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INSTRUMENT RETRIEVAL IN ENDODONTICS: A MAGNETIZATION-BASED APPROACH FOR OPEN-APEX TEETH

RECUPERAÇÃO DE INSTRUMENTO EM ENDODONTIA: UMA ABORDAGEM BASEADA EM MAGNETIZAÇÃO PARA DENTES COM ÁPICE ABERTO

RECUPERACIÓN DE INSTRUMENTOS EN ENDODONCIA: UN ENFOQUE BASADO EN MAGNETIZACIÓN PARA DIENTES CON ÁPICE ABIERTO

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ABSTRACT

Background: Intracanal instrument fracture is a recognized procedural complication in endodontics, occurring in approximately 2 to 6 percent of treatments and more frequently in curved or narrow canals. Retrieval is particularly challenging in teeth with an open or immature apex, where thin residual dentin and irregular canal walls limit conventional ultrasonic or mechanical extraction. Magnetization-based devices have recently been proposed as a less invasive alternative for mobilizing ferromagnetic fragments. Objective: To critically review the available literature on magnetization-based approaches for retrieving separated endodontic instruments in teeth with open apices, and to compare their reported effectiveness and clinical applicability with conventional retrieval techniques. Methodology: A narrative literature search was conducted in PubMed, Scopus, and Web of Science using combinations of the terms magnetization, electromagnetic device, separated instrument, instrument retrieval, open apex, and root canal, without date restriction. Case reports, in vitro studies, and reviews addressing intracanal fragment removal techniques were screened, with emphasis on studies directly comparing magnetization-based devices to ultrasonic or

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mechanical systems. Results: The reviewed evidence indicates that electromagnetic devices achieve high retrieval success for fragments located in the coronal third of the canal, but effectiveness declines markedly in the middle and apical thirds, where ultrasonic-based techniques remain superior, albeit with greater dentin removal. Conclusion: Current evidence suggests magnetization is a conservative option for coronal fragments in open-apex teeth, but insufficient on its own for deeper segments. Well-designed comparative studies specific to immature root morphology are still lacking.

Keywords: Root Canal Treatment. Separated Instrument. Magnetization. Open Apex. Instrument Retrieval. Dentin Preservation.

RESUMO

Antecedentes: A fratura de instrumentos intracanais é uma complicação procedural reconhecida em endodontia, ocorrendo em aproximadamente 2 a 6 por cento dos tratamentos e com maior frequência em canais curvos ou estreitos. A recuperação é particularmente desafiadora em dentes com ápice aberto ou imaturo, onde a dentina residual fina e as paredes de canal irregulares limitam a extração ultrassônica ou mecânica convencional. Dispositivos baseados em magnetização foram recentemente propostos como uma alternativa menos invasiva para mobilizar fragmentos ferromagnéticos. Objetivo: Revisar criticamente a literatura disponível sobre abordagens baseadas em magnetização para recuperar instrumentos endodônticos separados em dentes com ápices abertos, e comparar sua eficácia relatada e aplicabilidade clínica com técnicas convencionais de recuperação. Metodologia: Uma busca narrativa da literatura foi conduzida no PubMed, Scopus e Web of Science usando combinações dos termos magnetização, dispositivo eletromagnético, instrumento separado, recuperação de instrumento, ápice aberto e canal radicular, sem restrição de data. Relatos de casos, estudos in vitro e revisões abordando técnicas de remoção de fragmentos intracanais foram avaliados, com ênfase em estudos que comparavam diretamente dispositivos baseados em magnetização com sistemas ultrassônicos ou mecânicos. Resultados: A evidência revisada indica que dispositivos eletromagnéticos alcançam alto sucesso de recuperação para fragmentos localizados no terço coronal do canal, mas a eficácia diminui marcadamente no terço médio e apical, onde técnicas baseadas em ultrassom permanecem superiores, embora com maior remoção de dentina. Conclusão: A evidência atual sugere que magnetização é uma opção conservadora para fragmentos coronais em dentes com ápice aberto, mas insuficiente por si só para segmentos mais profundos. Estudos comparativos bem planejados específicos para morfologia radicular imatura ainda estão faltando.

Palavras-chave: Tratamento de Canal Radicular. Instrumento Separado. Magnetização. Ápice Aberto. Recuperação de Instrumento. Preservação de Dentina.

RESUMEN

Antecedentes: La fractura de instrumentos intracanales es una complicación procedural reconocida en endodoncia, que ocurre en aproximadamente el 2 a 6 por ciento de los tratamientos y con mayor frecuencia en canales curvos o estrechos. La recuperación es particularmente desafiante en dientes con ápice abierto o inmaduro, donde la dentina residual delgada y las paredes de canal irregulares limitan la extracción ultrasónica o mecánica convencional. Los dispositivos basados en magnetización han sido recientemente propuestos como una alternativa menos invasiva para movilizar fragmentos ferromagnéticos. Objetivo: Revisar críticamente la literatura disponible sobre enfoques basados en magnetización para recuperar instrumentos endodónticos separados en dientes con ápices

abiertos, y comparar su eficacia reportada y aplicabilidad clínica con técnicas convencionales de recuperación. Metodología: Se realizó una búsqueda narrativa de la literatura en PubMed, Scopus y Web of Science utilizando combinaciones de los términos magnetización, dispositivo electromagnético, instrumento separado, recuperación de instrumento, ápice abierto y conducto radicular, sin restricción de fecha. Se evaluaron reportes de casos, estudios in vitro y revisiones que abordaban técnicas de remoción de fragmentos intracanales, con énfasis en estudios que comparaban directamente dispositivos basados en magnetización con sistemas ultrasónicos o mecánicos. Resultados: La evidencia revisada indica que los dispositivos electromagnéticos logran un alto éxito de recuperación para fragmentos ubicados en el tercio coronal del conducto, pero la eficacia disminuye marcadamente en el tercio medio y apical, donde las técnicas basadas en ultrasonido siguen siendo superiores, aunque con mayor remoción de dentina. Conclusión: La evidencia actual sugiere que la magnetización es una opción conservadora para fragmentos coronales en dientes con ápice abierto, pero insuficiente por sí sola para segmentos más profundos. Aún faltan estudios comparativos bien diseñados específicos para la morfología radicular inmadura.

Palabras clave: Tratamiento del Conducto Radicular. Instrumento Separado. Magnetización. Ápice Abierto. Recuperación de Instrumento. Preservación de Dentina.

1 INTRODUCTION

Instrument fracture during root canal treatment remains one of the most common procedural complications in endodontics. Reported incidence rates vary considerably depending on the type of instrument, with stainless-steel hand files separating in approximately 0.25% to 6% of cases and nickel-titanium (NiTi) rotary instruments in 1.3% to 10.0% of cases, a difference largely attributed to cyclic fatigue and torsional stress inherent to continuous rotary motion (Coelho *et al.*, 2018). Regardless of the underlying mechanism, instrument separation has a documented impact on treatment outcome, particularly when the fragment obstructs the apical portion of the canal and prevents adequate chemomechanical debridement of the tissue apical to it (Spili *et al.*, 2005).

Numerous devices and techniques have been proposed to remove separated fragments once bypassing has failed, ranging from ultrasonic tips and file-removal kits to microtube-and-screw-wedge systems, with success rates that vary considerably according to fragment location, canal curvature, and visibility under magnification (Terauchi *et al.*, 2022). Case reports have illustrated successful retrieval using ultrasonic instruments combined with endodontic micro forceps in curved canals (Meidyawati *et al.*, 2019), and current evidence suggests that fragments located in the coronal third, with greater visibility and accessibility, carry a more favorable prognosis than those situated in the middle or apical thirds (Terauchi *et al.*, 2022).

This challenge becomes considerably more delicate in teeth with an open or immature apex. In these cases, the apical diameter of the canal is frequently larger than the coronal diameter, complicating debridement, while the thin, divergent dentinal walls that characterize incomplete root development are inherently prone to fracture, making aggressive mechanical enlargement a poor option (Mohammadi, 2011). Any retrieval technique that requires substantial removal of dentin to create space around the fragment therefore carries an elevated risk of iatrogenic weakening or outright loss of an already fragile root.

Magnetization has been proposed as a potential alternative for fragment retrieval in this context, based on the ferromagnetic properties of stainless-steel instruments. Daryaeian *et al.* (2019) first formulated this hypothesis, demonstrating experimentally that permanent magnets could attract stainless-steel files with minimal direct mechanical intervention on the canal walls, and suggested that this approach could offer a more conservative retrieval option than traditional ultrasonic or mechanical systems, particularly where dentin preservation is a priority. Despite this early theoretical groundwork, evidence specifically addressing

magnetization-based retrieval in the distinct clinical scenario of open-apex, structurally compromised teeth remains scarce, warranting a focused review of the available literature.

2 METHODOLOGY

A narrative literature search was conducted in PubMed, Scopus, and Web of Science, combining the terms “separated instrument,” “magnetization,” “electromagnetic device,” “instrument retrieval,” “open apex,” and “root canal treatment,” without restriction on publication date. Reference lists of relevant reviews and case reports were additionally screened to identify further studies. Case reports, in vitro or ex vivo experimental studies, and narrative or systematic reviews addressing intracanal fragment removal techniques, with particular attention to magnetization-based approaches and to studies involving open or immature apices, were considered for inclusion.

3 RESULTS

3.1 INCIDENCE AND INSTRUMENT TYPE

Reported instrument separation rates vary by file type. Stainless-steel hand files separate in 0.25% to 6% of treated canals, while nickel-titanium rotary instruments separate more frequently, at 1.3% to 10.0%. A retrospective PennEndo database study of 4,865 endodontic cases identified 81 separated instruments (12 hand stainless-steel, 69 rotary NiTi), yielding incidences of 0.25% for hand files versus 1.68% for rotary files, an odds ratio of 6.9 favoring rotary separation. A separate 10-year postgraduate institute review recorded 190 separated instruments, the majority NiTi, reflecting the near-total shift of contemporary practice away from stainless steel. This shift is directly relevant to magnetization-based retrieval, since the technique's efficacy is contingent on ferromagnetism.

3.2 MAGNETIZATION VERSUS ULTRASONIC RETRIEVAL: QUANTITATIVE COMPARISON

An in vitro study comparing a novel electromagnetic device against the ultrasonic Terauchi File Removal Kit (TFRK) across 180 decoronated single-rooted teeth (five groups of 36) found:

- Coronal third: 100% retrieval success with the electromagnetic device.
- Middle and apical thirds: significantly lower success with the electromagnetic device than with TFRK ($p = 0.010$ and $p = 0.018$, respectively).

- Retrieval time: 2.81–11.76 minutes for the electromagnetic device versus 1–5.72 minutes for TFRK, with TFRK faster specifically at the apical third.
- Non-ferromagnetic control group (NiTi K-files, n = 36): 0% retrieval success with the electromagnetic device in every attempt.

This pattern is broadly consistent with the wider ultrasonic retrieval literature, which reports success rates of 67% (controlled ultrasonic penetration removal), 70% (combined hand/rotary retrieval under magnification, with median retrieval times of 40 minutes for straightforward ultrasonic technique versus 55 minutes for instrument retrieval system approaches on more curved canals), and up to 80% for ultrasonic removal of fractured rotary NiTi instruments specifically. Magnetization's 100% coronal success rate therefore compares favorably at that specific location, but its complete failure against NiTi fragments places it well below the ultrasonic literature's overall performance once all canal thirds and instrument types are considered together.

3.3 COMPARISON WITH OLDER MECHANICAL SYSTEMS

The Masserann technique, the most extensively documented mechanical alternative, shows success rates that are highly location-dependent: 73% in anterior teeth versus 44% in posterior teeth in one frequently cited series, though other series report an overall success rate as low as 55%, and root-specific data from a separate report show success ranging from 93% (maxillary molars) up to 100% (maxillary premolars, anterior, and canine teeth). This wide range mirrors the coronal-versus-deeper-third pattern seen with magnetization, reinforcing that fragment accessibility, rather than the specific retrieval technology used, is the dominant variable across virtually every technique reviewed.

3.4 PREDICTORS OF RETRIEVAL TIME AND SUCCESS

A clinical series of 128 separated instruments referred for retreatment found that 114 fragments (89%) were removed with ultrasonic tips alone, 13 (10%) required an additional loop device, and 1 required the XP-endo Shaper unscrewing technique. Regression modeling confirmed that both instrument length and canal curvature independently predicted log-transformed retrieval time, while fragment length alone had no significant association with success rate or secondary fracture occurrence. This is directly comparable to the electromagnetic device data above, where retrieval time (but not necessarily success) also

increased with depth, suggesting that time-to-retrieval, rather than binary success, may be the more sensitive outcome measure across techniques, including magnetization.

4 DISCUSSION

The findings reviewed here indicate that magnetization-based retrieval performs best when the separated fragment is located in the coronal third of the canal, where the magnetic field can act directly on the exposed metal surface without needing to overcome friction from surrounding dentin or canal curvature. As the fragment moves deeper into the middle or apical third, the effectiveness of the electromagnetic approach declines sharply, and conventional ultrasonic-based systems become comparatively more reliable, although at the cost of greater dentin removal and, consequently, greater structural risk to the root.

A critical factor shaping the clinical applicability of this technique is the metallurgical basis of the magnetic effect itself. Stainless-steel instruments are ferromagnetic and respond readily to an external magnetic field, which is precisely why magnetization-based retrieval works at all. Nickel-titanium instruments, however, are essentially non-ferromagnetic; the titanium component behaves paramagnetically, producing an attraction too weak to be clinically useful. Because the overwhelming majority of contemporary canal preparation is performed with NiTi rotary or reciprocating systems, this represents a substantial limitation on the real-world applicability of magnetization as currently conceived. In practice, the technique is likely to remain most relevant for legacy stainless-steel hand-file fractures rather than for the modern rotary fragments endodontists most commonly encounter today.

This limitation is particularly relevant when considering the specific population of interest in this review: teeth with an open or immature apex. These teeth are frequently treated conservatively, sometimes even with hand instrumentation, precisely because their thin, divergent dentinal walls cannot tolerate the mechanical stresses associated with aggressive rotary preparation. This creates a paradox worth noting: the clinical scenario in which magnetization would be most valuable, namely a fragile root that cannot absorb further dentin removal, is also the scenario in which stainless-steel hand files (the ideal candidate for magnetic retrieval) are more likely to be the instrument in use, somewhat aligning the technique with the population that needs it most.

Several limitations temper enthusiasm for this approach. Most of the supporting evidence derives from extracted, single-rooted anterior teeth with simulated fractures and simulated open apices, a setup that does not capture the anatomical complexity of curved,

multirooted posterior canals where instrument separation is, in fact, more common. Retrieval times also increase substantially with canal depth for both magnetic and ultrasonic methods, raising questions about clinical feasibility in a single appointment. Furthermore, no long-term outcome data exist comparing magnetization-assisted retrieval with conventional techniques in terms of post-treatment root fracture rates or overall treatment survival, which is arguably the most clinically meaningful endpoint for this fragile population.

5 CONCLUSION

Magnetization-based retrieval represents a genuinely conservative option for stainless-steel fragments located in the coronal third of teeth with an open apex, where its minimal mechanical footprint aligns well with the structural fragility of immature roots. However, its effectiveness drops considerably for deeper fragments, and its complete lack of efficacy against nickel-titanium instruments limits its relevance to a shrinking subset of clinical cases. Rather than replacing ultrasonic and mechanical systems, magnetization is best regarded as a complementary first-line, low-risk step, useful for triaging coronal fragments before resorting to more invasive techniques for deeper or non-ferromagnetic separations. Clinical studies in actual immature teeth, rather than simulated models, are needed before this approach can be recommended as standard practice.

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