Sterilization and Infection Control in Ophthalmic Operation Theatres: A Narrative Review.

Abstract:

Sterilization and infection control are essential for ensuring patient safety during ophthalmic surgery. Although the risk of infection after ophthalmic surgery is low, inadequate cleaning and sterilization of surgical instruments or poor adherence to aseptic techniques can lead to serious complications such as postoperative endophthalmitis and toxic anterior segment syndrome (TASS). These complications may result in severe inflammation, permanent vision loss, and the need for additional treatment or surgery. As the number of ophthalmic procedures, particularly cataract surgeries, continues to increase worldwide, effective infection prevention has become more important than ever.

This narrative review aims to summarizes the current evidence on sterilization methods, infection control practices, reprocessing of ophthalmic surgical instruments, operation theatre management, and recent technologies that improve patient safety. A literature search was conducted using PubMed, Scopus, Google Scholar, and ScienceDirect. Relevant international guidelines from organizations such as the World Health Organization (WHO), Centers for Disease Control and Prevention (CDC), American Academy of Ophthalmology (AAO), Association of perioperative Registered Nurses (AORN), and the Asia Pacific Society of Infection Control (APSIC) were also reviewed.

The review highlights the importance of proper instrument cleaning and sterilization, hand hygiene, environmental cleaning, preoperative ocular antisepsis, and adherence to evidence-based infection control practices. It also discusses recent advances, including hydrogen peroxide plasma sterilization, ultraviolet-C (UV-C) disinfection, and automated instrument tracking systems, which improve the quality and safety of ophthalmic surgical care.

In conclusion, following evidence-based sterilization protocols, infection control guidelines, and continuous staff training is essential for reducing postoperative infections and improving patient safety in ophthalmic operation theatres.

Keywords: Ophthalmic surgery; Sterilization; Infection control; Operation theatre; Endophthalmitis; Surgical instruments; Disinfection; Patient safety.

Introduction

Ophthalmic surgery has transformed the management of eye diseases and restored vision to millions of people worldwide. Among these procedures, cataract surgery is one of the most commonly performed and successful operations. Advances in microsurgical techniques, sophisticated ophthalmic instruments, and improved perioperative care have greatly enhanced surgical outcomes. However, despite these achievements, postoperative infections remain a significant concern because even a single episode of infection can lead to severe visual impairment or permanent blindness.

The prevention of postoperative infections relies on a multidisciplinary approach involving surgeons, anaesthesiologists, operation theatre technologists, nurses, and central sterile services department (CSSD) personnel. Effective infection prevention begins with meticulous cleaning, disinfection, and sterilization of surgical instruments and extends to strict adherence to aseptic techniques, environmental cleaning, operating theatre ventilation, hand hygiene, appropriate use of personal protective equipment, and compliance with established infection control policies. Continuous education of healthcare professionals and regular monitoring of sterilization processes are equally important in maintaining a safe surgical environment.

The increasing complexity of ophthalmic procedures and the widespread adoption of minimally invasive microsurgical techniques have further emphasized the need for standardized sterilization and infection control practices. International organizations, including the World Health Organization (WHO), Centers for Disease Control and Prevention (CDC), American Academy of Ophthalmology (AAO), American Society of Cataract and Refractive Surgery (ASCRS), Association of perioperative Registered Nurses (AORN), and the Asia Pacific Society of Infection Control (APSIC), have developed evidence-based recommendations to reduce the incidence of healthcare-associated infections and improve perioperative safety. In addition, recent technological advances such as hydrogen peroxide plasma sterilization, ultraviolet-C environmental disinfection, automated instrument tracking systems, and digital sterilization monitoring have enhanced the quality and efficiency of infection prevention programs.

This narrative review aims to summarize the current evidence on sterilization and infection control in ophthalmic operation theatres, with particular emphasis on instrument reprocessing, operating theatre practices, international guidelines, and emerging technologies. It also highlights the important role of the anaesthesia and operation theatre team in maintaining aseptic standards and ensuring patient safety throughout the perioperative period.

Literature Search Methodology

This narrative review was prepared to provide an overview of the current evidence on sterilization and infection control in ophthalmic operation theatres. A literature search was carried out using electronic databases, including PubMed, Scopus, Google Scholar, and ScienceDirect. Relevant international guidelines and recommendations published by the World Health Organization (WHO), Centers for Disease Control and Prevention (CDC), American Academy of Ophthalmology (AAO), American Society of Cataract and Refractive Surgery (ASCRS), Association of periOperative Registered Nurses (AORN), and the Asia Pacific Society of Infection Control (APSIC) were also reviewed.

The search included keywords such as *ophthalmic surgery*, *sterilization*, *infection control*, *instrument reprocessing*, *endophthalmitis*, *operating theatre*, *disinfection*, and *ophthalmic instruments*. Preference was given to English-language articles published between 2015 and 2025, while a few landmark studies published before 2015 were included because of their continued relevance to current clinical practice.

The retrieved literature included original research articles, review articles, clinical practice guidelines, and consensus statements related to sterilization, infection prevention, instrument reprocessing, operation theatre management, and emerging technologies in ophthalmic surgery. The selected publications were critically reviewed and synthesized to provide a comprehensive overview of current evidence and best practices in infection prevention and patient safety within ophthalmic operation theatres.

Principles of Sterilization

Sterilization is the process of completely destroying or removing all forms of microorganisms, including bacteria, viruses, fungi, and bacterial spores, from surgical instruments and medical devices. In ophthalmic surgery, effective sterilization is essential because even a small number of microorganisms can cause serious postoperative infections, such as endophthalmitis, which may result in permanent loss of vision. Therefore, every surgical instrument that enters the sterile field must be properly cleaned, disinfected, and sterilized before use (1–3).

The first and most important step in sterilization is **cleaning**. Blood, tissue debris, ophthalmic viscoelastic devices (OVDs), and other organic materials should be removed immediately after surgery because they can reduce the effectiveness of the sterilization process. Cleaning may be performed manually or with automated washer-disinfectors, following the manufacturer's recommendations. Proper cleaning helps ensure that the sterilizing agent reaches all instrument surfaces (2,4).

After cleaning, instruments should be carefully inspected for cleanliness and damage, dried thoroughly, and packaged appropriately before sterilization. Packaging materials should allow the sterilizing agent to penetrate while maintaining sterility during storage and transportation. Sterilization indicators, including chemical and biological indicators, should be used routinely to monitor the effectiveness of each sterilization cycle (2,5).

Steam sterilization (autoclaving) is the preferred method for most reusable ophthalmic surgical instruments because it is effective, reliable, and economical. However, heat-sensitive instruments may require low-temperature sterilization methods, such as hydrogen peroxide plasma sterilization or ethylene oxide gas sterilization, depending on the manufacturer's recommendations. Appropriate selection of the sterilization method is necessary to avoid damage to delicate ophthalmic instruments while ensuring complete microbial destruction (2,5).

Proper storage and handling of sterilized instruments are equally important. Sterile packs should be stored in clean, dry, and protected areas to maintain sterility until use. Healthcare workers should also receive regular training in sterilization procedures, quality assurance, and infection prevention to minimize the risk of contamination and improve patient safety. Regular monitoring and documentation of sterilization processes are essential components of an effective infection control program in ophthalmic operation theatres (1,2,5).

Infection Control Practices

Infection control is an essential part of ophthalmic surgical care and plays a major role in preventing healthcare-associated infections and postoperative complications. Although the incidence of infection following ophthalmic surgery is low, strict infection control measures are necessary because even minor contamination can lead to serious conditions such as postoperative endophthalmitis and toxic anterior segment syndrome (TASS) (1,2).

Hand hygiene is considered the most effective measure for preventing the spread of microorganisms in healthcare settings. All members of the surgical team should perform hand hygiene before and after patient contact, before aseptic procedures, and after contact with contaminated surfaces. Alcohol-based hand rubs or soap and water should be used according to international recommendations (1,2,4).

The use of appropriate personal protective equipment (PPE), including sterile gloves, surgical gowns, face masks, head covers, and protective eyewear, helps reduce the risk of contamination during surgery. Surgical attire should be clean and changed regularly, and all healthcare workers must follow standard precautions while working in the operation theatre (1,4).

Proper preoperative preparation of the surgical site is another important infection control practice. Cleaning the eyelids and surrounding skin with povidone-iodine before surgery has been shown to significantly reduce the number of microorganisms on the ocular surface and lower the risk of postoperative endophthalmitis. Sterile draping should also be used to isolate the eyelashes and surrounding skin from the surgical field (2,6).

Environmental cleaning and disinfection of the operation theatre should be performed before and after each surgical session. Frequently touched surfaces, operating tables, surgical microscopes, instrument trolleys, and other equipment should be cleaned using approved hospital disinfectants. Adequate ventilation, positive air pressure, controlled temperature, and appropriate humidity should be maintained to reduce airborne contamination (1,2,4).

Proper reprocessing of reusable ophthalmic surgical instruments is essential for preventing cross-contamination. Instruments should undergo cleaning, inspection, packaging, sterilization, storage, and transportation according to established protocols. Sterilization cycles should be monitored using chemical and biological indicators, and complete documentation should be maintained for quality assurance (2,3,4,5).

Continuous surveillance of surgical site infections and regular staff education are important components of infection prevention programs. Healthcare institutions should conduct periodic audits of infection control practices, provide ongoing training for operating theatre personnel, and ensure compliance with national and international guidelines. These measures help improve patient safety, reduce postoperative infections, and maintain high standards of ophthalmic surgical care (1,2,4).

Instrument Reprocessing

Proper reprocessing of ophthalmic surgical instruments is essential to prevent the transmission of microorganisms and ensure patient safety. Ophthalmic instruments come into direct contact with delicate eye tissues and intraocular structures; therefore, any contamination can lead to serious complications such as postoperative endophthalmitis or toxic anterior segment syndrome (TASS). Instrument reprocessing includes a series of steps: point-of-use care, cleaning, inspection, packaging, sterilization, storage, and transportation (2–5,8–11,19).

The first step in reprocessing begins immediately after surgery. Blood, tissue debris, ophthalmic viscoelastic devices (OVDs), and other contaminants should be removed as soon as possible to prevent drying on the instrument surface. Delayed cleaning can make debris difficult to remove and reduce the effectiveness of sterilization. Enzymatic detergents and cleaning solutions recommended by the manufacturer should be used to protect delicate ophthalmic instruments (2–5,19,27)

After cleaning, each instrument should be carefully inspected for visible debris, corrosion, or damage. Fine instruments such as forceps, scissors, and phacoemulsification handpieces require special attention because even minor damage may affect surgical performance. Instruments should then be dried completely before packaging, as residual moisture may interfere with sterilization and increase the risk of contamination (2–5,19)

Steam sterilization remains the preferred method for most reusable ophthalmic instruments because it is reliable, cost-effective, and highly effective in eliminating microorganisms, including bacterial spores. However, heat-sensitive instruments may require low-temperature sterilization methods such as hydrogen peroxide plasma sterilization or ethylene oxide gas sterilization. The sterilization method should always follow the manufacturer's instructions to avoid instrument damage while ensuring complete sterility (2–5,19,27)

Sterilized instruments should be packaged using approved sterilization wraps or containers that maintain sterility until use. Proper storage in clean, dry, and dust-free environments is necessary to preserve sterility. Healthcare facilities should also maintain documentation of sterilization cycles and routinely use chemical and biological indicators to verify the effectiveness of the sterilization process (2–5,19)

Regular staff training, adherence to standardized reprocessing protocols, and periodic quality audits are essential for maintaining high standards of infection prevention in ophthalmic operation theatres. A well-organized instrument reprocessing system not only reduces the risk of postoperative infections but also extends the lifespan of surgical instruments and improves the overall quality of patient care (1–5,19,24,25)

Prevention of Endophthalmitis

Postoperative endophthalmitis is one of the most serious complications of ophthalmic surgery. Although its incidence is low, it can result in severe visual impairment or permanent blindness if diagnosis and treatment are delayed. The infection usually occurs when microorganisms enter the eye during or shortly after surgery. Therefore, strict infection prevention measures throughout the perioperative period are essential to minimize the risk of postoperative infection and ensure successful surgical outcomes **(6–8,11–13).**

Preoperative ocular antisepsis is considered the single most effective measure for reducing the risk of postoperative endophthalmitis. The application of **5% povidone-iodine** to the conjunctival sac and **10% povidone-iodine** to the eyelids and surrounding skin before surgery significantly reduces the microbial load on the ocular surface. Multiple studies and international guidelines continue to recommend povidone-iodine as the standard antiseptic before ophthalmic procedures **(6,7,12,17,18,28).**

Strict aseptic technique should be maintained throughout the surgical procedure. All members of the surgical team should perform proper hand hygiene and wear appropriate personal protective equipment, including sterile gloves, gowns, masks, and head covers. Sterile draping should effectively isolate the eyelashes and eyelids, which are common sources of bacterial contamination. Compliance with standard infection control practices and operating theatre protocols further reduces the risk of surgical site contamination **(1–4,7,25,26).**

Proper cleaning, disinfection, sterilization, and handling of ophthalmic surgical instruments are equally important in preventing postoperative infections. Reusable instruments should undergo thorough cleaning to remove blood, tissue debris, and ophthalmic viscoelastic devices before sterilization. Inadequate cleaning may result in microbial contamination or toxic anterior segment syndrome (TASS). Sterilization processes should be validated using chemical and biological indicators as part of routine quality assurance **(2–5,9–11,19).**

The use of intracameral antibiotics at the completion of cataract surgery has become an important strategy for preventing postoperative endophthalmitis. Large clinical studies have demonstrated that intracameral cefuroxime significantly reduces the incidence of postoperative infection. Intracameral moxifloxacin has also shown excellent outcomes and is increasingly used because of its broad antimicrobial coverage and ease of preparation, depending on institutional protocols and local antibiotic availability **(7,12,17,18).**

Maintaining a clean ophthalmic operation theatre environment is another key component of infection prevention. Regular environmental cleaning, appropriate ventilation systems, positive air pressure, controlled temperature and humidity, and routine disinfection of frequently touched surfaces help reduce environmental contamination. Continuous monitoring of sterilization processes, infection surveillance, and regular audits further strengthen infection prevention programs and improve patient safety **(1,4,20–22,24–26).**

Early recognition and prompt management of postoperative endophthalmitis are essential for preserving vision. Patients should be educated about warning signs such as increasing ocular pain, redness, decreased vision, photophobia, and excessive discharge following surgery. Immediate ophthalmic evaluation, vitreous sampling when indicated, and prompt administration of intravitreal antibiotics, with or without pars plana vitrectomy depending on disease severity, significantly improve visual outcomes **(8,11–13,16).**

Overall, preventing postoperative endophthalmitis requires a multidisciplinary approach involving ophthalmologists, anaesthesiologists, operation theatre technologists, nurses, and infection control teams. Adherence to evidence-based infection prevention measures remains the most effective strategy for reducing the incidence of this sight-threatening complication.

Operation Theatre Environment and the Role of the Anaesthesia and Operation Theatre Team

A well-maintained operation theatre (OT) environment is essential for preventing infections and ensuring patient safety during ophthalmic surgery. Because ophthalmic procedures involve delicate ocular tissues and microsurgical techniques, maintaining a clean and sterile environment is critical for minimizing the risk of postoperative infections, including endophthalmitis. Effective environmental control, strict adherence to infection prevention protocols, and coordinated teamwork are key components of safe ophthalmic surgical practice **(1,4,20–22,26).**

The operation theatre should be designed to minimize microbial contamination. Adequate ventilation with positive air pressure, high-efficiency particulate air (HEPA) filtration where available, and recommended air exchanges help maintain clean air within the operating room. Temperature and humidity should be monitored regularly to provide a safe environment for both patients and healthcare professionals. Routine cleaning and disinfection of operating tables, surgical microscopes, instrument trolleys, anaesthesia workstations, and other frequently touched surfaces should be carried out before and after each operating session using approved hospital disinfectants **(1,4,20–22,26).**

Proper biomedical waste management is another important component of infection control. Biomedical waste should be segregated, handled, and disposed of according to institutional policies and national regulations. Safe handling of sharps, contaminated materials, and used surgical supplies helps prevent healthcare-associated infections and reduces the risk of occupational exposure among healthcare workers **(1,2,4,25,26).**

The anaesthesia and operation theatre team plays a vital role in maintaining aseptic practices throughout the perioperative period. Anaesthesiologists and anaesthesia technologists are responsible for preparing anaesthesia equipment, ensuring the cleanliness and disinfection of airway devices, monitoring equipment, and intravenous accessories, and following standard infection prevention practices during patient care. Hand hygiene should be performed before and after every patient contact, and reusable equipment should be cleaned, disinfected, or sterilized according to established guidelines **(2,4,24–26).**

Operation theatre technologists are responsible for preparing the operating room before surgery, arranging sterile instruments, assisting with patient positioning, maintaining the sterile field, and ensuring that sterilized instruments are handled appropriately throughout the procedure. They also assist in instrument counts, monitor sterile supplies, identify any breach in aseptic technique, and support compliance with sterilization protocols. Their role is essential in preventing contamination, maintaining patient safety, and ensuring an efficient surgical workflow **(3–5,24,25,27).**

Effective communication among ophthalmologists, anaesthesiologists, nurses, operation theatre technologists, and infection control personnel is equally important. The use of standardized surgical safety checklists, accurate patient identification, verification of the surgical procedure, and confirmation of instrument sterility before surgery help reduce preventable errors and improve patient safety. Continuous professional education, regular infection control training, and periodic quality audits promote adherence to national and international infection prevention guidelines and support continuous quality improvement **(1,4,24–26).**

Overall, a clean operation theatre environment supported by a well-trained multidisciplinary team forms the foundation of safe ophthalmic surgical practice. Strict adherence to evidence-based infection prevention measures, appropriate environmental management, and effective teamwork significantly reduce the risk of postoperative infections and contribute to improved surgical outcomes **(1–5,7,20–26).**

Emerging Technologies in Sterilization and Infection Control

Recent advances in technology have significantly improved sterilization and infection control practices in ophthalmic operation theatres. These innovations help reduce the risk of contamination, improve the efficiency of sterilization processes, and enhance patient safety. Healthcare facilities are increasingly adopting modern technologies to complement conventional infection prevention measures **(2,5,19,22,23).**

One of the most important developments is **hydrogen peroxide vapor (HPV)** and **hydrogen peroxide plasma sterilization**. These low-temperature sterilization methods are suitable for heat- and moisture-sensitive ophthalmic instruments that cannot withstand steam sterilization. They are highly effective against bacteria, viruses, fungi, and bacterial spores while minimizing damage to delicate microsurgical instruments. These technologies are increasingly being used as alternatives to conventional sterilization methods in specialized healthcare settings **(2,5,19).**

Ultraviolet-C (UV-C) disinfection is another emerging technology used for environmental cleaning in operating theatres. UV-C light inactivates microorganisms by damaging their DNA and RNA, thereby preventing their replication. It is primarily used as an adjunct to routine manual cleaning and has been shown to reduce microbial contamination on frequently touched surfaces and operating room equipment **(20–22).**

Digital instrument tracking systems using **radio-frequency identification (RFID)** or **barcode technology** have improved the management of surgical instruments. These systems enable healthcare facilities to monitor every stage of instrument reprocessing, including cleaning, sterilization, storage, and clinical use. Instrument tracking enhances traceability, reduces processing errors, improves inventory management, and provides complete documentation for quality assurance and regulatory compliance **(4,19,23).**

Automation has further improved the quality and consistency of instrument reprocessing. Modern washer-disinfectors and automated sterilization systems provide standardized cleaning and sterilization cycles, reducing human error associated with manual processing. Automated recording of sterilization parameters also supports quality assurance, accreditation requirements, and continuous monitoring of sterilization performance **(2,4,5,19).**

Artificial intelligence (AI) and digital monitoring technologies are increasingly being explored for infection prevention programs. AI-based systems can assist in monitoring hand hygiene compliance, evaluating environmental cleaning practices, predicting infection risks, and supporting surveillance of healthcare-associated infections. Although these technologies are still evolving, they have considerable potential to improve infection control practices and assist healthcare professionals in making timely, evidence-based decisions **(23).**

Despite these technological advances, they should complement rather than replace standard infection prevention practices. Proper hand hygiene, strict aseptic technique, meticulous instrument cleaning and sterilization, environmental cleaning, and continuous staff education remain the foundation of safe ophthalmic surgical care. Combining evidence-based infection prevention strategies with emerging technologies offers the most effective approach to reducing postoperative infections and improving patient outcomes **(1,2,4,5,19,23,26).**

Challenges and Future Perspectives

Despite significant advances in sterilization and infection control, several challenges continue to affect ophthalmic operation theatre practice. One of the major challenges is maintaining strict adherence to infection control protocols in busy surgical settings where a large number of procedures are performed each day. Time constraints, inadequate staff training, and non-compliance with standard operating procedures can increase the risk of contamination and postoperative infections.

Another important challenge is the proper reprocessing of delicate ophthalmic surgical instruments. These instruments have fine tips and narrow lumens that require careful cleaning and sterilization. Incomplete removal of blood, tissue debris, or ophthalmic viscoelastic devices may reduce the effectiveness of sterilization and contribute to complications such as toxic anterior segment syndrome (TASS) or postoperative endophthalmitis .

Healthcare facilities in low- and middle-income countries may also face limitations due to inadequate infrastructure, lack of advanced sterilization equipment, shortage of trained personnel, and limited financial resources. These factors may affect the consistent implementation of international infection control guidelines. Continuous education, regular competency assessment, and institutional support are therefore essential to improve infection prevention practices .

Future developments in ophthalmic operation theatres are expected to focus on automation, digital monitoring, and environmentally sustainable sterilization methods. Technologies such as automated washer-disinfectors, hydrogen peroxide plasma sterilization, ultraviolet-C (UV-C) environmental disinfection, and digital instrument tracking systems may improve the accuracy and efficiency of instrument reprocessing. Artificial intelligence and electronic surveillance systems may further support infection monitoring, quality assurance, and compliance with sterilization protocols .

Future research should evaluate the effectiveness, safety, and cost-effectiveness of these emerging technologies in different healthcare settings. In addition, greater emphasis should be placed on multidisciplinary teamwork, regular infection surveillance, and continuous quality improvement programs. Strengthening these areas will help reduce healthcare-associated infections, improve patient safety, and enhance the quality of ophthalmic surgical care.

Conclusion

Sterilization and infection control are essential components of safe and effective ophthalmic surgical practice. Proper cleaning, disinfection, sterilization, and handling of surgical instruments, together with strict adherence to aseptic techniques, play a crucial role in preventing postoperative infections such as endophthalmitis and toxic anterior segment syndrome. Maintaining a clean operation theatre environment and following evidence-based infection prevention practices further improve patient safety and surgical outcomes.

International guidelines provided by organizations such as the World Health Organization (WHO), Centers for Disease Control and Prevention (CDC), American Academy of Ophthalmology (AAO), and Association of periOperative Registered Nurses (AORN) offer valuable recommendations for standardizing infection control practices. The combined efforts of ophthalmologists, anaesthesiologists, operation theatre technologists, nurses, and infection control teams are essential for ensuring compliance with these recommendations.

Recent advances in sterilization technologies, automated instrument reprocessing, digital monitoring systems, and environmental disinfection methods have further strengthened infection prevention strategies. However, these technologies should complement, rather than replace, established infection control practices. Continuous staff education, regular monitoring of sterilization processes, and adherence to standardized protocols remain the foundation of patient safety.

In conclusion, maintaining high standards of sterilization and infection control is essential for reducing postoperative infections, preserving vision, and improving the overall quality of ophthalmic surgical care. Continued research, technological innovation, and commitment to evidence-based practice will further enhance patient outcomes and support safer ophthalmic operation theatre services.

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