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Clinical Practices Toward Infection Control During Surgical and Dental Procedures-An Updated Review for Healthcare Professionals

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Abstract

Background: Dental and surgical healthcare environments represent major sources for the transmission of infectious microorganisms because healthcare professionals are routinely exposed to blood, saliva, respiratory secretions, contaminated instruments, and aerosol-generating procedures.

Aim: This updated review aimed to evaluate current clinical practices related to infection prevention and control during surgical and dental procedures and to highlight the importance of standard precautions, transmission-based precautions, sterilization, disinfection, hand hygiene, personal protective equipment, and occupational exposure management.

Methods: The article reviewed and synthesized current literature and evidence-based recommendations concerning infection control measures within dental and surgical healthcare settings.

Results: The review demonstrated that adherence to comprehensive infection control protocols significantly reduces the risk of pathogen transmission in healthcare environments. Standard precautions including hand hygiene, sterilization, environmental cleaning, and appropriate use of personal protective equipment remain fundamental for all patients regardless of infectious status. Transmission-based precautions are necessary for managing airborne and respiratory infections, particularly during aerosol-generating procedures. Vaccination, proper sharps management, and effective post-exposure protocols were also identified as critical strategies for protecting healthcare workers from occupational infections. Furthermore, enhanced infection control measures introduced during the COVID-19 pandemic improved awareness regarding aerosol management and respiratory protection within dental settings.

Conclusion: Strict implementation of evidence-based infection prevention and control measures is essential for maintaining safe surgical and dental healthcare environments. Continuous education, vaccination, adherence to sterilization standards, and consistent application of standard and transmission-based precautions are necessary to minimize occupational risks, prevent cross-contamination, and improve patient and healthcare worker safety.

Key Words: Infection control, dental procedures, surgical procedures, sterilization, disinfection, personal protective equipment, occupational exposure, bloodborne infections, transmission-based precautions, hand hygiene.

Introduction

Dental healthcare environments represent high-risk clinical settings for the transmission of infectious microorganisms because dental professionals routinely interact with saliva, blood, respiratory secretions, and contaminated instruments during patient care procedures. Infectious agents within dental clinics may spread through several routes, including inhalation of airborne particles, accidental injections, ingestion, or direct contact with contaminated mucosal surfaces and skin tissues. Consequently, infection prevention and control practices constitute an essential component of safe dental care delivery and are fundamental for protecting both patients and healthcare personnel from communicable diseases. These preventive strategies are designed to reduce or eliminate the transmission of pathogenic microorganisms among patients, between patients and dental healthcare workers, and from healthcare personnel back to patients. Furthermore,

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infection control measures contribute significantly to minimizing the dissemination of infectious diseases beyond the clinical environment into the wider community. The implementation of rigorous infection prevention protocols is therefore mandatory in all dental healthcare facilities. Standard precautions should be consistently applied to every patient regardless of confirmed or suspected infectious status, as many infectious diseases may remain asymptomatic during early stages. These precautions include appropriate hand hygiene, use of personal protective equipment, safe handling of contaminated instruments, sterilization procedures, and environmental surface disinfection. In addition, transmission-based precautions must be adopted when patients present with infectious conditions that can spread through airborne, droplet, or contact routes, particularly respiratory infections that pose substantial risks within enclosed healthcare environments. Such preventive approaches are critical for maintaining occupational safety and ensuring continuity of effective dental services [1][2].

Dental professionals are particularly vulnerable to occupational exposure because dental procedures frequently involve the use of sharp instruments such as needles, scalpels, explorers, burs, and other invasive devices. The repeated handling of these instruments during routine clinical practice places dentists and other dental healthcare workers at persistent risk of percutaneous injuries. These injuries are clinically significant because they may expose healthcare personnel to blood and other potentially infectious biological materials originating from patients. Occupational exposure following percutaneous injuries may subsequently result in transmission of serious bloodborne pathogens and infectious diseases. Among the most concerning bloodborne pathogens affecting dental healthcare workers are hepatitis B virus (HBV), hepatitis C virus (HCV), and human immunodeficiency virus (HIV). These viral infections continue to represent major occupational health concerns due to their chronic complications and potential impact on healthcare personnel safety. Nevertheless, the probability of occupational transmission is influenced by several important factors, including the prevalence of infectious diseases within the community, the nature of clinical procedures performed, adherence to infection control guidelines, vaccination coverage, and overall workplace safety conditions [1][2].

Potential Routes of Transmission of Infectious Agents in Dental Practice

Dental healthcare environments constitute important settings for the transmission of infectious microorganisms because clinical dental procedures routinely involve close physical contact with patients and continuous exposure to saliva, blood, respiratory secretions, and contaminated instruments. The transmission of pathogenic agents within dental practice may occur through several recognized pathways, including direct contact transmission, indirect contact transmission, and airborne spread. Direct transmission commonly occurs through person-to-person exposure involving blood, saliva, or other contaminated body secretions during clinical procedures. Indirect transmission may arise from contact with contaminated dental instruments, environmental surfaces, or improperly disinfected equipment. In addition, airborne transmission represents a significant concern in dentistry because many dental procedures generate aerosols and droplets capable of carrying infectious microorganisms over varying distances within the clinical environment [1]. Among the different mechanisms of transmission, direct exposure to blood and body fluids remains one of the most clinically significant routes in dental settings [2]. Gingival bleeding frequently contaminates saliva during dental procedures, which necessitates considering all saliva as potentially infectious material regardless of the patient's medical history or apparent health status [2]. This precautionary principle is essential because several infectious diseases may remain asymptomatic while still being transmissible. Although numerous infectious diseases can theoretically spread within dental clinics, certain bloodborne viral infections pose greater occupational risks to dental healthcare workers due to the invasive nature of dental procedures and the routine use of sharp instruments.

Hepatitis B virus (HBV), hepatitis C virus (HCV), and human immunodeficiency virus (HIV) are among the most concerning bloodborne pathogens associated with occupational exposure in dentistry. Percutaneous injuries, particularly needlestick injuries and accidental punctures from contaminated instruments, represent the most common route of HBV transmission in dental practice. The average risk of HBV transmission following occupational exposure has been estimated at approximately 30% [2]. Furthermore, HBV demonstrates remarkable environmental resistance because the virus can remain infectious in dried blood at room temperature for up to one week [2]. Consequently, dental professionals experience a substantially elevated occupational risk, with estimates indicating that dentists are approximately ten times more likely to develop chronic hepatitis B infection compared with the general population [3]. Although HIV transmission within dental settings is comparatively less common, occupational exposure remains a serious concern. The highest probability of HIV transmission occurs following percutaneous injuries involving contaminated blood. However, the estimated risk of HIV transmission after a needlestick injury involving HIV-positive blood is approximately 0.3% per exposure [4]. In comparison, exposure to hepatitis C

virus-positive blood carries an estimated transmission risk of approximately 1.8%, whereas HBV continues to demonstrate the highest transmission potential among these bloodborne pathogens within dental healthcare environments.

In addition to bloodborne viral infections, dental healthcare workers may also encounter exposure to several respiratory and communicable viral diseases. Common viral infections potentially transmissible in dental clinics include rubella, measles, mumps, herpes viruses, human papillomaviruses, adenoviruses, coxsackie viruses, influenza viruses, and coronavirus disease (COVID-19) [5]. These infections may present substantial health risks, particularly among immunocompromised individuals and nonimmune pregnant women, who are more vulnerable to severe complications [5]. Moreover, bacterial pathogens such as Mycobacterium tuberculosis, methicillin-resistant Staphylococcus aureus, and streptococcal species may also spread within dental environments, particularly when infection prevention measures are inadequate [6]. The successful transmission of infectious diseases within dental practice depends on the simultaneous presence of several critical factors irrespective of the specific transmission route involved. These include the existence of a sufficient quantity of pathogenic microorganisms capable of causing disease, the presence of an appropriate reservoir such as blood, saliva, or respiratory secretions, and an effective route of transmission from the infected source to a susceptible host [1]. Additionally, pathogens require a portal of entry into the host's body and the presence of an individual lacking adequate immunity against the infectious agent. The interaction of these factors collectively determines the likelihood of disease transmission and emphasizes the importance of comprehensive infection prevention and control strategies within dental healthcare settings [1].

Standard and Transmission-Based Precautions in Dental Infection Control

Infection prevention and control measures in dental healthcare settings are primarily designed to interrupt the chain of infection transmission by targeting one or more factors required for the spread of infectious diseases. Effective infection control practices reduce the likelihood of cross-contamination among patients, dental healthcare personnel, and the surrounding clinical environment through the implementation of evidence-based preventive strategies. These measures are generally categorized into standard precautions and transmission-based precautions, both of which play essential roles in minimizing occupational and patient-related risks associated with infectious pathogens. Standard precautions represent the fundamental and routine infection prevention measures that must be consistently applied to all patients regardless of their known or suspected infectious status. This universal approach is based on the principle that every patient may potentially harbor transmissible microorganisms, including bloodborne pathogens, respiratory viruses, and other infectious agents. Consequently, standard precautions form the cornerstone of infection control in dental practice and are essential for maintaining a safe clinical environment for both patients and healthcare workers. One of the most important components of standard precautions is regular and appropriate hand hygiene. Hand washing significantly reduces microbial contamination and limits the transmission of pathogens between individuals and contaminated surfaces. Dental healthcare personnel are required to perform hand hygiene before and after patient contact, after handling contaminated instruments or surfaces, and following glove removal. In addition to hand hygiene, the consistent use of personal protective equipment is essential for minimizing direct exposure to infectious materials. Such protective equipment includes gloves, surgical masks, eye protection, face shields, and protective gowns, all of which create physical barriers against blood, saliva, aerosols, and respiratory secretions generated during dental procedures [1].

The selection of protective equipment should also correspond to the specific clinical task being performed. For example, heavy-duty utility gloves are recommended during the cleaning, transportation, and processing of contaminated instruments because they provide greater resistance to punctures and chemical exposure compared with examination gloves. Furthermore, safe management and disposal of sharp instruments constitute another critical element of standard precautions due to the substantial occupational risks associated with percutaneous injuries. Proper sharps handling practices, including the use of puncture-resistant sharps containers and safe disposal techniques, significantly decrease the probability of accidental injuries and subsequent exposure to bloodborne pathogens [1]. Another major aspect of infection prevention involves the proper cleaning, disinfection, and sterilization of patient-care instruments and equipment. Dental instruments that come into contact with oral tissues, blood, or saliva may become contaminated with pathogenic microorganisms and therefore require meticulous decontamination procedures before reuse. Similarly, environmental surfaces within dental clinics, including dental chairs, countertops, light handles, and radiographic equipment, must undergo routine cleaning and disinfection to reduce environmental contamination and prevent indirect disease transmission. Safe work practices designed to prevent occupational injuries also represent an integral component of standard precautions and contribute to enhancing overall infection control compliance within clinical settings [1]. Standard precautions must be implemented whenever dental personnel are exposed to mucous membranes, non-intact skin, blood, saliva, or other potentially infectious secretions. These precautions are equally necessary during routine non-

clinical activities within the dental environment, including cleaning treatment rooms, processing contaminated instruments, and handling materials that have been exposed to saliva, such as radiographic films. Moreover, contact with body fluids including blood and oral secretions necessitates strict adherence to infection control protocols because such materials may contain viable pathogenic microorganisms capable of causing disease transmission. In situations where patients are suspected or confirmed to carry highly transmissible infectious diseases, additional protective measures known as transmission-based precautions become necessary. These precautions provide enhanced protection against pathogens transmitted through contact, droplet, or airborne routes and are implemented alongside standard precautions to further minimize the risk of healthcare-associated infections. Collectively, adherence to standard and transmission-based precautions remains fundamental for ensuring patient safety, occupational health protection, and effective infection prevention within dental healthcare environments [1].

Transmission-Based Precautions

Transmission-based precautions constitute additional infection prevention strategies implemented when standard precautions alone are insufficient to control the spread of highly transmissible infectious agents within healthcare environments. These precautions are specifically designed according to the route of transmission of the infectious microorganism, including airborne, droplet, or contact transmission pathways. In dental healthcare settings, transmission-based precautions are particularly important for managing airborne infectious diseases because many dental procedures routinely generate aerosols and droplets capable of carrying viable microorganisms over extended distances. Consequently, dental professionals face substantial occupational risks when treating patients with respiratory or airborne infections. Airborne transmission represents one of the most challenging routes of infection control in dentistry because aerosol-generating procedures, such as ultrasonic scaling, air polishing, and high-speed handpiece usage, can disseminate infectious particles throughout the treatment environment. To minimize the transmission of airborne pathogens, current evidence recommends the use of negatively pressurized treatment rooms, which help prevent contaminated air from spreading to adjacent clinical areas. Additionally, the use of high-filtration respiratory protective equipment, particularly P2 or N95 surgical respirators, is strongly recommended because these respirators provide a tighter facial seal and greater filtration efficiency than conventional surgical masks. Such protective measures are essential for reducing occupational exposure to infectious aerosols and respiratory pathogens. Non-emergency dental treatment should generally be postponed for patients diagnosed with or suspected of carrying highly contagious airborne infections, including viral influenza, active tuberculosis, chickenpox, and measles. Delaying elective procedures in these patients reduces the possibility of cross-infection within dental clinics and protects healthcare personnel and other patients from unnecessary exposure. However, in situations where emergency dental treatment cannot be deferred, strict transmission-based precautions become mandatory to ensure safe patient management [1][2][3].

Several infection prevention measures are recommended when providing urgent dental care for patients with viral influenza or similar respiratory infections. Patients should ideally be scheduled as the final appointment of the day to minimize interaction with other individuals within the clinic. Alternatively, sufficient time intervals, preferably at least thirty minutes, should separate appointments to allow for adequate environmental decontamination and air exchange. Prior to treatment initiation, patients should perform an antimicrobial mouth rinse to reduce the microbial burden and potentially lower the concentration of infectious agents present in saliva and aerosols. The use of dental dam isolation during restorative procedures is also strongly encouraged because it limits saliva contamination and decreases aerosol dissemination during operative treatment. Furthermore, aerosol-generating procedures should be avoided whenever possible or minimized to the lowest extent clinically feasible. Reducing aerosol production significantly decreases the potential airborne spread of infectious microorganisms within enclosed treatment areas. Environmental cleaning and surface disinfection protocols should also be intensified, with contaminated surfaces undergoing repeated decontamination to ensure effective elimination of pathogens. Additionally, dental healthcare personnel responsible for treating patients with influenza-related infections should be appropriately immunized against the circulating influenza strains to reduce occupational susceptibility and enhance workplace safety. Following the global emergence of coronavirus disease 2019 (COVID-19), dental infection control protocols underwent substantial modifications to address the elevated risks associated with aerosol transmission [7]. Recent evidence has suggested that preprocedural mouth rinses containing hydrogen peroxide diluted to 1% with distilled water may help reduce salivary viral load before dental treatment [7]. Similarly, rubber dam isolation has gained increased importance during the COVID-19 pandemic because it effectively reduces aerosol contamination during clinical procedures [7]. Despite these recommendations, many dental facilities are not structurally designed to implement all airborne infection control measures, particularly negatively pressurized rooms. Therefore, effective patient

screening systems, early identification of potentially infected individuals, and comprehensive infection management protocols remain essential components of modern dental infection prevention strategies [1].

Respiratory Hygiene and Management of Patients with Bloodborne Infections

Respiratory hygiene represents an essential component of infection prevention and control strategies within dental healthcare environments, particularly for limiting the transmission of infectious agents spread through airborne particles and respiratory droplets. Because dental procedures frequently involve close patient interaction and aerosol generation, strict respiratory hygiene practices are necessary to reduce the spread of communicable respiratory diseases among patients, visitors, and healthcare personnel. Recommended preventive measures include implementing visible educational instructions at clinic entrances encouraging individuals to cover their mouths and noses while coughing or sneezing to minimize respiratory secretion dispersion [8]. Additionally, providing protective masks to patients presenting with respiratory symptoms contributes to reducing environmental contamination and airborne pathogen transmission within clinical settings. Patients and accompanying individuals experiencing symptoms of respiratory infections should generally avoid attending dental appointments unless urgent or emergency care is required. This preventive approach significantly decreases the likelihood of cross-infection within the healthcare environment. Furthermore, proper hand hygiene following contact with respiratory secretions remains a critical measure for interrupting pathogen transmission and maintaining infection control standards [8]. The management of patients diagnosed with bloodborne infections, including hepatitis B virus, hepatitis C virus, and human immunodeficiency virus, relies primarily on the consistent application of standard precautions during all dental procedures. No additional sterilization or environmental cleaning protocols are required solely based on a patient's infectious status because standard infection prevention measures are designed to provide adequate protection for all individuals receiving dental care. Dental healthcare personnel must maintain confidence in the effectiveness of established infection control protocols and apply these precautions uniformly and consistently with every patient regardless of known or suspected infectious conditions. Such an approach promotes patient safety, reduces stigma and discrimination, and ensures comprehensive occupational protection within dental healthcare settings.

Issues of Concern

Hand hygiene remains the single most important and most frequently emphasized measure for interrupting the transmission of pathogenic microorganisms in healthcare environments, including dental practice. The hands of healthcare workers serve as the principal vehicle for cross-contamination because they come into repeated contact with patients, instruments, contaminated surfaces, and body fluids during routine clinical activity [1]. For this reason, the consistent performance of hand hygiene is not merely a recommended practice but a central pillar of infection prevention and control. It contributes directly to reducing the spread of healthcare-associated pathogens and indirectly supports the containment of antimicrobial resistance within clinical settings [1]. When hand hygiene compliance is poor, microorganisms may be transferred from one patient or environmental surface to another, thereby sustaining transmission cycles that can compromise patient safety and occupational health. In this context, hand hygiene should be understood as a comprehensive concept that includes routine hand washing, antiseptic hand washing, antiseptic hand rubbing, and surgical hand antisepsis [1]. Each of these approaches serves a distinct clinical purpose, yet all share the common objective of decreasing microbial burden before, during, or after patient contact. Routine hand washing refers to cleansing the hands with plain soap and water and is the foundational method used to remove visible soil and transient microorganisms. Antiseptic hand washing, by contrast, employs soaps containing antimicrobial agents such as triclosan or chlorhexidine, which provide an enhanced reduction in microbial load. Alcohol-based hand rubs, which typically contain 60% to 95% ethanol or a comparable alcohol formulation, have also become an important component of hand hygiene programs because of their convenience and rapid antimicrobial effect. Nevertheless, alcohol hand rubs should not be regarded as complete substitutes for washing with soap and water, particularly when hands are visibly soiled or contaminated with organic material. Surgical hand antisepsis represents a more intensive form of hand hygiene performed by surgical personnel before operative procedures [1]. It is intended to reduce both transient and resident skin flora, thereby lowering the risk of microbial transfer during invasive care. Together, these methods form an integrated framework that supports safe clinical practice and reduces the probability of infection transmission.

The timing of hand hygiene is equally critical to its effectiveness. Hand hygiene should be performed before and after caring for each patient, with particular attention to the transition between donning and removing personal protective equipment. It is also necessary after direct contact with blood, saliva, and oral or respiratory secretions when hands may have been exposed to contamination [1]. Additional indications include the handling of sterile instruments, whether wrapped or unwrapped, prior to their use in patient care, and before surgical gloving when a sterile procedure is planned [1]. Hand hygiene must also be completed during environmental cleaning and decontamination activities, including the washing of instruments and devices and the completion of all

decontamination tasks. Before leaving the dental office, healthcare workers should perform hand hygiene to ensure that microorganisms are not transported outside the clinical area. These indications highlight the fact that hand hygiene is not a singular event but a repeated professional obligation that must be embedded throughout the workflow of dental practice. Personal protection is another major concern in infection control, particularly because dental professionals are routinely exposed to a variety of occupational hazards. Immunization represents a critical preventive measure that protects healthcare workers from vaccine-preventable infections and contributes to the maintenance of a resilient workforce. Dental healthcare personnel are exposed to infectious agents through close patient contact, exposure to aerosols, and accidental injuries, and are therefore at risk for acquiring common communicable diseases. Among these, hepatitis B is especially significant because of its efficiency of transmission and potential severity. All clinical staff should receive hepatitis B immunization within 10 days of patient contact [2]. Completion of the vaccination series generally occurs over a period of two to six months, during which workers may continue patient care as clinically necessary [2]. Protective immunity is considered achieved when hepatitis B surface antibody levels exceed 100 mIU/ml. Levels between 10 and 100 mIU/ml indicate a poor response, whereas levels below 10 mIU/ml classify the individual as a non-responder. This distinction is important because it informs the need for additional preventive action and reinforces the importance of post-vaccination testing in occupational health programs.

Beyond hepatitis B, immunization against other common vaccine-preventable illnesses is strongly recommended for dental personnel [9]. These include varicella in individuals who are seronegative, measles, mumps, and rubella for those who are not immune, pertussis, and annual influenza vaccination to protect against circulating strains [8]. Such immunizations help reduce the likelihood that healthcare workers become infected themselves and also reduce the risk of transmitting infections to vulnerable patients. Immunization, therefore, is not only a personal protective strategy but also a public health measure that supports patient safety, continuity of care, and outbreak prevention within healthcare facilities. Personal protective equipment constitutes another essential component of standard precautions and functions as a physical barrier against exposure to infectious agents. PPE is designed to protect the eyes, mucous membranes, skin, and clothing of the healthcare provider from splashes, sprays, and other forms of contamination [1]. In dental practice, this equipment typically includes masks, gloves, protective clothing, and protective eyewear [1]. The rationale for PPE use is grounded in the recognition that routine procedures may generate droplets or splatter containing blood, saliva, or other potentially infectious material. The appropriate selection and correct use of protective barriers are therefore integral to preventing occupational exposure. Masks are used to protect the nasal and oral mucosa as well as the exposed skin of the face and neck from splashes and spatter. However, masks do not provide reliable protection against aerosolized particles, which is why their limitations must be clearly understood. To maximize their protective value, masks must fit closely to the face [2]. They are intended for single use, and a fresh mask should be worn for each patient. The filtration performance of a mask declines over time, especially when moisture accumulates during prolonged procedures. For that reason, masks should be replaced during extended treatments when they become visibly damp or when filtration efficiency is likely to have diminished. Continuous mask use also helps prevent contamination of environmental surfaces with respiratory secretions from the operator, thereby supporting broader infection control efforts.

Glove use is equally important, although gloves must never be considered a substitute for hand hygiene. Hands should always be washed before donning gloves and again after their removal. Gloves should be changed whenever they are torn, punctured, or otherwise compromised [1]. Certain behaviors increase the risk of glove failure and percutaneous injury. Long fingernails and rings can puncture gloves and are therefore discouraged [1]. Wedding rings may be retained only when the underlying skin can be cleaned and dried effectively. Over prolonged periods, moisture accumulates beneath gloves, allowing the build-up of skin microorganisms. This reinforces the need to remove gloves promptly after procedures and to perform hand hygiene immediately afterward [1]. Gloves should also be removed in a manner that minimizes the chance of contaminating clean instruments or surfaces. Any cuts, abrasions, or breaks in the skin of the hands must be covered before gloves are worn, because damaged skin provides a portal of entry for microorganisms. Protective clothing is another core safeguard in dental infection control. Scrubs are commonly used as the daily uniform in dental practice, but additional protective layers, such as disposable or reusable gowns, should be worn when providing treatment. The design of the gown varies depending on the nature of the procedure. Short-sleeved gowns may be used for non-surgical care because they permit simultaneous washing of the forearms during hand hygiene, whereas long-sleeved sterile gowns are required for surgical procedures. Protective clothing worn in clinical areas must be removed before entering non-clinical spaces such as lunch areas or outside the clinic. An alternative approach is to wear street clothing beneath scrubs and remove the scrubs before moving outside the clinical

zone. When procedures involve a high risk of contamination with blood or substantial body fluids, especially aerosol-generating procedures, protective gowns are particularly important [2]. Because long sleeves become contaminated during treatment and can interfere with hand hygiene, these gowns should be changed after each patient [2]. Footwear also matters. Shoes should be closed to protect against injury from dropped instruments, resistant to slipping, and easy to clean so that they do not become reservoirs of contamination.

Protective eyewear is required to shield the eyes from penetrating trauma, flying debris, splashes, and sprays of biological fluids. Eye protection is especially important during scaling procedures, the use of rotary instruments, instrument cleaning, and the cutting or manipulation of wire. Effective protective eyewear should include side shields because ordinary reading glasses do not cover the orbit adequately and therefore offer insufficient protection. In situations where procedures are expected to produce substantial aerosols or splatter, face shields are recommended [1]. However, face shields should not be used in isolation because they do not protect against airborne pathogens. They must be combined with a surgical mask to provide comprehensive facial protection. Dental safety glasses can also be offered to patients during procedures to reduce the risk of chemical or physical injury from materials used in treatment. Tinted glasses may provide the added benefit of reducing glare from operating lights, improving comfort and visual tolerance during care. The safe removal of PPE is as important as its correct use because removal creates a high-risk moment for self-contamination. If PPE is taken off incorrectly, the wearer may transfer pathogens from contaminated outer surfaces to the hands, face, or clothing. The correct sequence begins with glove removal, since gloves are the most heavily contaminated item. They should be removed in a way that leaves them inside out and prevents contact with the external surface. Hands must be cleaned immediately if contamination occurs during this step. The disposable apron or gown should be removed next by breaking the neck strap and touching only the inside surface while gathering the material for disposal. The mask should then be removed without touching the outer surface, typically by lifting it from the ear loops or by breaking the straps. Protective eyewear should be removed last among the items listed, again avoiding contact with the contaminated exterior. Once all PPE has been removed, hand hygiene must be performed again without delay [10]. This sequence reduces the possibility that pathogens will be carried from the clinical setting to the healthcare worker's body or to the wider environment.

Sharps management is a further area of concern because percutaneous injuries remain one of the most serious occupational hazards in dentistry. A sharp is any object capable of cutting, puncturing, or otherwise injuring tissue. Needles and scalpel blades are the most obvious examples, but matrix bands, endodontic files, wires, and other dental devices may also produce injury if they are mishandled. To reduce the risk of exposure, all disposable sharps must be placed in puncture-resistant rigid containers located as close as possible to the point of use [7]. These containers should never be overfilled and should be sealed when they are approximately two-thirds full. Proper disposal practices minimize accidental injuries during transportation, handling, or later processing. Prevention of sharps injuries requires both engineering controls and safe work practices. Engineering controls refer to physical modifications that reduce the likelihood of injury, such as needle recapping devices, self-sheathing needles and scalpels, and rigid sharps containers [11]. These controls are important because they reduce dependence on individual technique alone. Work practice controls refer to behavior-based safeguards that support safe handling. Examples include avoiding the passing of unsheathed needles between staff members, not recapping needles using a one-handed technique, and minimizing the use of fingers during anesthesia administration [11]. These measures are practical, low-cost, and highly relevant because they directly address the moments when accidental exposure is most likely to occur. Together, consistent sharps management, rigorous hand hygiene, vaccination, and PPE use form a comprehensive system of protection that is essential for maintaining safety in dental practice. Overall, the concerns addressed above are interconnected and mutually reinforcing. Infection control in dentistry cannot rely on a single intervention. It depends instead on disciplined adherence to hand hygiene, targeted immunization, correct use of PPE, careful management of sharps, and a culture of safety that supports every phase of patient care. When these measures are applied consistently, the risk of transmission of infectious agents is substantially reduced, and both patients and dental healthcare personnel are better protected from preventable harm.

Cleaning and Disinfection

Cleaning, disinfection, and sterilization procedures represent essential foundations of infection prevention and control within dental healthcare settings. Dental instruments and clinical surfaces are routinely exposed to blood, saliva, oral secretions, and contaminated biological materials during patient care procedures, making effective decontamination practices critical for reducing the risk of cross-infection and maintaining a safe clinical environment. Proper cleaning and sterilization protocols contribute significantly to interrupting the transmission of pathogenic microorganisms among patients and healthcare personnel while ensuring compliance with established infection control standards. The initial stage of instrument processing involves thorough cleaning before sterilization because residual organic debris may interfere with the effectiveness of

subsequent sterilization procedures. Mechanical cleaning methods are generally preferred over manual cleaning because they provide greater efficiency, consistency, and safety during instrument decontamination [12]. Mechanical cleaning systems substantially reduce direct handling of contaminated instruments, thereby lowering the risk of occupational exposure to bloodborne pathogens and decreasing the likelihood of percutaneous injuries among dental healthcare workers [12]. Common mechanical cleaning methods include the use of thermal disinfectors, instrument washers, and ultrasonic cleaning devices, all of which facilitate effective removal of organic debris and microbial contamination from dental instruments. Manual cleaning is generally discouraged because it increases the probability of accidental injuries and direct contact with contaminated materials. However, when manual cleaning becomes necessary, strict procedural precautions must be followed to minimize occupational hazards. Instrument cleaning should occur within a specifically designated sink containing lukewarm water and an appropriate detergent formulated for instrument decontamination. The temperature of the water used during cleaning is particularly important because excessively hot water may cause coagulation of proteins present in blood and body fluids, making debris more difficult to remove from instrument surfaces. Conversely, cold water may solidify lipids and organic materials, further complicating the cleaning process. Instruments should be cleaned using long-handled brushes while maintained beneath the water level within the sink to reduce splashing and aerosol generation. Following cleaning, instruments must be rinsed with warm or hot water because elevated temperatures facilitate faster drying. Subsequently, all instruments should undergo careful visual inspection under appropriate lighting and magnification to ensure complete removal of debris and confirm cleanliness prior to sterilization [7].

Within the dental environment, all removable equipment capable of withstanding sterilization procedures should undergo sterilization after use. This includes dental handpieces and other reusable instruments that come into direct contact with oral tissues or contaminated body fluids. Certain fixed equipment, including dental chairs, radiographic devices, operating lights, and related environmental surfaces, cannot typically undergo heat sterilization and therefore require routine disinfection using approved chemical agents [7]. Digital radiographic sensors require additional protective measures because they are frequently contaminated during intraoral imaging procedures. The use of disposable protective barriers around digital sensors helps reduce contamination during patient use, after which the sensors should undergo cleaning followed by heat sterilization or high-level disinfection between patients [1]. Dental handpieces are classified as semi-critical devices because they come into contact with mucous membranes and potentially contaminated materials during treatment procedures. Due to the complex internal structure of handpieces, chemical disinfectants alone are often incapable of penetrating and eliminating microorganisms present within internal components. Consequently, heat sterilization remains the preferred and recommended method for decontaminating dental handpieces between patients [1]. Similarly, ultrasonic scaler components require appropriate decontamination practices, including immersion in 70% isopropyl alcohol to assist in removing organic debris and reducing microbial contamination [1]. Environmental surface disinfection also constitutes a major component of infection prevention in dental settings because microorganisms may survive on clinical contact surfaces for prolonged periods. Various chemical disinfectants may be utilized for environmental decontamination, including sodium hypochlorite solutions ranging from 0.1% to 0.5%, ethanol concentrations between 62% and 71%, and 2% glutaraldehyde solutions [7]. These disinfectants are commonly applied to surfaces frequently contacted during clinical activities, including door handles, dental chairs, desks, elevators, and bathroom facilities. Additionally, clinical contact surfaces should ideally be covered with disposable protective barriers during patient care procedures. These barriers must be replaced after every patient to reduce surface contamination and limit indirect transmission of infectious agents. Immersion of contaminated instruments in sodium hypochlorite solutions before sterilization may also be performed as an additional disinfection step to reduce microbial load prior to definitive sterilization procedures [7].

Sterilization refers to the complete elimination or destruction of all viable microorganisms, including highly resistant bacterial spores, from reusable instruments and equipment. Effective sterilization is essential for preventing healthcare-associated infections and ensuring the safe reuse of dental instruments during clinical practice. Several sterilization techniques are available in dentistry, each possessing specific indications, advantages, and limitations. The most widely used methods include steam pressure sterilization and dry heat sterilization, while other specialized approaches include unsaturated chemical vapor pressure sterilization and ethylene oxide sterilization [1]. Steam pressure sterilization, commonly known as autoclave sterilization, remains the most frequently utilized sterilization method within dental healthcare facilities because of its reliability, efficiency, and practicality. This technique employs steam under high pressure and elevated temperatures to destroy microorganisms and bacterial spores effectively. Standard autoclave cycles

commonly involve temperatures of approximately 121 °C under a pressure of 15 pounds for around 20 minutes [2]. Alternative rapid sterilization cycles may use temperatures of 134 °C for approximately three to four minutes [9]. Steam sterilization offers several advantages, including rapid processing times and the ability to verify sterilization efficacy through biological and chemical monitoring systems. Nevertheless, certain disadvantages exist. Instruments that are sensitive to high temperatures or moisture cannot safely undergo autoclave sterilization. Additionally, carbon steel instruments and burs may experience corrosion and rusting following repeated steam sterilization cycles, and instruments require thorough drying at the completion of the sterilization process to prevent moisture-related contamination and damage [1].

Dry heat sterilization represents another important sterilization method in dentistry, particularly for instruments that cannot tolerate moist heat exposure. This method utilizes conventional dry heat ovens operating at high temperatures for defined periods. Dry heat sterilization may involve either static air systems or forced air systems depending on the equipment design. Although high temperatures may damage certain heat-sensitive materials, dry heat sterilization provides several advantages, including the absence of instrument corrosion and the ability to verify sterilization effectiveness through monitoring procedures. Lower-temperature cycles generally require longer processing times, and ovens must undergo regular calibration to ensure accurate temperature control and effective sterilization [1]. Industrial hot air ovens also possess the advantage of processing larger quantities of instruments simultaneously, making them useful in facilities with high instrument turnover. Unsaturated chemical vapor pressure sterilization is another sterilization technique occasionally utilized within dental practice. This method employs chemical vapors composed primarily of alcohol and formaldehyde under pressure to achieve sterilization. One major advantage of this method is the relatively short sterilization cycle combined with the production of dry instrument loads upon cycle completion. Additionally, corrosion-sensitive instruments are less likely to rust using this technique, and sterilization effectiveness can be reliably monitored [1]. However, certain limitations exist because instruments must be completely dry before processing, and thick surgical wrappings may inhibit adequate penetration of chemical vapors, thereby reducing sterilization efficiency [1].

Ethylene oxide sterilization represents a specialized low-temperature sterilization method suitable for heat-sensitive equipment and instruments that cannot tolerate conventional heat sterilization procedures. This method utilizes ethylene oxide gas within a fumigation chamber, allowing the gas to penetrate deeply into complex instruments and equipment such as dental handpieces [1]. Ethylene oxide sterilization provides effective microbial destruction and allows verification of sterilization efficacy through monitoring systems. However, important disadvantages limit its widespread use in routine dental practice. The process requires specialized aeration chambers to remove residual gas after sterilization because ethylene oxide possesses toxic properties and may present mutagenic and carcinogenic risks with improper handling or prolonged exposure [1]. Consequently, strict safety protocols are necessary when employing this sterilization technique. Overall, cleaning, disinfection, and sterilization processes represent indispensable elements of comprehensive infection prevention and control within dental healthcare environments. The consistent implementation of evidence-based decontamination procedures significantly reduces the transmission of infectious microorganisms, enhances patient safety, and protects healthcare personnel from occupational exposure to pathogens. Effective infection control depends not only on selecting appropriate cleaning and sterilization methods but also on ensuring strict adherence to standardized protocols, proper equipment maintenance, and ongoing monitoring of sterilization efficacy within clinical practice.

Clinical Significance

Accidental percutaneous injuries remain among the most important occupational hazards encountered in dental healthcare practice because dental professionals routinely work with sharp instruments in close proximity to blood, saliva, and oral tissues. These injuries frequently occur during the administration of local anesthesia, instrument cleaning, surgical procedures, recapping needles, or handling contaminated devices. A percutaneous injury is generally defined as an unintentional penetrating wound to the skin caused by a needle, scalpel blade, orthodontic wire, endodontic file, or any sharp object contaminated with blood or body fluids [13]. Such incidents are clinically significant because they expose healthcare personnel directly to potentially infectious biological material, thereby creating a substantial risk for the transmission of blood-borne pathogens including human immunodeficiency virus (HIV), hepatitis B virus (HBV), and hepatitis C virus (HCV). The clinical implications of occupational exposure extend beyond immediate physical injury because these incidents may also result in significant psychological distress, anxiety, and long-term health consequences for exposed personnel. Following accidental exposure, several important factors must be evaluated to determine the degree of transmission risk and the need for post-exposure management. The type of exposure is one of the most critical considerations because penetrating injuries generally carry a higher risk of pathogen transmission than superficial mucosal splashes. Similarly, the nature of the contaminated body fluid involved in the exposure must be assessed, since blood presents a substantially greater infectious

risk than saliva alone. The volume of contaminated fluid, duration of exposure, time elapsed since the incident, and the type of instrument or procedure involved are also essential determinants of transmission probability [8]. Additional considerations include whether the injury occurred through gloves or protective clothing and whether the source patient is actively viraemic, meaning that active viral replication and circulation are present within the bloodstream [8]. Deep injuries involving hollow-bore needles contaminated with fresh blood are generally associated with greater risk compared with superficial injuries caused by solid instruments. Consequently, every occupational exposure incident must undergo immediate and comprehensive clinical assessment to guide appropriate management decisions and minimize the likelihood of infection transmission.

If a percutaneous injury such as a needlestick injury occurs during dental treatment, the healthcare provider should immediately discontinue the procedure and initiate the established post-exposure management protocol [2]. Immediate wound care is considered essential for reducing contamination at the injury site. The affected area should be thoroughly washed with soap and running water while allowing gentle bleeding from the wound to facilitate removal of contaminants [1]. Vigorous scrubbing or tissue squeezing should be avoided because these actions may cause additional tissue damage. Following initial wound management, the incident must be promptly reported to the designated supervisor or occupational health authority, and detailed documentation should include the date of exposure, nature of the injury, type of device involved, and patient-related information. Serological testing often forms an essential component of exposure assessment and management. Recommended laboratory investigations may include testing for HIV antibodies, hepatitis C antibodies, and antibodies against hepatitis B surface antigens (anti-HBs) for both the exposed healthcare worker and the source patient when appropriate [8]. Although patients cannot be legally compelled to undergo testing, they should be appropriately counseled and encouraged to consent to diagnostic evaluation [2]. Furthermore, exposed personnel should undergo immediate medical consultation because physicians or occupational health specialists are responsible for conducting comprehensive risk assessments and determining the necessity of post-exposure prophylaxis according to the patient's infectious status, clinical history, and exposure characteristics [2]. Exposure to blood contaminated with HIV represents one of the most psychologically concerning occupational incidents among healthcare workers despite the relatively low transmission rate associated with such exposures. The estimated risk of seroconversion following a sharps injury involving HIV-positive blood is approximately 0.3%, whereas mucosal exposure to HIV-contaminated blood carries an estimated transmission risk of approximately 0.09% [8]. Although these percentages appear relatively low, the potentially life-threatening nature of HIV infection necessitates immediate and appropriate post-exposure evaluation. Even when post-exposure prophylaxis is not administered, exposed individuals require baseline testing, ongoing clinical monitoring, and serial follow-up investigations.

If the source patient is confirmed or suspected to be infected with HIV, post-exposure prophylaxis should be considered as early as possible because the primary goal of prophylactic therapy is to inhibit viral replication before systemic infection becomes established. Standard HIV post-exposure prophylaxis regimens commonly involve combinations of antiretroviral medications such as zidovudine and lamivudine. Alternative combinations may include lamivudine with stavudine or didanosine with stavudine. Expanded therapeutic regimens may additionally incorporate agents such as indinavir, nelfinavir, efavirenz, or abacavir depending on the level of exposure risk and resistance considerations [13]. However, the administration of HIV post-exposure prophylaxis must always consider the possibility of adverse drug reactions and medication-related toxicity. Consequently, prophylaxis is only recommended when significant occupational exposure has occurred and proper clinical risk assessment has been completed. The timing of prophylactic treatment is critically important because maximum effectiveness is generally achieved when medications are initiated within 24 to 36 hours after exposure [8]. HIV post-exposure prophylaxis is not indicated for exposure to non-blood-stained saliva because the transmission risk under such circumstances is considered negligible [8]. Follow-up management includes repeated HIV antibody testing at baseline, six weeks, twelve weeks, and six months after exposure to monitor for possible seroconversion [13]. During this period, exposed individuals should also be advised to report any acute flu-like symptoms, unexplained febrile illness, or manifestations suggestive of retroviral syndrome. Monitoring for adverse reactions associated with prophylactic medications is equally important to ensure treatment adherence and patient safety. In situations where the infectious status of the source patient is initially unknown, clinical decisions should be based on overall exposure risk and the likelihood that the source may belong to a high-risk group, such as intravenous drug users [13]. When rapid HIV testing becomes available and the source patient consents to testing, prophylaxis may be initiated immediately and later discontinued if test results are negative.

Occupational exposure to hepatitis C virus presents another important clinical challenge because no effective post-exposure prophylactic therapy

currently exists for HCV infection [14]. Following exposure to HCV-positive blood, the primary management approach involves careful clinical follow-up and early referral for specialized care if infection develops. The risk of HCV transmission varies according to the viral replication status of the source patient. When the source patient is HCV RNA negative on polymerase chain reaction testing, the estimated transmission risk ranges from approximately 1.8% to 3.1%. However, if active viral replication is present and the source patient tests polymerase chain reaction positive, the risk may increase to approximately 10% [14]. Recommended follow-up for exposed individuals includes baseline testing followed by repeat serological evaluation at three and six months after exposure. Liver function monitoring also constitutes an important component of surveillance because early hepatic inflammation may indicate developing infection. Consequently, laboratory investigations including aminotransferase and aspartate aminotransferase measurements are recommended at two, three, and six months following exposure [14]. Clinical follow-up should ideally be supervised by an infectious disease specialist or gastroenterologist capable of monitoring symptoms, interpreting laboratory findings, and initiating treatment when necessary. Hepatitis B virus exposure remains particularly significant in dentistry because HBV demonstrates extremely high infectivity compared with other blood-borne viruses. Post-exposure management for HBV involves both passive and active immunization strategies [14]. Hepatitis B immune globulin, a preparation containing human antibodies directed against hepatitis B surface antigens, is administered to reduce the likelihood of infection development after acute exposure [15]. If the source patient tests positive for hepatitis B surface antigen, the exposed healthcare worker's immunity status must be evaluated immediately. Individuals who have never been vaccinated, failed to develop immunity after vaccination, or demonstrate antibody levels below 10 mIU/mL are considered nonimmune and therefore require urgent intervention.

Management for nonimmune individuals includes administration of a single dose of hepatitis B immune globulin within 48 to 72 hours after exposure in addition to initiation of the hepatitis B vaccination series [14]. The recommended vaccination schedule includes the initial dose shortly after exposure, a second dose one to two months later, and a third dose six months after the first injection. Antibody levels should subsequently be reassessed approximately two to four weeks after completion of the vaccination series to confirm adequate immune response. Without appropriate post-exposure prophylaxis, the transmission risk of HBV from an infected source may exceed 30%, emphasizing the critical importance of rapid intervention and immunization [14]. The clinical significance of infection prevention and occupational safety in dentistry extends beyond individual exposure management because dental healthcare personnel encounter potentially infectious agents on a daily basis as part of routine patient care activities. Consequently, comprehensive infection control protocols remain essential for minimizing occupational risks and reducing disease transmission within dental environments [16]. Vaccination programs, proper utilization of personal protective equipment, adherence to sterilization standards, and effective environmental disinfection collectively contribute to maintaining safe clinical practice and protecting both patients and healthcare workers. Protocols specifically designed to prevent percutaneous injuries should be clearly established within every dental facility and communicated thoroughly to all clinical personnel, particularly newly recruited staff members. Regular review, reinforcement, and evaluation of these protocols are necessary to maintain compliance and ensure preparedness in the event of accidental exposure [14]. Similarly, healthcare institutions should establish detailed exposure management procedures and standardized risk assessment protocols to facilitate rapid and effective responses following occupational injuries.

Continuing education programs related to infection control and occupational safety remain critically important because advances in infectious disease management, sterilization technologies, and post-exposure protocols continue to evolve. Ongoing professional training helps reinforce awareness of infection prevention principles and strengthens adherence to evidence-based clinical practices. Proper sterilization and instrument processing techniques are also indispensable for preventing cross-contamination between patients and reducing healthcare-associated infections [14][16]. Ultimately, infection control principles must remain continuously integrated into all aspects of dental healthcare delivery. Dental professionals must maintain awareness of infection prevention not only during patient treatment but also during instrument processing, movement between clinical and non-clinical areas, environmental cleaning, and completion of daily work activities. Consistent adherence to these measures substantially reduces the risk of pathogen transmission, enhances occupational safety, and promotes the delivery of high-quality patient care within dental healthcare environments.

Conclusion:

Infection prevention and control practices remain fundamental components of safe clinical care within surgical and dental healthcare environments. Dental healthcare professionals face continuous occupational exposure to blood, saliva, respiratory secretions, contaminated instruments, and aerosol-generating procedures, all of which increase the risk of infectious disease transmission. The review demonstrated that effective implementation of standard precautions, including hand hygiene, sterilization, environmental disinfection, respiratory

hygiene, and appropriate use of personal protective equipment, significantly reduces cross-contamination and protects both patients and healthcare personnel. Furthermore, transmission-based precautions provide additional protection against airborne and highly transmissible infectious diseases, particularly during emergency treatment situations and respiratory outbreaks such as COVID-19. Proper management of sharps injuries, vaccination programs, and post-exposure protocols for HBV, HCV, and HIV remain essential for minimizing occupational hazards. Continuous professional education, adherence to evidence-based infection control guidelines, and regular monitoring of sterilization and safety practices are necessary to maintain high standards of healthcare quality and occupational safety. Consistent compliance with these preventive measures ensures safer healthcare environments and supports the delivery of effective patient-centered care.

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