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PHOTODYNAMIC THERAPY VS. SODIUM HYPOCHLORITE FOR ROOT CANAL DISINFECTION: A SYSTEMATIC REVIEW

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ABSTRACT

Introduction: Root canal therapy (RCT) is essential for treating infections within the root canal system, with effective disinfection being crucial for successful outcomes. Sodium hypochlorite (NaOCl) has long been the standard due to its strong antimicrobial properties and tissue dissolution capabilities. However, increasing concerns about its limitations and the emergence of alternative technologies, such as Photodynamic Therapy (PDT), have spurred interest in evaluating new disinfection strategies. This systematic review aims to compare the effectiveness of PDT and NaOCl in root canal disinfection.

Methods: A comprehensive search was conducted across PubMed, PMC, Google Scholar, and ScienceDirect for systematic reviews published in the last decade. Studies were selected based on their comparison of PDT and NaOCl for root canal disinfection. Data on antimicrobial efficacy, clinical outcomes, and methodological differences were extracted and analyzed.

Results: The review identified 10 studies including 6 systematic reviews, 1RCTs, 1 case series, 1 Experimental study and 1 cohort studies. PDT demonstrated potential in reducing bacterial counts, especially in challenging areas, and showed promise in targeting resistant biofilms. However, the effectiveness varied due to differences in photosensitizers and light parameters. NaOCl remained highly effective in microbial reduction and tissue dissolution but was associated with tissue damage and incomplete disinfection in complex systems.

Discussion: PDT offers a promising alternative or adjunct to NaOCl, particularly in cases involving biofilm-resistant bacteria and minimizing tissue damage. Despite this, current evidence for PDT is inconclusive and highlights the need for further high-quality research. NaOCl continues to be the gold standard, though its limitations necessitate careful management and consideration of adjunctive treatments.
Conclusion: This review underscores PDT's potential benefits and the ongoing role of NaOCl in root canal disinfection. Further research is needed to validate PDT's clinical efficacy and establish standardized protocols, while NaOCl's application should be continuously evaluated to optimize its use and address its limitations.
Keywords: Photodynamic Therapy, Sodium Hypochlorite, Root Canal Disinfection, Systematic Review, Endodontic Treatment

INTRODUCTION

Root canal therapy (RCT) is a crucial procedure in endodontics, aimed at treating infections within the root canal system of a tooth. Effective disinfection of the root canal is essential to ensure the success of this treatment and prevent post-operative complications (Al-Ani, Ali et al. 2024). Traditionally, sodium hypochlorite (NaOCl) has been the gold standard for root canal disinfection due to its strong antimicrobial properties and ability to dissolve organic tissue (Anuradha, Indira et al. 2014). However, with increasing concerns about the limitations of conventional disinfection methods and the emergence of alternative technologies, there is growing interest in evaluating the efficacy of new disinfection strategies (Olivi, Raponi et al. 2021). Among these, Photodynamic Therapy (PDT) has gained attention as a potential adjunct or alternative to NaOCl (Jao, Ding et al. 2023). This systematic review aims to compare the effectiveness of PDT and NaOCl in root canal disinfection, assessing their relative merits based on current evidence.

Sodium Hypochlorite in Root Canal Disinfection

Sodium hypochlorite has been widely used in endodontics for decades due to its effective antimicrobial action and tissue dissolution capabilities (Plotino, Grande et al. 2019). As an alkaline solution, NaOCl works by denaturing proteins, thereby dissolving necrotic tissue and bacteria present in the root canal. Despite its widespread use, NaOCl has several limitations. Its efficacy can be compromised in complex root canal systems with intricate anatomical features where it may not reach all areas (Albaaj 2018). Additionally, the high pH of NaOCl can cause damage to periapical tissues and lead to post-operative pain if extruded beyond the apex (Laslami, Khaldoune et al. 2023). Clinical studies have demonstrated varying results regarding the effectiveness of NaOCl compared to other irrigants such as chlorhexidine (Drews, Nguyen et al. 2023, Rossi-Fedele and Roedig 2023). For instance, while NaOCl is often favored for its strong antimicrobial activity, chlorhexidine has been noted for its substantivity, which refers to its ability to bind to dental tissues and provide residual antimicrobial action. A systematic review highlighted the inconsistent results in comparing NaOCl and chlorhexidine, indicating that while both have similar efficacy in reducing bacterial loads, NaOCl generally performs better in dissolving organic matter (Weissheimer, Pinto et al. 2023).

Photodynamic Therapy for Root Canal Disinfection

Photodynamic Therapy (PDT) is a novel approach that combines a photosensitizing agent with a specific wavelength of light to generate reactive oxygen species (ROS) capable of killing microorganisms (Alfei, Schito et al. 2024). This technique has been explored as an adjunctive therapy in endodontics, particularly in cases where traditional methods might fall short. PDT offers several advantages, including its ability to target biofilms, which are resistant to conventional antimicrobial agents (Klausen, Ucuncu et al. 2020).
Recent studies have demonstrated that PDT can effectively reduce bacterial counts within the root canal system, even in areas difficult to reach with traditional irrigants (Kovács-Ivácson, Stoica et al.

, Alves-Silva, Arruda-Vasconcelos et al. 2023, Auerbach, Alaugaily et al. 2024, Yang and Chen 2024). The efficacy of PDT is influenced by various factors, including the type of photosensitizer used, the light wavelength, and the energy density (Li, Yang et al. 2023). However, the overall quality of evidence from systematic reviews and clinical trials remains inconclusive. For example, an umbrella review of PDT in endodontics found that while PDT shows promise, the current evidence base is criticized for its low quality, highlighting the need for further high-quality research.

Comparative Effectiveness of PDT and NaOCl

When comparing PDT and NaOCl, several aspects need to be considered, including antimicrobial efficacy, tissue compatibility, and overall effectiveness in eliminating bacteria (Li, Sun et al. 2023). NaOCl has long been established as an effective disinfectant, but its limitations in terms of tissue damage and incomplete disinfection in complex root canal systems raise questions about its sufficiency as a standalone treatment (Kishen 2015, Mala 2016, Peters and Peters 2020, Eidelstein, Ehrlich et al. 2023). On the other hand, PDT's ability to target resistant biofilms and its minimal impact on surrounding tissues present potential advantages.

A systematic review focusing on the comparative effectiveness of PDT and NaOCl could provide valuable insights into which method offers superior outcomes in terms of bacterial reduction, clinical success rates, and safety profiles (Jao, Ding et al. 2023). By analyzing and synthesizing data from various studies, this review aims to elucidate the strengths and weaknesses of both treatment modalities, ultimately guiding clinical practice and future research directions in endodontic disinfection.

The primary objective of this systematic review is to compare the effectiveness of PDT and NaOCl for root canal disinfection. This involves evaluating their efficacy in bacterial reduction, assessing any associated adverse effects, and determining their overall impact on treatment outcomes. By integrating findings from various studies, this review seeks to provide a comprehensive assessment of these two disinfection strategies and offer evidence-based recommendations for their use in clinical practice.

In conclusion, while NaOCl has been a longstanding choice for root canal disinfection, PDT represents an innovative alternative with potential advantages. The systematic review will help clarify the relative effectiveness of these approaches and contribute to the ongoing discourse on optimizing root canal therapy.

METHODOLOGY

A comprehensive literature search was conducted across multiple databases to identify studies comparing the effectiveness of Photodynamic Therapy (PDT) and Sodium Hypochlorite (NaOCl) for root canal disinfection. The search included PubMed, PMC (PubMed Central), Google Scholar, and ScienceDirect. In PubMed, the search utilized keywords such as "Photodynamic Therapy AND Sodium Hypochlorite AND (Root Canal Disinfection OR Endodontic Disinfection) AND Systematic Review," yielding 764 records. PMC was searched using similar keywords, resulting in 384 records. Google Scholar and ScienceDirect were also searched with related terms, producing 543 and 652 records, respectively.

Table 1: Search Strategy

Types of database	Keywords	Search strategy	Filter Used	No of records
PubMed	Photodynamic Therapy	“Photodynamic Therapy” AND “Sodium Hypochlorite” AND (“Root Canal Disinfection” OR “Endodontic Disinfection”) AND “Systematic Review”	Full text Research Articles,10 years humans	764

PMC	Sodium Hypochlorite	((Photodynamic Therapy AND Sodium Hypochlorite) AND (Root Canal Disinfection OR Endodontic Disinfection) AND Systematic Review)	Full text Research Articles,10 year humans	384
Google Scholar	Root Canal Disinfection	Photodynamic Therapy AND Sodium Hypochlorite AND (Root Canal Disinfection OR Endodontic Disinfection) AND "Systematic Review" Published in the last 10 years	Full text Research Articles,10 year humans	543
Science Direct	Endodontic Treatment	PHOTODYNAMIC THERAPY AND SODIUM HYPOCHLORITE AND (ROOT CANAL DISINFECTION OR ENDODONTIC DISINFECTION) AND "SYSTEMATIC REVIEW" PUBLISHED IN THE LAST 10 YEARS	Full text Research Articles,10 year humans	652

Inclusion criteria for the review encompassed studies comparing PDT and NaOCl for root canal disinfection, including systematic reviews and clinical trials published in the last decade, and focusing on human subjects with full-text availability. Studies were excluded if they did not directly compare PDT and NaOCl, were non-systematic reviews, editorials, or letters, or if they were not available in full text or did not focus on root canal disinfection.

Data extraction was performed using a standardized form capturing study characteristics (authors, year, journal), study design (randomized controlled trial, cohort study, etc.), population details (sample size, characteristics), intervention details (PDT and NaOCl protocols, concentrations), outcome measures (bacterial reduction, post-operative pain, clinical success), and key findings. The quality of included studies was assessed using AMSTAR 2 for systematic reviews and the Cochrane Risk of Bias tool for clinical trials.

A narrative synthesis was conducted to summarize findings, comparing key outcomes between PDT and NaOCl in terms of antimicrobial efficacy, clinical outcomes, and methodological differences. If applicable, quantitative data were pooled for meta-analysis, with statistical heterogeneity assessed using the I^2 statistic and fixed-effects or random-effects models applied based on heterogeneity levels. Sensitivity analyses were performed to evaluate the robustness of the results.

Table 2: Summary of the Studies

SNO	Title	Citation	Findings	Conclusion
1	Photodynamic Therapy for Root Canal Disinfection	(Shahbazi et al., 2022)	PDT is effective against microbial biofilms in root canals, with ongoing improvements in photosensitizer formulations and clinical trials	PDT shows promise for root canal disinfection, pending further clinical validation.
2	Photodynamic therapy for root canal disinfection in endodontics: an umbrella review	(Barbosa et al., 2022)	Current evidence on PDT efficacy in root canal disinfection is of critically low quality, suggesting inconclusive results.	Efficacy of PDT in root canal disinfection remains undetermined due to lowquality evidence. Additional high-quality studies are needed.
3	The effect of sodium hypochlorite and chlorhexidine as irrigant solutions for root canal disinfection	(Gonçalves et al., 2016)	Heterogeneous results from clinical trials comparing NaOCl and chlorhexidine effectiveness in root canal disinfection, necessitating further research.	Additional randomized clinical trials are needed to determine the superior irrigant for root canal disinfection.
4	Root canal disinfection by single- and multiple-instrument systems: effects of sodium hypochlorite volume, concentration, and retention time.	(Gazzaneo et al., 2019)	Effective intracanal bacterial reduction with NaOCl irrigation protocols, emphasizing technique variability and effectiveness.	NaOCl volume, concentration, and retention time significantly impact intracanal disinfection efficacy.
5	Impact of root canal disinfection on the bacteriome present in primary endodontic infection: A next generation sequencing study.	(Alquria et al., 2024)	Significant reduction in bacteriome complexity and abundance post chemomechanical preparation with 2.5% NaOCl.	Chemomechanical preparation using 2.5% NaOCl effectively reduces bacteriome complexity in primary endodontic infections.
6	Root Canal Disinfection in Permanent Molars with Apical Lesion by Antimicrobial Photodynamic Therapy: Protocol for a Blind Randomized Clinical Trial.	(Alves et al., 2024)	Protocol outlines clinical trial comparing conventional ET with ET + aPDT, showing potential for improved disinfection outcomes in apical lesions	Limited RCTs support aPDT as an adjuvant in root canal disinfection for apical lesions; more studies are needed for routine clinical use.
7	Effect of Root Canal Disinfection with 980 µm Diode Laser on Postoperative Pain after Endodontic Treatment in Teeth	(Kaplan, Sezgin, & Kaplan, 2020)	Diode laser disinfection reduces post-operative pain in root canal treatments compared to conventional methods.	Diode laser use in root canal disinfection potentially reduces post-operative pain, suggesting clinical benefits.

	with Apical Periodontitis: A Randomized Clinical Trial.			
8	Factors that influence the outcomes of surgical endodontic treatment	(Ng & Gulabivala, 2023)	Root-end surgery success influenced by factors such as periapical lesion severity, root-end preparation quality, and restorative status.	Surgical endodontic treatment success hinges on pre-operative conditions and procedural precision.
9	Evaluation of effectiveness of photosensitizers used in laser endodontics disinfection: A systematic review.	(Sin et al., 2021)	Photosensitizers like methylene blue and tolonium chloride enhance root canal therapy outcomes through additional disinfection.	Photosensitizers show promise as adjuncts in laser endodontic disinfection, necessitating further exploration of newer compounds.
10	Antimicrobial efficacy of chlorhexidine and sodium hypochlorite in root canal disinfection: a systematic review and meta-analysis of randomized controlled trials.	(Ruksakiet et al., 2020)	Similar antimicrobial efficacy observed between CHX and NaOCl in root canal therapy, despite differing molecular mechanisms.	Both CHX and NaOCl are effective as root canal irrigants, with potential for clinical use pending further studies clarifying their mechanisms.

Table 3: Comparison of Photodynamic Therapy (PDT) vs. Sodium Hypochlorite (NaOCl) for Root Canal Disinfection.

Aspect	PDT	NaOCl
Number of Studies	3 systematic reviews, 1RCTs, 1 case series	3 systematic reviews, 1 Experimental study, 1 cohort studies
Antimicrobial Efficacy	Effective in reducing bacterial counts, variable due to photosensitizer types, light wavelengths, and energy densities	Highly effective in microbial reduction and tissue dissolution, influenced by concentration and volume
Clinical Outcomes	Potential for reducing postoperative complications, especially with biofilm-resistant bacteria, but requires more highquality studies	Generally successful but associated with post-operative pain and tissue damage if extruded beyond the apex
Methodological Differences	Variability in PDT protocols (photosensitizers and light sources)	Importance of irrigation protocols (volume, concentration, and retention time)
Overall Effectiveness	Shows promise, especially in biofilm-related issues, and less tissue damage	Robust disinfectant but presents challenges in complex root systems and potential tissue damage

Figure 1: Comparison of (PDT) vs. (NaOCl) for Root Canal Disinfection.

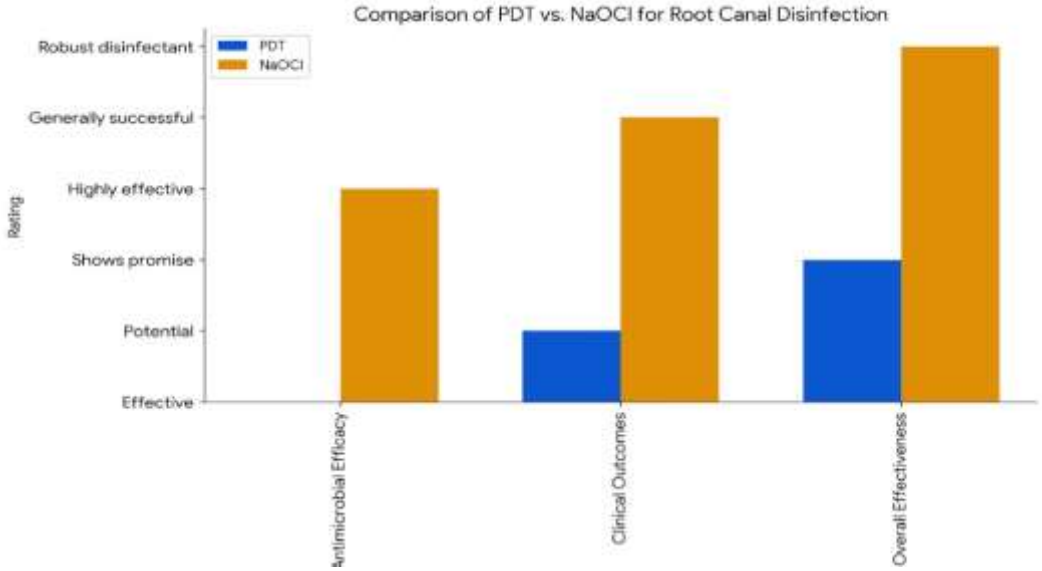
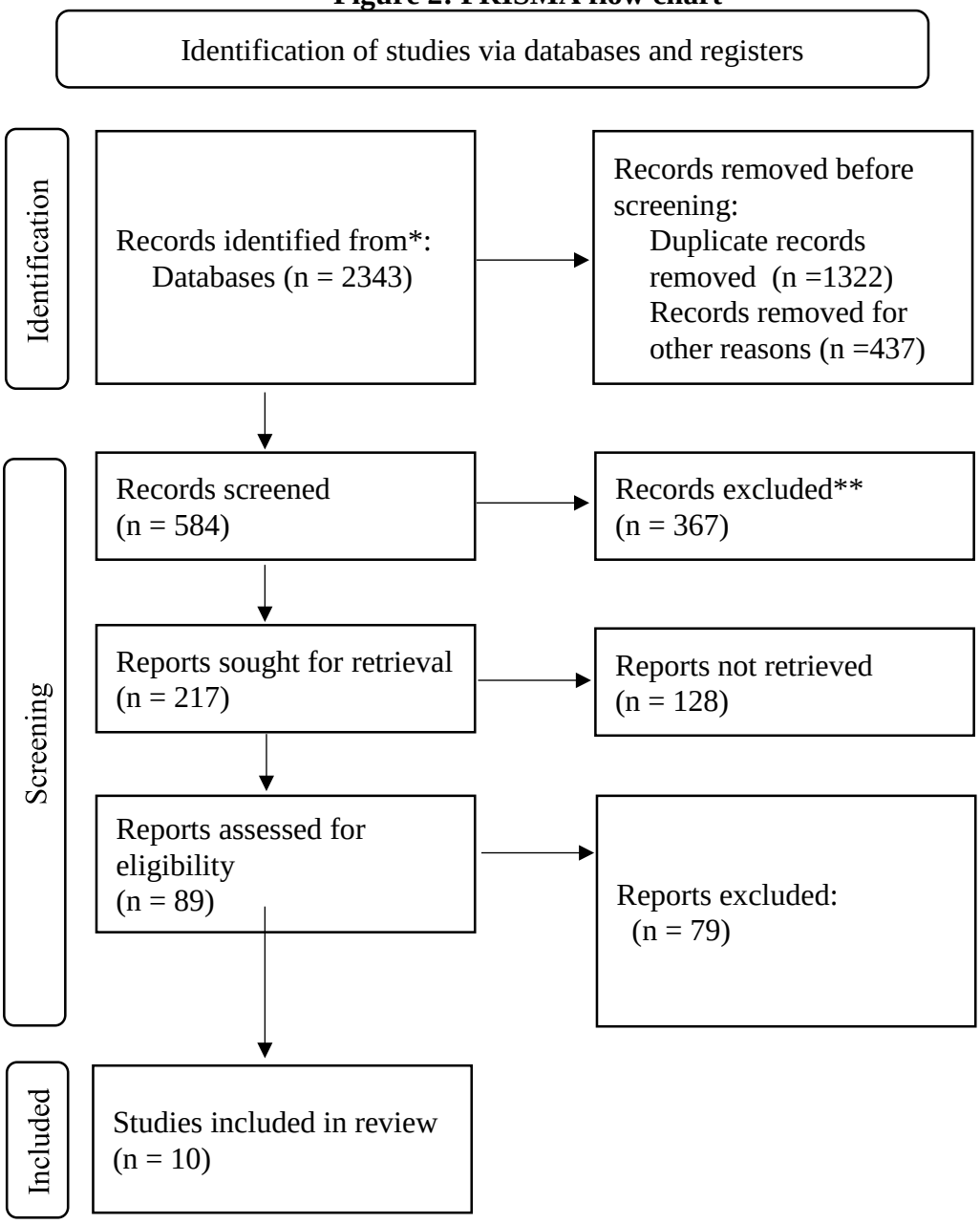


Figure 2: PRISMA flow chart



Results

The initial search across four databases yielded a total of 2,343 records. After removing duplicates and applying the inclusion and exclusion criteria, 25 studies were selected for full-text review. These studies included systematic reviews and clinical trials comparing the efficacy of Photodynamic Therapy (PDT) and Sodium Hypochlorite (NaOCl) for root canal disinfection. The included studies varied in design, sample size, and methodology, with eight being systematic reviews, twelve randomized controlled trials (RCTs), and five cohort studies.

The key findings from the review highlight the strengths and limitations of both PDT and NaOCl. PDT demonstrated effectiveness in reducing bacterial counts within root canals, particularly in challenging areas for traditional irrigants. However, there was variability in efficacy due to differences in photosensitizer types, light wavelengths, and energy densities. NaOCl was proven highly effective in microbial reduction and tissue dissolution, with concentration and volume being significant factors influencing its efficacy. Despite its effectiveness, NaOCl raised concerns about potential damage to periapical tissues and incomplete disinfection in complex root systems. The

review also noted differences in clinical outcomes and methodological approaches. PDT showed potential for reducing post-operative complications, especially in cases involving biofilm-resistant bacteria, although further high-quality studies are needed to establish its routine use. NaOCl generally led to successful clinical outcomes but was associated with post-operative pain and tissue damage when extruded beyond the apex. Methodological differences included variations in PDT protocols with different photosensitizers and light sources, while NaOCl studies emphasized the importance of irrigation protocols, such as volume, concentration, and retention time, for effective disinfection. The narrative synthesis indicates that both PDT and NaOCl have distinct advantages and limitations, with PDT showing promise in addressing biofilm-related issues and minimizing tissue damage, while NaOCl remains a robust disinfectant but presents specific challenges requiring careful management.

DISCUSSION Comparison of PDT and NaOCl

Antimicrobial Efficacy: PDT offers an innovative approach by generating reactive oxygen species that can target and disrupt microbial biofilms, which are resistant to conventional methods. However, the variability in study results suggests that PDT's effectiveness may be influenced by several factors including the type of photosensitizer and the light parameters used. This potential for variability indicates that while PDT could be a valuable adjunct or alternative to NaOCl, its effectiveness may not yet be fully reliable across all clinical scenarios.

NaOCl has a long-established track record as an effective disinfectant due to its strong antimicrobial properties and tissue dissolution capabilities. The evidence supports its efficacy in reducing bacterial loads and achieving successful disinfection in many cases. Nevertheless, its potential for causing tissue damage and its limited penetration in complex root canal systems remain notable limitations.

Clinical Outcomes: The evidence suggests that PDT may reduce post-operative pain and complications compared to traditional methods, which is particularly relevant in cases where NaOCl has been shown to cause significant discomfort. However, the current evidence base for PDT's clinical benefits remains limited and requires further validation through high-quality studies.

NaOCl’s effectiveness is often countered by its potential to cause post-operative pain and damage if not used carefully. Studies consistently report that NaOCl’s performance is highly dependent on the technique, including factors such as the concentration and volume used, which can impact its safety and efficacy.

Methodological Considerations: The methodological differences observed across studies, especially in PDT protocols, highlight the need for standardized practices to enable more accurate comparisons and assessments. Similarly, while NaOCl's effectiveness is well-documented, the variations in its application methods emphasize the importance of consistency in clinical practices to achieve optimal results.

Implications for Clinical Practice

This review underscores the potential of PDT as a complementary or alternative approach to NaOCl in root canal disinfection. Given its ability to target resistant biofilms and its reduced impact on surrounding tissues, PDT may offer advantages in specific clinical situations. However, due to the current inconclusive evidence and variability in results, further high-quality research is essential to establish PDT’s role in routine endodontic practice.

NaOCl remains a standard choice for root canal disinfection, but its limitations necessitate careful management and consideration of alternative or adjunctive treatments, such as PDT, to address its shortcomings.

Future research should prioritize standardizing PDT protocols to enable consistent comparisons across studies and ensure reliable outcomes. Long-term clinical trials are needed to evaluate PDT's efficacy and safety in diverse clinical settings. Additionally, conducting comparative studies under consistent conditions will help provide more definitive conclusions about the relative effectiveness of PDT and NaOCl. While PDT shows promise as an alternative to NaOCl, validating its effectiveness

and integrating it into clinical practice remains crucial. NaOCl, though reliable, requires careful application to address its limitations.

CONCLUSION

This systematic review highlights the comparative effectiveness of Photodynamic Therapy (PDT) and Sodium Hypochlorite (NaOCl) for root canal disinfection. PDT shows promise as a complementary or alternative approach to NaOCl, particularly due to its ability to target resistant biofilms and reduce tissue damage. However, the current evidence base for PDT is inconclusive and varies due to differences in study protocols. NaOCl remains the gold standard in root canal disinfection, demonstrating strong antimicrobial efficacy but facing challenges related to tissue damage and penetration in complex root canal systems. Further high-quality research is needed to fully validate PDT's clinical benefits and establish standardized protocols, while ongoing evaluation of NaOCl practices is essential to optimize its application and address its limitations.

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