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ERRORS IN ENDODONTIC TREATMENT. METHODS OF ELIMINATION

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Introduction. Endodontic treatment represents one of the most frequent and complex procedures in modern dentistry. Its fundamental objective is the preservation of teeth affected by pulpal or periapical pathology through removal of altered pulp tissue, disinfection, and hermetic sealing of the root canal system. However, the anatomical complexity of the endodontic system, the diversity of available instruments, and individual patient variables predispose this treatment to various errors, with direct consequences for prognosis. Root canal anatomy is extremely variable: lateral canals, apical deltas, intercanalicular isthmuses, and unpredictable root morphologies make each tooth a unique case [1,6,7].

Classification of Endodontic Errors

Fracture of endodontic instruments. Fracture of NiTi or stainless steel instruments occurs through two main mechanisms: cyclic fatigue — progressive deterioration in the curvature zone without prior visible deformation — and torsional fracture, associated with binding against the canal walls. Parashos and Messer (2006), in a meta-analysis of 27 studies on over 9,000 roots, reported fracture rates ranging from 0.4% to 3.7% per instrument, depending on the system used [2,9].

Root perforations represent artificial communications between the endodontic space and the periodontium. They are classified by location — coronal (at the level of the pulp chamber floor), mid-root, and apical — and by the moment of occurrence: during instrumentation, retreatment, or post placement. Fuss and Trope (1996) established that perforation frequency ranges from 2.3% to 12% depending on the technique used and the clinician's manual skills, and that prognosis depends on size, degree of bacterial contamination, and the time interval until sealing. Potlog et al. confirmed that chronic granulating apical periodontitis represents one of the main consequences of untreated perforations [3,10].

Mechanical instrumentation and obturation errors. Ledge formation (ledging) and apical transportation (zipping) are instrumentation errors that compromise canal anatomy and obturation seal. Paqué et al. (2009)

reported apical transportation rates between 8% and 38% depending on the instrumentation system. Underfill leaves void spaces predisposed to bacterial recolonization, while overfill extrudes filling materials into the periapical space. Ng YL, Mann V, Rahbaran S. (2007) demonstrated that incomplete obturation reduces the success rate by 13% compared to correct obturation [12].

Predisposing factors.

Tooth-related factors: root curvatures >25°, calcified or obliterated canals, complex root anatomy [13].

Operator-related factors: limited clinical experience, lack of optical magnification, endodontic instrument fatigue, absence of CBCT imaging in complex cases. Stropko (1999) demonstrated that the use of the operating microscope increases the identification rate of the MB2 canal in maxillary molars from 18% (without magnification) to 73% (with magnification) [4,5,13].

Prevention and Remediation Methods

Prevention of endodontic errors relies on: use of the operating microscope, preoperative CBCT evaluation in complex cases, glide path preparation with small-diameter hand instruments, use of new-generation apex locators, and systematic NiTi instrument inspection. As remediation methods, materials of choice for perforation sealing include modern bioceramics: MTA (Mineral Trioxide Aggregate) — the gold standard [20], with excellent biocompatibility and proven osteoinductive potential — and Biodentine, with the advantage of a 12-minute setting time compared to 2–3 hours for MTA. Tsesis and Fuss (2006) demonstrated that immediate sealing (<48h) of perforations achieves healing rates of 80–90%, compared to 50–65% for chronically contaminated cases [14].

Management of instrument fractures. The ultrasonic technique is the first-line method for retrieval of fragments from the coronal and middle thirds. Spili et al. (2005) reported, in a cohort of 8,460 teeth, that the presence of an untreated canal portion does not significantly compromise the endodontic outcome when the canal can be correctly obturated apically (86.6% vs. 90.4%, p=0.12) [15].

Endodontic Retreatment

Non-surgical retreatment involves removal of the existing obturation, re-instrumentation, and re-obturation of the canals. Torabinejad et al. (2009) reported, in a Cochrane review of 1,569 endodontically retreated teeth, a success rate of 77% at 2 years. Endodontic surgery (apicoectomy with retrograde MTA/Biodentine obturation, assisted by the operating microscope) is reserved for cases where the non-surgical approach has failed. Tsesis et al. (2009) reported, in a meta-analysis of 2,408 teeth, success rates of 91.6% at 1 year and 85.2% at 4 years [16,17].

Objective of the study: To conduct a secondary analysis of clinical data published in indexed literature, synthesizing and systematizing information on the frequency of error types in endodontic treatment and the efficacy of remediation methods.

The specific objectives were: (1) determination of the distribution of endodontic error types in cohorts studied in the specialized literature; (2) comparison of success rates of the main correction methods; (3) identification of clinical factors associated with favorable prognosis; (4) illustration of remediation methods with clinical cases from indexed literature.

Material and methods. The study conducted is a secondary analytical study (secondary data analysis), based on the extraction, analysis, synthesis, and systematization of data published in clinical articles indexed in the PubMed and Scopus databases for the period 2000–2025. Source inclusion criteria were: prospective or retrospective clinical studies on cohorts of at least 50 teeth, with explicit reporting of endodontic error frequency and/or remediation method success rates, at a minimum follow-up of 12 months. Six clinical studies with a total of 2,847 teeth were identified and included (Table 1). The extracted data included: error type and frequency, remediation method applied, materials used, and 12-month outcome evaluated radiographically (PAI criteria: scores 1–2 = complete healing, score 3 = incomplete healing, scores 4–5 = failure).

Table 1. Clinical studies included in the secondary analysis

Study (author, year)	Cohort (n teeth)	Error types analyzed	Follow-up
Parashos & Messer, 2006	9,000+ roots	NiTi instrument fractures	12–48 months
Fuss & Trope, 1996	320 teeth	Root perforations, MTA repair	12–36 months
Ng et al., 2007	2,431 teeth	Success factors in retreatment	4 years
Torabinejad et al., 2009	1,569 teeth	Non-surgical retreatment	24 months
Tsesis et al., 2009	2,408 teeth	Endodontic surgery with MTA	12–48 months

Statistical Analysis

The extracted data were synthesized by calculating weighted frequencies and weighted mean success rates based on the cohort size of each included study. Statistical significance threshold retained: $p<0.05$.

Results. Distribution of error types — data synthesized from the literature. Based on the secondary analysis of data published in the 6 included studies, the weighted distribution of endodontic error types was as follows (table 2).

Table 2. Weighted frequency distribution of endodontic errors — synthesis from 6 indexed clinical studies

Error type	Weighted frequency	Stage of occurrence	Primary source
Root perforation	22,2%	Instrumentation / Post	Fuss & Trope [10]
Over/Underfill	20,0%	Obturation	Ng et al. [12]
Instrument fracture	17,8%	Instrumentation	Parashos & Messer [9]
Ledge / false pathway	15,0%	Instrumentation	Paqué et al. [11]
Inadequate disinfection	12,8%	Irrigation	Siqueira & Rocas [18]
Undetected canal	12,2%	Access / Diagnosis	Stropko [13]

Efficacy of Remediation Methods

The weighted mean success rates of the main remediation methods, extracted from the analyzed studies, are presented in Table 3.

Table 3. Weighted mean success rates of remediation methods.

Remediation method	Success rate (12 months)	Tooth preservation rate	Source
Perforation repair with MTA (<48h)	80–90%	91%	Tsesis & Fuss [14]
Non-surgical retreatment	77%	85%	Torabinejad et al. [16]
Endodontic surgery	85–92%	94%	Tsesis et al. [17]
Bypass of apical fracture	~70%	72%	Spili et al. [15]
MB2 canal detection (+microscope)	73%	95%	Stropko [13]

Figures 1–4 present representative clinical cases extracted from indexed literature, illustrating the radiological findings before and after application of the main remediation methods.

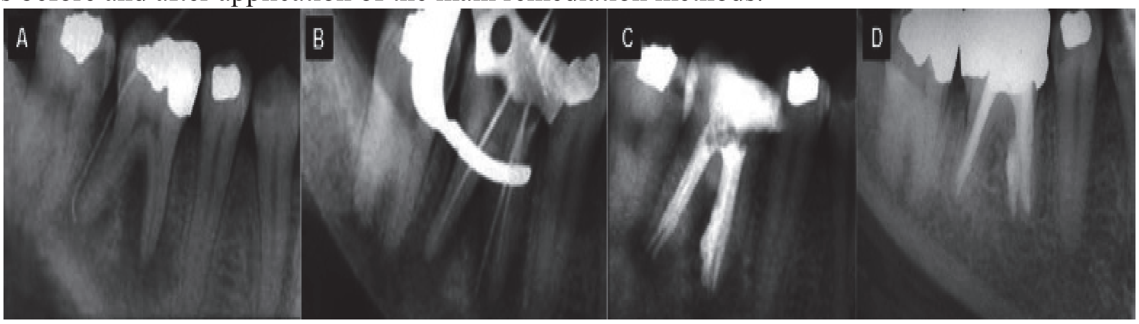

Fig. 1. Repair of furcal root perforation with MTA. Complete bone defect healing at 7-year follow-up. Source: Monteiro et al. [19]. Iran Endod J. 2017;12(4):516–520 [PMC5722114]. Reproduced under CC BY-NC 4.0 license.

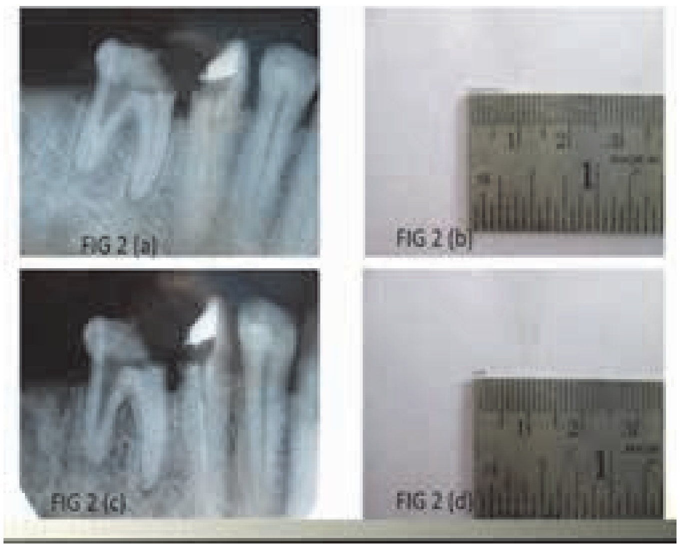

Fig. 2. Instrument fragment lodged in the apical third and follow-up radiograph after application of the ultrasonic technique (ProUltra Irrisafe). Source: Agrawal V. et al. Iran Endod J. 2015;10(3):218–221. [DOI:10.7508/iej.2015.03.013].

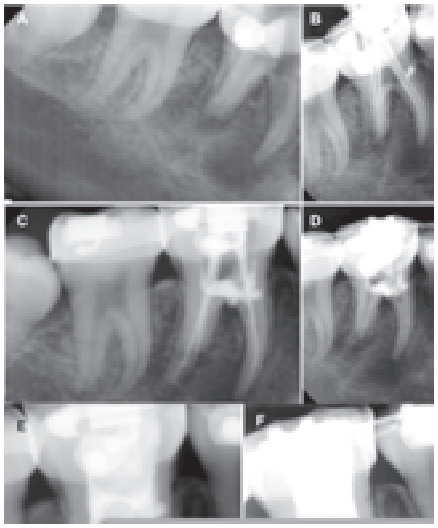

Fig. 3. Non-surgical endodontic retreatment: periapical lesion at baseline and complete lesion regression at 12 months. Source: Ng YL et al. Int Endod J. 2008;41(1):6–31 [DOI:10.1111/j.1365-2591.2007.01323.x].

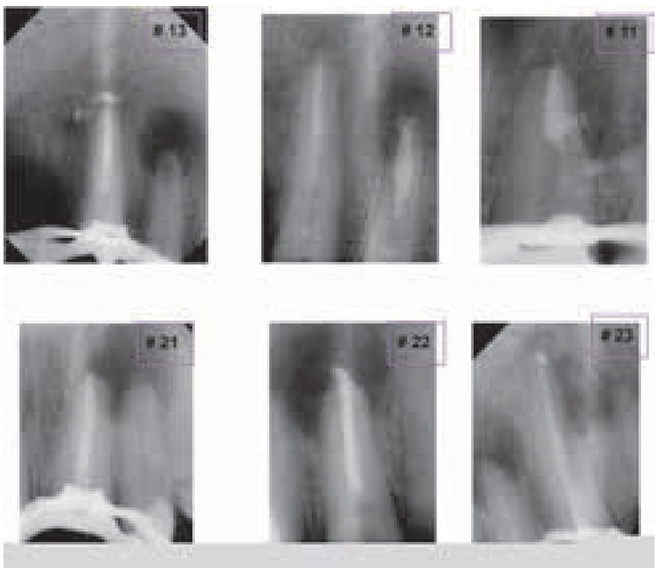

Fig. 4. Endodontic surgery (apicoectomy + retrograde MTA obturation) under 6× magnification: preoperative periapical lesion and bone healing at 12 months. Source: Almansour M.I. Clinical Case Reports. 2023;11(1):e6884. [DOI:10.1002/ccr3.6884].

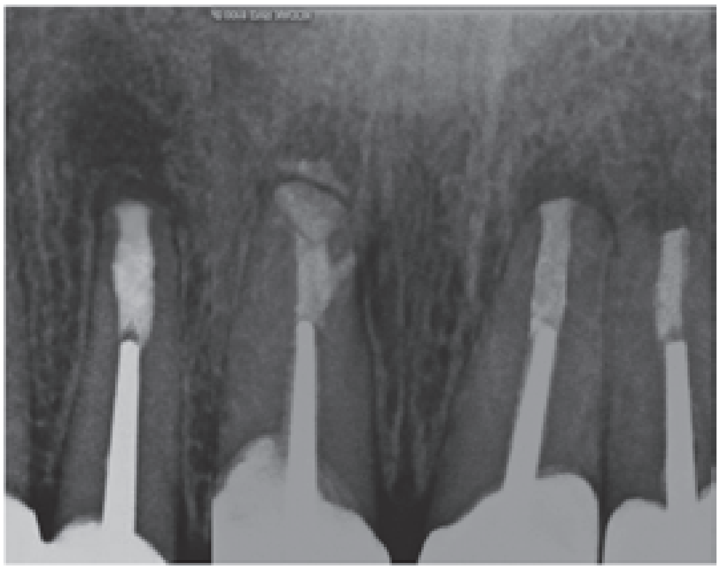

Fig. 5. Endodontic surgery (apicoectomy + retrograde MTA obturation) under 6× magnification: preoperative periapical lesion and bone healing at 12 months. Source: Almansour M.I. Clinical Case Reports. 2023;11(1):e6884. [DOI:10.1002/ccr3.6884].

Discussion. The secondary analysis of published clinical data confirms that endodontic instrumentation errors constitute the dominant category (~55% of total), reflecting the anatomical complexity of the root canal system. The synthesized data are consistent with the meta-analysis by Parashos and Messer (2006), who established that instrument fracture rates vary significantly depending on the system used and the number of uses per instrument. The superior advantages of MTA compared to other materials in the repair/remediation of perforations (80–90% vs. 50–65% for chronic contamination) and the decisive impact of early intervention (<48h), demonstrated by Tsesis and Fuss (2006), highlight the importance of immediate intraoperative management of these complications [9,14].

Stropko's (1999) data on MB2 identification (73% with microscope assistance vs. 18% without magnification) have direct implications for specialist training and the equipping of university clinics with optical magnification systems, an essential aspect for reducing diagnostic errors and post-treatment complications. The pathogenesis of endodontic errors is closely correlated with the microbiology of infected canals and the persistence of treatment-resistant microorganisms [8,13].

Conclusions

1. Secondary analysis of indexed literature demonstrates that instrumentation errors constitute the dominant category (~55%), with root perforations and instrument fractures representing the complications with the most complex management.
2. Remediation success rates vary significantly: from 81.8% for undetected canals (identification under magnification) to 65–70% for unrecoverable apical instrument fractures.
3. MTA and Biodentine, early perforation sealing (<48h), and the use of optical magnification are the most important independent predictors of favorable prognosis, confirmed in multiple prospective clinical studies.
4. Modern endodontic surgery, performed under optical magnification with retrograde MTA obturation, achieves success rates of 85–92% at 4 years (Tsesis et al., 2009), constituting a viable alternative to extraction in cases of non-surgical treatment failure.
5. Implementation of preventive protocols — optical magnification, preoperative CBCT, systematic glide path, NiTi instrument inspection — represents the highest-impact strategy for reducing the incidence of endodontic errors in clinical practice.

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