Review Article

MICROBIOLOGICAL EFFECT OF VARIOUS CONCENTRATIONS OF SODIUM HYPOCHLORITE (NAOCL) DURING ENDODONTIC TREATMENT: A SYSTEMATIC REVIEW

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ABSTRACT

The most efficient root canal irrigation solution is NaOCl, a potent disinfectant with advantageous properties, including tissue solubility, proteolytic impacts on microorganisms, and bactericidal effects on bacterial endodontic biofilms. NaOCl is most frequently utilized as a root canal detergent in endodontic procedures at concentrations between 0.5 and 5.25%. A systematic literature review from 2000 to 2023 was performed using PubMed, Medline, and ScienceDirect databases. 10 studies were reviewed to determine the effects of different concentrations of sodium hypochlorite (NaOCl) on root canal disinfection and patient outcomes. The higher doses of NaOCl were more effective in lowering bacterial counts, but there were no significant changes in patient outcomes, such as healing rates or discomfort levels. NaOCl demonstrated effective antibacterial activity against various bacteria, including Enterococcus faecalis, Actinomyces naeslundii, Candida albicans, and Streptococcus aureus. It was found that applying NaOCl as an irrigant, combined with appropriate irrigation protocols and sufficient exchange of the solution, is crucial for achieving optimal antibacterial efficacy. Additional studies are warranted to investigate further the effects of NaOCl concentration and its interaction with other irrigants on the outcomes of root canal treatment.

Key words: Sodium hypochlorite, Endodontics, Microbiological effect, Systematic review.

Introduction

Endodontic therapy aims to eliminate germs from the root canal(s) and prevent microbial infection of the pulp and periapical tissues [1]. The primary method for removing canal germs is chemomechanical debridement of the root canal, which uses mechanical instruments and chemical cleaning solutions. Nevertheless, even after thorough mechanical and chemical cleaning, resistant bacterial strains might persist in the root canal, resulting in a root canal infection [2]. Planktonic bacteria in the root canal are readily responsive to antibacterial agents. Still, bacteria in biofilms attached to the canal wall or in more complex root canal areas, such as the end portions of dentinal tubules and lateral channels, are less accessible to certain treatments. There is a need for specific therapeutic techniques to get over these restrictions [3].

The most efficient root canal irrigation solution is NaOCl, a potent disinfectant with advantageous properties, including tissue solubility, proteolytic impacts on microorganisms, and bactericidal effects on bacterial endodontic biofilms. NaOCl is most frequently utilized as a root canal detergent in endodontic procedures at concentrations between 0.5 and 5.25% [4]. The structure of the E. faecalis biofilm calcifies with increased biofilm growth, making it more challenging to remove this mature and mineralized biofilm using traditional procedures and eventually increasing the risk of resistant root canal infections. The E. faecalis biofilm is known to show symptoms of mineralization and complete maturity after six weeks. As a result, the biofilm maturity index is determined by the development of the biofilm during six weeks. While most earlier research used young biofilms, most biofilms in root canals at the time of treatment are several weeks or months old. As a result, there are no exact correlations between laboratory study findings and clinical reality. Examine the various phases of biofilm to comprehend the connection between the organization and development of biofilm and its susceptibility to antimicrobial therapy [5].

The current study sought to determine the bactericidal effects of various NaOCl concentrations on biofilms on the results of root canal therapy.

This study used PubMed, Medline, and ScienceDirect to conduct a comprehensive literature search spanning 2000–2023. Search terms included "systematic review," ""sodium hypochlorite" "root canal treatment." To illustrate how we chose which papers to search, we used the PRISMA flowchart **(Figure 1)**.

Inclusion criteria

Case-control and randomized-control trials published in English between 2000 and 2023 were included.

Exclusion criteria
tabExpert opinion, narrative reviews, systematic reviews
research conducted outside the given time frame
studies conducted in languages other than English
studies conducted in vitro

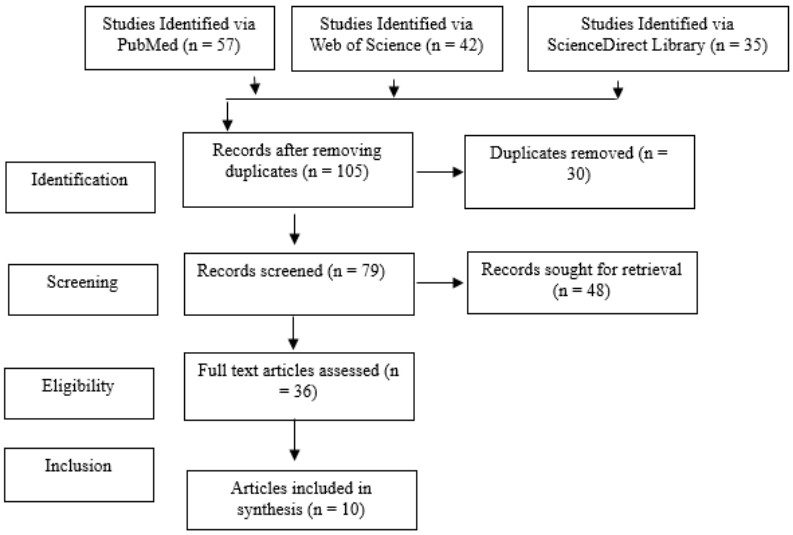

Figure 1. PRISMA Flow Diagram

Risk of bias assessment
Cochrane risk of bias assessment method was used to assess the quality of the studies included **(Table 1)**.

Table 1. Summary of Cochrane Risk of Bias Assessment

Study	Selection Bias/Appropriate control selection/baseline characteristics similarity	Selection bias in randomization	Selection bias in allocation concealment	Performance-related bias in blinding	Reporting bias/Selective reporting of outcomes	Detection bias Blinding outcome assessors	Accounting for confounding bias
Ulin *et al*., 2020	+	+	+	-	+	+	+
Radcliffe *et al*., 2004	-	+	+	+	-	+	+
Siqueira *et al*., 2000	+	+	-	+	+	+	+
Verma *et al*., 2019	+	+	+	+	+	+	+
Reyhani *et al*., 2017	+	+	+	+	+	+	-
Shakouie *et al*., 2014	+	-	+	+	+	+	+
Rôças *et al*., 2016	+	+	+	-	+	+	+
Zand (2016)	+	+	+	+	+	-	+
Torabinejad *et al*., 2003	+	-	+	+	+	+	+
Câmara *et al*., 2009	+	+	+	+	-	+	+

Results and Discussion

Table 2 shows that Ulin *et al*., 2020 [6] conducted a trial, where 298 individuals were enrolled and divided into two random groups: 0.5% NaOCl and 3% NaOCl. Included were all endodontic diagnoses..The percentage of NaOCl. variation had no appreciable effect on the number of positive cultures, and it had no bearing on the frequency or intensity of postoperative pain. Patients who received a higher concentration (3% NaOCl) experienced a considerably higher incidence of postoperative edema.

The research done by Radcliffe *et al*., 2004 [7] reported that for A. naeslundii and Candida albicans, all NaOCl doses reduced cfu below the detection limit within 10 seconds. NaOCl showed to be more effective against E. faecalis, though. Both studied strains had their cfu reduced to zero by 0.5% NaOCl after 30 minutes. This contrasts

with 1.0% for 10 minutes, 2.5% for 5 minutes, and 5.25% for 2 minutes (P 0.001).

The study represented by Siqueira *et al*., 2000 [8] assessed the in vitro intracanal bacterial decrease from irrigation with saline or sodium hypochlorite (NaOCl) solutions at 1%, 2.5%, and 5.25%. Before and after preparation, samples of canals were taken. Test solutions drastically decreased the amount of bacterial cells in the root canal (p 0.05). The three NaOCl solutions under test did not differ significantly from one another (p > 0.05). However, all NaOCl solutions considerably reduced the number of bacterial cells in the root canal more than the saline solution (p=0.05).

The study accomplished by Verma *et al*., 2019 [9] aimed to compare the effects of 2 different sodium hypochlorite concentrations on post-primary endodontic treatment recovery and discomfort.. Each patient was required to rate their pain level on a visual analog scale every 24 hours for a week. The teeth were permanently repaired during the second appointment after the canals had been obturated. For 12 months, clinical and radiographic examinations were conducted every three months. At the one-year follow-up, 86 teeth were available for review. The observed healing rate was 76.7% overall. The HC group (72.1%) showed more healing than the LC group (81.4%). Still, the difference was not statistically significant (P >.05).

The investigation presented by Reyhani *et al*., 2017 [10] assessed how different sodium hypochlorite (NaOCl) solution concentrations inhibited the establishment of Enterococcus faecalis biofilms in root canals. One hundred four patients' maxillary central incisor root canals underwent chemomechanical debridement. The root canals were filled with 5.25% sodium hypochlorite solution for 3 minutes to eliminate the smear layer. Due to the complete elimination of E. faecalis biofilms in groups 2 and 3, there was no bacterial growth (P 0.0001). In contrast, group 1 had lower bacterial counts at intervals of 4, 6, and 10 weeks compared to the control group. Compared to young biofilms, the bacteria in mature and elderly biofilms are more resistant to 1% NaOCl solution. However, the growth of the E. faecalis biofilm was completely inhibited by the 2.5% and 5.25% NaOCl solutions at every stage of development.

The objective of the experimental work done by Shakouie *et al*., 2014 [11] was to evaluate the antibacterial activity of sodium hypochlorite (NaOCl) at concentrations of 0.5, 1, 2.5, and 5% with that of Triphala, a plant-derived solution, against Enterococcus faecalis (E. faecalis) [12]. The mean diameter of the inhibition zones in the Triphala group was considerably larger than those in the 0.5 and 1% NaOCl groups, according to the Mann-Whitney U test (P 0.05). Triphala showed superior antibacterial efficacy in this investigation compared to 0.5 and 1% NaOCl against E. faecalis (P=0.05).

A randomized clinical experiment was done by [13] Rôças *et al*., 2016, who examined fifty single-rooted teeth with apical periodontitis had their root canals cleaned with BioRaCe rotary equipment and 2.5% NaOCl (n = 25) irrigation. There were microbes in every S1 sample, which is a favorable result. In 44% and 40% of the root canals after chemomechanical preparation with 2.5% NaOCl, bacterial traces were still visible. Regarding total bacterial counts, the NaOCl group's S1 samples had an average of 3.7 105 bacterial cell equivalents, while S2 samples had a significantly lower average of 5.49 102 cell equivalents (P<.001).

The in vitro study conducted by Zand (2016) [14] used sixty removed single-rooted teeth from patients had their root canals contaminated with E. faecalis and cultured for six weeks. Compared to 2.5% NaOCl gel, the results of 2.5% and 5.25% NaOCl solutions were significantly better (P 0.05).

This study performed by [15] Torabinejad *et al*. 2003 revealed that when modest concentrations of NaOCl are utilized as an intracanal irrigant before using MTAD as a final rinse, the ability of MTAD to entirely remove the smear layer is improved. The dentinal tubules' structural makeup appears unaffected remarkably by this regimen.

Câmara *et al*., 2009 [12] conducted a vitro study; the objective was to assess the antibacterial activity of sodium hypochlorite at concentrations of 0.5%, 1%, and 2.5% when used in root canals utilizing the ProTaper Universal system as the instrumentation. According to the irrigant used, the specimens were randomly divided into five groups with ten root canals each: group 1 received 0.5% NaOCl, group 2 received 1% NaOCl, group 3 received 2.5% NaOCl, group 4 received 0.85% sterile saline solution as a positive control, and group 5 received 0.85% clean saline solution as a negative control, free of microorganisms. Except for one sample in S1 at 0.5% NaOCl, which demonstrated positive development, all the tested irrigants were clean after experimenting with the S1 file. The studied irrigants showed no discernible statistical difference (P = 1.000).

Table 2. Summary of the findings from included studies

Author's name	Samples	Objectives	Concentrations of NaOCL	Results

Ulin *et al*., 2020 [6]	298	To determine whether irrigation with 3.0% NaOCl during root canal preparation will produce fewer postoperative samples with cultivable bacteria than irrigation with 0.5% buffered NaOCl.	0.5% NaOCl and 3% NaOCl	It was significant (p=0.0084) that the mean difference was 12.7.
Radcliffe *et al*., 2004 [7]		To ascertain whether bacteria linked to refractory endodontic infections resist sodium hypochlorite when employed as a root canal irrigant	0.5, 1.0, 2.5, and 5.25%	Both studied strains had their cfu reduced to zero by 0.5% NaOCl after 30 minutes.
Siqueira *et al*., 2000 [8]		This study assessed the in vitro intracanal bacterial decrease from irrigation with saline or sodium hypochlorite (NaOCl) solutions at 1%, 2.5%, and 5.25%.	1%, 2.5%, and 5.25%.	The three NaOCl solutions under test did not differ significantly from one another (p > 0.05).
Verma *et al*., 2019 [9]	86	This study aimed to compare the effects of 2 different sodium hypochlorite concentrations on post-primary endodontic treatment recovery and discomfort	1% and 5%	The difference was not statistically significant (P >.05)
Reyhani *et al*., 2017 [10]	104	This study assessed how different sodium hypochlorite (NaOCl) solution concentrations inhibited the establishment of Enterococcus faecalis biofilms in root canals	5.25%	Due to the complete elimination of E. faecalis biofilms in groups 2 and 3, there was no bacterial growth (P =0.0001).
Shakouie *et al*., 2014 [11]	38	The objective of the current experimental work was to evaluate the antibacterial activity of sodium hypochlorite (NaOCl) at concentrations of 0.5, 1, 2.5, and 5%	0.5, 1, 2.5, and 5%	The mean diameter of the inhibition zones in the Triphala group was considerably larger than those in the 0.5 and 1% NaOCl groups.
Rôças *et al*., 2016 [13]	50	During the preparation of infected root canals with rotating nickel-titanium instruments, this randomized clinical trial examined the antibacterial effects of irrigation with either 2.5% sodium hypochlorite (NaOCl) or 2% chlorhexidine (CHX)	2.5% sodium hypochlorite	
Zand (2016) [14]	60	On an Enterococcus faecalis (E. faecalis) biofilm, this in vitro study examined the antibacterial effectiveness of 2.5% sodium hypochlorite gel and 2.5% and 5.25% sodium hypochlorite.	2.5% and 5.25% NaOCl	There was no discernible difference between the 2.5% and 5.25% NaOCl solutions (P>0.05)
Torabinejad *et al*., 2003 [15]	80	This study aimed to examine the effects of different sodium hypochlorite (NaOCl) concentrations used as an intracanal irrigant before applying MTAD.	5.25% NaOCl	The dentinal tubules' structural makeup appears unaffected remarkably by this regimen.
Câmara *et al*., 2009 [12]	50	This in vitro study's objective was to assess the antibacterial activity of sodium hypochlorite at concentrations of 0.5%, 1%, and 2.5% when used in root canals	0.5%, 1%, and 2.5%	The studied irrigants showed no discernible statistical difference (P = 1.000).

This investigation showed that the difference in NaOCl content (0.5% versus 3%) did not significantly affect the number of positive cultures or the frequency or intensity of postoperative discomfort [16]. However, those with a higher concentration (3% NaOCl) had a considerably higher incidence of postoperative edema [17]. Consecutively recruited patients were those who took part in the study. However, most individuals assessed during the enrollment period were found to be ineligible, frequently due to "clinical discomfort" [18]. One of the elements that could negatively impact the results' internal and external validity is the large number of patients who choose not to participate. The current study design exists somewhere between efficacy and effectiveness studies.

Ten dentists, with clinical experience ranging from 2 to 35 years, contributed to the study—3 experts and seven post-graduate students—can be considered as a strength. However, the data compared specialists and post-graduate students indicated no discernible difference [19]. Odd or even days were chosen as a simple technique of randomization to finish the survey during daily activities without major hindrance. This method may raise the danger of selection- and performance bias [20].

According to the study's findings, using a 1% NaOCl solution, the bacterial count in biofilms older than ten weeks is higher than in biofilms older than six weeks and older than four weeks in both cases. These findings

demonstrate that removing bacteria from their structured, calcified, and highly coherent structure is more challenging as incubation duration and mature biofilm formation increase [21]. Previous investigations have shown that E. faecalis biofilms are significantly bactericidal when treated with NaOCl. NaOCl works against E. faecalis biofilms at all concentrations, but at different exposure durations, it has the most powerful antibacterial impact. According to research by Gomez *et al*., 2.5% NaOCl can eradicate all germs within 10 minutes. Our research shows that 2.5% and 5.25% NaOCl can eradicate mature and old E. faecalis biofilms at all time points; however, 1% NaOCl only partially reduces bacterial count compared to PBS [22].

A perfect intracanal irrigating solution would have the most potent antibacterial and tissue-elimination properties and the fewest harmful side effects [23]. NaOCl has a vigorous antibacterial activity against E. faecalis but relies on exposure time and concentration. In this work, we contrasted the gel form of NaOCl with its solutions since the gel form of NaOCl had fewer chances of extrusion through the apex. Through the use of #4 Gates-Glidden drills and #35 K-files for canal instrumentation and coronal flaring, it allowed for more excellent gel and irrigating solution penetration into the root canals. Therefore, it would not be assumed that there was no antibacterial action if the solutions did not penetrate the apical thirds of the channels [24].

Given the benefits of using natural remedies and the drawbacks of NaOCl, the results of this study demonstrated that Triphala has higher antibacterial activity than 0.5 and 1% NaOCl and can be utilized as an acceptable irrigation solution in endodontics. More research is required on this assertion. The use of E. faecalis biofilms in this study, which are more resistant to antibacterial treatments than planktonic bacteria, is another distinction between it and earlier investigations [25]. This investigation's findings showed no discernible difference between the antibacterial effects of NaOCl irrigation solutions at concentrations of 2.5% and 5.25% on E. faecalis [26]. In contrast to our research, earlier studies indicated that the most effective solution was 5.25%, followed by 2.5%. Additionally, a study revealed that irrigation with 2.5% NaOCl left around 40% of the canal surfaces polluted, indicating that this concentration is ineffective for eliminating E. faecalis [27]. The inconsistent findings of previous research regarding the antibacterial effectiveness of various concentrations of NaOCl examined in this study may be due to methodological variations, microbiological traits in the biofilm, exposure duration, and concentration of the tested chemical [26, 27].

It is essential to consider the complex root canal anatomy, the polymicrobial nature of root canal infections, and the presence of biofilms when evaluating the therapeutic efficacy of NaOCl [28]. In other places, biofilms are known to influence and restrict solute diffusion [29]. The presence of the smear layer, which may prevent an irrigant from entering dentinal tubules, is another aspect to consider. Furthermore, the interaction of NaOCl with blood, dentine, tissue fluids, and other organic material can lessen its efficiency. NaOCl stays in the root canal for just a short time during chemomechanical preparation, with the potential to reach the tubules. As found in the current experiment, it is reasonable to assume that the concentration and contact time of NaOCl within the root canal will affect its antibacterial activity. In other words, an efficient irrigating solution in the dental root canal in vitro against a specific bacteria may be less effective in real life [30].

Finally, it's important to remember that NaOCl's endodontic uses are not solely based on its antibacterial properties. Root canal irrigants also need to have strong detergent power, low surface tension, simplicity of handling, and high proteolytic and tissue solution ability, among other qualities. Since NaOCl is unstable and decomposes into oxygen and sodium chloride, both of which are present in the body naturally, it does not leave any harmful residues behind when used as an irrigant.

Conclusion

In conclusion, the various studies reviewed provide valuable insights into using sodium hypochlorite (NaOCl) as an irrigant in root canal treatment. Overall, the concentration of NaOCl (ranging from 0.5% to 5.25%) did not significantly affect the number of positive bacterial cultures or the frequency and intensity of postoperative pain. However, greater amounts of NaOCl (3% and 5.25%) were related to a higher prevalence of postoperative edema. NaOCl displayed effective antibacterial action against several bacteria, including Enterococcus faecalis, Actinomyces naeslundii, Candida albicans, and Streptococcus aureus. It was found that applying NaOCl as an irrigant, combined with appropriate irrigation protocols and sufficient exchange of the solution, is crucial for achieving optimal antibacterial efficacy. Additional studies are warranted to investigate further the effects of NaOCl concentration and its interaction with other irrigants on the outcomes of root canal treatment.

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