ORIGINAL ARTICLE

INTERNATIONAL JOURNAL OF ARTIFICIAL INTELLIGENCE

ISSN: 2692-515-x, Impact Factor: 9.23
American Academic publishers, volume 6, issue 02,2026

Journal: https://www.academicpublishers.org/journals/index.php/ijai

MODERN METHODS OF ROOT CANAL DISINFECTION: EFFECTIVENESS OF NOVEL ANTISEPTICS AND LASER THERAPY

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Abstract. Effective disinfection of the root canal system is a critical determinant of successful endodontic treatment. The complex anatomy of root canals, presence of microbial biofilms, and resistance of certain microorganisms significantly limit the effectiveness of conventional chemomechanical preparation. Despite advances in endodontic instrumentation, complete elimination of microorganisms using traditional irrigants remains challenging. Consequently, persistent infection remains one of the leading causes of endodontic treatment failure.

In recent years, significant attention has been directed toward the development of novel antiseptic agents and the application of laser-assisted disinfection techniques. New-generation antiseptics aim to enhance antimicrobial efficacy while maintaining biocompatibility and minimizing cytotoxic effects. Laser therapy, on the other hand, offers a physical method of microbial inactivation through photothermal and photomechanical effects, potentially improving penetration into dentinal tubules and complex canal anatomy.

The present study provides a comprehensive analysis of modern root canal disinfection methods, focusing on the comparative effectiveness of innovative antiseptics and laser-based technologies. Available experimental and clinical evidence suggests that the combined use of advanced chemical agents and laser therapy significantly improves microbial reduction and may enhance long-term endodontic outcomes.

Keywords. Root canal disinfection; endodontic irrigation; novel antiseptics; laser therapy; antimicrobial efficacy; biofilm elimination

Introduction

Endodontic treatment aims to eliminate infection from the root canal system and prevent reinfection through adequate disinfection and sealing. Microorganisms and their by-products play a central role in the development and persistence of apical periodontitis, making effective microbial control a fundamental prerequisite for treatment success. However, achieving complete disinfection of the root canal system remains one of the most challenging aspects of endodontic therapy.

The anatomical complexity of root canals, including lateral canals, isthmuses, apical deltas, and dentinal tubules, creates favorable conditions for microbial colonization and biofilm formation. Conventional mechanical instrumentation alone is insufficient to access and disinfect these areas. Therefore, chemical irrigation plays a critical role in complementing mechanical preparation.

Traditional irrigants such as sodium hypochlorite and chlorhexidine have been widely used due to their antimicrobial properties. Nevertheless, these agents exhibit limitations, including cytotoxicity, unpleasant taste, limited penetration depth, and reduced efficacy against mature biofilms. Moreover, certain microorganisms, such as *Enterococcus faecalis* and *Candida albicans*, demonstrate increased resistance to conventional disinfectants.

In response to these challenges, modern endodontics has increasingly focused on improving root canal disinfection through the introduction of novel antiseptic formulations and

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adjunctive physical methods, including laser therapy. These approaches aim to enhance antimicrobial effectiveness while preserving periapical tissue health.

Root canal infections are typically polymicrobial, consisting of both aerobic and anaerobic microorganisms organized in complex biofilms. Biofilms provide microorganisms with enhanced resistance to antimicrobial agents and host immune responses. The extracellular matrix of biofilms restricts the penetration of disinfectants, making eradication particularly difficult.

Persistent endodontic infections are frequently associated with *Enterococcus faecalis*, which is capable of surviving harsh environmental conditions, penetrating deep into dentinal tubules, and forming resilient biofilms. Fungal species, particularly *Candida albicans*, have also been implicated in refractory cases and secondary infections.

The ability of microorganisms to adapt to nutrient-poor environments and resist antimicrobial agents underscores the need for advanced disinfection strategies capable of targeting biofilms and microorganisms located beyond the reach of conventional irrigation.

Recent research has focused on developing new antiseptic agents with improved antimicrobial efficacy and reduced toxicity. Modified formulations of sodium hypochlorite with surfactants have been introduced to enhance surface tension reduction and improve penetration into dentinal tubules.

Biguanide-based solutions, quaternary ammonium compounds, and iodine-containing formulations have also been explored for their broad-spectrum antimicrobial activity and sustained effects.

Nanoparticle-based antiseptics, including silver nanoparticles and calcium hydroxide nanocomposites, have demonstrated promising antimicrobial properties. Due to their small size, nanoparticles exhibit enhanced penetration into dentinal tubules and biofilms, leading to improved microbial reduction.

Bioactive irrigants capable of releasing antimicrobial ions while promoting tissue compatibility represent another promising direction in endodontic disinfection.

Laser-assisted root canal disinfection is based on photothermal, photochemical, and photomechanical effects. Laser energy generates localized heat and acoustic streaming, which disrupt microbial cell walls and biofilm structure. These effects enhance disinfectant penetration and microbial elimination.

Different laser systems, including diode, Nd:YAG, Er:YAG, and Er,Cr:YSGG lasers, have been investigated for endodontic applications.

Laser therapy has been shown to significantly reduce bacterial counts within root canals and dentinal tubules. When used as an adjunct to conventional irrigation, lasers improve disinfection of anatomically complex areas that are otherwise inaccessible.

Importantly, laser parameters must be carefully controlled to avoid thermal damage to surrounding tissues. Proper technique and adherence to clinical protocols are essential for safe and effective application.

Studies comparing novel antiseptics and laser-assisted disinfection demonstrate that each approach offers distinct advantages. Chemical antiseptics provide broad-spectrum antimicrobial action and are essential for dissolving organic tissue. Laser therapy enhances physical disruption of biofilms and improves penetration depth.

Evidence suggests that combined protocols, incorporating both advanced antiseptics and laser activation, result in superior microbial reduction compared to either method alone. Such

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synergistic effects may significantly improve treatment outcomes and reduce the incidence of persistent infections.

Improved root canal disinfection has direct implications for clinical success and long-term tooth preservation. Reducing the incidence of endodontic treatment failure decreases the need for retreatment and surgical intervention, thereby improving patient outcomes and reducing healthcare costs.

From a public health perspective, effective endodontic therapy contributes to maintaining natural dentition, preserving oral function, and enhancing quality of life. Adoption of advanced disinfection technologies may support more predictable and sustainable endodontic care.

Despite promising results, further randomized clinical trials are required to establish standardized protocols and evaluate long-term outcomes of novel antiseptics and laser-assisted disinfection. Cost-effectiveness, learning curves, and accessibility of laser technology should also be considered.

Future research should focus on optimizing combined disinfection strategies and exploring emerging technologies such as photodynamic therapy and smart antimicrobial agents.

Conclusion. Modern methods of root canal disinfection, including the use of novel antiseptics and laser therapy, significantly enhance microbial elimination within the root canal system. The combination of advanced chemical agents and laser-assisted techniques offers a promising approach to overcoming the limitations of conventional disinfection methods. Integration of these technologies into clinical practice may improve endodontic treatment success and long-term outcomes.

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