# Surface Disinfection

# 12

MaryAnn T. Schneiderman and Deborah L. Cartee

## 12.1 Contaminated Environmental Dental Surfaces

There is the potential risk for dental health-care personnel (DHCP) and patients to be exposed to a variety of infectious materials during the delivery of dental care. Numerous pathogenic microorganisms that colonize the oral cavity, nasal, and respiratory tract have the potential to be disseminated both directly and indirectly throughout the dental treatment area. These organisms include but are not limited to: herpes viruses, HIV, hepatitis B and C, multiple species of *Staphylococci* and *Streptococci* and numerous other oral/respiratory viruses and bacteria [1]. Resultant contamination of environmental surfaces can serve as a reservoir for microbial dissemination to dental personnel, patients, instruments, devices, equipment, and other environmental surfaces. The longer organisms are allowed to remain on surfaces, the higher the chance of additional contamination and/or disease transmission [2].

Prevention of transmission of infections from contaminated surfaces is best accomplished by reduction of any source of contamination. The Centers for Disease Control and Prevention (CDC) document *Guidelines for Infection Control in Dental Health-Care Settings – 2003* reinforces the need for managing dental environmental surfaces and should serve as the standard for surface disinfection [1]. Reducing the degree of contamination on environmental surfaces in the dental treatment area lessens the probability of cross-infection and disease transmission. Contamination of the patient environment by bacterial and viral pathogens has frequently been associated with health-care-associated infections occurring in a wide range of health-care settings [3]. Improving environmental surface cleaning and disinfection is an integral component in preventing the transmission of pathogens and reducing health-care-associated infections [4].

M. T. Schneiderman (✉) · D. L. Cartee
Department of Advanced Oral Sciences and Therapeutics, School of Dentistry, University of Maryland, Baltimore, MD, USA
e-mail: mschneiderman@umaryland.edu



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### 12.1.1 Environmental Surfaces: Clinical Contact and Housekeeping

In the dental treatment area, any surface or equipment that does not directly contact a patient is designated as an environmental surface. Environmental surfaces in the dental treatment area are divided into two categories based on the degree and type of contamination to which the surface is exposed [1]. These categories include clinical contact surfaces and housekeeping surfaces. Clinical contact surfaces are any surfaces that might be directly or indirectly contacted or touched and become contaminated with blood or other potentially infectious materials by gloved hands, aerosol, instruments, devices, or other items in the course of providing dental care. Table 12.1 [5] provides a list of the most common clinical contact surfaces in the dental treatment area. All other surfaces that are not involved with patient contact and not directly touched during dental treatment, such as floors, walls, sinks etc., are designated as housekeeping surfaces.

**Table 12.1** Examples of Clinical Contact surfaces in a dental office

| |
|---|
| Air/water syringe handles |
| Air/water syringe hoses |
| Bracket tray or table |
| Chair control buttons |
| Chairside computers, keyboards, and mouse |
| Countertops |
| Dental team chairs (handles, backs) |
| Dental chair |
| Dental radiology equipment (including switches and dental sensors) |
| Doorknobs |
| Drawer handles |
| Evacuator controls |
| Evacuator hoses |
| Faucet handles |
| Handpiece control switches |
| Handpiece hoses |
| Headrest on dental chair |
| Intercom |
| Light curing handle and tip |
| Light handles and switch |
| Mobile carts and cabinets |
| Pens/pencils |
| Shade guides |
| Supply containers of dental materials |
| Telephones |
| Ultrasonic scaling units |

Adapted from: Miller, CH., Palenik C. Surface and Equipment Asepsis In: Infection Control and management of hazardous materials for the dental team, fifth ed. Mosby, Elsevier Inc.; 2014. p. 152–166

## 12.1.2 Mode of Transmission

### 12.1.2.1 Direct and Indirect Contamination

Dental personnel and the dental treatment areas are typically exposed to blood, saliva, and other potentially infectious materials during the course of patient care. Environmental surfaces in the dental treatment area are exposed to a multitude of contaminated items on a routine basis. Contamination from any of these organisms may result in disease transmission that may occur from direct contact with infected body fluids and tissues or indirectly by contacting surfaces and/or devices that have been contaminated [1]. Anything that is placed into a patient's mouth is contaminated with that patient's microflora. Additionally, any dental provider who touches an instrument, device, or material that was in a patient's mouth is also contaminated with that patient's microflora and has the potential to spread contamination to other surfaces and/or instruments and devices throughout the dental office. Furthermore, any environmental surface that comes in contact with an instrument, device, or material that was in a patient's mouth is also contaminated. This microbial contamination can be disseminated through the following potential routes of transmission:

1. Direct contact with blood, oral fluids including saliva, other body fluids, or other patient materials.
2. Indirect contact with contaminated objects including instruments, equipment, or environmental surfaces.
3. Contact of eyes, nose, mouth, and/or mucous membranes with droplets/spatter containing microorganisms generated from an infected person when they cough, sneeze, or talk.
4. By inhalation of airborne microorganisms that can remain suspended in the air for long periods [1].

### 12.1.2.2 Aerosols and Splatter

Instruments used frequently in routine dental procedures include rotary high- and low-speed dental handpieces, air abrasion, sonic and ultrasonic scalers, air polishers, and air–water syringes. All produce an aerosol spray and/or dental splatter. Depending on the dental procedure performed, aerosol from any of these instruments has the potential to contain droplets of water, saliva, blood, microorganisms, and other potentially infectious materials. Dental aerosols and splatter travel through the air, settle on treatment area environmental surfaces and equipment, the patient, dental personnel, or on the floor.

### 12.1.2.3 Aerosols as a Risk of Disease Transmission

The area contaminated by aerosols produced during dental procedures using high-speed rotary instruments is far larger than previously thought [6]. Additionally, when using an ultrasonic scaling instrument, aerosols have been found to remain in

the air for up to 30 min after the procedure [7]. Aerosols produced during dental procedures have the potential to transmit infectious diseases that can be transmitted by an airborne route. Numerous infections have been documented as being transmitted by an airborne route, the most common being the apparent transmission of cold and influenza viruses. There is evidence in the medical literature of the airborne spread of measles, tuberculosis, and severe acute respiratory syndrome (SARS) [8]. Therefore, aerosols generated in the dental treatment area create an additional potential risk for disease transmission to the immunocompromised patient and dental personnel [6, 7]. Reduction of the transmission of infections from aerosols and subsequent contaminated environmental surfaces in all health-care settings, including the dental treatment areas, is best accomplished by incorporating recommended infection control guidelines and standards into the routine practice of dentistry [1, 9].

## 12.2 Factors That Increase the Risk of Infection and Disease Transmission

### 12.2.1 Persistence of Pathogenic Microorganisms in the Dental Environment

Among the most important lapses of fundamental infection control principles are failure to perform hand hygiene and adequately disinfect environmental surfaces/devices [10, 11]. Contaminated environmental surfaces can serve as a reservoir for microbial pathogens. These bacterial, fungal, and viral pathogens can persist on inanimate surfaces for considerable periods of time (see Table 12.2a–c); for example, most Gram-positive bacteria can survive for months on dry surfaces [2]. Many Gram-negative species can also survive for weeks to months, and *Candida albicans* can survive up to 4 months on surfaces [2]. In one investigation, hepatitis C virus (HCV) was shown to maintain infectivity on surfaces for up to 6 weeks at 4 and 22 °C supporting the hypothesis that the increasing incidence of nosocomial HCV infections may be due to accidental contact with HCV-contaminated fomites and other hospital equipment even after prolonged periods following their deposition [11].

Antibiotic resistance is one of the biggest threats to global health [12]. Many resistant microorganisms cause infections that result in significant morbidity and mortality on a global scale [12, 13]. One of the most significant contributing factors in the spread of resistant infections, including MRSA as well as other drug-resistant organisms, is noncompliance with recommended infection control practices [14, 15]. The CDC estimates that more than two million people in the United States are sickened every year with antibiotic-resistant infections; and at least 23,000 Americans die each year from these infections [12]. Antibiotic-resistant infections are caused by numerous organisms such as:

- *Clostridium difficile.*
- Carbapenem-resistant *Enterobacteriaceae.*

**Table 12.2** Persistence of clinically relevant (a) bacteria on dry inanimate surfaces [2] (b) fungi on dry inanimate surfaces, and (c) viruses on dry inanimate surfaces

| | Duration of persistence (range) |
|---|---|
| (a) Type of bacterium | |
| Acinetobacter spp. | 3 days to 5 months |
| *Bordetella pertussis* | 3–5 days |
| *Campylobacter jejuni* | up to 6 days |
| *Clostridium difficile* (spores) | 5 months |
| *Chlamydia pneumoniae*, *C. trachomatis* | ≤30 h |
| *Chlamydia psittaci* | 15 days |
| *Corynebacterium diphtheriae* | 7 days to 6 months |
| *Corynebacterium pseudotuberculosis* | 1–8 days |
| *Escherichia coli* | 1.5 h to 16 months |
| *Enterococcus* spp. including VRE and VSE | 5 days to 4 months |
| *Haemophilus influenzae* | 12 days |
| *Helicobacter pylori* | ≤90 min |
| Klebsiella spp. | 2 h to >30 months |
| Listeria spp. | 1 day to months |
| *Mycobacterium bovis* | >2 months |
| *Mycobacterium tuberculosis* | 1 day to 4 months |
| *Neisseria gonorrhoeae* | 1–3 days |
| *Proteus vulgaris* | 1–2 days |
| *Pseudomonas aeruginosa* | 6 h to 16 months; on dry floor: 5 weeks |
| *Salmonella typhi* | 6 h to 4 weeks |
| *Salmonella typhimurium* | 10 days to 4.2 years |
| Salmonella spp. | 1 day |
| *Serratia marcescens* | 3 days to 2 months; on dry floor: 5 weeks |
| Shigella spp. | 2 days to 5 months |
| *Staphylococcus aureus*, including MRSA | 7 days to 7 months |
| *Streptococcus pneumoniae* | 1–20 days |
| *Streptococcus pyogenes* | 3 days to 6.5 months |
| *Vibrio cholerae* | 1–7 days |
| (b) Type of fungus | |
| *Candida albicans* | 1–120 days |
| *Candida parapsilosis* | 14 days |
| *Torulopsis glabrata* | 102–150 days |
| (c) Type of virus | |
| Adenovirus | 7 days to 3 months |
| Astrovirus | 7–90 days |
| Coronavirus | 3 h |
| SARS-associated virus | 72–96 h |
| Coxsackievirus | >2 weeks |
| Cytomegalovirus | 8 h |
| Echovirus | 7 days |
| HAV | 2 h to 60 days |
| HBV | >1 week |
| HIV | >7 days |
| Herpes simplex virus, type 1 and 2 | 4.5 h to 8 weeks |
| Influenza virus | 1–2 days |
| Norovirus and feline calicivirus (FCV) | 8 h to 7 days |
| Papillomavirus 16 | >7 days |

(continued)

**Table 12.2** (continued)

| | Duration of persistence (range) |
|---|---|
| Papovavirus | 8 days |
| Parvovirus | >1 year |
| Poliovirus type 1 | 4 h to < 8 days |
| Poliovirus type 2 | 1 day to 8 weeks |
| Pseudorabies virus | ≥7 days |
| Respiratory syncytial virus | up to 6 h |
| Rhinovirus | 2 h to 7 days |
| Rotavirus | 6–60 days |
| Vaccinia virus | 3 weeks to > 20 weeks |

Kramer A, Schwebke I, and Kampf G. How long do nosocomial pathogens persist on inanimate surfaces? A systematic review. BMC Infectious Diseases, 20,066:130, August 2006. Available at: https://bmcinfectdis.biomedcentral.com/articles/10.1186/1471-2334-6-130

- Drug-resistant *Neisseria gonorrhoeae.*
- Fluconazole-resistant *Candida,*
- Vancomycin-resistant *Enterococcus.*
- Multidrug-resistant *Pseudomonas aeruginosa.*
- Methicillin-resistant *Staphylococcus aureus* (MRSA).
- Drug-resistant *Streptococcus pneumoniae.*
- Multiple drug-resistant *Mycobacterium tuberculosis* [12–15].

Regarding level of concern, in 2013, the CDC prioritized bacterial concerns for the first time as "Urgent, Serious, and Concerning" [12].

#### 12.2.1.1 Urgent Threats

- *Clostridium difficile.*
- Carbapenem-resistant *Enterobacteriaceae* (CRE).
- Drug-resistant *Neisseria gonorrhoeae.*

#### 12.2.1.2 Serious Threats

- Multidrug-resistant *Acinetobacter.*
- Drug-resistant *Campylobacter.*
- Fluconazole-resistant *Candida* (a fungus).
- Extended spectrum β-lactamase producing *Enterobacteriaceae* (ESBLs).
- Vancomycin-resistant *Enterococcus* (VRE).
- Multidrug-resistant *Pseudomonas aeruginosa.*
- Drug-resistant Nontyphoidal *Salmonella.*
- Drug-resistant Salmonella Typhi.
- Drug-resistant *Shigella.*
- Methicillin-resistant *Staphylococcus aureus* (MRSA).
- Drug-resistant *Streptococcus pneumoniae.*
- Drug-resistant tuberculosis.

#### 12.2.1.3 Concerning Threats

- Vancomycin-resistant *Staphylococcus aureus* (VRSA).
- Erythromycin-resistant Group A *Streptococcus.*
- Clindamycin-resistant Group B *Streptococcus.*

### 12.2.2 Failure of Compliance with CDC Recommendations

Combating these emerging microbial threats necessitates strict adherence to the principles of infection control as delineated by the CDC [1, 16, 17]. Performing disinfection of environmental surfaces with an EPA-registered disinfectant after every patient contact is an essential component of this process that will help reduce the impact of antimicrobial resistance.

#### 12.2.2.1 Protocol for Emerging Pathogens

The CDC recommends that DHCP use chemical disinfectants approved by the EPA and FDA to disinfect environmental surfaces and medical equipment [18]. However, if no registered or approved products are available for a specific pathogen or use situation, DHCP are advised to follow the specific guidance regarding unregistered or unapproved (e.g., off-label) uses for various chemical germicides established by the CDC [18]. For example, no antimicrobial products are registered for use specifically against certain emerging pathogens (e.g., Norwalk virus), potential terrorism agents (e.g., variola major or *Yersinia pestis*), or disease agents [19].

## 12.3 Infection Control Recommendations

### 12.3.1 Standard Precautions

Infection control includes basic principles and guidelines that are designed to prevent disease transmission. *Standard Precautions* encompasses a broad range of infection control practices designed to reduce the risk of disease transmission in any health-care setting. These guidelines established by the Centers for Disease Control and Prevention (CDC) in 1996 replaced the *Universal Precautions* that were created in the 1980s to protect against the disease transmission of blood-borne pathogens. *Standard Precautions* guidelines are based on risk assessment and should be the foundation of infection control standards for all patient care [10]. They are designed to protect health-care personnel from infection and prevent cross-infection among patients from pathogens that can be spread by blood and any other body fluid [1]. Table 12.3 provides a list of the recommended CDC Standard Precautions in the dental setting [10]. Essential components of *Standard Precautions* include proper cleaning, management, and disinfection of all environmental surfaces [10].

Overall, the majority of dental practitioners accept and practice *Standard Precautions.* Because of this high degree of compliance, the rate of disease

**Table 12.3** CDC standard precautions in the dental setting [10]

| | |
|---|---|
| 1. | Perform hand hygiene |
| 2. | Use of personal protective equipment (PPE) |
| 3. | Respiratory hygiene/cough etiquette principles |
| 4. | Sharps safety (engineering and work practice controls) |
| 5. | Safe injection practices (i.e., aseptic technique for parenteral medications |
| 6. | Sterile instruments and devices |
| 7. | Clean and disinfect environmental surfaces |

Centers for Disease Control and Prevention (CDC). Standard Precautions, Updated June 18, 2018. Available at: https://www.cdc.gov/oralhealth/infectioncontrol/summary-infection-prevention-practices/standard-precautions.html

transmission in the dental office in the past three decades has been very low, but not inconsequential [1]. In 2007, a case of patient-to-patient transmission of hepatitis B virus infection associated with an oral surgery procedure was reported. Although the cause of infection could not be conclusively identified, this transmission was most likely linked to a contaminated surface and/or device [20, 21]. In 2014, a case of patient-to-patient transmission of hepatitis C virus was reported, again associated with oral surgery. While the exact mechanism, in this case, was not identified, contaminated surfaces may have played a role in the transmission [22]. In recent times, the increasing importance of contaminated surfaces that contribute to the spread of infectious diseases and the emergence and propagation of antimicrobial resistance raises the importance of adherence to Standard Precautions. Among the most important lapses of fundamental infection control principles are the failure to perform hand hygiene and adequately disinfect environmental surfaces/devices [23]. Performing disinfection of environmental surfaces in the dental setting is an essential component of infection control guidelines as established by the CDC [1].

### 12.3.2 CDC Guidelines for Surface Disinfection of Environmental Surfaces

The management of clinical contact surfaces in the dental setting is accomplished by either the use of surface barriers or the process of cleaning and disinfecting surfaces that are not barrier-protected. While disinfection and application of surface barriers are both effective, some surfaces are easier to cover, while disinfection may be the best methodology with other surfaces. The use of barrier protection or chemical disinfection is largely a matter of practicality and personal choice. Effectively managing clinical contact surfaces in the dental settings uses a combination of both approaches to reduce contamination. Each has advantages and disadvantages as well as specific indications. Table 12.4 provides a list of the advantages and disadvantages of surface barriers versus cleaning and disinfection of clinical contact environmental surfaces [24].

#### 12.3.2.1 Barriers

The purpose of surface barriers is to prevent contamination of the surface or equipment and reduce the need to clean and disinfect that surface or equipment before reuse [5]. Barrier protection is the most efficient way to protect difficult-to-clean,

**Table 12.4** Surface barriers versus cleaning and disinfection [24]

| Advantages | Disadvantages |
|---|---|
| *Surface barriers* | *Surface barriers* |
| Prevents contamination and cross-contamination | May need a variety of sizes and types of covers |
| Protects surfaces that are difficult to clean | Many plastics are nonbiodegradable |
| May be less time-consuming to perform | Undesirable aesthetic appearance |
| Reduces use and handling of disinfecting chemicals | May be more costly than chemical sprays and wipes |
| *Cleaning and disinfection* | *Cleaning and disinfection* |
| Fewer items to complete surface asepsis | Time-consuming when performed properly |
| May be less costly than surface barriers | PPE must be used to protect against chemical exposure |
| No alteration of office aesthetic appearance | Uncertainty if microbes are removed or killed |
| No plastic added to the environment | Some surfaces cannot be cleaned adequately |
| | Some chemicals may damage some surfaces |
| | Containers must be labeled properly |
| | Some disinfectants must be prepared daily |
| | Proper material safety data sheets must be on file in the office |
| | Chemicals are added to the environment |

Adapted from: Molinari, JA, Harte, JA. Environmental Surface Infection Control: Disposable Barriers and Chemical Disinfection. Cottone's Practical Infection Control in Dentistry, third ed., Baltimore: Wolters Kluwer, Lippincott, Williams & Wilkins; 2010. p. 171–183

electronic, and smaller surfaces. Surface barriers should be used on as many surfaces as possible, particularly on surfaces that are difficult to disinfect or access, and surfaces that are touched frequently by gloved hands during patient care and likely to become contaminated [1]. A variety of barrier materials are available, such as clear plastic wrap, bags, sheets, tubing, and plastic-backed paper. Any barrier material chosen to be used on clinical contact surfaces must be impervious to both moisture and fluid. Once properly affixed to the clinical contact surface, barriers are very effective in preventing both direct and indirect contamination [1]. Any barrier is considered a single-use disposable device and must be discarded after every patient encounter and replaced with a new barrier at the end of each patient contact. Figures 12.1, 12.2, 12.3, and 12.4 depict surfaces commonly protected by surface

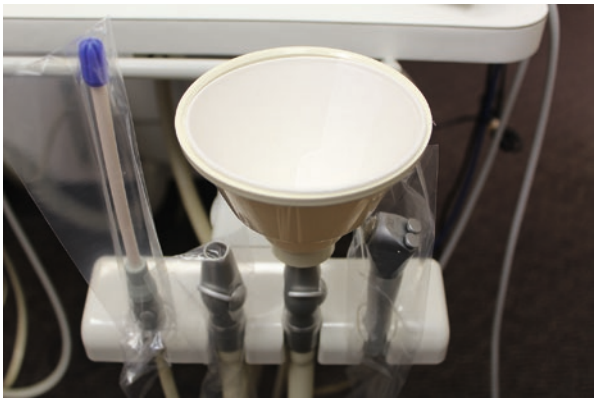

**Fig. 12.1** Barrier

**Fig. 12.2** Barriers

**Fig. 12.3** Mouse barrier

barriers in a dental treatment area. Barriers should never be used for more than one patient [1, 16, 17]. No surface disinfection is necessary if the barrier has remained intact throughout the entire procedure [1, 16, 17]. However, if a barrier has been breached (ripped, torn, fallen off) or the covered surface has evidence of contamination upon barrier removal, that surface needs to be cleaned and disinfected [1, 16, 17]. Barriers should be removed and discarded while the health-care personnel is

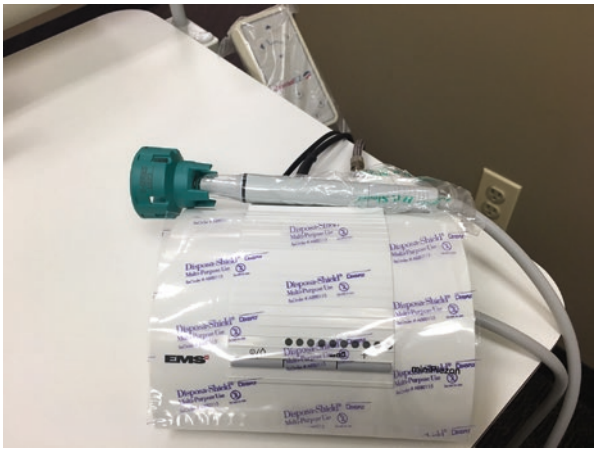


**Fig. 12.4** Piezo barrier

still wearing gloves. After ungloving and performing hand hygiene, the health-care personnel must cover these surfaces with clean barriers before the next patient encounter [25]. At the end of each day, every clinical contact surface, regardless if barriers are used, should be cleaned and then disinfected with an Environmental Protection Agency (EPA)-registered hospital disinfectant [1, 16, 17].

#### 12.3.2.2 Disinfectants

A surface barrier cannot effectively cover many surfaces in the dental treatment area. Clinical contact surfaces that do not have a surface barrier, or become contaminated during removal of a barrier, should be cleaned and disinfected after every patient contact with the use of an EPA-registered hospital disinfectant [1].

#### 12.3.2.3 Spaulding Classification

Earle H. Spaulding created an approach to disinfection and sterilization of patient-care items and equipment in health care. This classification system categorizes instruments and patient-care items that are intended for reuse as critical, semicritical, and noncritical based on the potential risk of infection posed to the patient from contamination on the device [26]. In 1991, the CDC proposed an additional category to Spaulding's classification system designated as "environmental surfaces", which further subdivided environmental surfaces into housekeeping surfaces and medical equipment surfaces [27]. Medical equipment surfaces are referred to in this text as clinical contact surfaces. Environmental surfaces are designated as noncritical because these surfaces generally do not come into direct contact with a patient or contact intact skin, and therefore carry the least risk of disease transmission [1]. Chemical disinfectants are categorized as high level, intermediate level, or low level based on the ability of the disinfectant to destroy or inactivate living organisms.

*High-level disinfectants* destroy all microorganisms, but not all bacterial spores.

*Intermediate-level disinfectants* destroy vegetative bacteria and the majority of fungi and viruses. Inactivates *Mycobacterium tuberculosis.* Does not necessarily kill bacterial spores.

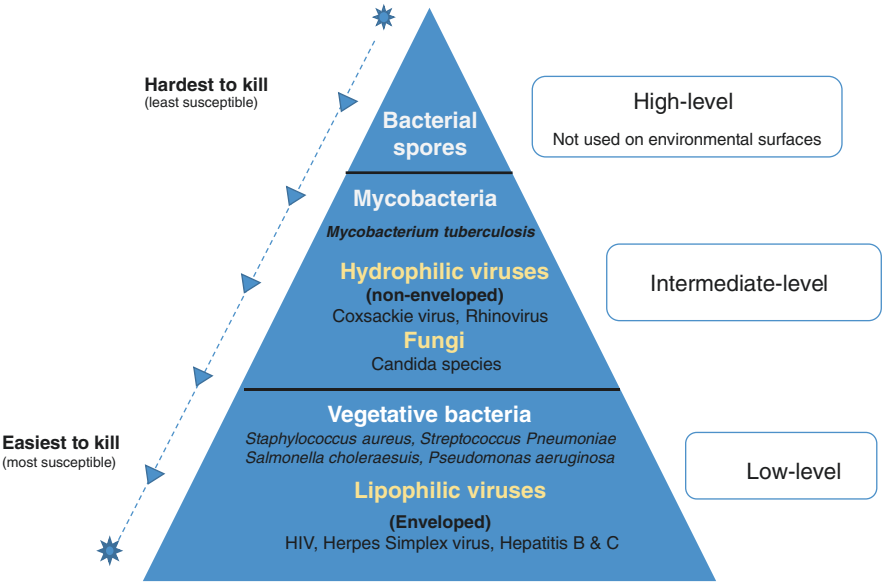


**Fig. 12.5** Microbial resistance to disinfectants [28]. (Modified from: Appendix A Regulatory Framework for Disinfectants and Sterilants: Centers for Disease Control and Prevention (CDC). Guidelines for infection control in dental health-care settings, 2003. *MMWR Morb Mortal Wkly Rep*. 2003, Dec. 19, 2003, Vol. 52, No. RR-17, 1–68. https://www.cdc.gov/mmwr/preview/mmwrhtml/rr5217a2.htm)

*Low-level disinfectants* inactivate vegetative bacteria, fungi, enveloped viruses (e.g., human immunodeficiency virus (HIV), and influenza viruses), and some non-enveloped viruses (e.g., adenoviruses) [25].

Figure 12.5 lists the microbes inactivated by intermediate- and low-level disinfectants [28]

### 12.3.3 Criteria for Selection of an Appropriate Disinfectant

Cleaning and disinfection of all clinical contact surfaces that are not covered with a surface barrier must be done between all patient contacts by using an EPA-registered hospital disinfectant. In 2003, the CDC broadened the list of agents acceptable for surface disinfection to include the use of a low-level disinfectant with an HIV/HBV claim on surfaces not visibly contaminated with blood [1]. However, an intermediate-level disinfectant may be used on any clinical contact surface regardless of the presence or absence of blood.

It is important to note that an intermediate-level disinfectant is specifically indicated when the surface is visibly contaminated with blood, and a low-level disinfectant is not appropriate to be used on surfaces contaminated with blood [1]. There is little if any cost differential between low- and intermediate-level disinfectants, and

the clinician may consider choosing the more versatile intermediate-level disinfectant [1]. Additionally, while low-level disinfectants may effectively inactivate blood-borne pathogens such as HIV and HBV, they are not effective against more resistant organisms that would be inactivated with a tuberculocidal product (an intermediate-level disinfectant) [1]. The use of a tuberculocidal agent that is effective against nonenveloped viruses offers a broader spectrum of antimicrobial activity, a property that is highly desirable for environmental surface disinfection in the dental office.

#### 12.3.3.1 EPA Registration

The EPA regulates liquid chemical disinfectants intended for use on clinical contact surfaces in the health-care setting [29]. Any other sterilants/disinfectants are regulated by the Food and Drug Administration (FDA) [30, 31]. Disinfectants intended for use on clinical contact surfaces (e.g., light handles, radiographic-ray heads, or drawer knobs) or housekeeping surfaces (e.g., floors, walls, or sinks) are regulated in interstate commerce by the Antimicrobials Division, Office of Pesticide Programs, EPA, under the authority of the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) of 1947, as amended in 1996 [32]. Enforcing FIFRA, the EPA requires registration of any substance or mixture of substances intended to prevent, destroy, repel, or mitigate any pest, including microorganisms [32]. Furthermore, *FIFRA explicitly requires users of products to follow the labeling directions on each product: all EPA-registered product labels states under the Directions for Use heading: "It is a violation of federal law to use this product inconsistent with its labeling."* [28]

The CDC *2003 Guidelines* state that only EPA-registered chemical disinfectants should be used in the dental setting to disinfect clinical contact surfaces. Therefore, the use of unregistered products is not recommended, and because it violates FIFRA, the user may be subject to fines and/or sanctions. Household bleach is not EPA-registered for this purpose, and diluted bleach is not acceptable to use on clinical contact surfaces in the dental office. Additionally, the use of liquid chemical sterilants/high-level disinfectants (such as glutaraldehyde and related chemicals) is not recommended for disinfecting environmental surfaces [1]. Whatever product a clinician elects to use, they must comply with all federal and state regulations regarding disinfectants. Clinicians must be aware of and adhere to manufacturer's directions for precleaning, appropriate personal protective equipment (PPE), safe handling, proper storage, and disposal of any product regulated by either the EPA or FDA.

The CDC/FDA designates any EPA-registered hospital disinfectant without a tuberculocidal claim as a low-level disinfectant and any EPA-registered hospital disinfectant with a tuberculocidal claim as an intermediate-level disinfectant [28]. However, EPA registers environmental surface disinfectants based on the manufacturer's microbiological activity claims when registering its disinfectant and does not use the terms intermediate-level or low-level disinfectants as used in CDC guidelines [33]. In order for a product to be labeled as an EPA hospital disinfectant, the manufacturer must submit data regarding the safety and effectiveness of the

product. Additionally, the product must pass the Association of Official Analytical Chemists (AOAC) effectiveness tests against three target organisms:

1. *Salmonella choleraesuis* for effectiveness against Gram-negative bacteria.
2. *Staphylococcus aureus* for effectiveness against Gram-positive bacteria.
3. *Pseudomonas aeruginosa* for effectiveness against a primarily nosocomial pathogen [1].

The EPA allows manufacturers to test specifically against organisms of known concern in health-care settings (HIV, HBV, HCV, and herpes). Any agents satisfying AOAC tests for hospital disinfectant designation would also be effective against these relatively fragile organisms when the product is used as directed by the manufacturer.

#### 12.3.3.2 Tuberculocidal Activity

Although tuberculosis is transmitted by airborne infective droplets and not transmitted by contaminated environmental surfaces, the ability to kill *Mycobacterium tuberculosis* is used as a benchmark to measure how effectively a disinfectant will kill microorganisms [34]. Tuberculosis is a very difficult organism to kill; only bacterial spores are more difficult to inactivate than *Mycobacterium tuberculosis.* Any chemical germicide with a tuberculocidal claim (Intermediate-level disinfectant) is considered capable of inactivating a broad spectrum of microorganisms of most concern in the dental setting, including less-resistant organisms such as blood-borne pathogens (e.g., hepatitis B and C viruses, HIV). More importantly, nonenveloped viruses such as coxsackievirus and rhinovirus (the cause of many upper respiratory infections), human papillomavirus (HPV, the cause of cervical and oropharyngeal cancer), and multiple species of fungi are inactivated by an intermediate-level disinfectant, but these organisms are not inactivated by low-level disinfectants [1, 15, 16].

#### 12.3.3.3 Selection of an Ideal Disinfectant

Although no perfect product for surface disinfection has been introduced to date, there is a large number of acceptable EPA-registered hospital disinfectants available for use in the dental setting. Table 12.5 [24, 35] describes the properties of an ideal disinfectant. The essential components for effective surface disinfection are the selection of the appropriate product for the intended purpose and correct application of the product while adhering to the manufacturer's label instructions [35]. The product selected for surface disinfection should be effective against the most common causes of health-care-associated infections (HAIs). Check the disinfectant label to verify the product is EPA-registered as effective against the microorganisms that are most commonly linked to HAIs. The contact time (or kill time) for a chemical disinfectant is the length of time it must remain in contact with a microorganism to achieve complete inactivation. A short contact time, of approximately 1–2 min, is desirable to ensure the product has killed the microorganisms before the disinfectant dries on the surface, and before staff or patient retouch the treated surface. A

**Table 12.5** Properties of an ideal disinfectant [24, 35]

| | |
|---|---|
| Broad spectrum | Wide antimicrobial spectrum. Lists kill claims for most common pathogens associated with HAIs and outbreaks |
| Fast-acting contact time | Rapid kill and short kill/contact time listed on label |
| Not affected by physical factors | Active in the presence of organic matter (e.g., blood, sputum, etc.) |
| Nontoxic | Not irritating to people. Should not induce allergic symptoms (including asthma and dermatitis). Choose product with lowest toxicity rating |
| Safe on surfaces | Should not corrode or disintegrate common health-care surfaces and equipment (e.g., rubber, plastic, cloth, metal, etc.) |
| Residual effect on treated surfaces | Should keep surface wet long enough to meet kill/contact times with a single application |
| Easy to use | Available in multiple forms, such as wipes, sprays, refills; directions for use are simple and contain PPE directions<br>Acceptable shelf-life; directions for use are simple and clear |
| Acceptable odor | Inoffensive odor to user and patients |
| Economical | Reasonable cost |
| Persistence | Sustained antimicrobial activity or residual antimicrobial effect on treated surface |
| Solubility | Should be soluble in water |
| Stability | Should be stable in concentrate and use dilution |
| Cleans and disinfects | Should have good cleaning properties |
| Nonflammable | Should have a flash point above 150 °F |

Adapted from:
Molinari, JA, Harte, JA. Environmental Surface Infection Control: Disposable Barriers and Chemical Disinfection. In: Cottone's Practical Infection Control in Dentistry, third ed., Baltimore: Wolters Kluwer, Lippincott, Williams & Wilkins; 2010. p. 171–183
Rutala WA, Weber DJ. Selection of the Ideal Disinfectant. Infection Control & Hospital Epidemiology. Cambridge University Press; 2014;35(7):855–65

surface must remain wet for the length of the required contact time. If a product dries too quickly, it will not achieve the required contact time to kill the microorganisms [35].

### 12.3.4 Disinfection Procedures

The fundamental first step in the disinfection process is cleaning the surface. The success of the disinfection process is compromised if the surface is not adequately cleaned first [34]. Incomplete removal of dust, dirt, and organic matter will interfere with the effectiveness of the chemical disinfectant by protecting the pathogen from adequate exposure to the disinfectant or reducing the antimicrobial activity of the disinfectant [35]. Products that accomplish both cleaning and disinfection offer a more efficient approach. A consideration for the selection of a chemical disinfectant is the product's ability to penetrate and preclean surfaces contaminated with blood and other organic matter [36].

#### 12.3.4.1 One-Step vs. Two-Step Disinfection

The one-step disinfectant contains a chemical formulation and/or detergent that allows for cleaning and disinfection with one single application, hence the terminology "One Step". A one-step product is effective in most clinical applications, and precleaning of the contaminated surface would only be required when the surface is visibly contaminated with organic or inorganic matter. The chemical composition of some disinfectants prevents them from being good cleaners. The use of these agents would require precleaning followed by disinfection under all conditions. Consequently, these are referred to as "Two-Step" germicides [21]. As suggested by the name, with the two-step product, the surface must first be cleaned with a detergent, and once the surface is thoroughly cleaned, it can be disinfected [3]. A second spray/wipe with an EPA-registered liquid chemical germicide is applied to the surface in the second phase of the two-step process [1]. The two-step process is commonly referred to as spray-wipe-spray, or wipe-discard-wipe when using a disposable disinfectant wipe [5].

The majority of disinfectants used in health-care settings are one-step products that clean and disinfect using the same product in one step rather than requiring two independent steps [35]. The most significant advantages of the one-step product are the application of a single disinfectant versus the use of two products saves considerable time and uses less product. The adverse effect that a disinfectant has on dental equipment such as chair upholstery, vinyl surfaces, etc., is an important consideration when choosing a product. Clinicians should check the manufacturer's label for surface compatibility of any chemical agent before application to the various surfaces in the dental office.

#### 12.3.4.2 Sprays and Wipe Formulations

Many EPA-registered hospital disinfectants are now available as presoaked wipes. The use of disinfectant wipes is becoming more widespread in the health-care environment [37, 38]. These products offer a convenient option for use of disinfectants and have a number of advantages. First, the wipe significantly limits the indiscriminate application of any chemical agent. The chemical is only applied to the area that the wipe contacts. This decreases human contact and the amount of chemical introduced into the environment. Wipes are also easy to use and store. The ease of use of ready-to-use cleaning-disinfection products has the potential to increase cleaning-disinfection compliance when compared to products that require daily preparation of solutions [38].

One drawback is that all staff must be educated to immediately close the lid on the wipe container. Leaving the next wipe exposed to air allows evaporation of the disinfectant liquid which may result in a reduction of the antimicrobial activity of the product [37]. Dental personnel who use the wipe for an insufficient amount of contact time, as stated on the manufacturer's label, may reduce the expected microbial decontamination of environmental surfaces and risk the spread of localized contamination over a wider area [37].

When using liquid germicide in either a premixed formula spray bottle or concentrate intended for dilution, it is important to follow the manufacturer's label

instructions for proper use. When using a one-step liquid cleaner disinfectant, the dental personnel should spray the surface with the disinfectant and wipe it with a disposable towel. If precleaning is required for visible contamination, the user would discard the towel and use a second spray to disinfect the surface [34]. Gauze sponges saturated with liquid germicide should not be stored in containers as this shortens the effectiveness of the solution [36]. Pump spray bottles, in most instances, are an appropriate method of applying liquid germicides, with the exception being the application of hypochlorite solutions. An advantage of a pump spray bottle is better penetration of the liquid germicide into crevices in the equipment where wipes may not effectively contact [36].

There is a lack of research about the safety implications of using spray disinfectant by health-care personnel [38]. The potential exists for a variety of clinical manifestations to be experienced by people exposed to chemical germicides. Symptoms that can occur from the excessive spraying of a disinfectant may include respiratory problems such as sneezing or wheezing, allergies, ocular irritation, and headaches [36]. Regardless of the type of surface disinfectant used, appropriate PPE must be utilized to protect the dental personnel from contact with any chemical agent.

#### 12.3.4.3 Environmental Surface Cleaning

Table 12.6 CDC recommendations for cleaning of environmental surfaces [1].

**Table 12.6** Environmental surfaces cleaning/disinfection recommendations [1]

| Environmental surface type | Examples | Recommendations for cleaning and disinfecting[a] |
|---|---|---|
| Clinical contact | Light handles<br>Switches<br>Computer keyboard/mouse<br>Drawer handles<br>Countertops<br>Faucets<br>Radiology equipment | Use barriers to protect surfaces, particularly for difficult to clean surfaces, and change barriers between patients<br>OR<br>Clean and disinfect surfaces that are not barrier-protected using an EPA-registered hospital disinfectant with low-level or intermediate-level properties<br>Use an intermediate-level disinfectant if surface is visibly contaminated with blood |
| Housekeeping | Floors<br>Walls<br>Sinks | Clean with a detergent and water or an EPA-registered hospital disinfectant on a routine basis, and when visibly soiled<br>Prepare fresh detergent or EPA-registered disinfecting solutions daily/or as instructed by manufacturer<br>Clean walls, blinds, and window treatments in patient-care areas when they are visibly dusty or soiled<br>Clean mops and cloths after use and allow to dry before reuse; or use single-use disposable mop heads and cloths |

Adapted from: Centers for Disease Control and Prevention (CDC). Guidelines for infection control in dental health-care settings, 2003. MMWR Morb Mortal Wkly Rep. 200; 52(RR-17):1–68. Available at: https://www.cdc.gov/mmwr/PDF/rr/rr5217.pdf

[a]High-level disinfectants should never be used on environmental surfaces

### 12.3.5 Disinfectant Chemical Formulation

There are many formulations of disinfectants and a product that contains a detergent has the obvious advantage of providing the clinician with a cleaner/disinfectant in one formulation. This reduces the number of items in the office inventory, is more convenient, and usually decreases cost. No two formulations of surface disinfectants are alike and they may vary greatly. Consequently, different chemical compositions afford different properties. Many disinfectants are used alone or in combinations (e.g., hydrogen peroxide and peracetic acid) in the health-care setting. These include alcohols, chlorine and chlorine compounds, formaldehyde, glutaraldehyde, ortho-phthalaldehyde, hydrogen peroxide, iodophors, peracetic acid, phenolics, and quaternary ammonium compounds, see Table 12.7 [42]. Commercial formulations based on these chemicals are considered unique products and must be registered with EPA or cleared by FDA [42].

## 12.4 International Disinfection Guidelines

The FDI World Dental Federation has published Infection Control in Dental Practice guidelines adopted in 2009 urge all dental health-care professionals to adhere to the principles of Standard Precautions [9, 39]. The stated general measures direct the dental team to incorporate principles of cleaning and disinfecting environmental surfaces in the workplace to protect themselves and patients against transmissible infections. The references for these guidelines are from the CDC [1] and the World Health Organization which indicate that the principles for surface disinfection of environmental surfaces are almost universally accepted [40].

The manufacturing and registration of environmental surface disinfectants is regulated by the Environmental Protection Agency (EPA) in the United States and by Health Canada as disinfectant drugs under the Food and Drugs Act and Regulations in Canada [32, 41]. Both regulatory agencies have similar disinfectant registration processes which review a manufacturer's test submissions of efficacy and safety data prior to approving their products and issuing an EPA registration number or a Health Canada drug identification number (DIN) for use and distribution in the respective countries [41].

Since 1998, with legislative revisions ongoing, the European Chemical Agency (ECHA), an agent of the European Union (EU), has been the regulatory authority for biocidal products such as household pesticides or disinfectants available on the European market. The current Directive establishes an approval procedure for biocides (disinfectants) and requires manufacturers, importers, or downstream users of substances or mixtures to: classify, label, and package hazardous chemicals appropriately before placing them on the European market [42]. The Health and Safety Executive (HSE) provides details of biocidal products authorized by the UK [43].

**Table 12.7** Widely Used Chemical Disinfectants in Health Care [42]

| Widely used chemical disinfectants in health care | | | |
|---|---|---|---|
| Agents | Spectrum | Advantages | Disadvantages |
| Quaternary ammonium compounds, also formulated with alcohol | Low-level | • Stable with good detergent properties (cationic detergent)<br>• Usually nonirritating | Relatively narrow microbicidal spectrum; range of activity can be expanded when combined with other agents, e.g., alcohols<br>Materials such as cotton and gauze pads can reduce microbicidal action |
| Alcohols (60–90%) including ethanol and isopropanol | Low- to intermediate-level | • Fast acting<br>• No residue<br>• Nonstaining<br>• Low cost | • Volatile, flammable, and an irritant to mucous membranes<br>• Inactivated by organic matter<br>• May harden rubber, cause glue to deteriorate, or crack acrylate plastic |
| Iodophores | Low-level | • Fast acting<br>• Nontoxic<br>• Nonirritating in normal use | • Occasional hypersensitivity reactions<br>• Inactivated by organic matter<br>• Expensive<br>• Avoid use on silicone<br>• Generally nonstaining, but some formulations may stain fabrics and synthetic materials |
| Chlorine and chlorine compounds: Sodium hypochlorite 5.25–6.15% (domestic bleach) at a concentration of 100–5000 ppm free chlorine | Low-to high-level | • Low cost<br>• Fact acting<br>• No residue<br>• Readily available<br>• Available as liquid, tablets or powders | • Corrosive to metals in high concentrations (>500 ppm)<br>• Inactivated by organic material<br>• Decolors or bleaches fabrics<br>• Releases toxic chlorine gas when mixed with ammonia<br>• Irritant to skin and mucous membranes, especially eyes (use in well-ventilated areas)<br>• Unstable if left uncovered, exposed to light, or diluted; store in opaque container<br>• Shelf life shortens when diluted (1:9 parts water) |
| Phenolics | Low- to intermediate-level | • Not inactivated by organic matter<br>• Commercially available with added detergents | • Leaves residual film on surfaces<br>• Harmful to the environment<br>• No activity against viruses |

(continued)

**Table 12.7** (continued)

| Widely used chemical disinfectants in health care | | | |
|---|---|---|---|
| Agents | Spectrum | Advantages | Disadvantages |
| Hydrogen Peroxide | Low (3%) to High (6%) level | • No activation—fast acting<br>• Strong oxidant<br>• No odor<br>• Environmentally friendly by products (oxygen, water, acetic acid) | Not compatible with brass, copper, zinc, nickel/silver plating |
| Aldehydes Gluteraldehyde: ≥2% alkaline or acidic solutions. Also formulated with phenol-sodium-phenate and alcohol | High-level | • Good material compatibility | • Allergic and irritating to skin and respiratory tract<br>• Must be monitored for continuing efficacy levels when reused |
| Ortho-phthalaldehyde (OPA) 0.55% | High-level | • Excellent stability over wide pH range<br>• Superior mycobactericidal activity compared to glutaraldehyde<br>• Does not require activation | • Expensive<br>• Stains skin and mucous membranes; may stain items not thoroughly cleaned<br>• Eye irritation<br>• Poor sporicide<br>• Must be monitored for efficacy during reuse |
| Peracetic acid 0.2–0.35% and other stabilized organic acids | High-level | • Rapid sterilization cycle time at low temperature (30–45 min at 50–55 °C)<br>• Active in presence of organic matter<br>• Environmentally friendly by products (oxygen, water, acetic acid | • Corrosive to some metals<br>• Unstable when activated<br>• May be irritating to skin, conjunctivae, and mucous membranes |

CDC Guidelines for Disinfection and Sterilization in Healthcare Facilities (2008) Available at: https://www.cdc.gov/infectioncontrol/guidelines/disinfection/disinfection-methods/chemical.html

## 12.5 Summary

Disinfection of noncritical environmental surfaces in the dental setting is an essential component of infection control guidelines. All clinical contact surfaces should be covered with a barrier or disinfected according to CDC recommendations [1]. Proper chemical disinfection can reduce the number of pathogens present in the dental environment and thereby reduce potential risk of infection to patients and dental health-care personnel.

## References


1. Centers for Disease Control and Prevention (CDC). Guidelines for infection control in dental health-care settings, 2003. MMWR Morb Mortal Wkly Rep. 2003;52(RR-17):1–68. https://www.cdc.gov/mmwr/PDF/rr/rr5217.pdf.
2. Kramer A, Schwebke I, Kampf G. How long do nosocomial pathogens persist on inanimate surfaces? A systematic review. BMC Infect Dis. 2006;20066:130. https://bmcinfectdis.biomedcentral.com/articles/10.1186/1471-2334-6-130
3. Carling PC, Huang SS. Improving healthcare environmental cleaning and disinfection current and evolving issues. Infect Contr Hosp Epidemiol. 2013;34(5):507–13. https://doi.org/10.1086/670222.
4. Donskey CJ. Does improving surface cleaning and disinfection reduce health care-associated infections? Am J Infect Control. 2013;41:S12–9. https://doi.org/10.1016/j.ajic.2012.12.010.
5. Miller CH, Palenik C. Surface and equipment asepsis. In: Infection control and management of hazardous materials for the dental team. 5th ed. Amsterdam: Elsevier; 2014. p. 152–66. https://evolve.elsevier.com.
6. Rautemaa R, Nordberg K, Wuolijoki-Saaristo K, Meurman JH. Bacterial aerosols in dental practice – a potential hospital infection problem? J Hosp Infect. 2006;64(1):76–81. https://doi.org/10.1016/j.jhin.2006.04.011.
7. Veena HR, et al. Dissemination of aerosol and splatter during ultrasonic scaling: a pilot study. J Infect Public Health. 2015;8(3):260–5. https://doi.org/10.1016/j.jiph.2014.11.004.
8. Harrel SK, Molinari J. Aerosols and splatter in dentistry: a brief review of the literature and infection control implications. JADA. 2004;135(4):429–37. https://doi.org/10.14219/jada.archive.2004.0207.
9. U.S. Department of Labor, Occupational Safety and Health Administration (OSHA). 29 CFR Part 1910.1030. Occupational exposure to bloodborne pathogens; needlesticks and other sharps injuries; final rule. Federal Register 2001; 66:5317–25. As amended from and includes 29 CFR Part 1910.1030. Occupational exposure to bloodborne pathogens; final rule. Federal Register. 1991;56:64174–82. http://www.osha.gov/SLTC/dentistry/index.html.
10. Centers for Disease Control and Prevention (CDC). Standard Precautions, Updated June 18, 2018. https://www.cdc.gov/oralhealth/infectioncontrol/summary-infection-prevention-practices/standard-precautions.html.
11. Paintsil E, Binka M, Patel A, Lindenbach BD, Heimer R. Hepatitis C virus maintains infectivity for weeks after drying on inanimate surfaces at room temperature: implications for risks of transmission. J Infect Dis Adv. 2013;23. http://jid.oxfordjournals.org/content/early/2013/11/22/infdis.jit648.full.pdf
12. Centers for Disease Control and Prevention (CDC). Antibiotic resistance threats in the United States. 2013. https://www.cdc.gov/drugresistance/threat-report-2013/pdf/ar-threats-2013-508.pdf.
13. The World Health Organization (WHO). Fact sheet October 2016, antimicrobial resistance. http://www.who.int/mediacentre/factsheets/antibiotic-resistance/en/.
14. Centers for Disease Control and Prevention (CDC). Healthcare-associated Infections: types of healthcare-associated infections, March 26, 2014. https://www.cdc.gov/hai/infectiontypes.html.
15. Centers for Disease Control and Prevention (CDC). CDC estimates 94,000 invasive drug-resistant staph infections occurred in the U.S. in 2005. October 16, 2007. https://www.cdc.gov/media/pressrel/2007/r071016.htm.
16. Centers for Disease Control and Prevention (CDC). Summary of infection prevention practices in dental settings: basic expectations for safe care. Atlanta, GA: Centers for Disease Control and Prevention, US Department of Health and Human Services; 2016. http://www.cdc.gov/oralhealth/infectioncontrol/guidelines/.
17. Centers for Disease Control and Prevention (CDC). Infection prevention checklist for dental settings: basic expectations for safe care. Atlanta, GA: Centers for Disease Control and

Prevention, US Department of Health and Human Services; 2016. http://www.cdc.gov/oralhealth/infectioncontrol/guidelines/.
18. Food and Drug Administration (FDA) and US Environmental Protection Agency (EPA). Memorandum of understanding between the FDA and EPA: notice regarding matters of mutual responsibility—regulation of liquid chemical germicides intended for use on medical devices. Rockville, MD: US Department of Health and Human Services, Public Health Service, Food and Drug Administration, US Environmental Protection Agency; 1993.
19. Food and Drug Administration (FDA). Interim measures for registration of antimicrobial products/liquid chemical germicides with medical device use claims under the memorandum of understanding between EPA and FDA. Rockville, MD: US Department of Health and Human Services, Food and Drug Administration; 1994.
20. Redd J, et al. Patient-to-patient transmission of hepatitis B virus associated with oral surgery. J Infect Dis. 2007;195:1311–4. https://academic.oup.com/jid/article/195/9/1311/892457.
21. Radcliffe RA, et al. Hepatitis B virus transmissions associated with a portable dental clinic, West Virginia. JADA. 2009;144(10):1110–8. http://jada.ada.org/article/S0002-8177(14)60523-7/pdf.
22. Weaver JM. Confirmed transmission of hepatitis C in an oral surgery office. Anesth Prog. 2014;61(3):93–4.
23. Siegel JD, Rhinehart E, Jackson M, Chiarello L, the Healthcare Infection Control Practices Advisory Committee. 2007 Guideline for isolation precautions: preventing transmission of infectious agents in healthcare settings. http://www.cdc.gov/ncidod/dhqp/pdf/isolation2007.pdf.
24. Molinari JA, Harte JA. Environmental surface infection control: disposable barriers and chemical disinfection. Cottone's practical infection control in dentistry. 3rd ed. Baltimore, MD: Wolters Kluwer, Lippincott, Williams & Wilkins; 2010. p. 171–83.
25. Sehulster LM, Chinn RYW, Arduino MJ, Carpenter J, Donlan R, Ashford D, Besser R, Fields B, McNeil MM, Whitney C, Wong S, Juranek D, Cleveland J. Guidelines for environmental infection control in health-care facilities. Recommendations from CDC and the Healthcare Infection Control Practices Advisory Committee (HICPAC). Chicago IL: American Society for Healthcare Engineering/American Hospital Association; 2004. https://www.cdc.gov/infectioncontrol/pdf/guidelines/environmental-guidelines.pdf.
26. Spaulding EH. Chemical disinfection of medical and surgical materials. In: Lawrence C, Block SS, editors. Disinfection, sterilization, and preservation. Philadelphia, PA: Lea & Febiger; 1968. p. 517–31.
27. Favero MS, Bond WW. Chemical disinfection of medical and surgical materials. In: Block SS, editor. Disinfection, sterilization, and preservation. 5th ed. Philadelphia, PA: Lippincott Williams & Wilkins; 2001. p. 881–917.
28. Centers for Disease Control and Prevention (CDC). Regulatory framework for disinfectants and sterilants. Appendix A. MMWR. 2003;52(RR17):62–4. https://www.cdc.gov/mmwr/preview/mmwrhtml/rr5217a2.htm.
29. Rutala, WA, Weber, DJ, and the Healthcare Infection Control Practices Advisory Committee (HICPAC). Centers for Disease Control and Prevention (CDC). Guideline for disinfection and sterilization in healthcare settings. 2008. https://www.cdc.gov/infectioncontrol/guidelines/disinfection/index.html.
30. Food and Drug Administration (FDA). Reprocessing medical devices in health care settings: validation methods and labeling guidance for industry and Food and Drug Administration staff. Rockville, MD: U.S. Department of Health and Human Services, Food and Drug Administration. March; 2015. https://www.fda.gov/downloads/MedicalDevices/DeviceRegulationandGuidance/GuidanceDocuments/UCM253010.pdf.
31. Food and Drug Administration (FDA). FDA-cleared sterilants and high level disinfectants with general claims for processing reusable medical and dental devices. Rockville, MD: U.S. Department of Health and Human Services, Food and Drug Administration; 2015. https://www.fda.gov/MedicalDevices/DeviceRegulationandGuidance/ReprocessingofReusableMedicalDevices/ucm437347.htm.

32. Environmental Protection Agency (EPA). Selected EPA-registered disinfectants. Antimicrobial registration. https://www.epa.gov/pesticide-registration/selected-epa-registered-disinfectants.
33. Food and Drug Administration (FDA). Memorandum of understanding between the United States Food and Drug Administration Public Health Service and The Department of Health and Human Services and The United States Environmental Protection Agency. MOU 225-93-4005. https://www.fda.gov/AboutFDA/PartnershipsCollaborations/MemorandaofUnderstandingMOUs/DomesticMOUs/ucm116796.htm.
34. Centers for Disease Control and Prevention (CDC). Cleaning and disinfecting environmental surfaces. March 25, 2016. https://www.cdc.gov/oralhealth/infectioncontrol/questions/cleaning-disinfecting-environmental-surfaces.html.
35. Rutala WA, Weber DJ. Selection of the ideal disinfectant. Infect Contr Hosp Epidemiol. 2014;35(7):855–65. https://doi.org/10.1086/676877.
36. Molinari JA, Harte JA. How to choose and use environmental surface disinfectants. Cottone's practical infection control in dentistry. 3rd ed. Baltimore, MD: Wolters Kluwer, Lippincott, Williams & Wilkins; 2010. p. 185–93.
37. Sattar SA, et al. Disinfectant wipes are appropriate to control microbial bioburden from surfaces: use of a new ASTM standard test protocol to demonstrate efficacy. J Hosp Infect. 2015;91:319–25. https://doi.org/10.1016/j.jhin.2015.08.026.
38. Kenters N, et al. Effectiveness of cleaning-disinfection wipes and sprays against multidrug-resistant outbreak strains. Am J Infect Control. 2017;45(8):e69–73. https://doi.org/10.1016/j.ajic.2017.04.290.
39. FDI World Dental Federation. Infection control in dental practice. Adopted by FDI General Assembly September 2009, Singapore. https://www.fdiworlddental.org/resources/policy-statements-and-resolutions/infection-control-in-dental-practice
40. World Health Organization (WHO). Practical guidelines for infection control in health care facilities. SEARO regional publication no. 41, WPRO regional publication. 2004. http://www.wpro.who.int/publications/docs/practical_guidelines_infection_control.pdf.
41. Health Canada. Guidance document – management of disinfectant drug applications. January 2018. https://www.canada.ca/en/health-canada/services/drugs-health-products/drug-products/applications-submissions/guidance-documents/disinfectants/management-disinfectant-drug-applications.html.
42. CDC guidelines for disinfection and sterilization in healthcare facilities. 2008). https://www.cdc.gov/infectioncontrol/guidelines/disinfection/disinfection-methods/chemical.html.
43. European Chemical Agency (ECA). An agency of the European Union. About us. https://echa.europa.eu/about-us.