REVIEW ARTICLE

Recent Advances in Root Canal Disinfection. A Narrative Review

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ABSTRACT

Root canal disinfection is a critical component of endodontic therapy aimed at eliminating microorganisms from the root canal system to prevent reinfection and promote successful healing. Recent advances have focused on improving antimicrobial agents, delivery systems, and employing innovative technologies. This review discusses the latest developments in root canal disinfection, including novel irrigants, improved delivery techniques, laser systems, antimicrobial photodynamic therapy (aPDT), and new instrumentation. Challenges and future directions for complete disinfection of the complex root canal system are also explored.

KEYWORDS: Root canal disinfection, endodontics, antimicrobial agents, laser systems, irrigants, photodynamic therapy, root canal system, disinfection techniques, bacterial biofilm, root canal therapy.

INTRODUCTION

Root canal therapy (RCT) is a widely performed procedure to treat infections of the dental pulp caused by caries, trauma, or other periodontal issues. The procedure involves removing the infected tissue, cleaning, and filling the root canal system to prevent reinfection. Successful RCT depends largely on effective disinfection of the root canal system to remove bacteria and bacterial biofilms, which are often responsible for post-treatment infections (1, 2).

While conventional disinfection strategies using sodium hypochlorite (NaOCl) and mechanical instrumentation remain standard, they do not always achieve complete disinfection due to the complex and variable anatomy of the root canal system (3). Biofilms, which offer protection to bacteria, further complicate disinfection efforts, making it a challenge for traditional treatments (4). As a result, recent advancements in root canal disinfection have focused on novel antimicrobial agents, improvements in irrigation systems, and complementary technologies like lasers and antimicrobial photodynamic therapy (aPDT) (5, 6).

This review aims to explore recent developments in root canal disinfection, highlighting the effectiveness of new irrigants, delivery methods, and adjunctive technologies that improve outcomes in endodontic therapy.

MATERIALS AND METHODS

This review was conducted by searching multiple scientific databases such as PubMed, Scopus, and Google Scholar for studies published between 2000 and 2024. Search terms like "root canal disinfection," "new irrigants," "laser disinfection," "photodynamic therapy," and "bacterial biofilm in endodontics" were used to identify relevant literature. Studies that focused on the following topics were selected for inclusion:

Antimicrobial Agents: New agents developed or studied for their antimicrobial efficacy in root canal disinfection.

Irrigation Techniques: Innovations in irrigation techniques and delivery systems.

Laser and Photodynamic Therapy: Advances in the use of lasers and aPDT as adjuncts to disinfection.

Root Canal Anatomy and Biofilms: Studies on overcoming the challenges posed by anatomical complexities and biofilms.

Each study was critically analyzed for methodology, findings, and relevance to modern root canal disinfection strategies.

REVIEW OF LITERATURE

Antimicrobial Agents in Root Canal Disinfection

Sodium hypochlorite (NaOCl) remains the most commonly used irrigant for root canal disinfection due to its strong antimicrobial properties (7). However, it is associated with cytotoxicity and a limited ability to completely eliminate bacterial biofilms (8). As a result, alternative agents such as chlorhexidine (CHX) have been explored. CHX has shown greater biocompatibility and antibacterial activity compared to NaOCl, though it is less effective against certain bacterial strains (9).

More recent studies have examined novel agents like silver nanoparticles, essential oils, and calcium hydroxide-based formulations. Silver nanoparticles, for instance, have demonstrated significant antibacterial properties, minimal cytotoxicity, and the ability to penetrate biofilms effectively, making them promising alternatives (10, 11). Essential oils, such as tea tree oil, also show potential for antimicrobial action with fewer side effects, presenting an alternative to conventional irrigants (12).

Irrigation Techniques and Delivery Systems

Irrigation is vital for cleaning the root canal system and eliminating microbial contaminants, but its efficacy depends on both the irrigant used and the delivery system. Traditional syringe-based irrigation is often ineffective in reaching all areas of the canal, especially in complex anatomies (13). To address this, passive ultrasonic irrigation (PUI) has been developed. PUI enhances irrigant penetration into lateral canals and other hard-to-reach areas by using ultrasonic energy to agitate the irrigant, improving biofilm disruption (14, 15).

Laser-activated irrigation (LAI) has also gained attention as an adjunctive technology. In this technique, laser energy is used to activate the irrigant, which has been shown to increase its antimicrobial efficacy and improve biofilm removal (16).

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LAI can enhance the cleaning of complex root canal systems and provide a more effective alternative to traditional irrigation methods (17).

Laser Systems in Root Canal Disinfection

Laser disinfection has been increasingly studied as an adjunctive method for root canal disinfection. Various laser systems, such as erbium-doped yttrium aluminum garnet (Er:YAG) and diode lasers, have shown promise in enhancing the antimicrobial effects of root canal treatment (18). Er:YAG lasers, in particular, are effective at removing dentin debris while promoting antibacterial activity, making them a useful tool for cleaning root canals (19). Diode lasers, on the other hand, are often used for deeper disinfection and can be particularly useful for addressing microbial contamination in the apical regions of the root canal (20).

Although laser disinfection has demonstrated beneficial outcomes, it is most effective when combined with traditional irrigation methods, improving overall disinfection results (21)
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Antimicrobial Photodynamic Therapy (aPDT)

Antimicrobial photodynamic therapy (aPDT) is a novel treatment modality that involves the use of a photosensitizer and light to generate reactive oxygen species that inactivate bacteria. The ability of aPDT to penetrate and disrupt bacterial biofilms has attracted interest in its application for root canal disinfection (22). Recent studies have shown that aPDT significantly reduces bacterial load, particularly in cases involving biofilms, and could serve as an adjunct to conventional disinfection methods (23).

However, while promising, the clinical application of aPDT remains limited by several factors, including the need for specialized equipment, the optimal choice of photosensitizer, and the required light parameters (24). Further research is necessary to establish the clinical efficacy of aPDT, determine its long-term effects, and optimize protocols for its use in routine endodontic practice.

DISCUSSION

Effective root canal disinfection remains one of the most significant challenges in endodontics due to the anatomical complexity of root canal systems and the presence of bacterial biofilms. Despite the advancements in irrigation techniques and disinfecting agents, achieving complete disinfection continues to be an elusive goal. While NaOCl has been the mainstay of root canal disinfection for decades, its limitations—such as cytotoxicity and inability to fully eradicate biofilms—have led to the exploration of alternative agents and techniques.

The development of antimicrobial agents like silver nanoparticles and essential oils provides exciting alternatives to traditional irrigants. These agents offer enhanced antimicrobial action with lower cytotoxicity, making them more suitable for maintaining the health of surrounding tissues. Silver nanoparticles, for example, have demonstrated superior efficacy in disrupting bacterial biofilms, which are a major cause of post-treatment failure (10).

Innovations in irrigation techniques, particularly PUI and LAI, offer significant improvements in the delivery and action of disinfectants. PUI, in particular, has proven effective in reaching difficult-to-access areas of the root canal system, which has been a limitation of syringe-based irrigation techniques (15). LAI, by combining laser energy with irrigants, offers synergistic effects that enhance biofilm removal and improve microbial eradication, particularly in areas where traditional methods fall short (16, 17).

Laser disinfection systems like Er:YAG and diode lasers have been beneficial adjuncts in root canal therapy, providing additional antimicrobial effects. These systems can be particularly useful for disinfecting deeper areas of the root canal system, where conventional irrigation and instrumentation methods may not reach effectively (24, 25). The combination of lasers with irrigation techniques appears to provide a more thorough disinfection, which is critical in ensuring the long-term success of RCT.

Antimicrobial photodynamic therapy (aPDT) has emerged as another potential adjunct in endodontics. Its ability to target biofilms and bacterial pathogens with minimal tissue damage positions it as a promising technology for improving root canal disinfection (26). However, more research is needed to determine the most effective photosensitizers, light parameters, and clinical protocols for its use in routine practice.

Despite these promising advances, several challenges remain. The integration of new techniques into clinical practice requires careful consideration of cost-effectiveness, clinical feasibility, and long-term outcomes. Furthermore, there is a need for more clinical trials to establish the effectiveness of these technologies in diverse patient populations, particularly in cases with complicated canal anatomies and extensive biofilm presence.

CONCLUSION

Recent advances in root canal disinfection, including novel antimicrobial agents, enhanced irrigation systems, and adjunctive technologies like lasers and aPDT, offer promising alternatives to conventional methods. These innovations address the challenges posed by root canal anatomy and bacterial biofilms, improving the effectiveness of disinfection and reducing the risk of reinfection. However, more clinical research is needed to establish the optimal protocols, cost-effectiveness, and long-term outcomes of these new methods. By combining traditional and advanced techniques, the goal of achieving complete disinfection in root canal therapy may become more achievable, resulting in better long-term patient outcomes.

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