REVIEW ARTICLE

Risk of Airborne Infection and Transmission-based Precautions in Dental Setting

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Abstract

In the current scenario of constant emergence and re-emergence of infectious diseases around the world, the dental fraternity must be well aware of the basic principles that govern infection prevention, and control to ensure preparedness and safe dental practice. Most dental procedures involve the use of one or more devices that generate spatter and aerosol. The dental aerosols may carry water, saliva, mucous, microorganisms, debris, calculus, blood, respiratory secretion, and/or metallic trace elements from restorative materials and possess a potential risk of disease transmission through inhalation to both the dental healthcare personnel (DHCP) and patients. Standard precautions taken during routine dental practice adequately protect the dental team and patients from the direct and contact-based transmission, but these precautions may not be sufficient to prevent airborne transmission of infectious diseases. Although the limited available evidence estimates the risk of airborne transmission in a dental setting to be low, it should not be underestimated. This narrative review aims to review the quantity, characteristic features, pathogenicity of aerosols produced in the dental settings, the associated risks, and precautions to be followed.

Keywords: Aerosols, Infection control, Infections, Saliva, Virulence.

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Introduction

In the year 1993, the Centers for Disease Control and Prevention (CDC) published recommended infection control practices for dentistry. It was primarily set on healthcare precedent, theoretical rationale, and expert opinion to reduce the risk of transmission of blood-borne pathogens among the dental healthcare personnel (DHCP) and patients.[1] These universal precautions were based on the principle that blood and all body fluids contaminated with blood is infectious. It also mandates to assume all patients to be asymptomatic carriers of blood-borne pathogens. In the year 1996, the CDC revised the above recommendations and adopted the term "standard precautions". Standard precautions apply to contact with (1) blood (2) all body fluid secretions, and excretions (except sweat), regardless of whether they contain blood, (3) nonintact skin, and (4) mucous membranes.[1] Hence, these precautions stand to embrace the standard of care provided to minimize the risk of disease transmission to the DHCP and patients through pathogens in blood and other body fluids, including saliva and respiratory secretions. Airborne transmission refers to the passage of microorganisms from a source to a person through aerosols, resulting in the infection of the person with or without the consequent disease.[2] Airborne transmission is categorized into three types: (1) Specific air transmission, that is, transmission caused by inhalation of aerosol particles under natural conditions [e.g., tuberculosis (TB)]; (2) Priority air transmission, that is, multiple transmission methods can cause the disease, but inhalation of aerosol particles is the primary mode (e.g., measles and chickenpox); (3) Opportunistic airborne transmission, occurs when a disease mainly spreads through contact and droplet transmission, but under certain conditions can also spread through inhalation of aerosol particle (e.g. influenza and SARS).[3] The World Health Organization (WHO) and CDC does not consider opportunistic airborne transmission as airborne.[4]

Only a few diseases (like TB, measles, and chickenpox) are recognized as 'true' airborne infectious diseases by American CDC infection control guidelines for healthcare and the WHO.[4] But there is an increasing understanding that many other organisms like *Bordetella pertussis*, influenza virus, adenovirus, rhinovirus, *Mycoplasma pneumoniae*, coronaviruses (SARS-CoV) and (SARS-CoV 2), Group A *Streptococcus* and *Neisseria meningitidis* where their acquisition, replication and/or colonization occur in the respiratory tract may also behave as 'airborne', given a favorable environment irrespective of their primary mode of transmission.[5] Reports also suggest that in a pandemic or massive, explosive outbreak situations diseases like influenza and SARS-CoV can become truly airborne.[6,7] Mouth as a part of the oronasal pharynx also harbors bacteria and viruses from the nose, throat, and respiratory tract in the saliva and oral fluids. Therefore, any dental procedure that aerosolizes saliva has the potential to cause airborne contamination of the dental setting.

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Airborne Transmission

Airborne transmission occurs through droplets and aerosols. Droplets are atomization of particulate liquid and solid particles when a person coughs or sneezes, or when water is converted into a fine mist through an aeration device or a shower head.[2]

Spatter refers to droplets usually greater than 100 µm in diameter, visible to the naked eye, with sufficient mass and kinetic energy dropping to the floor within seconds of expulsion. They may contain infectious bacteria and viruses harbored in blood, respiratory secretions, and saliva. They are capable of transmitting disease through direct contact with exposed mucous membranes of the eye, nose, and mouth or indirectly through fomites.[8] Human immunodeficiency virus (HIV) and hepatitis B (HBV) have been transmitted to healthcare workers by blood spatter.[9]

Aerosols are a dispersive system of suspended solid or liquid particles in gas and those aerosols that contain pathogens are considered infectious. They contain particle size ranging from 0.001 to over 100 μm.[10] Many have classified these droplets based on particle size, but it is generally accepted that (i) large droplets (>20 μm) that follow a more ballistic trajectory, as they are too large to follow inhalation airflow streamlines and usually associated with short-range transmission (1 m),[11] (ii) small droplets (<5–10 μm) that follow airflow streamlines and remain suspended for longer periods, (iii) intermediate droplets (10–20 μm) possess properties of both small and large droplets, settle faster than particles <10 μm, and potentially carry a smaller infectious dose compared to the large droplets.[8]

Fate of Spatter and Aerosol

The threshold size of large droplet fallout is 60–80 μm. Some exhaled large droplets (initial sizes of <60 μm) involved in droplet transmission can remain suspended in the air, but for a much smaller period than the air-change time scale of one hour in a typical room. Aerosols (particles <50 μm in diameter) are considered the greatest threat in airborne transmission diseases in dentistry. These can stay airborne and have the potential to enter respiratory passages around ill-fitted masks.[8]

A droplet nucleus is the airborne residue of a potentially infectious (microorganism bearing) spatter from which most of the liquid has evaporated.[12] Droplets that are less than 60 μm are more likely to evaporate, forming droplet nuclei (<10 μm) before hitting an object in its trajectory, remain airborne, and participate in long-range transmission.[2] In dry conditions, droplets evaporate quickly and can remain suspended in the air for a long time. There is evidence showing that the relative humidity, size distribution, and travel distances of droplet nuclei can significantly influence the risk of transmission of infectious diseases in the indoor environment. Early epidemiological and simulation studies of specific diseases have shown the risk range of droplet transmission is within 3 feet (0.9144 m) around the patient,[13,14] but SARS investigations during the 2003 outbreak showed that the spread of droplets from SARS patients was even greater than 6 feet (1.8288 m).[15] Droplet nuclei are implicated in the transmission of TB, SARS, measles, and herpes.[4]

Of particular interest are aerosol particles in the 0.5–10 μm diameter range (median particle diameter 5 μm). It is important to understand the role of the droplet size in disease transmission, particles of <5 μm can readily penetrate the airway down to the alveolar space and are highly capable of initiating a lower respiratory tract (LRT) infection. Particles of diameter around 10 μm can penetrate up to the glottis, beyond which the penetrability diminishes; particles >20 μm will probably impact respiratory epithelial mucosal surfaces or be trapped by cilia before reaching the LRT.[10] Older experimental studies and some recent field observations of influenza cases consistently associate aerosol-based transmission with a more severe form of the illness.[16–18] Therefore, particles of size <10 μm are of concern, for their significant qualitative differences including the prolonged suspension time, penetrability into the airways, and specific requirements for personal protective equipment (PPE).

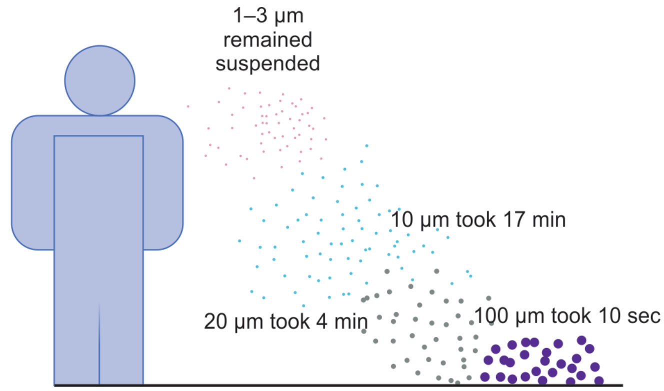

Fig. 1: Airborne particle size and time taken to fall on the floor from a height of 3m

Knight estimated the time taken for the particles of various diameters to fall 3 m.[10] Particles of diameter: 1–3 μm remained suspended almost indefinitely; 10 μm took 17 minutes; 20 μm took 4 minutes, and 100 μm took 10 seconds to fall to the floor (Fig. 1).[19] “Naked” viruses, bacteria, and fungal spores (i.e., without associated water, mucus, or pus droplets) range in approximate size from 0.02 to 0.3 μm, from 5 to 100 μm, and from 1 to 10 μm, respectively.[20] The amount of solid matter in a droplet ultimately determines its minimal size limit and infectivity. Infectious agents disseminated in mucus or saliva remain viable for a longer duration of time.

Risk of Airborne Transmission in Dental Setting

The microbial load of dental aerosol may vary widely depending upon its source. The common sources are the operating site (patient’s saliva, respiratory secretions, plaque, and tooth), water from the dental unit water lines (DUWLs), and/or contaminated dental instruments and devices. Qualitative and quantitative analysis of the makeup of dental aerosols would be extremely difficult, and the composition of aerosols probably varies with each patient and operative site. However, it is reasonable to suppose that components of saliva, nasopharyngeal secretions, plaque, blood, tooth components, and any material used in the dental procedure, like abrasives for air polishing and air abrasion, all are present in dental aerosols.

Micik et al. performed a series of interesting experiments to study the dynamics of dental aerobiology in the late 1960s and 1970s, recognizing the relevance of particles consisting of or conveying microorganisms, irritants, allergens, or other toxic substances that can be atomized into the air during the dental procedures as a potential source of disease transmission.[8,21,22] The results of their research showed that the dental procedures incorporating the use of water sprays or rotary instruments generated aerosols with significantly greater bacterial count (Box 1).[21]

The splatter landed six inches to four feet from the mouth of the patient and easily encompassed the area occupied by the dentist and his assistant.[23,24] An experiment using dye tracer demonstrated the spatter settled immediately and visible mist usually composed of droplets over 50 μm, gradually settled in less than one minute, within a few feet of their origin. The finest aerosols were invisible and traveled over 2 feet or more and continued to settle for at least 10 minutes despite air exchange rates of one every 4 minutes. The fluorescent dye not only coated the surfaces of the operator’s

Box 1: Aerosol generating activities

Patient activities	Sneezing	Produce 40,000 droplets projected to several meters which can evaporate to produce droplets of 0.5–12 µm in diameter[12,25]
	Coughing	Produce about 3,000 droplet nuclei
	Talking	5 minutes of talking approximate one cough[26]
Dental procedures	Polishing with cups	Similar to coughing[21]
	Air spray	
	Air turbine handpiece without water coolant	
	Air turbine handpiece with water coolant	An air turbine handpiece, when used with air-water spray coolant, atomized 20 times greater numbers of bacteria than with air spray alone[21]
	Ultrasonic scaling	Amounts to a maximum of aerosol generation[21,23,24]
	Polishing with a bristle brush	
	Air-water spray	

Note: The procedures involving air-water sprays generated aerosols with the greatest percentage of particles of 5 µm diameter or less[21]

arms, lower neck region, chest, and face shield but was detected in the nose of the operator too, through a single-layered face mask behind the face shields.[24]

Dental aerosol experiments were conducted in various dental setups. It was noticed that in a single closed or multiple chaired clinic, the aerosol required 10 minutes[24] to 2 hours to clear away from the operatory respectively, depending on the air changes.[27,28] The aerosol contaminated the whole room in a single closed operatory[29] and spread to areas distant from the treatment zone in multiple chaired open layout setup.[27,28,30]

Contaminated instruments and high-speed devices are the major sources of cross infection in dental settings. Viable virus was recovered from internal flushing of handpieces regardless of the antiretraction valve feature.[31–33] Blood-borne pathogens are rarely found in the oral cavity and when they do arise, they are present in low concentrations. A Lancet clinical trial clearly showed detectable levels of HIV and HBV, viral DNA recovered from the internal parts of the devices, and the connected air/water lines after treating known infected cases.[32] Many researchers demonstrated a significant increase in the quantity of airborne bacterial count during the dental procedures.[24,34–36] But most of them fail to identify, differentiate, and determine the pathogenicity of the dental aerosols owing to the inherent limitations of the methods used.

There is some evidence for greater prevalence of respiratory diseases among dentists.[37–39] Elevated antibody levels in dental workers[40] and a greater risk among susceptible patient groups[41] for *Legionella pneumophila,* has been documented. A study by Polednik revealed that dental drilling and grinding of restorations generated 16 times higher levels of the submicron sized particle with significantly elevated concentration of potentially toxic trace elements. This could pose serious health hazards to the dental team and patients on repeated exposures.[42]

Methods for Reducing Airborne Contamination in a Dental Setting

It is pertinent to meticulously follow the standard precautions, ensure strict adherence to hand hygiene and cough etiquette, disinfection and sterilization of dental instruments, and environmental disinfection to mitigate the risk of droplet and contact-based transmission. Although the risk of opportunistic airborne transmission in dental setup is believed to be low, the DHCP must be capable of identifying transmission-based risk, understand the basic principles of infection control and apply the same to break the cycle of infection.

Source Control

The best way to prevent airborne transmission is to prevent the pathogen from becoming airborne. The efficiency of operating field isolation with a rubber dam in reducing the levels of bacterial aerosols has been well documented since the 1960s.[21,43] Once the aerosol is disseminated from the oral cavity, properly installed high-velocity evacuation (HVE) during the dental procedures can be of a great value in eliminating most airborne particles.[21,44,45] But it is also important to note that the HVE will not attract or reduce the spatter and large droplets from the operating field as they have higher mass and kinetic energy to resist the airflow,[8] which further emphasizes the need for personal barrier and environmental disinfection. The HVE should not be released into the operatory.

Water from the DUWL makes up for most of the dental aerosol. Proper maintenance of the DUWL with a combination of commercially available micro filters, chemical treatment, and self-contained water systems is required to meet the quality standards recommended by American Dental Association (<500 CFU/mL).[46] Contaminated patient material has been shown to enter the DUWL through devices attached to them even though all dental units marketed post-1980 are prefitted with an antiretraction valve.[31,32] Therefore, it is essential to inspect water retraction periodically and add or replace antiretraction valves as and when indicated. The retraction effect is checked by observing the tip of the DUWL device coupling when the water is turned on and then off. A drop of water hanging from the tip is an indication that retraction is ineffective. Flushing of the device attached to the DUWL for 30 seconds at the beginning of the day and for 15 seconds after each patient is recommended by the CDC to limit cross-contamination.[46] The addition of extremely low concentrations of chemical disinfectants like sodium hypochlorite (0.01%),[47] povidone-iodine (0.5%), sodium chloride (0.05%), hydrogen peroxide (0.03%) to the DUWL has shown to effectively reduce the viability of microorganisms contained in the aerosol.[48] But their effect on handpieces and human safety has not been studied enough. High-speed devices that are attached to the DUWL must be cleaned, lubricated and heat sterilized between every use according to the manufacture's instruction.

The use of antimicrobial, preprocedural oral rinses has shown a reduction in the microbial count of dental aerosol[49,50] but its role in reducing the risk of disease transmission is not well-established. Antimicrobial rinses can only affect planktonic organisms in the oral cavity and it has no effect on dental plaque, does not penetrate subgingivally, is rapidly neutralized by blood in the operating field, and is less likely to affect viruses and bacteria harbored in the nasopharynx.[1] Yet the CDC recommends it as a good practice.[51]

Personal Protective Equipment

Standard precautions warrant the use of personal protective equipment like gloves, masks, protective eyewear, face shield, and gowns by the DHCP to protect the skin and mucosa from direct contact. Standard surgical masks would be considered an effective physical barrier against spatter and large droplets, as their size is too large to be inhaled around the sides of the mask which are not close-fitting. But, for effective protection from finer aerosol, protective eyewear with an adequate soft-tissue fit and multilayered, preformed, well-fitted face masks with higher filtration efficiency like N95 or equivalent are recommended.[1,22,24,52] The CDC also recommends respiratory protection (e.g., fit-tested, disposable N-95 respirators) while treating infected or suspected cases of TB.[1] To maximize protection, the mask must be worn at all times while the DHCP is within an aerosol generating operatory. Dental practices should have a respiratory protection program in place to train and test the fitting of respirators at least annually.

Engineering Controls

The three prerequisites for emphasizing the possibility of aerosol transmission are "closed environment", "high concentration", and "long-term exposure". Therefore, as long as one of the links is broken and the source and transmission routes are blocked, the spread of infectious diseases can be effectively prevented.

Aerosol generating procedures must be performed in a single-chaired, closed operatory with minimal items in the display when possible.[29] In dental practices or teaching institutions with multiple chair open layout, the recommended distance between 2 chairs is 6 feet,[51,53] but researches demonstrate an unacceptable increase in bacterial load and distances covered by aerosols generated in such settings. Easy to clean, floor to ceiling physical barriers between dental chairs are advised by the CDC for multiple chair dental setups (Fig. 2).[51]

Environmental Controls

Many environmental factors such as temperature, humidity, and airflow influence the viability and the fate of an airborne infectious agent.

Ventilation

Li et al., in their review on the transmission of infectious diseases found strong evidence between aerosol transmission and ventilation correlation.[2] Dilution and extraction ventilation, pressurization, airflow distribution and optimization, mechanical filtration, ultraviolet germicidal irradiation (UVGI), and humidity control are effective strategies for reducing the risk of dissemination of infectious aerosols.[54]

Mixing of the contaminated room air with uncontaminated air breaks the pockets of concentrated droplet nuclei. Eventually, the concentration of the contaminant in the room air will increase until the source is removed.

Dilution of the airborne contaminants with fresh air using natural (windows and doors), hybrid ventilation, or a heating ventilation and air conditioning (HVAC) system by increasing the air changes per hour (ACH) can greatly reduce the risk of indoor airborne transmission. Recommended ACH for the treatment room is a minimum of 6 to 12[20] and should be compatible with the occupancy and the equipment in the room.[51]

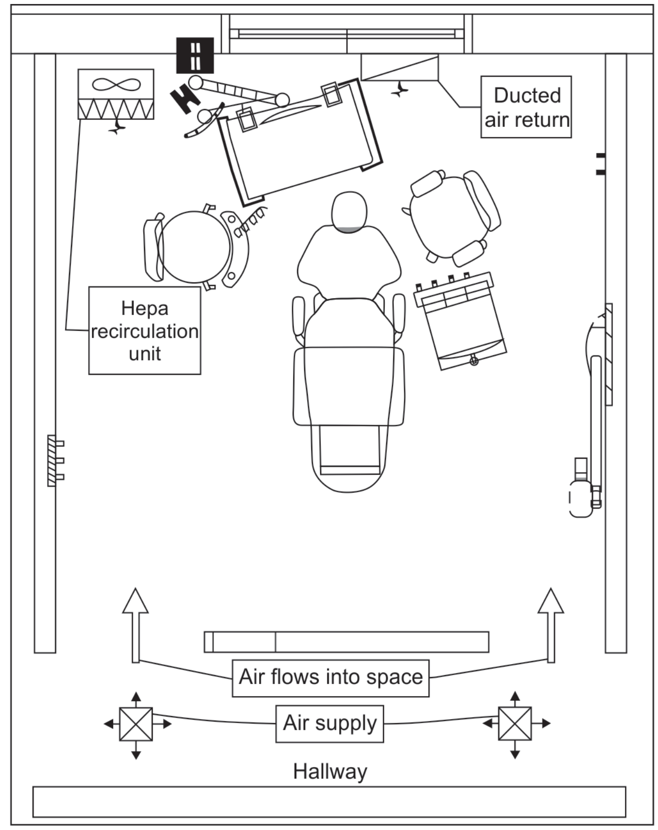

Fig. 2: Recommended dental setup blueprint given by CDC/NIOSH

Direction of Air Flow and Air Cleaning Strategies

The fresh air from the corridor should flow into the room, towards the DHCP and then the patient, and get exhausted to the outside. Slight changes in the natural airflow, temperature, or pressure differential might affect the direction of airflow. Better control over airflow can be achieved by careful positioning of the inlet vent in clean areas and the outlet exhaust in the dirty area closer to the patient.[51] The CDC recommends the treatment of a known case of airborne infectious transmissible disease to be done in an airborne infection isolation room (AIIR) or a negatively pressurized chamber.[1] Negative pressure rooms are fitted with ventilation modules capable of maintaining a pressure differential of 2.5 Pa (0.01 inch of water gauge). This ensures the airflow rate into the room is less than the exhaust flow rate to ensure the complete removal of airborne contaminants from the room.[20,55]

Filtration of the room air can effectively reduce airborne contaminants. A centralized HVAC system with an inbuilt high-efficiency particulate filter (HEPA 14) efficiently reduces the transport of airborne infectious agents in recirculated air.[56] Carefully selected and strategically placed single space HEPA filters (ceiling mount or portable) with CADR of 300–800 feet^3/minute, capable of achieving minimum 12 ACH can effectively reduce the airborne infectious load within a closed space and concurrently achieve directional airflow.[20,55] Although the evidence on the effect of air purification in the dental setting is limited,[57,58] the CDC recommends the use of portable HEPA filters (Fig. 3).[51]

Disinfection of the room air with (UVGI) of the Far-UVC energy range of 200–280 nm is the most germicidal and relatively safe. Most of the commercially available UVGI bulbs produce an optimum wavelength of 254 nm, which kills the microorganisms in the air by

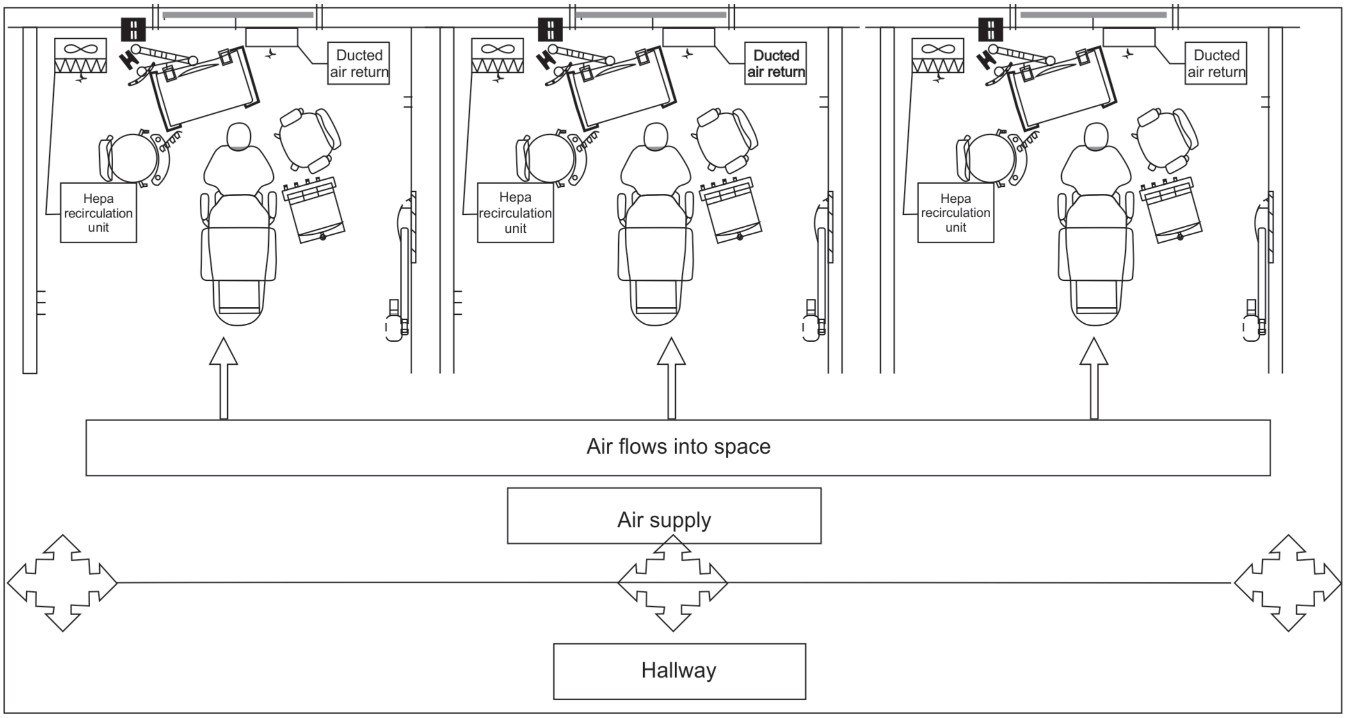

Fig. 3: Recommended design for multiple-chair open layout. Ensure there is at least 6 feet of space between patient chairs. Place physical barriers between patient chairs. Orient operatories parallel to the direction of airflow if possible

denaturing nucleic acid and proteins. The CDC interim guidelines during COVID-19 recommends the use of upper-room UVGI as an adjunct to improved air exchange and filtration.[54,55]

Temperature and Humidity

Ambient relative humidity (RH) can influence infectivity and spread of certain airborne infections like influenza.[54,59] Maintaining mid-range humidity levels of 40–60% indoor is reported to be the most detrimental to the survival of many microorganisms. Immunobiologists report RH levels below 40% increase the risk for disease by three folds, firstly by favoring the formation of droplet nuclei that remain airborne, secondly many viruses and bacteria are anhydrous resistant, and hence survive better at a lower relative humidity[60,61] and finally, RH below 40% is known to impair mucous membrane barrier and immune response.[62] Maintaining RH in low temperatures might run the risk of condensation and mold growth.

Conclusion

Currently, no evidence directly points to the spread of infectious diseases due to aerosols generated during the dental procedures, but the risk cannot be ignored. A suggested guideline for permissible microbial air contamination of hospital wards, surgeries, and operation theaters exists.[63] No such guidelines for dental setting exits. Most dental practices are isolated individual practice offering outpatient, ambulatory care, which lack epidemiologist or hospital infection control experts to monitor and track nosocomial infections. The recommendations and guidelines for safe dental practices are predominantly based on healthcare precedent, theoretical rationale, and expert opinion. Dental literature still lacks epidemiological surveys that accurately report occupation-related morbidity and mortality among the DHCP. In the absence of such data, it is only reasonable for the DHCP to adopt necessary precautions to ensure safe dental practice.

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