all groups to evaluate the morphological changes in the dentinal walls of the root. The irradiation parameters of the Nd: YAP laser were a power of 3 W, an energy of 300 mJ per pulse, a fiber diameter of 200 µm, a pulsed mode of irradiation with a frequency of 10 Hz, a pulse duration of 150 µs, and an energy density of 955.41 J/cm2 [32].

A case report study of a 41-year-old female patient complained of worsening pain in the left maxillary first molar for 3 days. This patient had been treated at another hospital 2 years earlier, but the discomfort persisted after treatment. Preoperative periapical radiography revealed a suspicious fractured endodontic instrument in the apical third of the mesiobuccal root (MB) and the middle third of the distal buccal root (DB), insufficient filling of the palatal root canal (P), and large hypodense areas around the periapical region of all roots. Then, the micro-ultrasound technique was used to remove the fractured endodontic instrument in the

DB canal; a bypass through the second MB canal (MB2) was created to fill the apical stop of the MB root, and the P canal was retracted. The therapeutic effect of the bypass technique was evaluated by comparing bypass treatment and removal treatment for fractured endodontic instruments. The 9- and 27-month follow-ups revealed that the periapical inflammation around the treated DB root after removal of the fractured endodontic instrument and bypass-treated MB root was significantly controlled compared with that before the operation [33].

Conclusion

It was concluded that comprehensive cleaning of the root canal system is often impossible in the presence of a broken instrument. No consensus has been reached on a safe technique with a high success rate for removing broken instruments. Fracture of nickel-titanium (Ni-Ti) instruments during root canal instrumentation leads to compromised results in endodontic treatments. Thus, irradiation for a clinical procedure involving the use of a Neodymium: Yttrium-Aluminum-Perovskite (Nd: YAP) laser has shown good performance for removing fractured nickel-titanium files. Thus, fractured instruments can be removed by a variety of methods, such as good ultrasonic tips, microtubule devices, and hemostatic pliers/forceps. These techniques require qualified use of the operating microscope. Removing a fractured file is associated with considerable risk, and therefore the fragment must be circumvented. Removing fractured instruments can be expensive in terms of time and equipment. Thus, a cost-benefit analysis of the treatment must be considered before selecting a definitive therapy for the patient.

CRediT

Author contributions: **Conceptualization -** Helena Favaro, Halana Boni Condessa Linhares de Castro, Fábio Pereira Linhares de Castro; **Data curation -** Helena Favaro, Halana Boni Condessa Linhares de Castro; **Formal Analysis -** Helena Favaro, Halana Boni Condessa Linhares de Castro; **Investigation -** Helena Favaro, Halana Boni Condessa Linhares de Castro; **Methodology -** Helena Favaro, Halana Boni Condessa Linhares de Castro; **Project administration -** Helena Favaro, Halana Boni Condessa Linhares de Castro; **Supervision-**Fábio Pereira Linhares de Castro; **Writing - original draft -** Helena Favaro, Halana Boni Condessa Linhares de Castro, Fábio Pereira Linhares de Castro; **Writing-review & editing -** Helena Favaro, Halana Boni Condessa Linhares de Castro, Fábio Pereira Linhares de Castro.

Acknowledgment

Not applicable.

Ethical Approval

Not applicable.

Informed Consent

Not applicable.

Funding

Not applicable.

Data Sharing Statement

No additional data are available.

Conflict of Interest

The authors declare no conflict of interest.

Similarity Check

It was applied by Ithenticate@.

Peer Review Process

It was performed.

About The License©

The author(s) 2024. The text of this article is open access and licensed under a Creative Commons Attribution 4.0 International License.

References

1. Immich F, de Araújo LP, da Gama RR, da Rosa WLO, Piva E, Rossi-Fedele G. Fifteen years of engine-driven nickel-titanium reciprocating instruments, what do we know so far? An umbrella review. Aust Endod J. 2024 Aug;50(2):409-463. doi: 10.1111/aej.12870. Epub 2024 Jun 24. PMID: 38923176.
2. Lakshmaiah D, Raj Kumar J, Sakthi N, Karunakaran J, Vishwanath S. The Management of Fractured Dental Instruments: A Case Series. Cureus. 2023 Nov 20;15(11):e49132. doi: 10.7759/cureus.49132.
3. Villela A.M., Kato A.S., Rios M. Fracture incidence of reciproc instruments in endodontic treatment provided by graduate students-a retrospective study. J. Dent. Oral. Health. 2017;3:2–4.
4. Tabassum S., Khan F.R. Failure of endodontic treatment: The usual suspects. Eur. Dent. 2016;10:144–147. doi: 10.4103/1305-7456.175682.
5. Gavini G., Santos M.D., Caldeira C.L., Machado

M.E.D.L., Freire L.G., Iglecias E.F., Peters O.A., Candeiro G.T.D.M. Nickel–titanium instruments in endodontics: A concise review of the state of the art. Braz. Oral. Res. 2018;32:e67. doi: 10.1590/1807-3107bor-2018.vol32.0067.

6. Lambrianidis T. Management of Fractured Endodontic Instruments. Springer; Berlin/Heidelberg, Germany: 2018. Therapeutic Options for the Management of Fractured Instruments; pp. 75–195.
7. Parashos P, Messer HH. Rotary Ni-Ti instrument fracture and its consequences. Endod. 2006;32:1031–1043. doi: 10.1016/j.joen.2006.06.008.
8. Boutsioukis C., Lambrianidis T. Management of Fractured Endodontic Instruments. Springer; Berlin/Heidelberg, Germany: 2018. Factors affecting intracanal instrument fracture; pp. 31–60.
9. Parashos P. Management of Fractured Endodontic Instruments. Springer; Berlin/Heidelberg, Germany: 2018. Prognosis of root canal treatment with retained instrument fragment (s) pp. 247–269.
10. Gencoglu N., Helvacioglu D. Comparison of the different techniques to remove fractured endodontic instruments from root canal systems. Eur. J. Dent. 2009;3:90–95. doi: 10.1055/s-0039-1697413.
11. Yang Q, Shen Y, Huang D, Zhou X, Gao Y, Haapasalo M. Evaluation of two trephine techniques for removal of fractured rotary nickel-titanium instruments from root canals. J. Endod. 2017;43:116–120. doi: 10.1016/j.joen.2016.09.001.
12. Gettleman BH, Spriggs K.A., ElDeeb M.E., Messer H.H. Removal of canal obstructions with the Endo Extractor. J. Endod. 1991;17:608–611. doi: 10.1016/S0099-2399(06)81834-0.
13. Arakawa S, Cobb CM, Rapley JW, Killoy WJ, Spencer P. Treatment of root fracture by CO2 and Nd: YAG lasers: An in vitro study. J. Endod. 1996;22:662–667. doi: 10.1016/S0099-2399(96)80060-4.
14. Gandevivala A, Parekh B, Poplai G, Sayed A. Surgical removal of fractured endodontic instrument in the periapex of mandibular first molar. J. Int. Oral Health. 2014;6:85–88.
15. Friedman S. Retrograde approaches in endodontic therapy. Dent. Traumatol. 1991;7:97–107. doi: 10.1111/j.1600-9657.1991.tb00192.x.
16. Angiero F, Benedicenti S, Signore A, Parker S, Crippa R. Apicoectomies with the erbium laser: A complementary technique for retrograde endodontic treatment. Photomed. Laser Surg. 2011;29:845–849. doi: 10.1089/pho.2011.3046.
17. Bader G, Lejeune S. Prospective study of two retrograde endodontic apical preparations with and without the use of CO2 laser. Dent. Traumatol. 1998;14:75–78. doi: 10.1111/j.1600-9657.1998.tb00814.x.
18. Tsesis I., Faivishevsky V., Kfir A., Rosen E. Outcome of surgical endodontic treatment performed by a modern technique: A meta-analysis of literature. J. Endod. 2009;35:1505–1511. doi: 10.1016/j.joen.2009.07.025.
19. Terauchi Y, Ali WT, Abielhassan MM. Present status and future directions: Removal of fractured instruments. Int Endod J. 2022 May;55 Suppl 3:685-709. doi: 10.1111/iej.13743.
20. McGuigan MB, Louca C, Duncan HF. The impact of fractured endodontic instruments on treatment outcome. Br Dent J. 2013 Mar;214(6):285-9. doi: 10.1038/sj.bdj.2013.271. PMID: 23518972.
21. McGuigan MB, Louca C, Duncan HF. Clinical decision-making after endodontic instrument fracture. Br Dent J. 2013 Apr;214(8):395-400. doi: 10.1038/sj.bdj.2013.379. PMID: 23619858.
22. Cvikl B, Klimscha J, Holly M, Zeitlinger M, Gruber R, Moritz A. Removal of fractured endodontic instruments using an Nd:YAG laser. Quintessence Int. 2014 Jul-Aug;45(7):569-75. doi: 10.3290/j.qi.a31961. PMID: 24847495.
23. Wefelmeier M, Eveslage M, Bürklein S, Ott K, Kaup M. Removing fractured endodontic instruments with a modified tube technique using a light-curing composite. J Endod. 2015 May;41(5):733-6. doi: 10.1016/j.joen.2015.01.018.
24. Brühl M, Urban K, Donnermeyer D, Schäfer E, Bürklein S. Tube Technique with Light-curing Composite for Removing Fractured Root Canal Instruments: Influence of Polymerization Cycles and Mechanical Exposure. J Endod. 2020 Mar;46(3):425-430. doi: 10.1016/j.joen.2019.12.006. Epub 2020 Feb 7. PMID: 32037054.
25. Nevares G, Cunha RS, Zuolo ML, Bueno CE. Success rates for removing or bypassing fractured instruments: a prospective clinical study. J Endod. 2012 Apr;38(4):442-4. doi: 10.1016/j.joen.2011.12.009. Epub 2012 Jan 9. PMID: 22414826.
26. Shahabinejad H, Ghassemi A, Pishbin L, Shahravan A. Success of ultrasonic technique in removing fractured rotary nickel-titanium

endodontic instruments from root canals and its effect on the required force for root fracture. J Endod. 2013 Jun;39(6):824-8. doi: 10.1016/j.joen.2013.02.008. Epub 2013 Apr 16. PMID: 23683286.

27. Castrisos T, Abbott PV. A survey of methods used for post removal in specialist endodontic practice. Int Endod J. 2002 Feb;35(2):172-80. doi: 10.1046/j.1365- 2591.2002.00466.x. PMID: 11843973.
28. Aminsobhani M, Hashemi N, Hamidzadeh F, Sarraf P. Broken Instrument Removal Methods with a Minireview of the Literature. Case Rep Dent. 2024 Jun 13;2024:9665987. doi: 10.1155/2024/9665987.
29. Tantiwanichpun B, Kulvitit S. Efficiency and complications in root canal retreatment using nickel titanium rotary file with continuous rotation, reciprocating, or adaptive motion in curved root canals: a laboratory investigation. BMC Oral Health. 2023 Nov 16;23(1):871. doi: 10.1186/s12903-023-03610-x.
30. Cruz A, Mercado-Soto CG, Ceja I, Gascón LG, Cholico P, Palafox-Sánchez CA. Removal of an instrument fractured by ultrasound and the instrument removal system under visual magnification. J Contemp Dent Pract. 2015 Mar 1;16(3):238-42. doi: 10.5005/jp-journals-10024-1668. PMID: 26057925.
31. Fu M, Huang X, Zhang K, Hou B. Effects of Ultrasonic Removal of Fractured Files from the Middle Third of Root Canals on the Resistance to Vertical Root Fracture. J Endod. 2019 Nov;45(11):1365-1370. doi: 10.1016/j.joen.2019.08.009. Epub 2019 Sep 26. PMID: 31564462.
32. Namour A, El Mobadder M, Matamba P, Misoaga L, Magnin D, Arany P, Nammour S. The Safety of Removing Fractured Nickel-Titanium Files in Root Canals Using a Nd: YAP Laser. Biomedicines. 2024 May 7;12(5):1031. doi: 10.3390/biomedicines12051031.
33. Chai R, Jiang X, Ma R, Zhang Q, Yang E, Zhang A. Different strategies for treating intracanal fractured instruments in a single tooth: A case report. Exp Ther Med. 2024 Aug 28;28(5):411. doi: 10.3892/etm.2024.12700.

MetaScience Press
The Best Science
https://zotarellifilhoscientificworks.com/