Review Article

Exploring the Efficacy of Hypochlorous Acid as a Cost Effective Environmental Decontaminant in Dentistry: A Scoping Review

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Abstract

Dental procedures result in the production of bioaerosols that contaminate various environmental surfaces in the dental clinic. In order to maintain a safe environment in the dental clinic and prevent cross contamination, it is important to find alternative disinfection methods and agents to ensure effective decontamination. Hypochlorous acid (HOCl) is a cost-effective antimicrobial agent that can be used for infection control. The purpose of this scoping review is to provide evidence from the literature supporting the routine use of HOCl as a biodecontamination and disinfection agent in dental clinics. An electronic search was completed on the following databases: PubMed, Web of Science, Scopus, Wiley, and Science Direct. The studies were included based on their titles, abstract, and relevance to HOCl and the ability to render pathogens deactivated after exposure to HOCl vapor. The search focused on studies in the past 5 years. The search resulted in a total of 15 articles being selected after exclusions based on duplications, title, and abstract assessment. The articles included studies that used various HOCl concentrations and expanded on the inactivation of several pathogens. The reviewed studies highlight HOCl's broad-spectrum antimicrobial efficacy, with significant reductions in severe acute respiratory syndrome coronavirus 2, methicillin-resistant *Staphylococcus aureus*, vancomycin-resistant Enterococcus, and *Clostridioides difficile*, reinforcing its role in optimizing disinfection protocols across healthcare and occupational settings. The articles selected provided clear evidence that under correct and established parameters, HOCl can provide a cheaper safer alternative to most disinfectants. Further studies are recommended on applications methods in clinical settings.

Keywords: *Biodecontamination, dental bioaerosols, disinfection, hypochlorous acid, infection control, sustainable*

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Introduction

Pathogens associated with dentistry are present in various sites in the oral cavity such as the teeth, mucosal membranes, and saliva and are transferred from one host to another via aerosol dissemination.[1] The major source of pathogenic load in the dental scenario originates from the sequential accumulation of bacteria, resulting in oral biofilm (plaque) formation.[2]

There are varying levels of aerosol production that are specific to dental treatments. These aerosols are generated during routine dental procedures by the use of rotary instruments, ultrasonic scalers, and water from contaminated units.[3] Consequently, bioaerosol, which is the end product of when the coolant of the handpiece, bur, and tooth cavity structure makes contact, is one of the major contributors of infection transmission between patients and the dental team members.[4]

Bioaerosols can range in size, with large droplets greater than 50 µm to fine particles less than 5 µm and

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intermediate particles between 5 and 50 μm droplets. Depending on the size of the particle, they can either remain suspended in the air for a time period or settle on surfaces rapidly.[5] The bioaerosols can contain microorganisms such as bacteria, viruses, and fungi. These pathogens can be transmitted directly and indirectly with infected particles, and this characteristic necessitates effective infection control measures in order to reduce the risk of nosocomial Infections. Examples of bacterial pathogens that are present in the oral cavity include: Streptococcus mutans, linked to dental caries and plaque formation; Streptococcus pyogenes, which causes throat infections and other complications; *Staphylococcus aureus*, known for skin infections and resistant strains (MRSA); Pseudomonas aeruginosa, an opportunistic pathogen resistant to many antibiotics; and Mycobacterium tuberculosis, which can be transmitted through aerosols and poses a risk of respiratory infections, which causes respiratory infections and is linked to dental unit water lines (DUWLs).[1]

Recently, the Coronavirus Disease 2019 (COVID-19) pandemic highlighted the transmission risk of severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) in dental clinics. The virus can be present in saliva and respiratory droplets, leading to its dissemination through aerosols generated during dental procedures.[4] The Hepatitis B Virus (HBV), Hepatitis C Virus (HCV), and Human Immunodeficiency Virus (HIV) can be transmitted through exposure to infected blood or saliva, posing occupational risks to dental professionals if proper infection control practices are not followed.[6]

Fungi found in various environments include Aspergillus spp., associated with respiratory issues; Penicillium spp., known for causing respiratory problems and allergies; Cladosporium spp., a common allergen linked to asthma; and Alternaria spp., another prevalent allergen found in damp settings. A common fungus associated with saliva contamination is Candida albicans. It is found in the oral cavity and can cause oral thrush and other infections, particularly in immunocompromised patients. It can be transmitted through aerosols and direct contact with contaminated surfaces.[7] The dispersion of bioaerosols within the dental clinic increases the risk of surface contamination with the aforementioned microorganisms.

Surface contamination within dental clinics is a significant concern due to the persistence of pathogens on various surfaces. Studies have shown that pathogens can survive on surfaces for extended periods, contributing to the risk of cross-contamination.[1] The Influenza virus can remain viable on surfaces for up to 48 hours,[8] while M. tuberculosis bacteria can persist for up to 4 months.[9] SARS-CoV-2 has been reported to remain infectious on surfaces for several days.[10] Van Doremalen *et al*.(2020)[11] found that SARS-CoV-2 can survive on various surfaces such as plastic and stainless steel for up to 72 hours, highlighting the prolonged stability of the virus in certain environmental conditions. Atmospheric factors like temperature and relative humidity can also influence the survival of aerosolized viruses, with lower humidity levels potentially prolonging viral viability.[6] Biofilms, protective matrices formed by pathogens, further complicate disinfection efforts and increase the risk of contamination.[10] The presence of antibiotic-resistant pathogens, including MRSA, underscores the need for robust infection prevention and control measures in healthcare settings.[11]

There are various methods to mitigate surface contamination and cross-infection. The use of personal protective equipment and methods of inhibiting cross-infection forms part of the daily activities in a dental clinic. The dental team which includes the dentist and auxiliary and cleaning staff are familiar with the methods of disinfection to limit the risk of cross-infection.[4]

There are several ways to mitigate the spread of infection in the dental clinic. These include:

- Minimizing the number of instruments and nonclinical items exposed in the area where treatment is being rendered.
- Avoid transferring of patient records from the treatment area to the administration area immediately after treatment is completed.
- Preprocedural mouth rinses have proven that it can aid in the reduction of the microbial content of the saliva. Antimicrobial mouth rinses like chlorhexidine, although widely used in dentistry, may not be effective against SARS-CoV-2; however, mouth rinses containing 0.5% hydrogen peroxide or 1% povidone-iodine are recommended.[3]
- Dental prosthesis and impressions should be disinfected before sending it to the laboratory to prevent exposure of the dental technician.
- Designing of the clinical area is essential in facilitating correct air flow. High-efficiency particulate air filters (HEPAs) in the ventilation system can aid in reducing aerosol contamination. It would be ideal if these filters are installed directly above the dental chair. This would help prevent air traveling from the treatment room to the waiting and administration area.
- Reinforcing the hand hygiene with all the members of the dental team.[12] Surface indirect transmission by touching infected surfaces has been proven to be the major contributor to the transmission of airborne disease. It is highly recommended that hands are

washed after the disposal of gloves due to the possible permeability of latex.
- High-risk exposed surface areas need to be cleaned frequently with a suitable disinfectant.[2-5,13]

Disinfection can be in the form of an effective surface sanitizer, or air disinfection is a major preventive measure to mitigate transmission of pathogens.

Disinfectants should be classified as safe for exposure times on personnel, equipment, and surfaces.[2] An ideal disinfectant exhibits low contact time with significant antiviral activity and a high kill rate of potential pathogens, while remaining safe for humans and showing low toxicity to the environment.[14] There are various physical and chemical methods to inactivate and eliminate the pathogens that are able to survive on any exposed surfaces in the clinical area.[13] Chemical disinfection used in conjunction with the spray and wipe method is classified into three categories: high-level, intermediate, and low-level disinfectants.[14] The classification is based on the efficacy against viruses and bacterial and fungal spores. According to the World Health Organization (WHO), hypochlorous acid (HOCl) is classified as a high-level disinfectant.[15]

The challenge lies in the need for alternate disinfectants and disinfection techniques. Biodecontamination or disinfection has always been an area of great emphasis. However, since the coronavirus pandemic (COVID-19), it has rapidly developed and evolved as a critical area of interest to ensure a safe dental environment.[16] There is recognition that current disinfectant techniques and agents may not always be effective, necessitating proactive measures to address evolving challenges.

HOCl has gained popularity after the COVID-19 pandemic as a potent and environmentally safe disinfectant with a wide range of efficacy against several human pathogens, even though it has been used in the medical field for more than a century.[17,18] Currently, HOCl is being used as an effective disinfectant in various sectors including water treatment facilities, food sanitation, farming, hospitality industry, and healthcare applications including hard surface disinfection and chronic wound care.[14]

In addition, it has been proven to have wide antimicrobial disinfectant properties that greatly reduce and inactivate bacteria, fungi, microorganisms, and viral loads on various surfaces.[19] In the medical field, HOCl offers an unequalled combination of antimicrobial efficacy and an enhanced rate of healing by inactivating the common bacteria and yeasts/fungi that infect wounds.[20]

HOCl is a weak acid from the chlorine family stabilized at the slightly acidic pH range of 3.5–5.5 that is formed when chlorine (gas) dissolves in water and is often referred to as electrolyzed water, activated water, super oxidized water, and enhanced water.[20] Certain studies have shown it is 80 to 120 times more successful in eradicating microorganisms than sodium hypochlorite.[21] This phenomenon can be explained by the fact that HOCl has no charge and low molecular weight and therefore is able to penetrate cell walls. Due to these characteristics, it reacts more rapidly with organic matter, resulting in oxidation reactions. The mechanism in which HOCl inactivates bacteria or viruses involves chemically linking chlorine atoms to nucleotide bases that disrupt the function of bacterial DNA/RNA by interacting with structural proteins impeding metabolic pathways in which cells use enzymes to oxidize nutrients and membrane-associated activities.[2,8]

In recent years, compelling evidence of the potency of pure, stable preparations of HOCl in the inactivation of the most resistant infectious agents has emerged, both of which are completely unaffected by some renowned disinfectants.[13] Applications of aqueous solutions containing approximately 30–2500 ppm HOCl have been proven to be effective in a variety of areas including dental care by acting as an antimicrobial as well as virucidal agent. Post the COVID-19 pandemic, it was recommended to use of HOCl as a mouthwash and hand sanitizer (at 100–200 ppm) as well as a surface disinfectant.[8,18-20]

HOCl with a concentration as low as 20 ppm was found to be effective as a disinfectant for soiled surfaces. When diluted 10-fold, HOCl solutions at 20 ppm were still effective in decontaminating environmental surfaces carrying viruses in a 10-minute contact time. Aerosolized or sprayed HOCl is effective in eliminating microstrains such as Staphylococcus epidermidis after an exposure of 1 min to 20 mg/L (equivalent to 20 ppm), while other studies have found that the concentration of HOCl to be effective at 200 ppm in decontaminating inert surfaces carrying noroviruses and other enteric viruses in a 1-minute contact time.[8,14,17-20]

HOCl formulation in a non-salt solution (also acceptable for disinfection, antisepsis, and wound care):
1. 150 parts per million or greater of HOCl.
2. pH less than 5.5, and greater than 99% pure HOCl.
3. An oxidation–reduction potential (ORP) greater than 1000 mV.
4. Salt-free water-based solution (rather than 0.9% saline) as an option for environmental use.[8,17,18]

The stability of HOCl is maintained by sustaining an optimal pH range of 3.5–5.5. HOCL can be generated by one of three methods: hydrolysis of chlorine gas, electrolysis of salt water, and acidification of hypochlorite. HOCl also has a shorter kill time than sodium hypochlorite (NaOCl) and hydrogen peroxide (H_2O_2), which is usually used in disinfection protocols.[13,16,21]

One of the greatest disadvantages of the latter mentioned disinfectants is their toxicity and corrosive characteristics, which is why hypochlorous acid appears to be the better choice.[14,21] Spray or fog application with an aerosol size of less than 20 μm is recommended due to the fact that smaller particles in spray form may help HOCl molecules to be suspended in the air for a longer duration. This low settling velocity rate may increase the solution's chance of coming into contact with pathogens and inactivating them.[20]

Procurement of HOCl has become relatively easier and can be either purchased commercially or generated in the dental clinic. Advancement in the manufacturing of HOCl now enables the production of stable, reliable, and pure HOCl in industrial quantities, thus allowing for uninterrupted supply of low-cost effective disinfectants, especially in third-world countries. The literature has provided evidence that HOCl is a nontoxic, safe, inexpensive disinfectant with the flexibility of applying methods (spray mist, fog, liquid).[5,13] This makes it ideal for use in hospitals and healthcare clinics, and like most disinfectants, its viricidal/bactericidal efficacy has also been studied when used in aerosolized/sprayed form using handheld vaporising devices on porous as well as nonporous surfaces.[8,14,17,18]

For third-world countries, one of the advantages of HOCl is that it is a reasonably priced highly effective chemical against pathogens, which allows for safe application with no risks to patients or staff. This is an added incentive to procure HOCl, especially after the COVID-19 pandemic as health care professionals have a heightened awareness of infectious diseases.[5,13,14,17]

In order to assure the public that the necessary measures have been taken to provide patients with a safe and low infection risk space, regular decontamination of surfaces and air has become imperative. This trend is unlikely to change especially with the heightened awareness of infectious disease and wider recognition of the need for infection risk reduction in healthcare facilities. Many disinfectant formulations that are currently being used in the arsenal of biodecontaminants involve less stringent applications. These disinfectants have been proven inappropriate for the more demanding, high-frequency applications in the clinical arena. Pathogens are known to adapt in order to survive, and bearing this in mind, HOCl deserves a place in every public health hospital or clinical space as a fundamental instrument of infectious disease control with minimal impact on the environment while still being highly effective.

Methodology

The comprehensive framework developed by Arksey and O'Malley (2005)[24] was used in this scoping review, following its six-stage process: (1) defining the research question to assess the evidence supporting HOCl as a routine biodecontaminant in dental clinics; (2) identifying relevant studies through systematic database searches; (3) selecting studies based on predefined inclusion and exclusion criteria to ensure relevance and methodological quality; (4) charting the data through systematic extraction, categorization, and synthesis of key findings; (5) collating, summarizing, and analyzing results to identify themes such as efficacy, safety, and application methods; and (6) involving stakeholders—including dental professionals, infection control experts, and researchers—to validate findings and assess the practical implications for clinical settings.

Additionally, to ensure methodological rigor and transparency, we adhered to the PRISMA Extension for Scoping Reviews (PRISMA-ScR) checklist. This involved structuring the review according to PRISMA-ScR guidelines, documenting search strategies, study selection processes, and data extraction methods in a systematic and replicable manner. The checklist also guided the reporting of results, ensuring clarity and comprehensiveness in presenting the scope and limitations of the available literature.

A study protocol was developed to guide researchers for this scoping review; however, it was not published. To enhance transparency, the unpublished study protocol is available upon request. To minimize potential selection bias during article selection, a rigorous multistep screening process was employed. Two independent reviewers (RA and SA) conducted the initial title and abstract screening, followed by a full-text review based on predefined inclusion and exclusion criteria. Any discrepancies were resolved through discussion or consultation to ensure objectivity. Additionally, manual data extraction was standardized using a predefined data charting form, reducing variability and enhancing consistency in data collection. This systematic approach helped mitigate selection bias and ensured a comprehensive and balanced synthesis of the available literature.

The titles were primarily screened to identify whether the criteria were met and to eliminate duplicates. Data extraction was completed manually after the researchers' excluded studies in which the abstract did not align with the focus question. The full texts of selected studies during primary screening were reviewed for the final study selection. This process was aided by a data extraction form created to assist in selecting the appropriate articles and allow for independent searches. Any conflict was resolved by sharing opinions and consultation with the other author, if necessary.

Aim and objective of the study

The purpose of this scoping review was to identify the research available in the literature and provide an overview of studies that focus on the use of hypochlorous acid in a dental clinic against pathogens associated with dental treatments and the effects thereof.

Objectives

1. To assess the literature available on the efficacy of HOCl in dental clinics for biodecontamination against pathogens associated with dental treatments.
2. To determine the most effective concentrations of HOCl for different applications in dental clinics by reviewing studies that evaluate its antimicrobial efficacy and safety for both patients and healthcare workers.
3. To investigate strategies for integrating HOCl into infection control protocols in dental clinics.

Research questions

1. How effective is HOCl in deactivating pathogens commonly found in dental settings, and what concentrations have been studied to assess its efficacy?
2. What concentrations of HOCl have been tested for antimicrobial efficacy in dental clinic environments, and how do they compare in terms of effectiveness?

PICO statement

Population: Dental clinics or dental settings

Intervention: Use of hypochlorous acid (HOCl) for biodecontamination

Comparison: Different concentrations of HOCl (e.g., low versus high ppm) or methods of application (e.g., fogging versus spraying)

Outcome: Efficacy against pathogens associated with dental treatments, measured by parameters such as reduction percentage in pathogen load, duration of effect, or pathogen deactivation time.

Search Strategy

The key themes for the scoping review include:

1. Efficacy against Pathogens: HOCl demonstrates effectiveness against various pathogens.
2. Safety and Compatibility: HOCl is generally safe for use in with minimal cytotoxicity and compatibility with various materials.
3. Application Methods: Various methods of applying HOCl in several industries have been explored, such as fogging and spraying, each with different effectiveness for airborne and surface disinfection.
4. Integration into Infection Control Protocols: There is interest in integrating HOCl into existing infection control protocols to enhance efficacy and reduce cross-contamination risks.
5. Challenges and Considerations: Challenges include maintaining consistent HOCl concentrations, optimizing application methods, and considering environmental impact.

Data extraction

An electronic search was completed on the following databases and scientific working groups for relevant publications: PubMed, Web of Science, Scopus, Wiley, and Science Direct and WHO and The South African Dental Association (SADA). The following terms were used in a combination of key Medical Subjects Heading (MeSH) terms and Boolean operators published between January 2018 and April 2024: ("Hypochlorous acid" OR "HOCl") AND (Dentistry OR "Dental clinic" OR "Dental surgery") AND (Decontamination OR Disinfection) AND (Surface OR Environmental).

This search strategy was used to comprehensively identify relevant literature for the scoping review on the efficacy of HOCl in dental clinics, specifically focusing on its role in surface and environmental decontamination practices.

Specific terms related to dentistry such as "Dental clinic" and "Dental surgery" were included to target literature specifically applicable to dental practices. Additionally, terms related to decontamination and disinfection were used to filter studies that explored these aspects of hypochlorous acid application. The inclusion of terms like "Surface" and "Environmental" further refined the search to encompass studies that addressed surface decontamination and environmental disinfection in dental settings.

Inclusion criteria

Studies published in the date range of January 2018 to April 2024 published in English that investigated the efficacy of hypochlorous acid as a disinfection agent that assists in biodecontamination in the dental environment or applicable in dental environments were considered for inclusion. Original research articles, articles published in peer-reviewed, scientific journals, and research conducted in dental-care or *in vitro* settings that measured or determined levels of biodecontamination were included.

Exclusion criteria

Articles such as editorials, commentaries, non-peer-reviewed articles, book chapters, conference papers, and surveillance reports were excluded. Studies in which the hypochlorous acid was used in scenarios not relatable to the dental environment were ignored.

Framework for reporting findings

Data extraction was conducted systematically to capture key parameters from relevant studies on hypochlorous acid (HOCL) and its applications in infection control and disinfection practices. The following fields were extracted and compiled using Excel, with Mendeley utilized for referencing and managing duplicates:

1. Study ID: Identified by author(s) and year of publication.
2. Author and Country: Origin of the study.
3. Aim and Objective: The primary goal of each study, focusing on infection control or disinfection efficacy.
4. Pathogen Reported On: Specific pathogens studied, including SARS-CoV-2, E. faecalis, and common oral pathogens.
5. Statistical Analysis/Study Design: Methods used for data analysis or study design employed, such as literature reviews, experimental designs, or comparative tests.
6. HOCL Concentration: Concentration of HOCL used in experiments or applications.
7. Methods of Testing: Techniques and procedures used to apply HOCL and evaluate its efficacy, including fogging, surface treatment, or aerosolized forms.
8. Outcomes and Clinical Significance: Results obtained from each study, highlighting findings related to pathogen reduction, disinfection efficacy, or implications for infection control practices.

The data extraction process ensured that only relevant studies within the specified criteria were included. This systematic approach facilitated the synthesis of comprehensive data essential for analyzing the effectiveness of HOCL across various applications in healthcare and other settings.

Results

Figure 1 illustrates that a total of 117 articles were retrieved, of which five were duplicates and 105 were unrelated to the focus question of the current scoping review. After reading the abstract, the full text of studies was assessed for eligibility. The final total of 8 met the inclusion criteria.

Benefits of HOCl as a versatile and safe disinfectant in healthcare and institutional settings

HOCl shows efficacy against a broad spectrum of pathogens and is considered safe for human use in aerosolized form. HOCl has the potential in reducing COVID-19 transmission through aerosolized misting in smart sanitizing chambers. HOCl solutions are cost-effective, stable over extended periods with proper pH and process controls, and environmentally friendly as they degrade quickly into harmless components.[15,27] HOCl's stability is maintained when stored in a cool, dark place, with the pH carefully regulated between 4.0 and 6.0. It is crucial to monitor temperature, exposure to light, and container integrity to prevent degradation as these factors can impact its antimicrobial efficacy.[25] Importantly, HOCl does not promote antibiotic resistance in pathogens. Its antimicrobial action is based on oxidative stress, which damages the cellular structures of pathogens (proteins, lipids, DNA). Unlike traditional antibiotics that target specific bacterial functions, such as protein synthesis or cell wall formation, HOCl's broad-spectrum oxidative mechanism makes it less likely to contribute to resistance development affirming its potential as a versatile disinfectant in healthcare and institutional settings.[13,29]

Global distribution of studies on disinfection practices: A countrywise overview

The studies took place in various countries, with the United States hosting the most studies (six in total), followed by Italy with two studies. Individual studies were conducted in Peru, Saudi Arabia, Spain, Taiwan, Canada, and Australia, each with one study.

The variation in the number of studies per country may reflect differences in research funding, institutional priorities, or healthcare systems. Countries with greater emphasis on public health research and infection control (such as the United States) may naturally conduct more studies, while others with fewer resources or different healthcare priorities may produce fewer studies. Additionally, cultural factors and local health challenges could influence the focus on disinfection practices in specific regions.

Advancements in disinfection strategies to mitigate pathogen transmission in healthcare and occupational settings

The studies reviewed aim to enhance disinfection protocols and mitigate transmission risks of SARS-CoV-2 and other pathogens in various settings. They explore diverse disinfection strategies and pathogen targets, with a focus on:

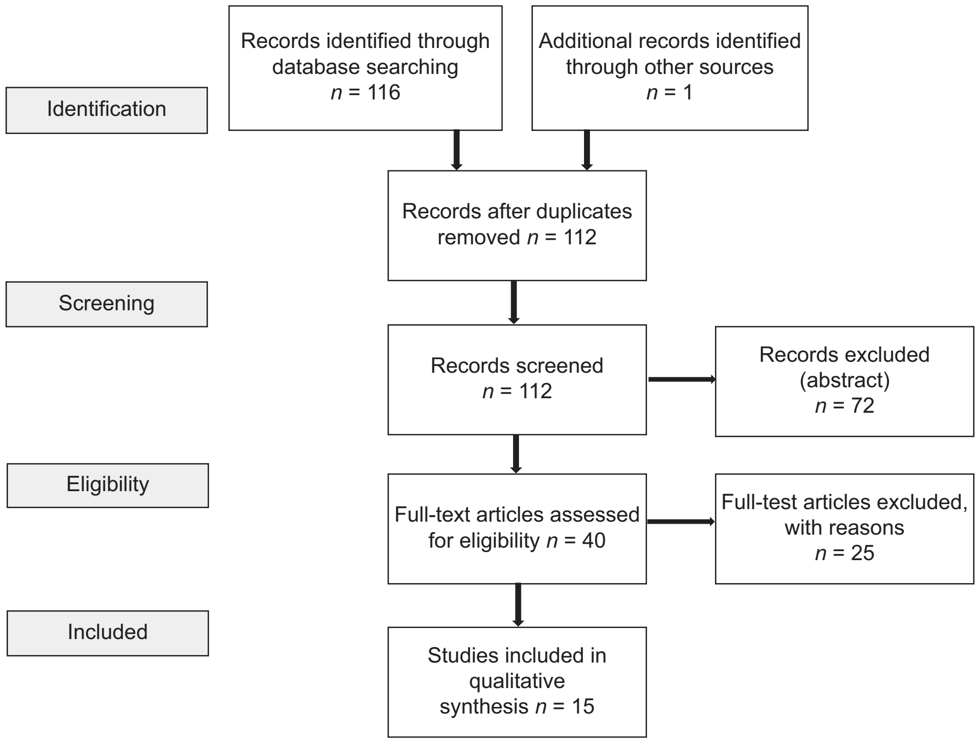

Figure 1: Flowchart illustrating the selection of studies

The following findings were summarized from Table 1:

Biosafety and disinfection methods in dental care

Siles-Garcia *et al*. (2021)[30] describe biosafety protocols in dental care to prevent transmission during routine procedures. Scarano *et al*. (2020)[24] review no-touch disinfection methods, which are designed to limit human contact and reduce infection risk in dental clinics. No-touch disinfection methods offer significant advantages over traditional manual cleaning in dental settings. These automated systems reduce human error, ensure consistent application, and effectively reach difficult-to-clean surfaces, minimizing cross-contamination risks. While traditional methods remain essential for removing organic debris, no-touch systems enhance biosafety by offering thorough, standardized disinfection in high-risk environments like dental clinics.

Hypochlorous acid as a disinfectant

Several studies investigate the efficacy of HOCl in various applications, such as fogging for pathogen survival,[22] floor sanitation,[23] and its virucidal activity.[17] Other research evaluates HOCl's impact on oral pathogens[4] and its role in decontaminating N95 masks.[28] Tsai *et al*. (2024)[13] compare the cytotoxicity of HOCl with other antiseptics, providing valuable insights into its safety profile. Farah *et al*. (2021)[25] examine the production and use of electrolyzed water, a potential alternative to traditional disinfectants in healthcare settings.

Research also explores the risks associated with HOCl emissions during cleaning, particularly the exposure concerns for healthcare workers. HOCl fogging can release aerosols that, if not properly managed, may pose inhalation risks in poorly ventilated areas.[28] Gessi *et al*. (2023)[23] emphasize the importance of proper ventilation during HOCl-based sanitation to minimize exposure. Tsai *et al*. (2024)[13] further highlight the need for protocols to assess and control exposure levels. To mitigate these risks, protocols such as using personal protective equipment (PPE) and monitoring air concentration levels are essential for ensuring safe usage.[25]

Comprehensive approaches to pathogen control: Insights from diverse settings and targeted research areas

The pathogens addressed in the studies vary widely, reflecting diverse research focuses across different settings. Studies on SARS-CoV-2 primarily aim to mitigate its transmission, with some exploring broader disinfection strategies against MRSA, VRE, and *C. difficile* in hospital environments.[22,28] The emphasis on these pathogens in hospitals is due to their association with hospital-acquired infections. MRSA and VRE are resistant to multiple antibiotics, posing significant risks to patients with weakened immune systems. SARS-CoV-2 is a high-priority target for decontamination efforts in hospitals due to its rapid spread through droplets, aerosols, and contaminated surfaces.

Table 1: Characteristics of studies included in scoping review

Study	Author and Country	Aim and Objective	Pathogen Reported On	Statistical Analysis/Study Design	HOCL Concentration	Methods of Testing	Outcomes and Clinical Significance	Particles and ppm Relationship to Dispensing Method
1	Siles-Garcia *et al*. 2020[33] Peru	To describe biosafety protocols for dental care after the emergence of COVID-19, focusing on patient protection and reducing the risk of cross-infection in dental settings.	SARS-CoV-2	No specific statistical analysis or study design mentioned	No specific HOCl concentration mentioned	Describes protocols for screening patients, PPE use, environmental disinfection, aerosol control, and hand hygiene	Highlights measures to ensure safety in dental settings, including use of masks, screening, disinfection, and aerosol control to reduce cross-infection risks during COVID-19	There is no specific mention of ppm (parts per million) related to HOCl or other disinfectants in the text.
2	WHO – cleaning and disinfection of environmental surfaces in the context of COVID-19[15]	To provide guidance on cleaning and disinfection of environmental surfaces to reduce the potential role of fomites in SARS-CoV-2 transmission.	SARS-CoV-2	No specific statistical analysis or study design; guidance document providing comprehensive recommendations based on various studies and reports	0.1% (1000 ppm) for general disinfection; 0.5% (5000 ppm) for large blood or body fluid spills	Provides recommendations for proper cleaning and disinfection, including training for cleaning staff, cleaning and disinfection techniques, and personal safety during preparation and use of disinfectants	Emphasizes cleaning and disinfection to minimize the risk of SARS-CoV-2 transmission and promotes proper practices to ensure safety in healthcare and non-health-care settings	The guidance advises against spraying disinfectants (spraying, fogging, or misting) due to potential health risks and limited efficacy in removing contaminants. Instead, it recommends applying disinfectants with a cloth or wipe soaked in the disinfectant.
3	Feng *et al*. 2022[25] USA	To assess the effectiveness of hypochlorous acid (HOCl) fogging in controlling the survival of E. faecalis on different surfaces, focusing on horizontal and vertical surfaces and the optimal mode of fogging.	E. faecalis	Study design included preparing bacterial cultures, applying them to surfaces, and assessing log reductions in bacterial counts to evaluate the efficacy of HOCl fogging	290 ppm to 512 ppm (EcoLogic Solutions eFFectant), 240 ppm (EcoloxTech Eco One), 750 ppm (RIPPO)	Ultrasonic fogging to create HOCl mist, continuous and pulsed modes for fogging, measuring log reductions in bacterial counts after fogging	Found that HOCl fogging was effective in reducing E. faecalis, achieving significant log reductions in bacterial counts. Horizontal surfaces were easier to disinfect, while vertical surfaces required longer fogging times.	Ultrasonic fogging produced micron-sized particles, allowing for a high surface-to-volume ratio, which contributed to the release of chlorine gas as the particles dried.

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Table 1: Contd...

Study	Author and Country	Aim and Objective	Pathogen Reported On	Statistical Analysis/Study Design	HOCL Concentration	Methods of Testing	Outcomes and Clinical Significance	Particles and ppm Relationship to Dispensing Method
4	Gessi *et al*. 2023[26] Italy	To evaluate the efficacy of electrolyzed HOCl for floor cleaning and sanitation, assessing its organic dirt and microbial removal, surface impact, and environmental effects.	General microbial and fungal contamination in floor cleaning	The study used comparative tests with Ecolabel detergent-based cleaning and water-only cleaning as controls. Statistical analysis was not specified.	10 ppm	Used a scrubbing machine integrated with HOCl production cells to clean and sanitize quartz-concrete and coated hardwood floors. Organic dirt removal, microbial charge reduction, and surface impact were assessed.	HOCl-based cleaning was effective in removing organic dirt and microbial contamination, with a lower environmental impact compared to detergent-based cleaning. No apparent damage to floor surfaces from HOCL treatment.	The electrochemical process uses tap water with a natural NaCl concentration, resulting in an HOCl concentration of approximately 10 ppm. The solution is applied to the floor through the scrubbing machine, which includes washing brushes and drying mechanisms.
5	Scarano *et al*. 2020[27] Italy	To evaluate scientific literature on no-touch disinfection procedures in dental clinics and understand how these methods can limit airborne and fomite-based transmission of SARS-CoV-2.	SARS-CoV-2, other pathogens found in hospital settings, MRSA, VRE, and C. difficile	Literature review analysing various no-touch disinfection procedures used in hospitals.	Ranges from 20 to 200 ppm	Discusses several no-touch disinfection techniques, including aerosolized hydrogen peroxide, hydrogen peroxide vapor, ultraviolet C light, pulsed xenon, and hypochlorous acid. Testing methods involved assessing the efficacy of these disinfection methods in reducing contamination.	The review concluded that no-touch disinfection methods, including aerosolized hydrogen peroxide and HOCl, are effective in reducing contamination in dental clinics.	HOCL is dispersed as a fine mist or dry fog through a turbine at high speed, with particle sizes typically between 20–50 µm.
6	Farah & Ali (2021)[28] Saudi Arabia	To describe the production of slightly acidic electrolyzed water (EW) from a diluted salt solution and vinegar in a dental office using a portable EW generator, evaluating its effectiveness as a	Major periodontal pathogens, Candida albicans (fungal biofilms), and SARS-CoV-2	No specific statistical analysis or study design; the report describes procedural methods for generating and testing the concentration of free available chlorine (FAC)	Target concentration for HOCl is 200 ppm	Chlorine test strips to measure FAC concentration and digital pH tester for pH range. FAC concentration is checked with test strips to confirm disinfectant potency.	Outcomes indicate that EW with 200 ppm HOCl can be effective against a variety of pathogens, including SARS-CoV-2. Clinical significance lies in the potential use of EW for surface	The text does not detail specific methods of dispensation

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Table 1: Contd...

Study	Author and Country	Aim and Objective	Pathogen Reported On	Statistical Analysis/Study Design	HOCL Concentration	Methods of Testing	Outcomes and Clinical Significance	Particles and ppm Relationship to Dispensing Method
		disinfectant during the COVID-19 pandemic.		and pH to ensure the disinfectant potency of the EW.			disinfection and as a preprocedural oral rinse in dental practices.	
7	Sorroche *et al*. 2022[19] Spain	To review scientific evidence on hypochlorous acid's virucidal activity against SARS-CoV-2 and explore its potential use as an antiseptic in ophthalmology and healthcare contexts.	SARS-CoV-2	Literature review collecting and analysing data from various studies on HOCl's virucidal activity.	0.01% (100 ppm)	The paper references various studies that tested HOCl's virucidal activity, primarily through in vitro studies, examining cell models, contact time studies, and HOCl application on tissues.	Outcomes generally suggest that HOCl at 0.01% concentration can effectively act as an antiseptic against SARS-CoV-2, with potential application in healthcare settings. The clinical significance lies in reducing the risk of SARS-CoV-2 transmission.	No clear indication was provided but it is inferred to be in a spray form.
8	Tazawa *et al*. 2023[4] United States	To evaluate the effectiveness of hypochlorous acid (HOCl) against common oral pathogens and a SARS-CoV-2 surrogate in the context of dental practice.	Common oral pathogens: Fusobacterium nucleatum, Prevotella intermedia, Streptococcus intermedius, and Parvimonas micra; SARS-CoV-2 surrogate: MHV-A59 virus	The study employed a controlled experimental design to assess the antimicrobial and virucidal efficacy of HOCl, measuring the minimum inhibitory volume ratio required to completely inhibit growth.	HOCl concentration ranged from 45 to 60 ppm; higher concentrations were used to obtain higher bacteriostatic activity.	Bactericidal and virucidal assays were conducted in vitro, with tests to determine the effectiveness of HOCl in controlling oral pathogens and a SARS-CoV-2 surrogate.	HOCl was effective in reducing oral pathogens and SARS-CoV-2 surrogates, suggesting a potential role in reducing infection risk in dental practices. Clinical significance lies in the potential use of HOCl for dental unit water lines, as a mouthwash, or other dental applications.	HOCl was dispensed as a solution, applied directly to bacterial suspensions, and passed through DUWLs to assess any changes in effectiveness. The study considered factors such as pH, storage, and the effect of saliva on HOCl's efficacy in real-world dental environments.
9	Block & Rowan[17] 2020 United States	To review the evidence for using hypochlorous acid (HOCl) in oral-maxillofacial surgery (OMS) offices on a daily	SARS-CoV-2	Literature review compiling data from various sources on HOCl's effectiveness against viruses and bacteria, focusing	Effective concentrations range from 50 ppm to 200 ppm	The study examines different studies and experiments where HOCl was used to assess its virucidal and bactericidal properties, including	Outcomes show HOCl's effectiveness against a broad range of viruses, including coronaviruses. Clinical significance	HOCl can be dispensed in various forms, including wet, dry, sonicated, and fogging methods.

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Study	Author and Country	Aim and Objective	Pathogen Reported On	Statistical Analysis/Study Design	HOCL Concentration	Methods of Testing	Outcomes and Clinical Significance	Particles and ppm Relationship to Dispensing Method
		basis, evaluating its effectiveness in reducing the spread of COVID-19 and other pathogens.		on COVID-19.		contact time and application methods.	involves its potential use in reducing COVID-19 transmission in healthcare settings, with a focus on OMS offices.	
10	Tsai *et al*. 2024[14] Taiwan	To evaluate the in vitro cytotoxicity and antibacterial activity of different concentrations of HOCl and compare it to other antiseptics like chlorhexidine (CHX) and sodium hypochlorite (NaOCl).	Gram-negative: Aggregatibacter actinomycetemcomitans, Porphyromonas gingivalis; Gram-positive: Streptococcus mutans, Streptococcus sanguinis	One-way ANOVA with Scheffe's multiple comparisons to determine significant differences between groups. Significant P value is less than 0.05.	HOCl concentrations ranged from 100 to 500 ppm	Testing involved bacteriostatic activity, measured using conventional spread plate methods and the alamarBlue assay, along with cytotoxicity assessed through cell viability assays. pH changes were also monitored.	Outcomes suggest that 400 ppm HOCl showed promising antibacterial activity with minimal cytotoxicity. Clinical significance involves the potential use of HOCl as an antimicrobial agent with low cytotoxicity for applications like mouthwash, endodontic irrigants, and treatment of periodontitis.	The paper does not explicitly discuss details on particle sizes or the methods of dispensing
Study 11	Stubbs, *et al*. 2023[29] Canada	To quantify the levels of HOCl in a residential bathroom during cleaning with a bleach-based product to understand exposure risks associated with HOCl emissions during common cleaning practices.	No specific pathogen mentioned, but bleach-based products are typically used for disinfection against a variety of pathogens.	The study design involved both stationary and mobile measurements of HOCl levels. Exponential decay functions were used to evaluate the rate of decline in HOCl concentrations after cleaning.	HOCL concentrations reached over 10 ppmv, with sustained levels until the bleach solution was removed by rinsing. Peak levels near the source reached up to 21 ppmv.	A cavity ring-down spectroscopy (CRDS) instrument was used to measure HOCl mixing ratios in real-time in a residential bathroom. Sampling inlets were positioned at different locations to measure spatial and temporal trends.	Exposure to HOCl can vary greatly within a small space. Elevated levels of HOCl near the source suggest a risk of respiratory health issues. The findings highlight the need for proper ventilation and cautious cleaning practices.	The bleach cleaner used in the study was dispensed as a foam, suggesting a potentially higher concentration of HOCl near the source.
Study 12	Hartig *et al*. 2021[30] USA	To provide guidance for dentists to identify weaknesses	SARS-CoV-2	The study used a review design with a PRISMA	The article does not specifically mention HOCl concentration.	Analysed existing literature, guidance, and protocols related	Effective infection control protocols can minimize the risk	No clear description provided.

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Table 1: Contd...

Study	Author and Country	Aim and Objective	Pathogen Reported On	Statistical Analysis/Study Design	HOCL Concentration	Methods of Testing	Outcomes and Clinical Significance	Particles and ppm Relationship to Dispensing Method
		in their disinfection and cross-infection prevention protocols to mitigate the risk of SARS-CoV-2 transmission in dental offices during the COVID-19 pandemic.		approach to identify relevant publications, compiling data from various sources to analyse cross-infection prevention protocols in dental offices.	The focus is on general disinfection practices and cross-infection prevention methods, without detailing specific disinfectants or concentrations.	to infection control in dental offices. PRISMA approach involved searching databases for relevant publications on COVID-19 guidelines for dentists.	of cross-infection in dental offices. Recommendations focus on enhanced disinfection protocols, personal protective equipment, social distancing, and other safety measures to reduce SARS-CoV-2 transmission risks.	
Study 13	Brooks *et al*. 2023[31] USA	To evaluate the impact of stabilized hypochlorous acid (HOCl) on the filtration performance of N95 filtering facemask respirators (FFRs) and its effectiveness in decontaminating these masks to reduce the risk of fomite-based transmission in hospital settings.	Escherichia coli, Staphylococcus aureus	Laboratory-based experimental setup to measure filtration efficiency, flow resistance, and bactericidal effect. Standard deviations and Prism 6 software were used for statistical evaluation.	The study used stabilized HOCl at a concentration of 0.15%.	Filtration performance was measured by generating aerosols and analysing their size distributions with a scanning mobility particle sizer (SMPS). Bactericidal tests involved treating bacterially contaminated N95 swatches with HOCl via spray or submersion.	Spraying HOCl did not affect the filtration performance of N95 FFRs but did not effectively decontaminate them. Complete submersion in HOCl for 1 minute effectively decontaminated the swatches without compromising filtration efficiency. This finding has clinical significance for extended use N95 respirators.	The study used a fingertip spray bottle to deliver HOCl as a wet spray. The particle size for filtration efficiency tests ranged from 30 to 500 nm, and HOCl was dispensed in spray form at a concentration of 0.15%, with each spray delivering roughly 0.15 ml of solution.
Study 14	Nguyen *et al*. 2021[23] Australia	To develop a smart prefabricated sanitizing chamber (SPSC) using aerosolized hypochlorous acid (HOCl) to reduce the risk of COVID-19 transmission in	SARS-CoV-2, other pathogens like Staphylococcus epidermidis, Escherichia coli, and Salmonella	The article is a review summarizing studies on HOCl's efficacy, focusing on its viricidal and bactericidal activity in aerosolized form.	Effective HOCl concentrations ranged from 20 ppm to 100 ppm, with aerosolized HOCl demonstrating significant viricidal/bactericidal activity.	Discusses HOCl applications in aerosolized or spray form for pathogen reduction. Examines safety and toxicity testing using animal models like rabbits and guinea pigs.	HOCl in aerosolized form is effective against various pathogens and generally safe for human use. The use of HOCl in an SPSC could reduce COVID-19	HOCl dispensed as a spray, mist, or fog. Smaller particle sizes (less than 200 µm).

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Study	Author and Country	Aim and Objective	Pathogen Reported On	Statistical Analysis/Study Design	HOCL Concentration	Methods of Testing	Outcomes and Clinical Significance	Particles and ppm Relationship to Dispensing Method
		occupational settings.				Clinical applications include healthcare and disinfection in occupational settings.	transmission, but further research is needed on safety when HOCl is deployed in a chamber setting.	
Study 15	Rasmussen 2021[32] USA	The aim of study was providing evidence that Aqueous Hypochlorous Acid (HOCl) should be added to the core Essential Medicines List (Disinfectant and Antiseptic products), and Category 13 (Wound Care) of the WHO.	Multiple virus such as Staphylococcus aureus, MRSA, Mycobacterium tuberculosis. Fungi such as Candida Albicans and gram positive and negative bacteria *Staphylococcus aureus* and *Pseudomonas aeruginosa*.	A review of reports and a collation of results of various studies.	150 parts per million or greater of hypochlorous acid (HOCl). Isotonic solution of 0.9% saline -preferred for clinical use. pH less than 5.5, and greater than 99% pure HOCl.	150 parts per million or greater of hypochlorous acid (HOCl).	The usefulness of large-scale misting/fogging equipment for HOCl dispersion into enclosed spaces in institutions and health care facilities. HOCl solutions have been proven to bring high level of inactivation of an entire spectrum of infectious diseases. Available at low cost and optimally stable. Pure HOCl at the proper pH with adequate process controls will maintain their properties for months or years. It does not encourage antibiotic resistance or any resistance of biological pathogens. Environmentally safe as pure HOCL degrades within minutes to NaCl and H2O.	No description provided

In dental care, research targets periodontal pathogens like *Aggregatibacter actinomycetemcomitans* and *Porphyromonas gingivalis*, as well as fungal biofilms such as *Candida albicans*, especially in immunocompromised patients. The inclusion of SARS-CoV-2 is critical due to its transmissibility in settings with close patient contact, particularly in aerosol-generating procedures.[4,24]

In floor cleaning settings, investigations focus on microbial and fungal contamination, with disinfectants like HOCl being evaluated for their effectiveness in high-traffic areas. HOCl's environmentally safe profile makes it an attractive option in settings where traditional chemicals may not be suitable.[23] Additionally, studies assess HOCl's efficacy against common oral pathogens such as *Escherichia coli* and *Staphylococcus aureus* and its effectiveness against SARS-CoV-2 in both dental and healthcare settings.[18]

To support the claims about HOCl's efficacy, quantitative data from several studies highlight its disinfecting capabilities across various settings. Scarano *et al*. (2020)[24] reported that aerosolized hydrogen peroxide and HOCl reduced microbial contamination by up to 99.9%, with particle sizes ranging from 20 to 50 μm enhancing effectiveness. Feng *et al*. (2022)[22] found that HOCl fogging achieved a 99.99% reduction in bacterial load on horizontal surfaces, though longer fogging times were required for vertical surfaces to reach similar reductions. Gessi *et al*. (2023)[23] demonstrated that 10 ppm HOCl effectively removed organic dirt and microbial contamination from floors, without damaging surfaces and offering a lower environmental impact compared to detergent-based cleaning. Tazawa *et al*. (2023)[4] showed that HOCl (45–60 ppm) significantly reduced oral pathogens, and a SARS-CoV-2 surrogate, reinforcing its potential to reduce infection risks in dental environments.

Pathogen-specific focus in different environments

The focus on specific pathogens in different settings is guided by the unique challenges each environment presents. For example, in hospital environments, MRSA, VRE, and C. difficile are prioritized due to their high prevalence in healthcare-associated infections (HAIs). These pathogens are often resistant to common antibiotics and can persist on surfaces, making them particularly difficult to control. In contrast, dental settings emphasize pathogens like Aggregatibacter actinomycetemcomitans, Porphyromonas gingivalis, and Candida albicans, which are directly related to oral health and the potential for infection during dental procedures, particularly those that involve aerosolization. The inclusion of SARS-CoV-2 in both contexts reflects the broader need to control viral transmission in clinical and community health settings.

By addressing these pathogens with targeted disinfectants like HOCl, researchers are developing protocols that can improve infection control measures in healthcare environments, thus safeguarding both patients and healthcare workers. The data from these studies collectively suggest that HOCl is a versatile and effective disinfectant, capable of reducing the transmission of a wide range of pathogens, from common bacteria to more challenging viruses like SARS-CoV-2.

Benefits of HOCl as a versatile and safe disinfectant in healthcare and institutional settings

HOCl shows efficacy against a broad spectrum of pathogens and is considered safe for human use in aerosolized form. HOCl has the potential in reducing COVID-19 transmission through aerosolized misting in smart sanitizing chambers. HOCl solutions are cost-effective, stable over extended periods with proper pH and process controls, and environmentally friendly as they degrade quickly into harmless components. Importantly, HOCl does not promote antibiotic resistance or resistance in biological pathogens, affirming its potential as a versatile disinfectant in healthcare and institutional settings.

Global distribution of studies on disinfection practices: A country-wise overview

The studies took place in various countries, with the United States hosting the most studies (six in total), followed by Italy with two studies. Individual studies were conducted in Peru, Saudi Arabia, Spain, Taiwan, Canada, and Australia, each with one study.

Advancements in disinfection strategies to mitigate pathogen transmission in healthcare and occupational settings

The studies reviewed aim to enhance disinfection protocols and mitigate transmission risks of SARS-CoV-2 and other pathogens in various settings. They explore diverse approaches such as describing biosafety protocols in dental care,[30] assessing the effectiveness of hypochlorous acid (HOCl) fogging on pathogen survival,[22] evaluating HOCl for floor sanitation,[23] and reviewing no-touch disinfection methods in dental clinics.[24] Other studies investigate HOCl's virucidal activity,[17] its efficacy against oral pathogens,[4] and its impact on N95 mask decontamination.[28] Additionally, research examines the production and use of electrolyzed water,[25] cytotoxicity of HOCl compared to other antiseptics,[13] and exposure risks associated with HOCl emissions during cleaning.[26] These studies collectively contribute to optimizing disinfection practices and reducing transmission risks in healthcare and occupational environments during the COVID-19 pandemic and beyond.

Comprehensive approaches to pathogen control: insights from diverse settings and targeted research areas

The pathogens addressed in the studies vary widely, reflecting diverse research focuses across different settings. Studies on SARS-CoV-2 primarily aim to mitigate its transmission, with some exploring broader disinfection strategies against multiple pathogens including MRSA, VRE, and C. difficile in hospital environments.[22,28] Specific to dental care, research targets major periodontal pathogens like Aggregatibacter actinomycetemcomitans and Porphyromonas gingivalis, as well as fungal biofilms such as Candida albicans, alongside SARS-CoV-2.[4,24] In general, microbial control, investigations focus on pathogens found in floor cleaning settings, emphasizing general microbial and fungal contamination.[23] Additionally, studies evaluate the efficacy of disinfectants against common oral pathogens such as *Escherichia coli* and *Staphylococcus aureus*, along with their effectiveness against SARS-CoV-2 and related viral surrogates.[26,27] These efforts collectively aim to optimize disinfection protocols across various environments, addressing specific pathogenic threats to enhance public health and safety measures.

Discussion

The scoping review presented strong evidence supporting the effectiveness of HOCl in deactivating viruses, bacteria, and fungi commonly found in dental splatter, with heightened interest in its use driven by the COVID-19 pandemic. The studies, conducted between 2020 and 2024, reflect a growing body of research, particularly in developed countries. However, there are potential biases to consider in the included studies. Some may lack rigorous statistical analysis, which could affect the reliability of their results and complicate the assessment of HOCl's true efficacy. Additionally, variations in study design and methodology may influence the consistency of outcomes. While these factors do not diminish the overall value of the research, they highlight the importance of considering the broader context when evaluating the findings. Furthermore, although most studies focus on developed countries, it is crucial to consider the potential challenges of implementing HOCl-based disinfection protocols in developing nations, where access to resources and infrastructure may be limited.

Themes in HOCl use and disinfection practices

Among the studies included in the scoping review, the key themes revolve around improved environmental surfaces disinfection, cross-contamination, innovative disinfection techniques, biosafety, efficacy, and clinical applications of HOCl use.[23,24,30] These studies aimed to provide alternative disinfection techniques that create a safe environment for patients and reduce cross-infection.[25]

This interest in alternative techniques was spearheaded by the COVID-19 pandemic, resulting in significant changes to disinfection methods and the management of pathogens.[24] Several aims in the selected articles focus on cleaning and disinfecting environmental surfaces to prevent fomite-based transmission of pathogens (WHO – cleaning and disinfection of environmental surfaces in the context of COVID-19, 2020). Siles-Garcia *et al*. (2020) and Feng *et al*. (2022)[33] emphasized the importance of cleaning and disinfection to minimize the risk of SARS-CoV-2 transmission. The innovative disinfection techniques mentioned in the studies refer to newer methods of applying disinfectants like HOCl in ways that differ from traditional cleaning practices. These techniques often include advanced methods such as fogging, electrochemical activation, and aerosolization, which enhance the spread and effectiveness of HOCl. For example, fogging or aerosolizing HOCl involves creating fine mist particles that can reach a broader surface area and penetrate hard-to-reach places, offering a more thorough disinfection compared to traditional wiping or spraying.[23,24] This innovation in application allows for faster and more efficient deactivation of pathogens across larger areas. Additionally, these techniques can target airborne pathogens, further reducing the risk of transmission, especially in environments like dental clinics where aerosols and splatter are common (WHO – cleaning and disinfection of environmental surfaces in the context of COVID-19, 2020). Traditional methods, on the other hand, often rely on manual cleaning and wiping, which can miss high-touch areas and be less effective against airborne microorganisms (Siles-Garcia *et al*., 2020).

HOCl is considered more environmentally friendly compared to many other disinfectants due to its composition and limited environmental impact. Unlike conventional disinfectants, such as bleach or hydrogen peroxide, HOCl breaks down into simple, nontoxic byproducts—mainly water and oxygen—after its disinfecting action, which makes it a more sustainable option.

In terms of sustainability, HOCl requires lower concentrations and shorter application times than many traditional disinfectants, reducing both its environmental footprint and the resources needed for its production and use. The use of HOCl also minimizes the reliance on harsh chemicals, which are often associated with long-term environmental damage, toxic exposure, and potential harm to human health when used frequently. By adopting HOCl, particularly in settings like dental clinics and hospitals, the overall environmental impact can be reduced, aligning with broader sustainability goals.[17]

The included studies emphasize the effectiveness of HOCl as a safe and practical disinfectant in dental settings. It consolidates the important themes of existing literature, focusing on the applications of HOCl that can be used successfully in enhancing hygiene standards and minimizing pathogen transmission in dental clinics.

Pathogens explored in disinfection studies

The collection of studies addressed the need to improve disinfection protocols within the medical and dental industry and to inactivate or eliminate a multitude of pathogens, with a significant focus on SARS-CoV-2. Siles-Garcia *et al*. (2020) explored protocols to improve disinfection within the medical industry, focusing on reducing the spread of SARS-CoV-2. Other pathogens that were included in the chosen studies include bacteria like *E. faecalis, Escherichia coli*, and biofilm forming fungi *like C. albicans.* Feng *et al*. (2022)[22] addressed broader healthcare disinfection needs by studying MRSA and Vancomycin-Resistant Enterococci (VRE).

Tsai *et al*. (2024)[13] explored pathogens like Aggregatibacter actinomycetemcomitans and how to manage its inactivation or elimination through disinfection. Gessi *et al*. (2023)[23], Brooks *et al*. 2023[28], Farah and Ali (2021)[25], and Scarano *et al*. (2020)[24] focused on pathogens in dental settings, including Fusobacterium nucleatum and Streptococcus mutans. Sorroche *et al*. (2022)[17] studied disinfection against various pathogens, including *Staphylococcus aureus*. Stubbs *et al*. (2023)[26] and Hartig *et al*. (2021)[27] analyzed the use of innovative disinfection techniques to combat various pathogens, including *Escherichia coli* and *C. albicans*. Nguyen *et al*. (2021)[21] and Rasmussen (2021)[29] expanded the list of pathogens to include fungi and other bacteria requiring advanced disinfection methods. Several of these listed pathogens assessed in these studies have been associated with dental surface contamination. The ability of HOCl to inactivate these pathogens is therefore a positive outcome.

Studies have demonstrated that HOCl's antimicrobial properties are potent against a wide range of pathogens, including bacteria like *E. faecalis* and *Escherichia coli*, as well as fungi such as *C. albicans*. Biofilm-forming organisms, such as *C. albicans*, present significant challenges in dental settings due to their ability to form resilient biofilms on both hard and soft surfaces, which are difficult to eradicate using conventional disinfection methods.[29]

The microorganisms within these biofilms are shielded by an extracellular matrix, providing them protection from environmental stressors, including disinfectants. The ability of HOCl to effectively target and break down biofilms is essential in preventing persistent infections and maintaining hygiene standards in dental environments. HOCl works by disrupting cell membranes and proteins, leading to the inactivation of these pathogens.[17] However, its efficacy can vary slightly across different pathogens due to differences in cellular structures. For instance, while HOCl shows strong effectiveness against common bacteria like *Streptococcus mutans* and *Fusobacterium nucleatum*, more complex pathogens such as *MRSA* and *VRE* may require longer exposure times or higher concentrations to achieve comparable inactivation.[22,28] This variability in efficacy underscores the importance of tailoring disinfection protocols to specific pathogens to ensure effective disinfection across various clinical environments, especially in dental settings where surface contamination and cross-infection are critical concerns.

Methodological approaches and statistical analysis in HOCl research

The studies within the scoping review utilized a varied range of methodologies, from controlled experimental setups to clinical studies. Studies used controlled experiment setups and clinical investigations that utilized bacterial cultures, which tested the effectiveness of HOCl in reducing bacterial counts.[13,22] Other studies, such as those by Siles-Garcia *et al*. (2020) and Brooks *et al*. (2023),[28] used observational or comparative methods to assess the effectiveness of disinfection protocols in real-world settings.

Tazawa *et al*. (2023)[4] and Block and Rowan (2020)[15] explore novel disinfection methods like fogging, targeting cross-infection risks in medical environments. Gessi *et al*. (2023)[23] evaluated electrolyzed HOCl for floor cleaning and sanitation, using comparative tests with detergent-based cleaning and water-only controls, focusing on organic dirt and microbial removal.

Sorroche *et al*. (2022)[17] reviewed the virucidal activity of HOCl against SARS-CoV-2 using low HOCl concentrations (0.01%) in *in vitro* studies to understand its antiseptic potential in healthcare settings. Scarano *et al*. (2020)[24] conducted a literature review on no-touch disinfection procedures in dental clinics, synthesizing evidence supporting the efficacy of HOCl in reducing airborne and fomite-based transmission of pathogens, including SARS-CoV-2. The most common effective disinfectant against bacteria, fungi, and viruses is either bleach or 60%–95% isopropyl alcohol or isopropanol. With its active ingredient sodium hypochlorite in bleach, it can effectively neutralize pathogens in a 10–60-minute contact time. The contraindication of sodium hypochlorite is that it can be easily inactivated by organic material and the increasing incidence of resistance development (Patel, 2020).[3] In light of the increase incidence of resistance, an alternative method is needed to eliminate pathogens associated with the dental clinic as well as eradicating any opportunistic infections.

Not all the studies specified the statistical approaches used to analyze their results; however, one-way ANOVA with Scheffe's multiple comparisons was one of the more common statistical methods, as seen in studies like Stubbs *et al*. (2023)[26] and Hartig *et al*. (2021).[27] Some studies, like Sorroche *et al*. (2022),[17] used exponential decay functions to understand trends over time. Others, such as Gessi *et al*. (2023)[23] and Scarano *et al*. (2020),[24] used comparative analyses without detailing the exact statistical techniques. This variation in methodologies and statistical approaches supports the need for a broader range of research designs to evaluate HOCl effectiveness comprehensively. A combination of controlled experimental studies, comparative analyses, and observational research can offer a more robust understanding of HOC role in disinfection, as well as the safety and efficacy of its use in various settings. These findings suggest practical implications for dentistry by demonstrating that HOCl effectively reduces bacterial counts and viral activity in controlled and real-world settings and therefore supports the use of HOCl in dental clinics for routine and deep cleaning, enhancing overall infection control measures.

It is important to note observational and comparative studies provide valuable insights into the real-world effectiveness of HOCl but also introduce variables that can influence outcomes. Factors such as environmental conditions, variations in disinfection protocols, and practitioner techniques may impact results, making it challenging to establish clear causal relationships. Additionally, potential biases, such as observer or selection bias, and variability in statistical methods may affect data interpretation. While these studies highlight practical applications and provide valuable real-world insights, incorporating well-controlled experimental research would further strengthen the reliability of findings on HOCl's disinfection efficacy.

Concentrations

The cited concentrations of HOCl (e.g., 0.01% to 0.5%) were generally effective across a range of pathogens, but their efficacy can vary depending on the type of pathogen, method of application, and environmental factors. For instance, concentrations between 0.01% and 0.1% (100 ppm to 1000 ppm) were effective against bacteria, fungi, and viruses, as indicated by studies such as Feng *et al*. (2022)[22] and Scarano *et al*. (2020).[24] However, for more challenging pathogens or conditions requiring stronger disinfection, such as large blood or body fluid spills, higher concentrations of 0.5% (5000 ppm) were recommended.[22] This higher concentration was likely necessary to ensure adequate efficacy against a broader range of pathogens or more substantial contamination.

The variations in recommended concentrations are largely influenced by both the type of pathogen and the method of application. For example, aerosolized HOCl at concentrations ranging from 20 ppm to 100 ppm has shown significant virucidal and bactericidal activity.[21] This lower concentration is sufficient for managing airborne pathogens, including viruses like SARS-CoV-2, as demonstrated in the study by Siles-Garcia *et al*. (2020). In contrast, for surface disinfection or in environments with more significant contamination, higher concentrations (290 ppm to 512 ppm) were often found to be effective.[13]

Additionally, different methods of application—such as fogging, surface wiping, or controlled spraying—also influence the required concentration. Fogging, for instance, may require slightly higher concentrations (290 ppm to 512 ppm) to ensure thorough dispersion and coverage, whereas direct surface wiping might be effective with lower concentrations, as seen with concentrations as low as 10 ppm.[28]

The variations in recommended HOCl concentrations are due to both the pathogen in question and the method of application; for example, lower concentrations (e.g., 10 ppm to 100 ppm) can be effective for general disinfection and airborne pathogens, and higher concentrations are needed for more challenging situations or for surface disinfection under more contaminated conditions. These factors highlight the versatility of HOCl as a disinfectant in different contexts, especially in environments like dental clinics, where both airborne and surface contamination risks must be managed.

In dental settings, effective concentrations are often between 50 ppm and 200 ppm, indicating a range of efficacy for disinfection and reducing cross-infection risks, as noted by Scarano *et al*. (2020)[24] and Tsai *et al*. (2024).[13] Studies focusing on general healthcare settings show similar ranges and results. Certain studies, such as Sorroche *et al*. (2022),[17] focus on cross-infection prevention without specific HOCl concentrations, emphasizing general disinfection practices and broader methods to mitigate pathogen spread.

The practical implications for dentistry from the use of HOCl include its effective application at concentrations from 0.01% to 0.5% for routine disinfection and concentrations of 290 ppm to 512 ppm are suitable for surface disinfection and fogging. These findings support HOCl as a versatile disinfectant in dental clinic, enhancing infection control and promoting a safer environment for patients and staff alike.

Method of dispersion

Notably, five studies were specifically conducted within dental clinics, while an additional ten studies explored clinical or experimental environments relevant to dental practice.[13,24,26,27,29] This broad scope of research emphasizes the versatility and potential of HOCl-based disinfection strategies in diverse healthcare settings.

HOCl can be dispensed in multiple forms, including spray bottles and bleach-based foam, aerosolized application, facilitated through electrolysis, ultrasonic devices, or specialized fogging equipment. These methods vary in terms of particle size and dispersion techniques, impacting both effectiveness and safety.

Innovative disinfection techniques have been extensively explored in the included studies. Studies by Tsai *et al*. (2024)[13] explored the efficacy of HOCl concentrations and its application in fogging, while Tazawa *et al*. (2023)[4] investigated novel no-touch disinfection methods, and Nguyen *et al*. (2021)[21] developed a smart sanitizing chamber utilizing aerosolized HOCl for effective disinfection. While various methods are used, there are concerns about the safety and efficacy of certain approaches, especially when they involve aerosolization or fogging. Studies suggest the use of more controlled applications, such as using cloths or wipes soaked in disinfectant, to reduce risks and ensure effective disinfection.[28]

Brooks *et al*. (2023)[28] have also contributed significant insights, examining the practical implementation of HOCl for disinfection purposes and its potential benefits in controlled environments. The study further supports the implementation of HOCL as a promising disinfection agent. Studies by Sorroche *et al*. (2022)[17] and Tazawa *et al*. (2023)[4] have specifically investigated these methods to combat airborne and fomite-based transmission of pathogens in diverse settings. The findings highlight the potential of these novel approaches to enhance infection control protocols effectively.

Scarano *et al*. (2020)[24] and Tsai *et al*. (2024)[13] explored the clinical applications of HOCl, particularly in dental settings. They have highlighted the efficacy of HOCl in reducing cross-infection risks and enhancing overall hygiene standards within dental clinics.

Tazawa *et al*. (2023)[4] used ultrasonic fogging to produce micron-sized particles, typically between 20 and 50 μm, allowing for a high surface-to-volume ratio. This process can lead to the release of chlorine gas as the particles dry, indicating potential risks during application. Stubbs *et al*. 2023[26] reported that a bleach cleaner was dispensed as foam, suggesting a potentially higher concentration of HOCl near the source. This indicates that different dispensing methods can lead to varied HOCl concentrations, impacting safety and efficacy, as noted by Scarano *et al*. (2020).[24]

A fingertip spray bottle was used to deliver HOCl as a wet spray, with each spray delivering roughly 0.15 ml of solution. This method, described by Tsai *et al*. (2024),[13] is common in smaller-scale applications where precise delivery is required. Ultrasonic fogging, producing particles between 20 and 50 μm, can lead to the release of chlorine gas as the particles dry, posing potential risks. This method was highlighted in Feng *et al*. (2022)[22] as part of the broader discussion on dispensing methods and associated safety concerns.

Farah and Ali (2021)[25] and Gessi *et al*. (2023)[23] reported that HOCl can be dispensed in solution form, applied directly to bacterial suspensions, or passed through DUWL, assessing its effectiveness in real-world environments. Factors such as pH, storage, and the effect of saliva on HOCl efficacy were considered, as discussed by Farah and Ali (2021)[25] and Gessi *et al*. (2023).[23] The general trend among the studies included in the scoping review emphasized the importance of safety measures in dental settings to reduce cross-infection risks. HOCl-based cleaning and fogging methods are effective in reducing bacterial contamination and removing organic dirt with minimal environmental impact.

Safety implications of ultrasonic fogging and chlorine gas release in dental clinics

Ultrasonic fogging disperses micron-sized HOCl particles (20–50 μm) into the air, enhancing surface disinfection but raising concerns about chlorine gas release as the particles evaporate. In confined dental clinic spaces, prolonged exposure or inadequate ventilation may lead to respiratory irritation and other health risks. To mitigate this, clinics should ensure proper ventilation, use air filtration systems, and adhere to safety guidelines regarding fogging duration and PPE use.

Practicality and accessibility of HOCl disinfection methods in low-resource settings

The feasibility of HOCl disinfection depends on the dispensing method and available infrastructure. Simple, low-cost methods like spray bottles and wipes are accessible and effective, particularly in resource-limited clinics. In contrast, advanced fogging systems require specialized equipment, stable power, and ongoing maintenance, which may present additional challenges for smaller clinics. While fogging offers broad coverage, simpler methods may be more sustainable and equally effective in reducing cross-infection risks.

Comparing HOCl with other disinfectants

In comparing HOCl with other disinfection methods like bleach (sodium hypochlorite) or isopropyl alcohol, several factors including efficacy, safety, and cost-effectiveness are crucial. Studies suggest that HOCl demonstrates comparable or even superior efficacy against a broad spectrum of pathogens, including bacteria and viruses, similar to bleach and IPA.[21,23]

HOCl has been shown to be effective in reducing bacterial counts and viral loads without compromising material integrity or leaving harmful residues, unlike bleach, which can be corrosive and irritate mucous membranes.[28]

Isopropyl alcohol, while effective, may not be as broad-spectrum as HOCl and can be flammable, posing additional safety concerns. Cost-effectiveness of HOCl is noted in its production from water, salt, and electricity, making it more economical than isopropyl alcohol and bleach, depending on concentrations used and application methods.[21,23]

HOCl generally exhibits low toxicity and is considered safe for humans and the environment when used appropriately, contrasting with the potential respiratory and skin irritations associated with isopropyl alcohol and environmental impact of bleach.[21,28] Based on these observations, HOCl surpasses other disinfectants in its effectiveness, safety profile, and cost-efficiency in various disinfections.

HOCl in dentistry

The selected studies in the scoping review support the use of HOCl in dental and healthcare settings, as demonstrated by several case studies and real-world examples. Siles-Garcia *et al*., 2020, described effective biosafety protocols in a Peruvian dental office post-COVID-19, emphasizing HOCl for environmental disinfection alongside stringent PPE use and aerosol control. Scarano *et al*. (2020)[24] provides evidence supporting HOCl role in reducing SARS-CoV-2 transmission in dental clinics and hospitals, highlighting its efficacy in enhancing infection control measures.

Gessi *et al*. (2023)[23] conducted a study in Italy on electrolyzed HOCl for hospital floor cleaning, showing it effectively removed organic dirt and microbial contamination without damaging surfaces. These examples highlight the effectiveness of HOCl in disinfection, reducing infection risks, and improving overall safety for both patients and healthcare providers.

HOCl has the additional advantage of being inexpensive, nontoxic, and gentle on surfaces, and when it is used in its pure form, there is minimal residue formation. This is imperative in dental clinics, where valuable equipment and instruments are sensitive to harsh chemicals as it may lead to corrosion. The positive outcome of the experimental intervention of these studies which demonstrated pathogen elimination and no reported damage to dental tools or equipment allows for the transference into the dental clinical area.[13,21,24]

Regular spray and wipe methods of disinfection are effective, but it has been established that it is operator-sensitive and there is always a need to improve efficiency of tasks. The vapor production which is used in the no-touch decontamination system or electrolyzed water has the ability to disinfect large areas where HOCl can be used effectively in varying concentrations and time periods. These methods reduce contact risks and can be used to disinfect large areas or hard-to-reach places. Studies found that HOCl at 0.01% (100 ppm) to 0.02% (200 ppm) can effectively disinfect surfaces, suggesting potential applications in healthcare and dental settings. This result allows for diversity in disinfectant choice for many practitioners with a variety of formulations to suit the needs of the clinic.[13,21]

Surfaces can be contaminated directly or indirectly, and this variation allows the clinician to make informed decisions based on the needs of the clinical space. The bacterial count on exposed surfaces in a dental clinic has been proven to be significantly lower post decontamination with HOCl fogging.[26] Before application, surfaces should be cleaned to remove organic matter, enhancing the efficacy of HOCl.[23] Exposure to HOCl can vary within small spaces, with higher concentrations near the source indicating a risk of respiratory health issues. This highlights the need for proper ventilation and cautious cleaning practices. HOCl solutions are environmentally friendly as they degrade into innocuous substances like NaCl and H2O. In addition, it does not promote antibiotic resistance, making it suitable for long-term use without contributing to broader resistance issues.

Previously, the storage of HOCl posed a dilemma as it would lose its efficacy and would denature rapidly when exposed to sunlight. HOCl decomposes into hydrochloric acid and oxygen, rendering it ineffective; therefore, correct storage is paramount.[29] Advancements have been made in the formulation that provides a greater structural stability, and this solution can be prepared and maintain efficacy for up to 2 weeks if stored appropriately.[21] Proper storage in sealed, labeled containers away from heat and sunlight is essential to maintain stability.[4,21]

The mitigating factor when using HOCl is that the solutions must be prepared according to the manufacturer's recommendations with regard to volume and contact time in order for it to be effective as inadequate dilution can result in a reduction of its efficacy. Based on findings from recent studies, implementing HOCl-based disinfection protocols in healthcare settings requires thorough training of staff on concentration requirements, application methods, and safety precautions. Educating personnel about potential hazards, especially when using HOCl in aerosolized forms or high concentrations, is crucial.[13,25]

The outcomes from these studies and guidance highlight the versatility of HOCl in disinfection, its effectiveness against a wide range of pathogens, and its applications in dental and healthcare settings. While HOCl is generally safe, proper protocols and safety measures are crucial to minimize risks and ensure effective disinfection practices.

Limitations

One key limitation is the potential for a broad scope to result in the inclusion of studies with varying methodologies and quality, making it challenging to draw definitive conclusions. Additionally, scoping reviews do not typically assess the risk of bias or the quality of evidence, which can affect the reliability of the findings. The heterogeneity of the studies included, particularly in terms of concentrations of HOCl, application methods, and clinical settings, may also limit the generalizability of the results.

Summary

Regular upskilling of staff with regard to risk assessment and changes in methods of biodecontamination is imperative, especially post the COVID-19 pandemic.[12] Great focus has been placed on providing patients and staff a safe environment when they attend any clinics, and adding HOCl to the regime will be highly beneficial since it has been studied in both clinical and laboratory studies.

HOCl provides a low-cost alternative that has low levels of resistance to opportunistic pathogens and in combination with its efficacy; it is an alternative for third-world countries in the search for cost-effective, easily accessible, and nontoxic biodecontamination. This scoping review has provided HOCl as an alternative to the disinfection arsenal which includes wipes, surface spray, waterline decontamination, impression disinfection, and mouthwash.

Conclusion

Dental staff are exposed to a varying degree of pathogens that remain airborne for a period of time and settle on surfaces, increasing the risk of cross-infection. HOCl plays a crucial role in mitigating these risks by effectively reducing airborne microbial load and surface contamination through fogging and direct application, enhancing biosafety in dental settings. Consequently, disinfection solutions used in dental clinics should be effective in neutralizing pathogenic microorganisms, providing a measure of safety for users while also being cost-effective. Before utilizing a new type of disinfectant, it is crucial to consider its efficacy against pathogens specific to the dental environment. Peer-reviewed journals have demonstrated the effectiveness of HOCl for surface and DUWL disinfection, with studies supporting its application in clinical settings. HOCl offers several key benefits for dental settings: It provides effective disinfection of surfaces and DUWLs, with customizable contact times and concentrations to meet specific clinic needs. Its broad-spectrum antimicrobial action helps prevent cross-contamination and controls pathogens, including resistant strains. Additionally, its low toxicity and environmental impact make it a safe, sustainable choice for routine infection control in dental clinics.

Recommendation

Future studies on HOCl in dental settings should prioritize randomized controlled trials (RCTs) to assess its efficacy across various concentrations, application methods, and real-world clinical environments. Standardizing disinfection protocols and investigating long-term safety and material integrity are essential. Particular attention should be given to the safety of aerosolized HOCl, with studies focused on mitigating risks like chlorine gas release. Additionally, cost-effectiveness analyses should be conducted to evaluate the practicality of HOCl use in low-resource settings, considering both financial and operational factors. Finally, broadening research to include diverse pathogens and clinical settings will provide a more comprehensive understanding of HOCl's potential.

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Conflicts of interest

There are no conflicts of interest.

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