JOURNAL OF HEALTHCARE SCIENCES
Volume 4 Issue 11 2024, Article ID: JOHS2024000947
http://dx.doi.org/10.52533/JOHS.2024.41110
e-ISSN: 1658-8967

Review

Prognostic Factors in Determining Success and Failure Rates in Endodontics

Reem Ali Alkaoud[1], Yahya Hady Mohammed[2], Amal Ali Galilah[3], Fatmah Saad Alghamdi[3], Nahed Abdullah Alhabashi[4]

[1] *Dental Department, Second Health Cluster Central Region, Riyadh, Saudi Arabia*
[2] *Dental Administration Department, Abha Specialized Dental Center, Abha, Saudi Arabia*
[3] *Almuhammadiyah 2 Primary Healthcare Center, Ministry of Health, Riyadh, Saudi Arabia*
[4] *Abu Shajrah Primary Healthcare Center, Prince Sultan bin Abdulaziz Health Care in Diriyah, Riyadh, Saudi Arabia*

Correspondence should be addressed to **Reem Ali Alkaoud**, Dental Department, Second Health Cluster Central Region, Riyadh, Saudi Arabia. Email: reem2266@gmail.com

Received: 16 November 2024, Reviewed: 23 November 2024, Accepted: 24 November 2024, Published: 25 November 2024.

Abstract

Endodontic treatment success depends on a complex interplay of anatomical, microbial, patient-related, and procedural factors. Variations in root canal anatomy, such as apical deltas, accessory canals, and isthmuses, can harbor bacteria despite advanced cleaning techniques, contributing to reinfection and treatment failure. The use of modern imaging technologies and precision tools like rotary instrumentation improves canal visualization and accessibility, while innovative irrigation techniques and adjuncts enhance microbial control, addressing limitations of conventional methods. Microbial factors, particularly the persistence of biofilm-forming bacteria such as Enterococcus faecalis, challenge complete disinfection. These resilient species can survive intracanal treatments, necessitating a multi-modal approach combining antimicrobial agents and advanced activation techniques to disrupt biofilms. Patient-specific variables, including systemic health conditions, immune status, and age, further impact endodontic outcomes by influencing healing capacities and susceptibility to reinfection. Diabetic patients, for example, face delayed healing, increasing the likelihood of complications. The long-term success of endodontically treated teeth also relies heavily on post-treatment restoration. A well-sealed, full-coverage restoration prevents microbial infiltration and protects the tooth from fractures under occlusal load. Adhesive materials and fiber posts provide added reinforcement, especially for teeth with substantial coronal damage, and help distribute functional forces evenly. Timely and durable restorations contribute significantly to the survival of treated teeth, with immediate or early definitive restorations showing improved outcomes. Effective endodontic care requires a comprehensive understanding of these prognostic factors, emphasizing personalized treatment strategies to improve success rates. Advances in procedural techniques, restorative materials, and an in-depth appreciation of patient-related variables collectively contribute to enhanced endodontic outcomes, reducing failure rates and increasing long-term tooth preservation.

Keywords: *Endodontics, failure rates, success rates*

Introduction

Endodontic treatment has evolved significantly, aiming to preserve natural teeth by treating the pulp and periapical tissues affected by disease, trauma, or degeneration. Despite advancements in technology and techniques, the success and failure rates of endodontic treatments remain influenced by numerous prognostic factors that impact long-term outcomes. Successful endodontic therapy often hinges on a complex interplay of anatomical, procedural, microbial, and patient-related factors, which collectively influence the longevity and functional integrity of treated teeth. These factors need thorough examination to refine treatment protocols and enhance patient outcomes (1).

The anatomical complexity of the root canal system poses a significant challenge to the complete eradication of pathogens, which is essential for successful outcomes (2). Variations in canal morphology, including accessory canals, apical deltas, and isthmuses, can harbor bacteria even after thorough mechanical and chemical debridement, potentially leading to persistent infections and treatment failure. Additionally, procedural factors, including the techniques and materials used for cleaning, shaping, and obturating the canal, directly impact the success of endodontic treatment. Studies have demonstrated that achieving an adequate seal at the apical and coronal levels is critical to preventing bacterial re-infection, which is a primary cause of endodontic failure (3).

Patient-related factors, such as systemic health conditions and individual immune responses, are increasingly recognized as key determinants of treatment outcomes. For instance, patients with systemic conditions, like diabetes or immune disorders, often experience compromised healing, which may affect the success of endodontic treatments. Similarly, age, genetic factors, and oral hygiene practices can also influence treatment success and highlight the need for personalized approaches to endodontic care (4). Given the multifactorial nature of endodontic success, it is essential for clinicians to understand and evaluate these prognostic factors in a comprehensive manner. This review aims to explore the critical factors affecting endodontic treatment outcomes and provide insights for improving clinical decision-making.

Review

The success of endodontic treatment relies on managing various prognostic factors, including microbial control, patient health, and procedural precision. Bacterial elimination from the root canal system is crucial, as persistent microbial presence is a leading cause of post-treatment failure. Effective disinfection techniques, such as advanced irrigants and rotary instrumentation, have been shown to reduce bacterial loads significantly, thereby improving success rates (5). However, challenges remain due to anatomical complexities, such as apical ramifications and lateral canals, where bacteria may survive, compromising long-term outcomes.

Patient-related factors, such as systemic health conditions like diabetes, have been observed to modulate immune responses and delay healing in endodontic procedures, increasing susceptibility to post-treatment complications (6). Personalized treatment approaches that consider patients' systemic health can enhance endodontic outcomes, especially in populations with compromised healing. Additionally, the role of restorative procedures following endodontic treatment cannot be underestimated. Proper coronal restoration provides a seal against bacterial re-entry, a critical factor in preventing reinfection and ensuring treatment durability. Future research should focus on identifying additional patient-specific factors that may affect outcomes and refining microbial control techniques to address anatomical challenges comprehensively, thus improving overall success rates in endodontic care.

Anatomical and Procedural Influences on Endodontic Outcomes

The complexity of the root canal system remains one of the most challenging factors in endodontics, with significant implications for treatment outcomes. Root canals vary widely in morphology,

http://dx.doi.org/10.52533/JOHS.2024.41110

featuring anatomical complexities such as isthmuses, accessory canals, apical deltas, and C-shaped canals, all of which may harbor bacteria and tissue remnants even after thorough instrumentation (7). These anatomical nuances contribute to the difficulty in achieving complete disinfection, especially when using conventional techniques. Studies show that missed canal spaces can lead to persistent infection, increasing the risk of treatment failure over time (8). Consequently, knowledge of root canal anatomy and advancements in imaging techniques, such as cone-beam computed tomography (CBCT), have become crucial for enhancing visualization and ensuring that all canals are properly located and treated.

The choice of instrumentation technique significantly impacts the mechanical preparation of root canals. Traditional hand-filing methods, though effective, are increasingly replaced by rotary and reciprocating systems, which offer superior efficiency in cleaning and shaping irregular canal morphologies. Rotary instruments, typically made from nickel-titanium (NiTi), are particularly effective in maintaining the original canal shape while minimizing procedural errors such as ledging, transportation, and perforations. Research suggests that rotary instrumentation not only improves the mechanical efficacy of canal preparation but also enhances the distribution of irrigants, reaching areas that are challenging to access manually (9). However, these systems are not without limitations; for instance, NiTi instruments may fracture under excessive torsional load or cyclic fatigue, which can compromise the treatment if retrieval or bypassing is unsuccessful.

Irrigation, a vital step in the endodontic process, further demonstrates the importance of procedural techniques. Sodium hypochlorite (NaOCl) is commonly used due to its tissue-dissolving and antimicrobial properties. However, studies indicate that irrigation alone cannot reach all areas of the root canal, especially in anatomically challenging spaces (10). To improve irrigant penetration, adjuncts such as ultrasonic and passive sonic activation are increasingly applied, which create acoustic streaming and cavitation effects, promoting more thorough disinfection. Advanced irrigants, including ethylenediaminetetraacetic acid (EDTA) and chlorhexidine, are also utilized to dissolve inorganic debris and eliminate specific bacterial species. The combination of these irrigants has been shown to enhance overall disinfection, particularly in cases with complex anatomy where standard irrigation may not suffice.

Obturating materials and techniques also play a critical role in determining endodontic success. The objective of obturation is to provide a three-dimensional seal that prevents bacterial infiltration into the periapical tissues. Traditional gutta-percha, combined with sealer, has been the gold standard for decades, yet alternative techniques, such as warm vertical compaction and thermoplasticized gutta-percha, offer enhanced adaptability to the canal walls and can fill intricate canal spaces more effectively. Research comparing these obturation techniques has highlighted that thermoplasticized methods yield a better seal in irregular and anatomically complex canals compared to cold lateral compaction, reducing microleakage potential and improving long-term outcomes (11).

The integration of magnification tools like dental operating microscopes and loupes has further advanced endodontic procedures by improving the clinician's ability to identify and address anatomical variations. The use of magnification in endodontic procedures not only increases accuracy but also helps in identifying accessory canals, avoiding iatrogenic errors, and ensuring complete debridement. Studies have shown that clinicians utilizing enhanced visualization techniques experience higher success rates in complex cases, particularly when dealing with challenging canal anatomies (12). As anatomical and procedural complexities continue to shape endodontic outcomes, these innovations underscore the need for continued advancements and training in procedural techniques to mitigate potential treatment failures and enhance the success rates for patients with variable canal morphologies.

http://dx.doi.org/10.52533/JOHS.2024.41110

Microbial Factors and Their Role in Endodontic Success

Microbial control within the root canal system is essential to the success of endodontic treatment. The primary cause of pulpal and periapical diseases is microbial invasion; thus, effective disinfection is critical to prevent post-treatment infection. Studies reveal that bacterial biofilms, primarily composed of facultative and obligate anaerobes, are the main contributors to endodontic infections, often complicating treatment outcomes (12). These biofilms adhere to the canal walls and penetrate into dentinal tubules, creating a challenge for mechanical and chemical debridement. Persistent bacterial colonies, especially from species like *Enterococcus faecalis*, are well-adapted to survive within the harsh environment of treated canals, leading to recurrent infections and treatment failure (13).

E. faecalis is frequently isolated from failed endodontic cases and is known for its resilience and ability to survive nutrient-deprived conditions. Its cell wall-associated virulence factors, such as lipoteichoic acid, enable it to adhere firmly to dentin surfaces and resist removal by irrigation solutions. Additionally, it can endure high pH levels and adapt to the medicaments commonly used in endodontics, making it one of the most difficult bacteria to eliminate (14). Consequently, while traditional irrigants like sodium hypochlorite are effective against many pathogens, the presence of robust microbial agents like *E. faecalis* requires a multimodal approach for thorough disinfection.

One of the most significant advancements in addressing microbial factors has been the development and use of intracanal medicaments. Calcium hydroxide, for example, has been widely used for its antimicrobial properties and ability to elevate the canal's pH, which helps in killing acid-sensitive bacteria (15). However, its efficacy is limited against more resilient species, such as *E. faecalis* and *Candida albicans*, due to their high pH tolerance and biofilm-forming abilities. This limitation has led to the exploration of alternative intracanal medicaments, including antimicrobial peptides and nanoparticle-based solutions. These new medicaments show promise in penetrating biofilms more effectively than conventional agents and may offer a solution to persistent bacterial resistance.

Furthermore, disinfection efficacy is closely tied to irrigation techniques and the ability of irrigants to penetrate all areas of the canal, including lateral canals and apical regions. Passive ultrasonic irrigation (PUI) and laser-activated irrigation (LAI) have emerged as valuable techniques to enhance the effectiveness of root canal disinfection. These methods create fluid dynamics that aid in disrupting biofilms and improving the reach of irrigants into the complex anatomy of root canals, including areas that are typically difficult to access (16, 17). Studies indicate that these activation techniques enhance the bactericidal effectiveness of sodium hypochlorite and other irrigants, especially against established biofilms.

The application of advanced molecular techniques has allowed a deeper understanding of the microbial ecology within endodontic infections. Techniques such as 16S rRNA sequencing enable the identification of previously undetectable bacterial species and reveal the complexity of the polymicrobial communities within the root canal system. This expanded view of the microbial diversity associated with endodontic infections underscores the need for comprehensive disinfection strategies. Understanding the specific microbial profile of infections, particularly in resistant cases, can guide the selection of targeted antimicrobial strategies and improve endodontic success rates (16, 17).

Patient-Related Variables Affecting Prognosis in Endodontic Treatment

Patient-specific variables, including age, systemic health conditions, and oral hygiene habits, significantly impact the prognosis of endodontic treatments. These factors influence the body's ability to respond to treatment, heal adequately, and maintain long-term outcomes. Age, for instance, is a critical determinant; studies show that elderly patients are more prone to reduced healing capacities and changes in root canal morphology,

http://dx.doi.org/10.52533/JOHS.2024.41110

which can complicate treatment. With age, the pulp chamber and canals become narrower and more calcified, reducing accessibility and complicating both cleaning and shaping procedures (16-18). These anatomical changes may hinder optimal debridement and irrigation, leading to an increased risk of treatment failure in older patients.

Systemic health conditions, particularly diabetes and cardiovascular diseases, also play a substantial role in the success of endodontic procedures. Diabetic patients, for example, often experience delayed wound healing and a heightened risk of infection due to impaired immune response and altered blood flow to tissues (18, 19). These physiological challenges can complicate the healing process post-treatment, resulting in a lower success rate for endodontic therapies. In addition, patients with cardiovascular diseases may face increased risks due to the potential inflammatory response triggered by bacterial presence within the root canal, which can complicate their overall prognosis. For these patients, clinicians often need to adopt tailored approaches, such as pre-treatment consultations and medication adjustments, to minimize complications.

The immune system plays a central role in determining the body's response to endodontic infections and subsequent treatments. Patients with compromised immune systems, including those undergoing chemotherapy or suffering from immunodeficiency disorders, may struggle to combat residual infections even after thorough canal debridement and disinfection. This weakened defense can allow persistent bacteria to survive within the root canal system, increasing the likelihood of reinfection. Research underscores the importance of understanding each patient's immune status and adapting treatment strategies accordingly, which may involve the use of antimicrobial agents or adjunct therapies to support the immune response (19, 20). Moreover, studies indicate that patients with robust immune health are more likely to achieve favorable treatment outcomes, as their bodies can naturally suppress low levels of remaining bacteria.

Oral hygiene habits and patient compliance are also influential factors in endodontic prognosis. Individuals with good oral hygiene practices are less likely to experience reinfections and periodontal complications, which are crucial for the long-term success of endodontic treatments. Conversely, patients with poor oral hygiene may be at higher risk of secondary infections due to plaque buildup and bacterial migration into treated areas. Research suggests that regular dental follow-ups, along with reinforced oral hygiene education, can help improve prognosis by reducing bacterial load around the treated tooth (21). Additionally, patient compliance with post-operative instructions, such as avoiding chewing on the treated tooth and attending follow-up appointments, is essential for successful outcomes.

Psychological factors, including patient anxiety and pain perception, further influence endodontic prognosis by affecting patient cooperation and comfort during treatment. High anxiety levels can lead to increased pain perception, making it challenging for the patient to endure prolonged treatments and compromising procedural efficacy. Some studies have suggested the use of pre-operative counseling and relaxation techniques to alleviate anxiety and improve patient cooperation, which in turn can enhance treatment quality and prognosis (22). Tailoring treatment approaches to accommodate psychological factors not only support the patient's comfort but may also contribute to a smoother healing process, reducing the likelihood of complications.

The Impact of Post-Treatment Restoration on Long-Term Success

Post-treatment restoration is essential to the long-term success of endodontically treated teeth. One of the primary roles of a well-executed restoration is to prevent bacterial re-entry, which can otherwise lead to reinfection and treatment failure. Studies indicate that inadequate coronal restoration compromises the seal created during endodontic treatment, exposing the root canal system to oral bacteria and increasing the risk of apical periodontitis recurrence (23). Ensuring a hermetic seal at the coronal end is thus critical for maintaining a sterile root environment,

http://dx.doi.org/10.52533/JOHS.2024.41110

as even minor gaps can permit microbial infiltration that compromises treatment outcomes over time.

The choice of restorative material and technique further influences the longevity of endodontically treated teeth. Full-coverage crowns are frequently recommended for molars, where mechanical load is substantial, as they provide additional strength to the tooth structure. Crowns help in distributing occlusal forces, which can prevent fractures in structurally compromised teeth. Research suggests that teeth restored with crowns after endodontic treatment demonstrate significantly higher survival rates compared to those with simple direct restorations, especially in posterior teeth subjected to heavy occlusal forces (24). For anterior teeth, where aesthetic considerations play a larger role and functional demands are comparatively lower, composite resin or glass ionomer restorations may be effective and reduce the overall treatment cost for patients.

Adhesive techniques also play a pivotal role in achieving optimal sealing and reinforcement of endodontically treated teeth. Advances in bonding materials, such as resin-based adhesives, have improved the durability of restorations by creating strong bonds between the restoration and tooth structure. These adhesive systems work by forming a hybrid layer that can resist microleakage and enhance fracture resistance, which is especially important in teeth with extensive coronal damage. Studies show that adhesive restorations can help reduce the risk of restoration failure and improve the structural integrity of endodontically treated teeth (25). However, achieving a perfect adhesive bond requires meticulous technique, as moisture control and preparation of the bonding surfaces are critical to ensuring effective adhesion.

The timing of post-endodontic restoration is another crucial factor. Immediate placement of a temporary or definitive restoration following endodontic treatment minimizes the risk of coronal leakage and bacterial re-invasion. Delayed restoration can expose the treated canals to contamination, even when a temporary seal is applied, especially if the temporary material deteriorates over time. Evidence suggests that immediate or timely permanent restoration is associated with higher success rates, as it prevents exposure of the canal system to the oral environment, enhancing the prognosis of the treated tooth (26). Restorative approaches that incorporate fiber posts are commonly employed for teeth with significant loss of tooth structure. Fiber posts reinforce the tooth and distribute functional forces more evenly, reducing the risk of fracture in weakened roots. Fiber posts have shown favorable results due to their elastic modulus, which closely resembles that of dentin, allowing them to absorb and dissipate occlusal stresses effectively. Compared to metal posts, fiber posts are associated with a lower incidence of root fractures, making them a preferred choice in restorations requiring additional reinforcement (26). While the use of fiber posts is generally advantageous, the decision to place a post should be based on the extent of coronal damage and functional requirements, as overuse in structurally sound teeth may unnecessarily complicate the restorative procedure.

Conclusion

Successful endodontic treatment is influenced by a combination of anatomical, microbial, patient-related, and restorative factors. Recognizing and addressing these variables enables clinicians to tailor treatments that enhance the longevity and functionality of treated teeth. Effective disinfection tailored restorative approaches, and patient-centered care are key to minimizing complications. Continued research into these prognostic factors will further refine endodontic protocols, ultimately improving patient outcomes.

Disclosure

Conflict of interest

There is no conflict of interest.

Funding

No funding

Ethical Consideration

Not applicable.

http://dx.doi.org/10.52533/JOHS.2024.41110

Data availability

Data that support the findings of this study are embedded within the manuscript.

Author Contribution

The authors contributed to conceptualizing, data drafting, collection and final writing of the manuscript.

References

1. Peters OA. Current challenges and concepts in the preparation of root canal systems: a review. Journal of endodontics. 2004;30(8):559-67.

2. Vertucci FJ. Root canal anatomy of the human permanent teeth. Oral surgery, oral medicine, oral pathology. 1984;58(5):589-99.

3. Ingle JI. PDQ endodontics: PMPH USA; 2009.

4. Fouad AF. Diabetes mellitus as a modulating factor of endodontic infections. Journal of Dental Education. 2003;67(4):459-67.

5. SIQUEIRA JF, RÔÇAS IN. Microbiology and treatment of endodontic infections. Cohen's Pathways of the Pulp. 2011:559-600.

6. Segura-Egea J, Cabanillas-Balsera D, Jiménez-Sánchez M, Martín-González J. Endodontics and diabetes: association versus causation. International Endodontic Journal. 2019;52(6):790-802.

7. Pineda F, Kuttler Y. Mesiodistal and buccolingual roentgenographic investigation of 7,275 root canals. Oral Surgery, Oral Medicine, Oral Pathology. 1972;33(1):101-10.

8. Cleghorn BM, Christie WH, Dong CC. The root and root canal morphology of the human mandibular first premolar: a literature review. Journal of endodontics. 2007;33(5):509-16.

9. Peters OA, Paqué F. Current developments in rotary root canal instrument technology and clinical use: a review. Quintessence International. 2010;41(6).

10. Gu L-s, Kim JR, Ling J, Choi KK, Pashley DH, Tay FR. Review of contemporary irrigant agitation techniques and devices. Journal of endodontics. 2009;35(6):791-804.

11. Peng L, Ye L, Tan H, Zhou X. Outcome of root canal obturation by warm gutta-percha versus cold lateral condensation: a meta-analysis. Journal of endodontics. 2007;33(2):106-9.

12. Love R. Enterococcus faecalis–a mechanism for its role in endodontic failure. International endodontic journal. 2001;34(5):399-405.

13. Stuart CH, Schwartz SA, Beeson TJ, Owatz CB. Enterococcus faecalis: its role in root canal treatment failure and current concepts in retreatment. Journal of endodontics. 2006;32(2):93-8.

14. Sedgley C, Molander A, Flannagan S, Nagel A, Appelbe O, Clewell D, et al. Virulence, phenotype and genotype characteristics of endodontic Enterococcus spp. Oral microbiology and immunology. 2005;20(1):10-9.

15. Siqueira Jr J, Lopes H. Mechanisms of antimicrobial activity of calcium hydroxide: a critical review. International endodontic journal. 1999;32(5):361-9.

16. Vivan RR, Duque JA, Alcalde MP, Só MVR, Bramante CM, Duarte MAH. Evaluation of different passive ultrasonic irrigation protocols on the removal of dentinal debris from artificial grooves. Brazilian dental journal. 2016;27(5):568-72.

17. Van der Sluis L, Gambarini G, Wu M, Wesselink P. The influence of volume, type of irrigant and flushing method on removing artificially placed dentine debris from the apical root canal during passive ultrasonic irrigation. International endodontic journal. 2006;39(6):472-6.

18. Sue M, Oda T, Sasaki Y, Ogura I. Age-related changes in the pulp chamber of maxillary and mandibular molars on cone-beam computed tomography images. Oral Radiology. 2018;34:219-23.

19. Fouad AF, Burleson J. The effect of diabetes mellitus on endodontic treatment outcome: data from an electronic patient record. The Journal of the American Dental Association. 2003;134(1):43-51.

20. Waltimo TM, Haapasalo M, Zehnder M, Meyer J. Clinical aspects related to endodontic yeast infections. Endodontic topics. 2004;9(1):66-78.

http://dx.doi.org/10.52533/JOHS.2024.41110

21. Mohammadi Z, Abbott P. The properties and applications of chlorhexidine in endodontics. International endodontic journal. 2009;42(4):288-302.

22. Farias ZBBMd, Campello CP, da Silveira MMF, Moraes SLD, do Egito Vasconcelos BC, Pellizzer EP. The influence of anxiety on pain perception and its repercussion on endodontic treatment: a systematic review. Clinical Oral Investigations. 2023;27(10):5709-18.

23. Ray H, Trope M. Periapical status of endodontically treated teeth in relation to the technical quality of the root filling and the coronal restoration. International endodontic journal. 1995;28(1):12-8.

24. Aquilino SA, Caplan DJ. Relationship between crown placement and the survival of endodontically treated teeth. The Journal of prosthetic dentistry. 2002;87(3):256-63.

25. Ferrari M, Vichi A, García-Godoy F. Clinical evaluation of fiber-reinforced epoxy resin posts and cast post and cores. American journal of dentistry. 2000;13(Spec No):15B-8B.

26. Gillen BM, Looney SW, Gu L-S, Loushine BA, Weller RN, Loushine RJ, et al. Impact of the quality of coronal restoration versus the quality of root canal fillings on success of root canal treatment: a systematic review and meta-analysis. Journal of endodontics. 2011;37(7):895-902.

 http://dx.doi.org/10.52533/JOHS.2024.41110