REVIEW ARTICLE

Dental Science

DENTAL AEROSOLS TO SPLATTER – GENERATION, COMPOSITION, DEPOSITION, SAMPLING TECHNIQUES AND PREVENTIVE STRATEGIES.

KEY WORDS: Aerosol; Bioaerosol; Dentists; Preventive strategies; Sampling; Splatter.

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ABSTRACT

Every day, human lungs filter an infinite number of particles from inhaled air. Lungs behave as serial filters with increasing order of filtration from nose and trachea up to the terminal alveoli. The filtration of inhaled air is related to the health of the mucociliary system. The particulate matter from air gets deposited in lungs and is influenced by size, composition, diffusivity and environmental setting. Such factors play a key role in differentiating the noxious potential in aerosol and splatter.

In the dental microenvironment, the dental team is constantly exposed to bioaerosols generated during treatment procedures. An adequate knowledge of risk factors encountered is required in understanding the health risk potential of airborne spread of allergens and infectious materials. Further, an awareness of modes of generation, spread, infection control measures and preventive strategies are required for maintaining a safe dental set-up.

1. INTRODUCTION:

The atmosphere can be considered as a colloidal system composed of gaseous, liquid and solid components. The composition of the atmosphere varies with time, relative humidity, temperature, location and air-flow characteristics. This colloidal system dynamically shifts to other phases (suspension or solution) based on its varying composition.

Aerosols are characteristic of ambient air. Our lungs are constantly challenged with exposure to aerosols. The composition of the aerosol determines the potential for health risk (Heikinen, 2005). Health risk potential of outdoor air is limited due to the bactericidal effects of desiccation, ozone, ultraviolet irradiation and constant natural ventilation. Air in poorly ventilated spaces, may contain pathogenic organisms that are shed from the humans and animals (Salem et al., 1994). Aerosols are occupational hazards for individuals in the health care industry. Dentists are frequently exposed to harmful aerosol by the nature of the site and proximity to working region (Zeymouri et al., 2017). Therefore, this study aimed to review evidence on aerosols, bio-aerosols, and droplet nuclei in dental setting, their generation, composition, deposition, sampling techniques and preventive strategies.

2. AEROSOL, BIOAEROSOL, MIST, SPLATTER AND DROPLET NUCLEI:

Micik et al., in 1969, were credited to first use the terms "aerosol" and "splatter".

2.1 Aerosols broadly refer to liquid or solid particles suspended in air by humans, animals, instruments or machines (Zemouri et al., 2017). Aerosols are invisible to the human eye, thus require specialized techniques to study and explore the generation, diffusion and potential to remain airborne. Aerosols produced can remain in the surrounding for a period of 30 minutes to 2 hours if left undisturbed (Taira et al., 2009). The smaller particles of an aerosol (0.5 to 10 m in diameter) have the potential to reach the smaller passages of the lungs and are thought to carry the greatest potential for transmitting infections (Harrel and Molinari, 2004).

2.2 Bio-aerosols are colloidal suspensions of liquid droplets or solid particles in air as dispersing medium, containing or having attached to them one or more living organisms (Salem and Gardner, 1994; Heikinen et al., 2005). These organisms include viruses, bacteria, fungi, protozoa or algae. It may vary in composition and concentration per unit area.

2.3 Splatter: This is usually a mixture of air, water and solid substance.

Size ranges are more than 50 m in diameter and is visible to the human eye. Heavy splatter will fall rapidly to the floor. It has sufficient mass and kinetic energy to move ballistically (droplet transmission) and quickly settle on objects due to the action of gravitation forces (contact transmission). The range of splatter deposition is from 15 to 120 cm from a patient's oral cavity (Micik et al., 1969; Szymanska, 2007).

Aerosol and Splatter both have the potential to be breathed in.

2.4 Droplet Nuclei: Splatter on evaporation, leaves behind aerosolized particles (droplet nuclei –≤10 m) that contain suspended microorganisms. It is an important source of airborne transmission of infectious particles (Salem and Gardner, 1994; Heikinen et al., 2005; Taira et al., 2009).

3. Health Implications Of Particulate Aerodynamics :

Aerosols are described in terms of Particle Aerodynamic Diameter (DAE) and Diffusive/Thermodynamic Diameter (DTH) that help characterize the behaviour of particles based on its size (Heikinen et al., 2005). As particle size decreases, the diffusion coefficient, diffusivity and particle deposition increases. In addition to particle characteristics, the dose of a biological agent in the respiratory tract also depends on pulmonary anatomy, breathing rate and pattern (nasal vs. oral breathing), health of the lung tissue, and host immune status (Salem and Gardner, 1994; Heikinen et al., 2005).

3.1 NASAL VS. ORAL BREATHING:

The inhaled air is sequentially filtered by the respiratory tract.

Site of deposition of the inhaled particles within the tract may vary in accordance with the type of breathing: nasal or oral breathing. Nasal breathing by design is more efficient at filtration than oral breathing. Nearly all inhaled particles larger than 10 micrometer are deposited in the naso-pharynx region during nasal breathing, but only 65% collect there with oro-nasal breathing. Mouth breathing allows particles to bypass the nose at least partially and increases the overall aerosol deposition in the deep lung (Salem and Gardner, 1994; Heikinen et al., 2005).

3.2 MECHANISM OF DEPOSITION

Not all particles that enter the respiratory tract are deposited in deep lung. There are five mechanisms for particle deposition in the respiratory system: impaction, interception, sedimentation, Brownian diffusion and electrostatic precipitation. Also, hygroscopic growth of particles influences the deposition by modifying their effective size. In combination with environmental conditions and hydrophilicity, the probability of deposition increases (Heikinen et al., 2005). Electrostatic charges may also alter the deposition potential of particles (Heikinen et al., 2005).

3.3 CRITICAL SITE & THRESHOLD DOSE:

Cytotoxic agents and allergens cause damage and necrosis of cells in proximity with no specific target site. Infectious particles (bio-aerosols) must be deposited as virulent organisms at a critical site and should be of threshold dosage, in order to incite a significant immune response (Wells et al., 1948; Salem and Gardner et al., 1994; Heikinen et al., 2005). The outcome of exposure to such agents depends on the concentration of microorganisms, the degree of virulence, and immune status of the host.

3.4 CLEARANCE OF DEPOSITED PARTICLES:

Depending on the site of deposition, the mechanism of clearance varies.

Particles that persist in the deep lung induce localized inflammatory reactions leading to tissue damage. The nature of the particle dictates their elimination potential. Materials such as Gold particles, Silica, Co-Cr alloys, Porcelains, Stainless steel, Titanium have low dissolution potential. Whereas, tooth, bone, apatite, wax, silicon rubber and acrylic resin are easier to disintegrate and dissolve (Taira et al., 2009). It has been reported that ionic-bond dominant particles are easier to disintegrate when compared to covalent-bond dominant particles (Taira et al., 2009).

4. DAMAGE BY FINE PARTICLES:

4.1 Alveolar macrophage reaction to fine particles:

Activity and efficacy of macrophages vary based on the nature of particle encountered. Macrophages phagocytose particles forming intracellular phagosomes. Phagosomes are eliminated by intracellular mechanisms - free radicle generation and/or low pH (Taira et al., 2009).

Damage to Macrophages occurs by: i) increased oxidative stress due to failure to eliminate inert particles or long fibers, ii) over phagocytosis leading to reduced cell mobility and iii) induced lymphocytic damage against specific phagocytosed biological particles (allergens) – type IV hypersensitivity (Taira et al., 2009).

4.2 Damage to lungs and organs:

Fine particles have the potential to cause damage not only to the lungs, but also to surrounding structures once deposited (Taira et al., 2009) (Figure II).

5. Sites With Highest Potential For Contamination:

Sites showing microbiological contamination due to aerosol and splatter in descending order are doctor's and assistant's masks, unit lamp, surfaces close to spittoons, mobile instruments and material tables. Operators and assistants have been demonstrated to be at significant risk for exposure to aerosols and splatter (Bentley et al., 2000). The central area of operator's face has been reported to be contaminated to a higher degree (Nejatidanesh et al., 2013). The most commonly isolated microorganisms from such contaminated surfaces are bacteria of the *Streptococcus* genus (42%), *Staphylococcus* (41%) and Gram-negative bacteria (17%) (Prospero et al., 2003).

6. COMPOSITION OF AEROSOL-SPLATTER:

Composition broadly varies with:

- Type of procedure
- Site and tissue involved
- Surrounding environment (dry/wet field)

(Harrel and Molinari, 1995)

6.1 Micro-organisms in aerosol:

Microorganisms may be incorporated in the aerosol through two major sources. These include:

6.1.1) Patient's oral cavity

- Saliva
- Plaque
- Naso-pharyngeal secretions
- Blood borne pathogens
- Tooth components

6.1.2) Dental equipment

- Dental unit water lines (DUWLs)
- High speed instruments

6.1.1 Oral Cavity:

It has been reported that patient's oral cavity can be a significant source of aerosol harboring pathogenic microbes providing optimal environment favouring microbial growth (Harrel and Molinari, 1995). Pathogenic microbes such as bacteria, viruses and fungi have been isolated and cultured from air samples, with hazardous implications. The bacterial species isolated from patient's oral cavity are *Streptococci sp.* and *Staphylococci sp.* (including Methicillin resistant *Staphylococcus aureus*), *Mycobacterium tuberculosis*, Gram negative organisms such as *Porphyromonas gingivalis* (Osorio et al., 1995 and Bennet et al., 2000).

Viruses such as Rhino virus, Influenza virus, Herpes virus Hepatitis B and C and HIV have also been isolated (Grenier et al., 1995). Further, it was reported that *Staphylococcus epidermidis* (37.1%), *Micrococcus spp.* (32.6%), Non-diphterial corynebacteria (28.2%) were abundantly found in air samples in a dental surgery followed by *Staphylococcus aureus* (0.6%), *Pseudomonas spp.* (0.6%) , and Fungi (0.9%) at the end of the day. Syzmanska et al., in 2007 reported the presence of opportunistic microorganims (*Staphylococcus epidermidis*, non-diphterial corynebacteria, *Pseudomonas* spp.) as significant. Higher risk of the dentist and the dental hygienists acquiring Herpes Simplex Virus (HSV)-1 by bioaerosol contamination has been demonstrated (Browning and McCarthy, 2012). Studies have reported an increased risk of exposure to M. tuberculosis due to hazardous bioaerosol in dental environment (Bennet et al., 2000) and SARS-CoV.

6.1.2 Dental Equipment:

6.1.2.1 Dental Water Lines (DUWL):

Two types of water circulation in dental unit waterlines may be distinguished by the water supply. They are the open and closed systems. The open system of water circulation is where a municipal water system is the source of water whereas the closed system is where water is drawn from a container (reservoir) belonging to a unit (Syzmanska et al., 2007). Dental water lines are a source of potentially pathogenic microbes, if left unchecked. It was reported that contaminated DUWL could harbor gram positive bacteria such as *Micrococcus leteus* and *Streptococci sp.;* gram negative bacteria such as *Brevundimonas vesicularis*, *Moraxella sp.* and *Ralstonia pickettii* rods and fungi such as *Candidiasis albicans* and *Aspegillus amstelodami.*

Other microbes such as Legionella, Pseudomonas, and Non-tuberculous mycobacteria pose hazardous health risks. Bacterial endotoxin was also found in excess of the proposed safe value, creating a potential risk for both doctor and patient (Syzmanska et al., 2007).

6.1.2.2 Dental High Speed Instruments:

Various studies have been able to isolate microorganisms from aerosols produced during different dental procedures. Micrococcus, Staphylococcus, Viridans Streptococci and Staphylococci were isolated from aerosols produced during endodontic and restorative therapies. Commonly found microorganism in aerosols produced during endodontic access was Streptococcus. Periodontal therapy usually resulted in aerosols containing Actinomyces, Fusobacterium, Capnocytophaga and Streptococcus. Ultrasonic scalers produce the maximum amount of aerosol, followed by air driven hand-piece, air polisher and air-water syringe (Harrel and Molinari, 2004). Additionally, use of different water flow rates, bur size ranges and bur material types during tooth cutting procedures with air driven hand-piece, resulted in significant differences in aerosol being generated (Madden et al., 2015).

7. AIR SAMPLING TECHNIQUES:

Air sampling is used to monitor air composition as a function of time. The composition of bio-aerosols sampled at a given time interval are highly variable, depending on the method of sampling (active versus passive), microbiological techniques (different culture methods used), the setting of the study (specific clinics versus dental clinics) and time of collection (pre- or post- procedure). Time frame is an important determinant of aerosol contamination as its composition decreases 50-70% after 30 minute interval (Al Maghlouth et al., 2004).

Air Sampling Techniques can be classified as Passive or Active Sampling techniques. Sample results are typically expressed in Colony Forming Units (CFU) per cubic meter (CFU/m^3).

7.1 Passive Sampling:

Passive sampling is done using 'settle plates'. These are standard petri dishes with appropriate culture media, exposed for a given time and then incubated to allow growth of visible colonies to develop and be counted. Settle plates are limited to monitoring viable biological particles that settle onto the media over the given time of exposure. However, specific volumes of air and smaller suspended particles cannot be analysed accurately.

7.2 Active Sampling:

A microbiological air sampler is used to actively draw a specific volume of air over, or through, a particle collection device. The components of Active Air Samplers include impingers, impactors and the filter. An impinger is a liquid medium for particle collection which is then cultured and analysed using methods such as PCR. Impactors use a solid media such as agar for sample collection. Commercial samples using the impaction principle include Andersen sampler and Casella slit sampler. Filters used are polycarbonate or cellulose acetate membrane.

8. METHODS TO SAFEGUARD AGAINST HAZARDOUS AEROSOL EXPOSURE:

The following methods can be advocated to safeguard against hazardous aerosol exposure:

- Screening and a history of illness must be recorded prior to procedure
- Immunisation of a dental team in their workplace through specific or non-specific immunisation (Syzmanska et al., 2007).
- Procedural modifications such as:

a. The use of appropriate personal protective barriers for dentist, assistant and patient
b. Rinsing with a pre-procedural antimicrobial rinse (Harrel and Molinari, 2004).
c. The position of a patient during dental treatment should minimize direct exposure to splatter
d. Isolation of procedural site using rubber dam and supplemental techniques
e. The use of high-performance evacuators (HVE) during aerosol production
f. Prior sanitation step and hand hygiene while doffing off the protective equipment.

- Disinfection of Dental Water Unit Lines, before and after procedure.
- Improving the ventilation of the operatory
- Use of devices that reduce air contamination in a dental surgery – HEPA filters, UV light fixtures. Positioning of such devices has shown to improve efficiency.
- Adhering to sterilization and disinfection protocols for equipment, operatory and clinic set-up.

9. CONCLUSION:

The unique atmosphere of a dental operatory is in a constant flux of change. It is important to focus on limiting exposure to aerosols generated. The potential contraction and spread of harmful infections by exposure to invisible aerosols is a serious factor that requires practice of definitive protective strategies. It is the responsibility of the dentist, assistant and patient to safeguard the collective welfare of the dental environment.

REFERENCES:

1. Advisory Committee on Immunization Practices, Centers for Disease Control and Prevention (CDC. Immunization of health-care personnel: recommendations of the Advisory Committee on Immunization Practices (ACIP). MMWR. Recommendations and reports: Morbidity and mortality weekly report. Recommendations and reports. 2011;60:1-45.
2. Al Maghlouth A, Al Yousef Y, Al Bagieh N. Qualitative and quantitative analysis of bacterial aerosols. J Contemp Dent Pract. 2004;5:91-100.
3. Bennett AM, Fulford MR, Walker JT, Bradshaw DJ, Martin MV, Marsh PD. Microbial aerosols in general dental practice. British dental journal. 2000; 189:664-7.
4. Bentley CD, Burkhart NW, Crawford JJ. Evaluating spatter and aerosol contamination during dental procedures. J Am Dent Assoc. 2000;125:579-84.
5. Browning WD, McCarthy JP. A case series: herpes simplex virus as an occupational hazard. J Esthet Restor Dent. 2012;24:61-6.
6. CarolineL, Pankhurst, NW Johnson. Microbial contamination of dental uni0t waterlines: the scientific arguments. Int Dent J. 1998;48:359-68.
7. Day CJ, Price R, Sandy JR, Ireland AJ. Inhalation of aerosols produced during the removal of fixed orthodontic appliances: A comparison of 4 enamel cleanup methods. Am J Orthod Dentofacial Orthop. 1998;133:11-7.
8. Grenier D. Quantitative analysis of bacterial aerosols in two different dental clinic environments. Appl Environ Microbiol. 1995;61:3165-8.
9. Harrel SK, Molinari J. Aerosols and splatter in dentistry: a brief review of the literature and infection control implications. J. Am. Dent. Assoc. 1995;135:429-37
10. Hausler JR WJ, Leaverton PE. Study of some factors contributing to aerosol production by the air-turbine handpiece. J. Dent. Res. 1969;48:341-5.
11. Heikkinen MS, Hjelmroos-Koski MK, Hägglblom MM, Macher JM. *Aerosols Handbook: Measurement, Dosimetry, and Health Effects.* ed(s) Ruzer L, Harley NH Madden RM. Boca Raton. CRC Press. 2005; 291-342.
12. Micik RE, Miller RL, Mazzarella MA, Ryge G. Studies on dental aerobiology: I. Bacterial aerosols generated during dental procedures. J. Dent. Res. 1969; 48: 49-56.
13. Nejatidanesh F, Khosravi Z, Goroohi H, Badrian H, Savabi O. Risk of contamination of different areas of dentist's face during dental practices. Int. J. Prev. Med. 2013;4:611.
14. Osorio R, Toledano M, Liebana J, Rosales JI, Lozano JA. Environmental microbial contamination. Pilot study in a dental surgery. Int. Dent. J. 1995; 45: 352-7.
15. Prospero E, Savini S, Annino I. Microbial aerosol contamination of dental healthcare workers' faces and other surfaces in dental practice. Infect. Control Hosp. Epidemiol. 2003;24:139-141.
16. Salem H, Gardner DE. *Health aspects of bioaerosols. In Atmospheric microbial aerosols*. Springer, Boston, MA. 1994;304-330.
17. Szymanska J. Dental bioaerosol as an occupational hazard in a dentist's workplace. Annals of Agricultural and Environmental Medicine. 2007;14.
18. Takako Oyabu, Yasuo Morimoto. Factors Related to Lung Injury Induced by Silica. Aerosol Res. 2001;16:275-79.
19. Taira M, Sasaki M, Kimura S, Araki Y. Characterization of aerosols and fine particles produced in dentistry and their health risk assessments. Nanobiomedicine. 2009;1:9-15.
20. Zemouri C, de Soet H, Crielaard W, Laheij A. A scoping review on bio-aerosols in healthcare and the dental environment. PLoS One. 2017;12: e0178007.