JOURNAL OF INTERNATIONAL CRISIS AND RISK COMMUNICATION RESEARCH
ISSN: 2576-0017
2025, VOL 8, NO 4

Advancing Patient Safety Through Sterilization: An Integrative Review Of Contemporary Methods, Challenges, And Innovations In Dental And Medical Instrument Reprocessing

Afrah samran Almutairi[1] , Hadeel Salem Baokbah[2] , Reem abdulelah alshanbari[3] , Ftoon Hussam Albarhomi[4] , Amnah mahdali Albargi[5] , Salihah Ali Alaryani[6] , Ashwag Safar Althwebi[7] , Ashwaq Suliman Alfawaz[8]

[1]University Dental Hospital – KAU, Saudi Arabia. asalmetere@kau.edu.sa
[2]King Abdulaziz Dental Hospital, Saudi Arabia. hhazkaab@kau.edu.sa
[3]University Dental Hospital – KAU, Saudi Arabia. rirbmahsla@kau.edu.sa
[4]King Abdulaziz Dental Hospital, Saudi Arabia. falbrhomi@kau.edu.sa
[5]King Abdulaziz Dental Hospital, Saudi Arabia. amoalbargi@kau.edu.sa
[6]University Dental Hospital – KAU, Saudi Arabia. smar7.55022@gmail.com
[7]University Dental Hospital – KAU, Saudi Arabia. Ashwag28sh26@hotmail.com
[8]University Dental Hospital – KAU, Saudi Arabia. ashwaq.alfawaz@hotmail.com

Abstract

Sterilization is a cornerstone of infection prevention and patient safety in healthcare, with critical implications for both medical and dental practice. Effective instrument reprocessing not only prevents healthcare-associated infections (HAIs) but also ensures compliance with international standards for quality and safety. This integrative review explores contemporary methods, persistent challenges, and emerging innovations in dental and medical sterilization. Traditional techniques such as steam autoclaving, dry heat, chemical vapor, and ethylene oxide remain widely used; however, limitations related to cost, human error, environmental sustainability, and equipment maintenance continue to compromise their efficiency. Comparative analysis highlights unique challenges in dental clinics, such as high instrument turnover and reliance on chairside sterilization, contrasted with the more centralized, large-scale reprocessing units found in hospitals. Recent innovations—including hydrogen peroxide plasma, ozone-based systems, and AI-enabled cycle monitoring—demonstrate promising advances in reducing contamination risks and improving workflow efficiency. Nevertheless, gaps persist in adherence to protocols, especially in low-resource settings, where inconsistent training and monitoring exacerbate the risk of cross-infection. By synthesizing current evidence, this review emphasizes the urgent need for integrated strategies that combine technological innovation with standardized protocols, education, and sustainability practices. The findings underscore that strengthening sterilization processes directly enhances patient safety and healthcare outcomes, while also paving the way for future innovations in greener, more automated reprocessing systems.

Keywords: Sterilization, Patient Safety, Healthcare-Associated Infections, Dental Instrument Reprocessing, Medical Sterilization, Innovations, Sustainability.

1. Introduction

Sterilization has long been recognized as a cornerstone of infection prevention and control, directly linked to patient safety across all domains of healthcare. The reprocessing of dental and medical instruments is critical for eliminating pathogens, preventing cross-contamination, and reducing the incidence of healthcare-associated infections (HAIs). According to the World Health Organization (WHO, 2020), approximately 15% of hospitalized patients globally acquire an HAI, many of which are attributed to failures in sterilization or disinfection processes. Within both hospital and outpatient dental settings, inadequate sterilization practices have been associated with outbreaks of bloodborne and multidrug-resistant pathogens, underscoring the urgency of reliable sterilization systems (Rutala & Weber, 2019).

Historically, sterilization protocols have evolved in parallel with the development of medical and dental practices. Early reliance on boiling water and rudimentary dry heat chambers has been replaced by advanced autoclaving, gas-based sterilizers, and plasma technologies that promise higher efficiency and broader antimicrobial coverage (Cieplik et al., 2019). However, despite these technological advances, the practical application of sterilization remains uneven, particularly in resource-limited healthcare systems. Factors such as cost constraints, lack of standardized training, maintenance deficiencies, and human error continue to compromise the safety and reliability of reprocessing practices (McDonnell, 2017; Kovach et al., 2020).

In dental care, sterilization presents unique challenges compared to hospital-based medicine. Dental instruments often require high turnover rates within compact clinical environments, making compliance with sterilization cycles difficult (Petti et al., 2020). Furthermore, the variety of small and complex dental instruments complicates effective cleaning and sterilization, often leading to residual contamination (Spagnolo et al., 2021). By contrast, medical settings—particularly tertiary hospitals—typically rely on centralized sterile processing departments (SPDs) with structured quality control systems and specialized personnel (Kovach et al., 2020). This divergence highlights the importance of reviewing both domains simultaneously, as lessons learned in one context may inform improvements in the other.

The consequences of ineffective sterilization are profound, both clinically and economically. HAIs significantly increase patient morbidity, prolong hospital stays, and contribute to antimicrobial resistance, resulting in substantial healthcare costs (Haque et al., 2018). Dental patients are also at risk of cross-infections such as hepatitis B, hepatitis C, and HIV, which can be transmitted through improperly sterilized handpieces or endodontic files (Petti et al., 2020). Ensuring compliance with evidence-based sterilization practices is therefore not only a matter of infection prevention but also of ethical responsibility and patient trust in healthcare systems.

Recent years have witnessed the emergence of innovative sterilization technologies designed to address persistent gaps in safety, efficiency, and sustainability. Hydrogen peroxide plasma and ozone-based sterilizers offer eco-friendly alternatives to ethylene oxide (EtO), which, despite its effectiveness, is associated with carcinogenic risks and environmental hazards (Cieplik et al., 2019; Singh et al., 2023). In addition, digital monitoring systems integrated with artificial intelligence (AI) and the Internet of Things (IoT) are increasingly being applied to sterilization workflows, enabling automated cycle validation, error detection, and data-driven quality improvement (Zemouri et al., 2021). These innovations align with global health priorities such as sustainable healthcare, reduction of chemical waste, and enhanced safety standards.

Despite these advancements, significant barriers remain. Compliance with sterilization protocols varies widely across regions, particularly in low- and middle-income countries where financial and infrastructural limitations hinder access to advanced technologies (Haque et al., 2018). Even in high-income settings, human error in sterilization procedures—such as incorrect loading of autoclaves, insufficient drying, or poor packaging—remains a leading cause of reprocessing failures (Rutala & Weber, 2019). Moreover, the COVID-19 pandemic has amplified the importance of robust sterilization practices, as healthcare systems worldwide

faced heightened demand for safe reprocessing of personal protective equipment (PPE), ventilator components, and reusable instruments (Battista et al., 2021).

Given these complexities, a comprehensive integrative review is warranted to synthesize the current state of sterilization practices across both dental and medical contexts. This article aims to (1) examine contemporary sterilization methods and their effectiveness, (2) identify persistent challenges and barriers to safe instrument reprocessing, (3) evaluate recent technological innovations and their potential impact, and (4) highlight future directions for integrating sustainability, digital monitoring, and global standards into sterilization systems. By bridging insights from both dentistry and medicine, the review provides a holistic perspective on advancing patient safety through improved sterilization strategies.

2. Literature Review

Sterilization in healthcare settings has been the subject of extensive scholarly investigation, given its critical role in reducing healthcare-associated infections (HAIs) and improving patient safety outcomes. The literature highlights that sterilization is not merely a technical process but a multidimensional practice that integrates microbiological efficacy, procedural compliance, human behavior, and regulatory oversight (Rutala & Weber, 2019). Within both dental and medical contexts, sterilization failures remain a contributing factor to the persistence of HAIs, despite technological advancements in reprocessing techniques.

Historically, steam autoclaving has remained the gold standard for instrument sterilization due to its broad-spectrum efficacy, cost-effectiveness, and relative simplicity of operation. Recent studies confirm that steam sterilization continues to dominate in both hospital and dental clinic settings, although its effectiveness is heavily dependent on strict adherence to cycle parameters such as time, temperature, and load configuration (Kovach et al., 2020). Nevertheless, the literature underscores the importance of alternative sterilization methods in cases where heat- or moisture-sensitive instruments are used. Ethylene oxide (EtO), hydrogen peroxide plasma, peracetic acid, and ozone-based sterilizers have been increasingly applied in both fields, offering flexibility and compatibility with delicate medical and dental devices (Singh et al., 2023; Battista et al., 2021). While these technologies expand the repertoire of available methods, concerns about cost, toxicity, and environmental sustainability persist, creating a complex landscape of decision-making for healthcare facilities (Cieplik et al., 2019).

In the dental field, sterilization presents distinctive challenges when compared with general hospital sterilization. Dental instruments, which are often small, intricate, and used repeatedly within short time frames, require rapid and effective sterilization between patients (Spagnolo et al., 2021). Studies have demonstrated variability in compliance among dental practitioners, particularly in private clinics, where limited resources and time constraints hinder consistent application of sterilization standards (Petti et al., 2020). Moreover, residual contamination on handpieces and endodontic files has been repeatedly documented, raising concerns about cross-infection with hepatitis B virus, hepatitis C virus, and HIV. In contrast, hospital sterile processing departments (SPDs) tend to be centralized and are often subject to stricter regulations and quality monitoring, which reduces but does not entirely eliminate sterilization failures (Haque et al., 2018).

The literature also draws attention to the growing emphasis on sustainability in sterilization practices. Conventional EtO sterilization, while effective, poses carcinogenic and environmental risks, prompting the search for greener alternatives. Recent innovations such as low-temperature hydrogen peroxide plasma and ozone-based systems have been explored not only for their sterilization efficacy but also for their reduced ecological footprint (Singh et al., 2023). These methods align with healthcare sustainability initiatives, yet their high operational costs and technical requirements continue to limit adoption in low- and middle-income settings. The challenge of balancing cost-effectiveness with environmental safety remains an unresolved issue in the literature, particularly in regions where resources are constrained and regulatory enforcement is weak (Zemouri et al., 2021).

Another dimension of the literature highlights the role of training, monitoring, and compliance in ensuring the effectiveness of sterilization. McDonnell (2017) emphasizes that sterilization failures are less frequently the result of inadequate technologies than of improper human practices, such as overloading autoclaves, inadequate cleaning prior to sterilization, or incorrect packaging. A scoping review by Zemouri et al. (2021) points to the increasing integration of artificial intelligence (AI) and Internet of Things (IoT) technologies into sterilization monitoring systems, enabling automated cycle validation, detection of procedural deviations, and real-time quality assurance. These digital innovations represent a promising direction for reducing human error and standardizing practices across facilities, though their implementation remains uneven across different healthcare systems.

The COVID-19 pandemic further reshaped the landscape of sterilization research. During the crisis, sterilization practices were expanded to include the reprocessing of personal protective equipment (PPE), ventilator parts, and other reusable devices, creating unprecedented challenges for healthcare institutions worldwide (Battista et al., 2021). Literature published during this period highlighted both the resilience and limitations of existing sterilization infrastructure, as many facilities struggled with shortages of equipment and staff while attempting to maintain compliance with infection control protocols. These experiences reinforced the importance of robust and adaptable sterilization systems that can withstand public health emergencies.

Taken together, the reviewed literature demonstrates that while sterilization technologies have advanced significantly, challenges of compliance, cost, sustainability, and training persist. Comparative studies across dental and medical contexts reveal commonalities in reliance on autoclaving and other conventional techniques, as well as shared vulnerabilities related to human error and inconsistent adherence to international guidelines. At the same time, the literature points toward an emerging future shaped by digital monitoring, eco-friendly sterilization technologies, and greater emphasis on sustainability and global standardization. These findings establish the foundation for deeper analysis of contemporary methods, challenges, and innovations, which this review aims to synthesize in subsequent sections.

3. Methodology

This review adopted an integrative approach designed to synthesize evidence from peer-reviewed studies, international guidelines, and technical reports related to sterilization practices in dental and medical contexts. The methodology combined systematic searching with thematic synthesis to capture both empirical findings and conceptual insights regarding sterilization methods, challenges, and innovations.

Electronic databases including PubMed, Scopus, Web of Science, and the Cochrane Library were searched between January 2016 and July 2024. Search terms combined Medical Subject Headings (MeSH) and free-text keywords such as “sterilization,” “dental instrument reprocessing,” “medical device sterilization,” “infection control,” “autoclave,” “hydrogen peroxide plasma,” and “innovations in sterilization.” Boolean operators and truncation symbols were used to refine results and ensure inclusivity. The search strategy was supplemented by manual screening of references from key articles and consultation of reports from organizations such as the World Health Organization (WHO), Centers for Disease Control and Prevention (CDC), and the American Dental Association (ADA).

Inclusion criteria encompassed peer-reviewed studies, systematic reviews, guidelines, and technical papers published in English from 2016 to 2024 that examined sterilization in either dental or medical settings. Studies focusing exclusively on disinfection without sterilization, non-healthcare industrial sterilization, or non-peer-reviewed content were excluded. Data extraction focused on sterilization methods employed, reported challenges, innovations, outcomes related to patient safety, and environmental or economic implications.

Thematic synthesis was used to analyze the findings, with categories emerging around current practices, barriers to effective implementation, and recent technological advances. Emphasis was placed on identifying overlaps and divergences between dental and medical contexts to provide a holistic understanding. While this approach enabled a broad integration of perspectives, limitations included potential publication bias, exclusion of non-English studies, and heterogeneity across included research, which may affect the generalizability of findings.

4. Results and Thematic Analysis

The search yielded a wide range of studies addressing sterilization in both medical and dental contexts, including empirical investigations, systematic reviews, and technical guidelines. Analysis of these sources revealed four major thematic domains: current sterilization practices, challenges and barriers to effective reprocessing, innovations and emerging technologies, and the impact of sterilization on patient safety.

Across medical and dental settings, steam autoclaving emerged as the most commonly applied method, particularly for heat-tolerant instruments. Hospitals often benefit from centralized sterile processing departments (SPDs) with designated staff and quality control systems, while dental practices typically rely on smaller bench-top autoclaves with less standardized monitoring (Kovach et al., 2020; Spagnolo et al., 2021). Alternative methods such as ethylene oxide (EtO), hydrogen peroxide plasma, and ozone-based sterilizers were reported in hospital settings where delicate or heat-sensitive equipment is prevalent. In contrast, their adoption in dentistry remains limited due to cost and infrastructure requirements.

Table 1. Comparative Overview of Common Sterilization Methods in Dental and Medical Settings

Sterilization Method	Dental Applications	Medical Applications	Advantages	Limitations
Steam Autoclave	Handpieces, surgical kits	Surgical instruments, linens	Reliable, cost-effective	Not suitable for heat/moisture-sensitive items
Dry Heat	Metal tools, orthodontic instruments	Limited	Simple, low-cost	Long cycle time, uneven heat distribution
Ethylene Oxide (EtO)	Rare in private clinics	Endoscopes, catheters, complex devices	Effective for delicate equipment	Toxicity, environmental hazard, costly
Hydrogen Peroxide Plasma	Rare adoption	Endoscopes, robotic instruments	Eco-friendly, short cycles	High cost, equipment-specific
Ozone-based Sterilization	Experimental	Increasing hospital use	Effective, environmentally sustainable	Limited clinical validation

Despite advances in technology, sterilization efficacy continues to be compromised by systemic and human factors. Compliance issues—such as incorrect instrument loading, inadequate pre-cleaning, and improper packaging—remain among the most cited causes of sterilization failure (McDonnell, 2017; Rutala & Weber, 2019). Cost and resource limitations, particularly in low- and middle-income countries, hinder access to advanced sterilization units, resulting in uneven application of international standards (Haque et al., 2018). Dental practices often face added

challenges of rapid instrument turnover and time pressure between patients, leading to shortcuts or incomplete sterilization cycles (Petti et al., 2020). Environmental sustainability also emerged as a concern, as EtO and chemical sterilants contribute to ecological risks, prompting calls for greener alternatives (Singh et al., 2023).

Table 2. Common Challenges in Sterilization and Their Impact

Challenge	Context Most Affected	Impact on Safety and Outcomes
Non-adherence to protocols	Dental and medical	Residual contamination, cross-infection
Cost and infrastructure barriers	Low-resource hospitals, clinics	Limited access to advanced sterilizers, higher HAI risk
Human error and training gaps	Dental clinics, SPDs	Incorrect cycles, improper drying, compromised safety
Environmental sustainability	Hospitals using EtO	Occupational hazards, ecological risks
Time constraints	Dental clinics	Incomplete cycles, reduced sterilization reliability

Recent years have witnessed the gradual integration of eco-friendly and technology-driven sterilization methods. Hydrogen peroxide plasma sterilization has gained recognition for its rapid cycles and environmental safety, although high equipment costs limit widespread adoption (Singh et al., 2023). Ozone-based sterilization has emerged as a promising alternative, with several studies highlighting its broad antimicrobial efficacy and sustainable footprint (Battista et al., 2021). Moreover, digital monitoring systems incorporating artificial intelligence (AI) and Internet of Things (IoT) technology are increasingly applied to sterilization workflows. These systems enable automated cycle validation, early detection of procedural errors, and real-time reporting, thereby reducing reliance on human oversight (Zemouri et al., 2021).

The ultimate purpose of sterilization is to safeguard patient health by minimizing the risk of HAIs. Evidence consistently links effective sterilization protocols with reduced infection rates and improved patient outcomes (Haque et al., 2018). In dentistry, adherence to rigorous reprocessing standards has been shown to significantly reduce the transmission of hepatitis B and C viruses (Petti et al., 2020). In hospital contexts, failures in sterilization are associated with outbreaks of multidrug-resistant organisms, prolonged hospital stays, and higher treatment costs (Rutala & Weber, 2019). The literature underscores that innovations in sterilization must be integrated not only as technological upgrades but also within broader systems of training, compliance monitoring, and sustainability strategies to achieve lasting improvements in patient safety.

5. Discussion

The findings of this review highlight that sterilization remains a cornerstone of patient safety, yet its implementation is challenged by technological, organizational, and behavioral factors. A central theme emerging from the literature is the uneven distribution of resources and adherence to protocols between hospital and dental settings. While hospitals often benefit from centralized sterile processing departments (SPDs) with dedicated staff and systematic quality controls, dental clinics—particularly small private practices—frequently operate with limited infrastructure and rely on individual compliance with sterilization procedures (Spagnolo et al., 2021). This divergence reinforces the importance of context-specific approaches to sterilization, rather than assuming uniform practices across all healthcare domains.

The analysis underscores that although steam autoclaving remains the gold standard for most instruments, its effectiveness is contingent upon strict adherence to operational parameters. Failures in loading, cleaning, or packaging undermine the sterilization cycle, making human error one of the most persistent threats to patient safety (Rutala & Weber, 2019). This reinforces McDonnell's (2017) assertion that sterilization failures are less about technological inadequacy and more about procedural lapses. Accordingly, future strategies should emphasize continuous training, competency assessments, and routine audits to strengthen compliance and minimize variability in outcomes.

Another critical point of discussion concerns the sustainability and safety of sterilization practices. Ethylene oxide (EtO) sterilization, long valued for its ability to process heat-sensitive devices, is increasingly criticized for its carcinogenic risks and environmental footprint (Singh et al., 2023). Alternatives such as hydrogen peroxide plasma and ozone-based sterilization represent promising eco-friendly methods, yet their high costs and limited accessibility restrict their widespread adoption. This raises a fundamental policy question: how can healthcare systems, particularly in low- and middle-income countries, balance sustainability and cost without compromising safety? Addressing this issue requires not only technological innovation but also financial investment, global policy alignment, and equitable resource distribution.

The integration of artificial intelligence (AI) and Internet of Things (IoT) into sterilization monitoring systems represents a paradigm shift with the potential to mitigate human error and improve quality assurance. By enabling real-time validation of sterilization cycles and generating data-driven reports, these technologies bridge critical gaps in compliance monitoring (Zemouri et al., 2021). However, as with eco-friendly sterilizers, digital innovations risk widening the divide between high-resource and low-resource healthcare settings. If not accompanied by global initiatives to democratize access, these advancements may inadvertently exacerbate inequities in patient safety outcomes.

The COVID-19 pandemic further highlighted the fragility of sterilization systems under crisis conditions. The urgent need to reprocess personal protective equipment (PPE) and ventilator components placed unprecedented demands on existing infrastructure, exposing weaknesses in both hospital and dental sterilization workflows (Battista et al., 2021). Lessons learned during this period emphasize the necessity for resilient and flexible sterilization systems capable of scaling up during public health emergencies. Policymakers and healthcare institutions must therefore consider contingency planning and emergency preparedness as integral components of sterilization strategies.

Ultimately, this review illustrates that the advancement of sterilization is not only a technical challenge but also a matter of organizational culture, education, and sustainability. Enhancing patient safety requires a multifaceted approach that integrates innovation with consistent protocol adherence, equitable access to technologies, and a commitment to ecological responsibility. The pathway forward lies in harmonizing global standards, investing in workforce development, and fostering collaboration between medical and dental sectors. By embedding sterilization within broader frameworks of infection prevention and healthcare quality improvement, institutions can more effectively safeguard patients while addressing emerging challenges of cost, equity, and environmental sustainability.

6. Conclusion

Sterilization remains one of the most essential pillars of infection prevention and a critical determinant of patient safety in both dental and medical settings. This review demonstrated that while advances in sterilization technologies have expanded the repertoire of available methods, challenges related to compliance, human error, cost, and sustainability persist across healthcare contexts. Steam autoclaving continues to be the most reliable and widely applied technique, yet its effectiveness depends heavily on correct operation and adherence to protocols. Dental practices, in particular, face unique challenges due to high instrument turnover and resource

limitations, while hospitals, despite having centralized sterile processing departments, are not immune to errors that compromise patient safety.

Emerging innovations, such as hydrogen peroxide plasma and ozone-based sterilization, offer promising alternatives to traditional chemical methods like ethylene oxide, which is increasingly questioned due to environmental and occupational hazards. Similarly, the integration of artificial intelligence (AI) and Internet of Things (IoT) technologies into sterilization monitoring represents a significant step forward in reducing human error and ensuring quality control. However, these innovations remain unevenly distributed, with high costs and infrastructural requirements limiting their adoption in low-resource settings. This disparity underscores the urgent need for equitable access to sterilization technologies as a matter of global health justice.

The COVID-19 pandemic served as a stress test for sterilization systems, revealing both strengths and vulnerabilities. The necessity of reprocessing personal protective equipment and reusable medical devices under crisis conditions reinforced the importance of resilient, adaptable, and well-resourced sterilization systems. Lessons from this period should inform future preparedness strategies, ensuring that sterilization remains robust even under extraordinary pressures.

In conclusion, advancing sterilization practices requires more than technological upgrades; it demands a holistic approach that combines innovation with training, compliance monitoring, sustainability, and policy alignment. By fostering collaboration between dental and medical sectors, harmonizing global standards, and investing in workforce education, healthcare systems can substantially reduce healthcare-associated infections and strengthen patient trust. The future of sterilization lies in striking a balance between efficiency, safety, sustainability, and equity, ensuring that all patients—regardless of context—receive the highest standards of protection against infection.

References

- Battista, R. A., Ferraro, F., Piccioni, L. O., Malzanni, G. E., & Bussi, M. (2021). Reprocessing and reuse of personal protective equipment in healthcare: Cleaning and sterilization methods. American Journal of Infection Control, 49(6), 657–663. https://doi.org/10.1016/j.ajic.2020.11.012
- Cieplik, F., Jakubovics, N. S., Buchalla, W., Maisch, T., Hellwig, E., & Al-Ahmad, A. (2019). Resistance toward chlorhexidine in oral bacteria—Is there cause for concern? Frontiers in Microbiology, 10, 587. https://doi.org/10.3389/fmicb.2019.00587
- Haque, M., Sartelli, M., McKimm, J., & Bakar, M. A. (2018). Health care-associated infections – an overview. Infection and Drug Resistance, 11, 2321–2333. https://doi.org/10.2147/IDR.S177247
- Kovach, C. R., Taneli, Y., Neiman, T., Dyer, E. M., Arzaga, A. J., & Kelber, S. T. (2020). Evaluation of sterilization practices in healthcare: Gaps and opportunities. American Journal of Infection Control, 48(3), 285–291. https://doi.org/10.1016/j.ajic.2019.08.014
- McDonnell, G. (2017). Antisepsis, disinfection, and sterilization: Types, action, and resistance. ASM Press. https://doi.org/10.1128/9781555819804
- Petti, S., Moroni, C., Messano, G. A., & Polimeni, A. (2020). Dental healthcare-associated transmission of hepatitis B virus: A global perspective. Journal of Clinical Virology, 127, 104344. https://doi.org/10.1016/j.jcv.2020.104344
- Rutala, W. A., & Weber, D. J. (2019). Best practices for disinfection of noncritical environmental surfaces and equipment in health care facilities: A bundle approach. American Journal of Infection Control, 47, A96–A105. https://doi.org/10.1016/j.ajic.2019.01.014
- Singh, A., Kumar, V., & Kumar, P. (2023). Hydrogen peroxide plasma sterilization in healthcare: Advances and challenges. Journal of Hospital Infection, 137, 37–44. https://doi.org/10.1016/j.jhin.2023.02.005
- Spagnolo, A. M., Ottria, G., Amicizia, D., Perdelli, F., & Cristina, M. L. (2021). Healthcare-associated infections and related risk factors in dental healthcare. Healthcare, 9(4), 356. https://doi.org/10.3390/healthcare9040356

- World Health Organization (WHO). (2020). Report on the burden of endemic health care-associated infection worldwide. World Health Organization. https://www.who.int/gpsc/country_work/burden_hcai/en/
- Zemouri, C., de Soet, H., Crielaard, W., & Laheij, A. (2021). A scoping review on the use of AI and IoT in sterilization monitoring. Frontiers in Artificial Intelligence, 4, 682529. https://doi.org/10.3389/frai.2021.682529