



Aerosols in Dental Practice- A Neglected Infectious Vector

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Authors' contributions

This work was carried out in collaboration between all authors. Author NR designed the review and drafted the initial manuscript. Author SM managed literature search and manuscript writing. Authors HSS and NP managed the literature search and proof reading. All authors read and approved the final manuscript.

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ABSTRACT

An aerosol is a suspension of solid or liquid particles in air or other gaseous environment. Sources of bacterial aerosols exist within and outside the dental clinic. The generation of bacterial aerosols and splatters appears to be highest during dental procedures. The use of rotary dental and surgical instruments and air-water syringes generates visible infectious spray, that enclose large-particle spatter of water, saliva, microorganisms, blood, and other debris. Several infectious diseases could be transmitted to staff and patients by airborne bacterial and other contaminants in the dental clinic. The vigilant use of barriers along with appropriate immunizations procedures could safe guard the dental fraternity from the ill-effects of the aerosols.

Keywords: Aerosols; splatter; vaccines; DHCP (Dental Health Care Providers); CDC (Centers for Disease Control); ACDP (Advisory Committee of Dangerous Pathogens).

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1. INTRODUCTION

The spread of infection through aerosol and splatter has long been considered one of the main concerns in the dental community. Even before the discovery of specific infectious agents such as bacteria and viruses, the potential infection by the airborne route was recognized. Dentists use high-energy equipment, such as drills and scalers, in the presence of bodily fluids such as blood, saliva and dental plaque. This combination has been shown to generate aerosols of oral micro-organisms, and blood. Combined effect, referred as Bioaerosols present a considerable microbial challenge to the patients, the dentist and nursing staff. Recent studies have confirmed that an aerosolized bacterial contamination is produced during the use of ultrasonic scalers, dental hand pieces and other dental equipments that produce an aerosol spray.

While the normal oral microflora of a patient contains high concentrations ($c10^8$. ml^{-1}) of Advisory Committee on Dangerous Pathogens (ACDP) hazard group 2 micro-organisms, [1,2] their aerosolisation is not thought to pose a serious health risk. However, when patients harbour viruses, either blood-borne or respiratory bacterial pathogens such as Mycobacterium tuberculosis, aerosol generation may prove a significant health hazard to dentists and their assistants. If infective aerosols persist there may be some danger of exposure in the waiting area and for subsequent patients. There is some evidence for greater prevalence of respiratory diseases [3,4,5] and elevated antibody levels to Legionella Pneumophila, [6] in dental workers. This paper aims to report and discuss the current literature on the hazards of aerosols in dentistry.

2. SOURCES OF MICROBIOLOGICAL RISK FACTORS

There are 4 basic routes of spreading harmful microorganisms in a dental surgery:

1. Blood borne route - Through the blood of an infected patient, viruses spread through blood (hepatitis B and C viruses, HIV virus) which cause serious health and life-threatening diseases.
2. Saliva droplet route -Through a droplet aerosol, emitted by an infected patient and containing particles of saliva, secretions from the gum, periodontium and teeth.

3. Direct contact with a patient and contaminated equipment.
4. Water droplet route - Through a water droplet aerosol emitted from handpieces of a dental unit which may contain microorganisms present in a unit reservoir, or developing in biofilm inside a unit tubing.

In particular, the use of oxygen masks, [7,8] and power tools in dental practice [9-12] and orthopaedics [12,13] may pose a risk of aerosol infection.

A recent systematic review demonstrated that adequate or inadequate ventilation has an effect on the risk of infection via infectious aerosols [14]. This interdisciplinary review, authored by a large group of engineers, microbiologists and epidemiologists, defined the following terms. Aerosols are a suspension of solid or liquid particles in a gas, with particle size from 0.001 to over 100 μm . Airborne transmission refers to the passage of micro-organisms from a source to a person through aerosols, resulting in infection of the person with or without consequent disease [15]. Infectious aerosols contain pathogens. A droplet nucleus is the airborne residue of a potentially infectious (micro-organism bearing) aerosol from which most of the liquid has evaporated [16].

On the basis of these definitions, the following clinically applicable distinctions are made between short-range airborne infection routes (between individuals, generally less than 1-m apart) and long-range routes (within a room, between rooms or between distant locations, generally greater than 1-m distances): The short-range airborne infection route depends on the close proximity of the infected source and susceptible host. A study was performed recently to define more clearly the size of the droplets originally referred to by Wells [16]. These terms are also in common current use. This study proposes the following size definitions: 'large-droplet' diameter $>60 \mu m$, 'small droplet' diameter 10 - 60 μm . Note that small droplets may also participate in short-range transmission, but they are more likely than larger droplets to evaporate to become droplet nuclei and then be considered as having the potential for long-range airborne transmission.

3. DENTAL AEROSOL AND SPLATTER

The terms "aerosol" and "splatter" in the dental environment were used by Micik and associates

in his pioneering work on aerobiology. The microflora of Dental Unit Water Lines (DUWL) and that of a patient's oral cavity exerts a decisive influence on the microbiological composition of dental aerosol produced by unit handpieces. Some of the characteristic features of aerosol and splatter is enumerated below (Table 1) [17-25].

The most intensive aerosol and splatter emission occurs during the work of an ultrasonic scaler tip and of a bur on a high-speed handpiece [21,26,27]. (Table 2) during conservative treatment and professional oral hygiene procedures, the sites showing the highest microbiological contamination due to aerosol and splatter are: doctor's and assistant's masks, a unit lamp, surfaces close to spittoons, and mobile instrument material tables. The main contamination route involves inhalation of infectious particles, that remain suspended in air, settle on surfaces and are reaspirated [28]. Among the microorganisms which are isolated from these contaminated surfaces include *Streptococcus* genus (42%), *Staphylococcus* (41%) and gram negative

bacteria. Microorganism isolated from the environment of dental clinic includes non-Diphtherial *Corynebacterium*, *Staphylococcus aureus* (0.6%), *Pseudomonas* spp. (0.6%) and fungi (0.9%) [29,30].

The dynamic oral environment being moist, contains certain metabolites that can favor bacterial growth. Hence the use of personal protection is critical. Study done by Nejabanes and associates in 2013 demonstrated that areas around nose and inner corner of the eyes are significantly at a higher risk of contamination [31]. Modern dental chair units consist of a network of interconnected narrow-bore plastic tubes called dental unit water lines. Quality of water delivered through these water lines pose considerable importance due to regular exposure of aerosols during dental procedures. Favourable environment for microbial proliferation and biofilm formation exist in the water pipeline. Contamination with high densities of gram negative microorganism like *Pseudomonas Aeruginosa* and *Legionella* species have been reported [32]. The microflora from the DUWL and the patient's oral cavity in the form of aerosol

Table 1. Characteristic features of aerosol and splatter


	Aerosol	Splatter
Definition	Liquid/solid particles	Mix of air, water, solid sub-fragments of dental fillings, carious tissues, sandblasting powder etc.
Particle size	<50 microns in diameter	50-100 microns in diameter or 15-120cm from patient's oral cavity
Suspension	Remains suspended for long duration	Have mass, kinetic energy, travel in a ballisted fashion on the faces and clothing of the operator and assistant and on near by surfaces.
		
Distribution	Capable of penetrating deep into respiratory system	Shows limited penetration into respiratory system
Inhalation	Common	Common
Skin contact	Common	Common

Table 2. Some of the dental devices/procedures known to cause air borne contamination [17,29,33]

Device	Contamination
Ultrasonic and sonic scalers	> amount of aerosol contamination
Air polishing	Contamination is equal to the use of scalers
Air-water syringes	Contamination is equal to the use of scalers
Tooth preparation with air turbine hand piece/air abrasion	> amount of aerosol contamination

mixes with the surrounding air thus leading to change in the original composition of the environment. Eventually it acts as a source of infection for both the dentist as well as the patients. It can also contaminate the nearby instruments on the instrument trays which can further act as a source of infection to the patient. Failure to attain the infection control can affect the dental personnel as well as the patient. The mode of spread of infection is through inhalation, contact with the mucous membrane of the conjunctiva, nose and oral cavity [29,30].

Snophia and associates in 2011 reported two patients contaminated with *Pseudomonas Aeruginosa* when treated in a dental clinic, where DUWL was the source of infection. The microorganism which was isolated from the oral abscess developed in these patients was the same strain isolated from the DUWL [34]. Other respiratory infections reported were mild flu and pneumonia, which was caused by *Legionella Pneumophila*, non *Pneumophila* spp and *Mycobacterium* spp including *Mycobacterium Avium*, *Staphylococcal* and *Streptococcal* infection [35-37]. Pankhurst and associates reported that the presence of *Legionella* antibodies in dental personnel is higher in comparison to the general population [35]. Immunocompromised individuals like HIV patients can be infected by *Mycobacterium Avium* as well as non Tuberculous *Mycobacterium* by inhalation, ingestion or inoculation in oral wounds. *Acanthamoeba* derived from the biofilm in DUWL is proven to cause amoebic keratitis in dental personnel and patient who wears contact lenses [38]. *Staphylococcal* infection, viral infection, conjunctivitis and other skin infection can also occur [39].

Among the risks which are fatal includes tuberculosis (TB) and severe acute respiratory syndrome (SARS). (Table 3) Cases reported so far, hypothesized that blood borne pathogens like

HIV, HBV, and HCV can be transmitted through the inhalation of blood containing aerosol via the microlesion in the mucosa of the airways which acts as the potential access for such viruses [40,41]. Study done by Pankhurst and associates, in 2005 demonstrated a temporal association between occupational exposure to contaminated DUWL output water with aerobic bacterial counts of more than 200 CFU/ml at 37°C and development of asthma in a subgroup of dentist following commencement of dental training [42].

Aerosols produced during dental treatment contain air from the instruments, water from DUWL, patient's saliva and blood. It is also always accompanied by splatter which can be contaminated with bacteria, viruses, fungi and protozoa [44]. The most severe aerosol and splatter production occurs during the usage of ultrasonic scaler tips and burs on a high speed handpieces [29,45]. (Table 2) there are various methods to intervene aerosol contamination [12]. (Table 4) a study done by Maghloutha and associates in 2004 demonstrated that the bacterial contamination in the dental aerosol decreased by 50-70 % at the end of the working day [33].

Index of Air Microbial contamination (IMA) is been proved to be a reliable and useful tool for monitoring the microbial surface contamination settling from the air in any environment. However, its use is not consensual for critical environments such as operating theatres [46]. Pasquarella and associates described the Index of Air Microbial contamination (IMA) based on the count of the microbes on to Petri dishes left open to the air in a dental set up, according to the 1/1/1 scheme (for 1 h, 1 m from the floor, at least 1 m away from walls or any obstacle). Classes of contamination and maximum acceptable levels were noted and a threshold of 25 was considered adequate [46].

Table 3. Risk to dental surgeons and patients through aerosol [43]

Condition	Habitat	Routes of transmission
Respiratory diseases		
1. Common cold	Upper respiratory tract	Aerosol, contact
2. Sinusitis	Upper respiratory tract	Aerosol, droplet
3. Pharyngitis	Upper respiratory tract	Aerosol, droplet
4. Pneumonia	Respiratory tract	Aerosol, droplet
5. Tuberculosis	Respiratory tract	Aerosol, droplet
6. SARS	Respiratory tract	Aerosol, droplet, intimate contact
7. Avian influenza (H5N1 flu)	Respiratory tract	Aerosol, droplet, intimate contact
8. Avian influenza (swine flu)	Respiratory tract	Aerosol, droplet, intimate contact

Table 4. Methods to intervene aerosol contamination [12,47-53,54,55]

Devices / methods	Technique / uses
Air disinfection is irradiation with a lamp emitting ultra-violet radiation 250-265 nm (the so called UV-c).	A very high fungicidal, viricidal and bactericidal action through destruction of DNA chain and protein denaturation
A patient should be treated in the supine position	Makes it possible for a doctor to avoid work in the breath way of a patient
Use of rubber dam	The use of a rubber dam eliminates contaminants arising from saliva or blood. Its usage will restrict source for airborne contamination to the tooth that is undergoing treatment. Some of the restorative procedures such as subgingival restorations root planing, periodontal surgery and routine prophylaxis and the final steps of crown preparation, it often is impractical to use a rubber dam. The use of aerosol reduction devices such as high-volume evacuator would be beneficial in such situations.
Use of high performance sucking device	Correctly positioned near a handpiece, is an effective method for aerosol reduction
A ventilation and air-conditioning system	Reduce contamination of a dental surgery environment, and prevent circulation of microbiologically contaminated air.
Maintenance of handpieces- "do not disinfect when sterilization is possible".	Sterilization of handpieces ensures their internal and external sterility eliminating 1) patient-patient Infection, and 2) contamination of waterlines with tissue fragments and micrororganisms
Use valves	Preventing suck back of liquids into DUWL; the valves should be replaced at appropriate intervals
Rinsing of dental units	1 st rinsing- assures elimination of microflora whose presence is due to the night stagnation 2 nd rinsing- where 20-30 second rinsing is recommended, is to help reduce the risk of retraction of the oral cavity fluids, and aims at elimination of potential cross infection
Units with closed water systems- regular cleaning, disinfection and sterilization of the unit water reservoir, filling it with distilled water and application of chemicals to monitor the microbiological quality of DUWL water	Microbiological control of water and safety of the unit users
Barrier protection - clothes, gloves, masks, protective goggles, visor shields.	Standard precautions and relatively inexpensive. A NIOSH-approved mask is certified by the US National Institute for Occupational Safety and Health (NIOSH) to have 95% filter efficiency- which indicates BFE/PFE (Bacterial/particle filtration efficiency), The protection in case of ill fitting masks-change masks between patients (after 20 minutes of usage) and during treatment if the mask becomes wet as more air passes through the edges of the mask-weakens the seal between the mask and face.
Preprocedural mouth rinse	Decreases bacterial count in the mouth and saliva, relatively inexpensive

It is a well-known fact that private dental clinics sometimes employ dental assistants who have not received certified training. Improperly trained personnel, however, may lead to poor infection control practices. It is the responsibility of every dentist to educate and train his or her assistants in the standard procedures. Furthermore, dental

health care personnel (DHCP) immunization status should be up to date. (Table 5) eliminating the risk of exposure to dental aerosols remains a difficult task. The best way to reduce the risks, however, is to employ routine cross-infection protocols recommended by the health authorities, such as the centers for

Table 5. Recommended vaccine to dental health care providers [56]

Hepatitis B	Two doses IM 4 weeks apart, third dose 5 months after second 1 st dose-immediately 2 nd dose-in one month One antiHBS serologic tested 1-2 months after 3 rd dose
MMR	One dose subcutaneous. No booster
Influenza vaccine (inactivated whole virus and split-virus vaccine)	Annual vaccination-one dose
Tetanus-diphtheria (toxoid)	1 st dose as soon as possible (even when previous dose of Tdap has been received) pregnant HCWs (Health Care Workers) need to get a dose of Tdap during each pregnancy
Varicella (live virus vaccine)	Two doses of varicella vaccine 4 weeks apart

disease control (CDC), who and ministries of health. To date, various infection control reports and procedures have been published to inform and educate DHCP about the importance of practicing adequate infection control. The necessity of immunization of a dental team against biological hazards in their workplace through specific (vaccines) or non-specific (e.g. Gamma globulin) immunization of the organism seems obvious

4. CONCLUSION

Dental fraternities are highly exposed to the hazardous effects of the aerosols and splatter produced during dental procedures. Since it is virtually impossible to completely eliminate the risk posed by dental aerosols, minimizing the risk by adopting protective procedures along with universal barrier techniques together with immunization protocol requires attention.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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