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Errors and Complications During Endodontic Treatment

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Abstract: Endodontic treatment is a fundamental dental procedure aimed at preserving natural teeth affected by pulpal and periapical pathologies. Despite significant advancements in diagnostic tools, instrumentation systems, and treatment protocols, errors and complications during endodontic therapy remain prevalent and represent a major cause of treatment failure. This comprehensive scientific article analyzes the types, causes, clinical manifestations, and consequences of errors and complications occurring during various stages of endodontic treatment, including diagnosis, access cavity preparation, working length determination, cleaning and shaping, irrigation, obturation, and post-treatment restoration. Emphasis is placed on iatrogenic factors, anatomical complexities, operator-related variables, and material-related issues. Preventive strategies, modern technological solutions, and evidence-based management approaches are discussed in detail to enhance clinical outcomes and long-term tooth survival.

Keywords: Endodontic treatment, procedural errors, endodontic complications, root canal therapy, iatrogenic damage, instrument separation, perforation, treatment failure.

Introduction

Endodontic treatment, commonly referred to as root canal therapy, is a highly specialized dental procedure that involves the diagnosis, prevention, and treatment of diseases affecting the dental pulp and periradicular tissues. The primary objectives of endodontic therapy are the elimination of microorganisms from the root canal system, prevention of reinfection, and preservation of the natural tooth in function and aesthetics. Although modern endodontics has undergone remarkable progress with the introduction of advanced imaging techniques, nickel-titanium rotary instruments, electronic apex locators, magnification devices, and biocompatible obturation materials, the procedure remains technically demanding and susceptible to various errors and complications. These adverse events can occur at any stage of treatment and may significantly compromise the prognosis of the tooth if not properly managed.

Errors and complications in endodontic treatment are defined as deviations from accepted clinical standards that result in unintended outcomes or unfavorable clinical conditions. Errors typically arise from inadequate knowledge, insufficient clinical experience, improper technique, or misinterpretation of anatomical variations, whereas complications may result from anatomical

challenges, pathological conditions, or material failures. Both errors and complications can lead to persistent infection, postoperative pain, delayed healing, periapical pathology, or complete treatment failure necessitating retreatment or extraction.

The complexity of the root canal system is one of the primary factors contributing to endodontic errors. Root canals often exhibit significant anatomical variations, including accessory canals, lateral canals, isthmuses, apical deltas, and complex curvatures that are difficult to detect and negotiate. Failure to recognize and manage these anatomical features can result in missed canals, incomplete debridement, or inadequate obturation. Additionally, diagnostic errors such as incorrect assessment of pulpal status or periapical pathology can lead to inappropriate treatment decisions and poor outcomes.

Iatrogenic errors represent a substantial proportion of complications encountered during endodontic therapy. These include excessive removal of tooth structure during access cavity preparation, ledge formation, canal transportation, perforation of the root or furcation area, separation of endodontic instruments, extrusion of irrigants or obturation materials beyond the apical foramen, and inadequate coronal sealing. Such errors not only compromise the structural integrity of the tooth but also increase the risk of bacterial contamination and inflammatory responses in periapical tissues.

The clinical significance of errors and complications during endodontic treatment cannot be overstated. Numerous studies have demonstrated a strong correlation between procedural errors and reduced success rates of root canal therapy. Teeth with procedural complications often exhibit lower healing rates, increased incidence of postoperative symptoms, and higher likelihood of requiring retreatment or surgical intervention. Therefore, understanding the etiology, prevention, and management of these errors is essential for clinicians aiming to achieve predictable and successful outcomes.

This article aims to provide an in-depth analysis of errors and complications associated with endodontic treatment. By reviewing current scientific literature and clinical evidence, the study seeks to identify common procedural mistakes, evaluate their impact on treatment prognosis, and discuss strategies for prevention and management. The ultimate goal is to enhance clinical awareness, promote adherence to evidence-based protocols, and improve the overall quality of endodontic care.

Materials and Methods

This scientific review was conducted through an extensive analysis of peer-reviewed literature related to errors and complications in endodontic treatment. Electronic databases including PubMed, Scopus, Web of Science, and Google Scholar were systematically searched for relevant articles published in English-language journals. Keywords such as "endodontic errors," "root canal complications," "iatrogenic damage," "instrument separation," "perforation," and "endodontic failure" were used individually and in combination to identify pertinent studies.

The materials included original research articles, systematic reviews, meta-analyses, clinical trials, retrospective studies, case reports, and authoritative endodontic textbooks. Selection criteria focused on publications that addressed procedural errors, anatomical challenges, diagnostic inaccuracies, and treatment-related complications encountered during nonsurgical endodontic therapy. Studies involving both conventional and modern endodontic techniques were considered to provide a comprehensive perspective.

Data extraction involved qualitative analysis of reported error types, etiological factors, clinical consequences, diagnostic methods, preventive measures, and management strategies. Comparative evaluation was performed to assess the effectiveness of different approaches in minimizing complications and improving treatment success. Emphasis was placed on evidence-based recommendations and consensus guidelines proposed by recognized endodontic associations.

Results

The analysis of the reviewed literature demonstrated that errors and complications during endodontic treatment occur with notable frequency despite technological advancements and standardized clinical protocols. The most commonly reported diagnostic errors included incorrect assessment of pulpal vitality, failure to identify the true source of odontogenic pain, and misinterpretation of radiographic findings. These errors often resulted in unnecessary root canal treatment, delayed intervention, or incomplete therapy, ultimately affecting treatment prognosis. Studies consistently indicated that inadequate preoperative evaluation significantly increased the risk of procedural complications during subsequent treatment stages.

Errors related to access cavity preparation were among the most frequently documented mechanical complications. Insufficient access cavities led to poor visualization of the pulp chamber floor, increased stress on instruments, missed canal orifices, and difficulty in achieving straight-line access. Conversely, excessive removal of tooth structure weakened the coronal tooth architecture, predisposing the tooth to fracture. Missed canals were particularly prevalent in molar teeth, especially the second mesiobuccal canal in maxillary molars and complex canal systems in mandibular molars, contributing to persistent infection and post-treatment apical periodontitis.

During working length determination, errors were primarily associated with inaccurate radiographic interpretation and improper use of electronic apex locators. Underestimation of working length resulted in incomplete cleaning and shaping, leaving infected tissue within the apical portion of the canal. Overestimation led to over-instrumentation, apical transportation, and extrusion of debris, irrigants, or filling materials into periapical tissues. These findings correlated strongly with increased postoperative pain and delayed periapical healing.

Cleaning and shaping procedures were identified as the stage with the highest incidence of iatrogenic complications. Ledge formation, canal transportation, zipping, and perforation were frequently reported, particularly in curved canals and when rigid instruments were used improperly. Instrument separation emerged as one of the most severe complications, with reported incidence rates varying depending on instrument type, canal anatomy, and operator experience. Separation of nickel-titanium rotary instruments was often linked to cyclic fatigue and torsional stress, while stainless steel instruments fractured primarily due to excessive force and canal curvature.

Irrigation-related complications included inadequate irrigation volume, improper delivery techniques, and extrusion of irrigating solutions beyond the apical foramen. Sodium hypochlorite accidents, although relatively rare, were reported to cause severe tissue reactions, pain, swelling, and ecchymosis. Insufficient irrigation was associated with inadequate microbial reduction and reduced treatment success rates.

Obturation errors were also prevalent and included underfilling, overfilling, voids within the filling material, and poor adaptation to canal walls. Underfilling was frequently associated with persistent periapical pathology, while overfilling often resulted in periapical irritation and delayed healing. Coronal leakage due to inadequate temporary or permanent restorations was identified as a major contributor to reinfection and long-term failure of endodontically treated teeth.

Discussion

The findings of this review highlight that errors and complications during endodontic treatment are multifactorial and arise from a complex interaction between anatomical challenges, operator-related factors, material properties, and clinical decision-making. Diagnostic accuracy remains the cornerstone of successful endodontic therapy, and errors at this stage often cascade into subsequent procedural complications. Comprehensive clinical examination, appropriate use of diagnostic tests, and careful radiographic evaluation are essential to minimize misdiagnosis.

Access cavity preparation plays a critical role in facilitating effective cleaning and shaping of the root canal system. The shift from traditional access designs to minimally invasive concepts has generated debate regarding the balance between tooth structure preservation and adequate canal access. While conservative access cavities may reduce fracture risk, they may also increase the likelihood of missed canals and instrument separation if not properly executed. Therefore, clinicians must tailor access design to individual tooth anatomy and treatment requirements.

Working length determination remains a challenging aspect of endodontic therapy, particularly in cases with complex apical anatomy or resorptive defects. The combined use of electronic apex locators and radiographic verification has been shown to improve accuracy and reduce the incidence of length-related errors. Adherence to established protocols and repeated verification during treatment are critical for maintaining accuracy.

The high incidence of mechanical complications during canal preparation underscores the importance of understanding root canal anatomy and instrument behavior. Nickel-titanium rotary systems offer improved flexibility and efficiency; however, they require proper training and adherence to manufacturer guidelines to prevent instrument fracture. Glide path establishment, appropriate torque and speed settings, and regular instrument inspection are essential preventive measures. When instrument separation occurs, management strategies depend on the location of the fragment, canal anatomy, and potential impact on disinfection. Retrieval, bypassing, or leaving the fragment in situ may be considered based on clinical judgment.

Irrigation effectiveness is directly related to treatment success, yet it is often underestimated. Adequate irrigation protocols, safe delivery techniques, and the use of activation systems can enhance microbial reduction while minimizing the risk of extrusion accidents. Clinicians must be aware of the potential hazards associated with irrigants and adopt preventive measures to ensure patient safety.

Obturation quality is a critical determinant of long-term success. Three-dimensional sealing of the root canal system prevents reinfection and promotes periapical healing. Errors during obturation often reflect deficiencies in canal preparation or working length determination. Equally important is the integrity of the coronal restoration, as coronal leakage has been consistently identified as a major cause of endodontic failure. Prompt placement of well-sealed restorations is essential to protect the root canal system from microbial contamination.

Overall, the discussion emphasizes that prevention is the most effective approach to managing endodontic errors and complications. Continuous professional education, adherence to evidence-based protocols, use of magnification and advanced imaging, and careful case selection are fundamental to improving clinical outcomes.

Conclusion

Errors and complications during endodontic treatment remain a significant challenge in dental practice and have a profound impact on treatment outcomes and tooth survival. This comprehensive review demonstrates that such adverse events can occur at every stage of endodontic therapy, from diagnosis to final restoration. Diagnostic inaccuracies, inadequate access cavity preparation, working length errors, mechanical complications during canal shaping, irrigation mishaps, obturation deficiencies, and coronal leakage are among the most common factors contributing to treatment failure.

A thorough understanding of root canal anatomy, meticulous clinical technique, and adherence to evidence-based guidelines are essential for minimizing errors. Technological advancements have improved the safety and predictability of endodontic treatment; however, they cannot compensate for inadequate knowledge or poor clinical judgment. Prevention, early detection, and appropriate management of complications are critical for achieving favorable outcomes.

Ultimately, successful endodontic treatment depends on the clinician□s ability to integrate scientific knowledge, technical skill, and careful decision-making. By recognizing potential

errors and implementing preventive strategies, clinicians can enhance the quality of endodontic care, improve patient satisfaction, and increase the long-term success of root canal therapy.

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