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Review

The Efficacy and Safety of Various Root Canal Irrigants and Disinfectants

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Abstract

Root canal irrigation and disinfection are crucial steps in endodontic therapy that involve removing debris, lubricating the canal, and disinfecting the canal walls. The utilization of an appropriate irrigant and disinfectant is essential for the effective debridement and disinfection of the root canal system, and the choice of solution can affect the success of the treatment as well as the safety of surrounding tissues. Sodium hypochlorite, chlorhexidine, EDTA, and MTAD are commonly used irrigants and disinfectants in endodontics. Sodium hypochlorite is one of the most frequently used irrigants due to its high antimicrobial activity against a wide range of microorganisms, while chlorhexidine is less cytotoxic and has a lower risk of causing tissue damage. Advances in research have led to the development of new techniques and solutions, such as the use of nanoparticles, photodynamic therapy, and low-frequency ultrasound. While these novel developments show promise, more investigations are needed to evaluate their efficacy and safety for irrigation and disinfection in endodontic therapy.

Keywords: *root canal irrigants, root canal disinfectants, safety, efficacy*

Introduction

Root canal irrigation (RCI) and disinfection are important aspects of endodontic treatment for the elimination or minimization of bacterial infection in the canal system. RCI comprises debridement by flushing the canal system with a solution, lubrication, and disinfection of the canal walls. Successfully debriding and disinfecting the canals requires the use of a suitable irrigant and disinfectant. The choice of root canal irrigant and disinfectant can affect the success of root canal treatment, as some solutions are more effective than others at eliminating bacteria while maintaining the safety of the surrounding tissues (1). Advances in research have led to the development of new irrigation and disinfection techniques and solutions, providing clinicians with a range of options to optimize root canal treatment outcomes. Research on the efficacy and safety of root canal irrigants and disinfectants is a constantly evolving field (2). Endodontic therapy commonly uses various solutions for irrigating and disinfecting root canals, including sodium hypochlorite, chlorhexidine, EDTA (ethylenediaminetetraacetic acid), and MTAD (a mixture of doxycycline, citric acid, and a detergent) (3). Sodium hypochlorite is a widely used root canal irrigant due to its strong antimicrobial activity against a broad range of microorganisms, its ability to dissolve organic tissue and debris, and its effective disinfection of the root canal system. Chlorhexidine is also a widely used irrigant that has broad-spectrum antimicrobial activity against various microorganisms, including bacteria, fungi, and viruses. Unlike sodium hypochlorite, chlorhexidine is less cytotoxic and has a lower risk of causing tissue damage. MTAD is utilized for final rinsing in the canal disinfection process. Recent research has evaluated the effectiveness of MTAD against biofilm and persistent microorganisms, as well as its potential cytotoxicity and effect on the sealing ability of root canal fillings (4).

Methodology

This study is based on a comprehensive literature search conducted on March 14, 2023, in the Medline and Cochrane databases, utilizing the medical topic headings (MeSH) and a combination of all available related terms, according to the database. To prevent missing any possible research, a manual search for publications was conducted through Google Scholar, using the reference lists of the previously listed papers as a starting point. We looked for valuable information in papers that discussed the efficacy and safety of various root canal irrigants and disinfectants. There were no restrictions on the date, language, participant age, or type of publication.

Discussion

The following are some of the commonly used root canal irrigants and disinfectants in endodontics, along with their efficacy and safety considerations.

Sodium Hypochlorite (NaOCl)

Several studies have demonstrated the efficacy of NaOCl in removing bacteria from infected root canals and reducing bacterial load (5). A study published in the Journal of Endodontics in 2021 evaluated the antimicrobial efficacy of different concentrations of NaOCl against *Enterococcus faecalis*, a common bacteria found in infected root canals. The study found that higher concentrations of NaOCl (3% and 6%) showed significantly better antimicrobial efficacy than lower concentrations (1% and 2%) (6). However, the study also noted that the use of higher concentrations of NaOCl can lead to dentin erosion and other adverse effects. While NaOCl is generally considered safe for use as a root canal irrigant, there have been reports of adverse effects associated with its use. These adverse effects include chemical burns, tissue necrosis, and nerve damage (7-9). To minimize the risk of adverse effects, it is important to use the appropriate concentration of NaOCl and avoid overfilling the root canal. Researchers are also exploring new formulations of NaOCl that can improve its efficacy and safety as a root canal irrigant. For example, a recent study published in the Journal of Endodontics in 2020 evaluated the antimicrobial efficacy of a novel NaOCl formulation that included surfactants and chelating agents (10). The study found that the novel formulation showed better antimicrobial

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efficacy than traditional NaOCl solutions while also causing less dentin erosion. Overall, NaOCl is a widely used root canal irrigant that has demonstrated efficacy in removing bacteria from infected root canals. However, its use should be carefully controlled to minimize the risk of adverse effects.

Chlorhexidine (CHX)

Chlorhexidine (CHX) is a commonly used root canal irrigant in endodontics. Several studies have evaluated its efficacy and safety in this context. With respect to efficacy, CHX has been shown to be effective in reducing bacterial load in root canals, including the reduction of *E. faecalis*. (11)

According to a systematic review and meta-analysis, using CHX as an RCI led to a notable decrease in the number of bacteria in infected root canals compared to control groups (11). Additionally, CHX can remain active in the root canal for an extended period of time after application, which is known as substantivity (12). Although CHX is generally safe to use as a root canal irrigant, it can cause discoloration of teeth and restorations if not rinsed out properly. There have been reports of allergic reactions to CHX in some patients, although these are rare. In vitro studies have shown that CHX can have cytotoxic effects on some types of cells, although these effects are generally mild and only occur at high concentrations.

Ethylenediaminetetraacetic acid (EDTA)

EDTA is a commonly used chelating agent in endodontic treatment as an RCI. Its main purpose is to remove the smear layer from the root canal walls, which aids in better penetration of disinfectants and sealers. EDTA has the ability to bind to calcium ions, disrupting the bacterial biofilm and improving disinfection. Various studies have investigated the safety and efficacy of EDTA as a root canal irrigant. One study demonstrated that a 17% EDTA solution was effective in removing the smear layer from the root canal walls and enhancing the penetration of disinfectants (13). Another study found that a combination of sodium hypochlorite and EDTA was more successful in reducing bacterial growth than using only sodium hypochlorite (14). In terms of safety, EDTA has a low toxicity profile and is considered safe for use in endodontic treatment. However, there have been some reports of adverse reactions to EDTA, such as allergic reactions and irritation of the skin and mucous membranes (15). Therefore, it is important to use EDTA in the appropriate concentrations and to follow recommended safety protocols, such as wearing protective gloves and eyewear. Overall, EDTA is an effective and safe root canal irrigant that can improve disinfection and facilitate the sealing of the root canal system.

Calcium hydroxide

Calcium hydroxide ($Ca(OH)_2$) has been widely used in endodontics as an RCI and medicament. It is known to possess high antibacterial properties against a diverse range of microbial species predominantly found in infected canal systems, including *E. faecalis*, *Porphyromonas gingivalis*, and *Prevotella intermedia* (16). Several studies have investigated the efficacy and safety of calcium hydroxide as an RCI. One study found that calcium hydroxide was effective at reducing the number of bacteria in infected root canals, but it was less effective than other irrigants, such as chlorhexidine and MTAD (17, 18). In terms of safety, calcium hydroxide has been shown to have low toxicity and biocompatibility. However, it can cause damage to periapical tissues if overextended beyond the root canal system. Additionally, prolonged use of calcium hydroxide can lead to the weakening of the dentin and increased susceptibility to fracture. Overall, calcium hydroxide has been shown to be an effective root canal irrigant with antibacterial properties and low toxicity. However, it may not be as effective as other irrigants, and care should be taken to avoid overextension and prolonged use (19).

Ozonated water

Ozonated water has been proposed as an alternative root canal irrigant due to its antimicrobial and tissue-dissolving properties (20). However, there is

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limited research on its efficacy and safety as a root canal irrigant. A study published in 2022 evaluated the efficacy of ozonated water as a root canal irrigant compared to sodium hypochlorite and found that while ozonated water showed some antimicrobial efficacy, it was generally less effective than sodium hypochlorite in reducing the bacterial load in root canals (21). The review also noted that the quality of the evidence was low due to limitations in the study design and methodology. While there is some evidence to suggest that ozonated water may have antimicrobial properties, more research is needed to evaluate its efficacy and safety as a root canal irrigant.

Laser irradiation

Laser irradiation has been investigated as a potential root canal disinfectant. Some studies have suggested that laser irradiation may have antibacterial effects and could be effective in eliminating bacteria in root canals. For example, one study found that laser irradiation with an erbium-doped yttrium aluminum garnet (Er: YAG) laser significantly reduced bacterial counts in root canals compared to a control group (22). Another study found that a diode laser was effective in eliminating *E. faecalis (23).* However, some studies have reported conflicting results and questioned the efficacy and safety of laser irradiation as a root canal disinfectant. Some studies have suggested that laser irradiation may not be effective in eliminating bacteria and may even cause thermal damage to the tooth structure (24, 25). For example, one study found that laser irradiation with an Nd: YAG laser did not have any significant effect on bacterial counts in root canals (24).

Over the years, several innovations and developments have been made to improve their safety and efficacy.

Nanoparticles

There have been some studies investigating the efficacy and safety of using nanoparticles as root canal irrigants. Studies examining the utilization of silver nanoparticles as an RCI for endodontic treatment have found silver nanoparticles to display robust antibacterial activity against common pathogens found in endodontic infections, and to be successful in sanitizing the root canal system (26). Nonetheless, the research also highlighted the need for additional investigation to fully comprehend the safety and long-term consequences of employing silver nanoparticles as an RCI. In a distinct investigation, zinc oxide nanoparticles were assessed as a root canal irrigant (27). The findings revealed that zinc oxide nanoparticles effectively eliminated the smear layer and disinfected the root canal system without harming human cells. However, further research is required to fully assess the safety and long-term effects of utilizing zinc oxide nanoparticles as an RCI.

Photodynamic therapy (PDT)

Photodynamic therapy (PDT) has been explored as a promising method for endodontic irrigation and disinfection (28). PDT involves using a photosensitizer, which, when exposed to specific wavelengths of light, produces reactive oxygen species (ROS) that can destroy bacteria. In endodontics, PDT can be used after mechanical cleaning and shaping to disinfect the root canal system. According to a systematic review and meta-analysis, adjunctive PDT is more effective than conventional root canal treatment alone in decreasing bacterial load in the root canal system (29). PDT has been shown to be safe for use in endodontics. One study found that PDT did not cause any adverse effects on the pulp tissue or dentin structure of extracted human teeth (30).

Antibiotic-carrying polymers

Antibiotic-carrying polymers have the advantage of releasing antibiotics in a sustained and controlled manner, which can enhance their effectiveness in eliminating bacteria and preventing reinfection (31). One study that evaluated the antimicrobial activity of a polymer-based root canal irrigant containing minocycline, a broad-spectrum antibiotic, found that the minocycline-carrying polymer had significant antimicrobial activity against *E. faecalis* (32). The polymer also showed sustained release of minocycline over a period of seven days, indicating its potential as a long-lasting root canal disinfectant.

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The polymer also showed sustained release of amoxicillin over a period of 21 days, indicating its potential as a long-lasting root canal disinfectant. While these studies show promising results for the use of antibiotic-carrying polymers as root canal irrigants and disinfectants, the use of antibiotics in endodontics remains a controversial topic due to concerns about antibiotic resistance and the potential for adverse effects.

Low-frequency ultrasound

Low-frequency ultrasound has been studied as a potential root canal disinfection method. Several studies have shown that low-frequency ultrasound can significantly reduce the number of bacteria in root canals, including those that are resistant to conventional disinfection methods (33). In one investigation, low-frequency ultrasound in combination with sodium hypochlorite exhibited greater effectiveness in achieving root canal disinfection than sodium hypochlorite alone (34). Another study found that low-frequency ultrasound combined with an antimicrobial agent called cetrimide was more effective at eliminating bacteria from root canals than either treatment alone (35). Low-frequency ultrasound has also been shown to have other beneficial effects on root canal treatment, such as improving the penetration of disinfectants into the root canal system and removing debris and biofilms from the canal walls (36).

Plasma sterilization

Plasma sterilization is a novel method of disinfecting root canals that involves using a low-temperature plasma to kill bacteria and other microorganisms (37). There is limited research available on the efficacy and safety of plasma sterilization as a root canal irrigant and disinfectant, as it is a relatively new technology. One study assessed the antibacterial efficacy of plasma sterilization in comparison to traditional RCIs like sodium hypochlorite and CHX (38). The results revealed that plasma sterilization was successful in eliminating bacteria, yeasts, and fungi predominantly found in infected canal systems with similar or superior antimicrobial efficacy compared to the alternative irrigation techniques.

Conclusion

The safety and efficacy of these new technologies and materials need to be evaluated before they can be widely used in clinical practice. Nonetheless, these innovations have the potential for enhancing the safety and efficacy of RCIs and disinfectants in endodontics. In conclusion, RCIs and disinfectants play a crucial role in the success of endodontic therapy. Sodium hypochlorite and CHX are the most frequently utilized RCIs, followed by other choices such as EDTA, calcium hydroxide, ozonated water, and laser irradiation. It is important to use these agents with caution and to follow appropriate safety protocols to minimize the risk of tissue damage or other adverse effects.

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Conflict of interest

There is no conflict of interest

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

Author contribution

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

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