Redefining aerosol in dentistry during COVID-19 pandemic

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ABSTRACT

The corona virus malady 2019 (COVID-19) pandemic has rekindled the well established argument regarding the role of dental aerosol in transference of severe acute respiratory syndrome corona virus 2 (SARS-CoV-2). Aerosols and droplets are generated amid innumerable dental procedures. With the commencement of the COVID-19 pandemic droplet, a review of the infection/disease control strategies for aerosols is required. We do not know where this pandemic is directed. We do not have conclusive evidence for an optimal management strategy. Every day brings in varying information, so recognizing the hazard created by aerosols will help diminish the probability of infection transfer at the time of dental procedures. Hence, the author assessed the evidence-based medical and dental literature in relation to “aerosol” that documented the source of transmission of aerosol through various potential routes, addressed the risk potential to patients and the dental team, and assessed the additional measures that might minimize the viral transmission if regularly adopted. In this article, the author evaluated and compiled dental guidelines by various countries and various health-care associations in context to aerosol-generating procedures and has made recommendations for the restriction of dental aerosols and splatter in routine dental practice.

Key Words: Aerosols, COVID-19 virus, dentistry, severe acute respiratory syndrome coronavirus-2

INTRODUCTION

It has been stated that the mouth is a Petri dish and the cavity of the mouth is home to multiplex, potent, and diversified microbiologic compilations in the human body. Current studies propose that up to 1000 bacterial species exist in the oral cavity, occupying several diverse microbial niches, for example saliva, teeth, gingival sulcus, hard and soft palate, tongue, cheek, lip, and attached gingival.¹ ² By now, over 700 microbial species have been detected in saliva, many of which are associated with oral and systemic infections.³ Since saliva can host many distinct viruses including severe acute respiratory syndrome coronavirus-2 (SARS-CoV-2), the transmission risk of viruses through saliva is inevitable in a dental office. The WHO has asserted that the pandemic virus of SARS-CoV-2 could have a profound repercussion on dentistry as it predominantly transmits through droplets and aerosols.⁴ Aerosols can be defined as “suspensions of liquid and/or solid particles in the air generated by coughing, sneezing, or any other act that expels oral fluids into the air.”⁵ Dental procedures can provoke generation of the cross-infection, droplets, aerosols, and spills that are contaminated...
with saliva, which may specifically infect uncovered skin/conjunctiva/mucosa, or be breathed in by the professional, causing potential cross-contamination. In addition, saliva-infected aerosols and droplets can also contaminate inanimate areas in the dental operatory which too may lead to nosocomial infection. Dentists are at a high occupational risk of infection; therefore, we have to be proactively vigilant and pursue rigorous infection control protocol. We suspect getting to be another SARS-CoV-2 casualty, being an asymptomatic spreader, and tainting members of our family. Therefore, this review focuses on highlighting the potential sources and factors correlated with the transmission of aerosols, types of pathogens they can harbor, primary properties of aerosols generated during routine human activity and everyday dental procedures, its hazardous effects, and the different techniques to manage aerosol and to decrease the risk of cross-infection to patients and health-care workers.

MATERIALS AND METHODS

Literature research
The electronic research was carried out by searching the PubMed and Advanced Search (Basic Search) catalog to search evidence-based clinical trials related to aerosol-generating dental procedures and strategies adopted to prevent aerosol. A Google search was conjointly been undertaken to seek out different recommendations for dental practice and dental guidelines in context to aerosol generating procedures throughout COVID-19 pandemic. The electronic research was complemented with a hand search of the following websites: “Irish Dental Association, American Dental Association, Australian Dental Association, Swiss Dental Association, The Royal Dutch Dental Association, Scottish Dental Clinical Effectiveness Programme, Centers for Disease Control and Prevention, Biosafety Working Group of the São Paulo Regional Dentistry Council, Royal College of Dental Surgeons of Ontario, Chinese Stomatological Association, Croatian Chamber of Dental Medicine, Dental Council of India, Irish Dental Association, Myanmar Dental Association, Norway Dental Health Service – FHI, Philippine Dental Association Science Committee, The Polish Dental Association, Spanish National Dentistry Council.”

Three search strings were run in PubMed from inception to April 01, 2021. Search terms were combined in the search strategy using Boolean operators [Supplementary 1]. In PubMed, the following strings were combined: ([aerosols {Mesh} OR aerosol OR aerosols OR bioaerosol OR bio-aerosol OR “bio aerosol” OR bio-aerosols OR “bio aerosols”] OR [“Aerosol generating procedures”]) AND (COVID-19).

Study Selection
Eligibility assessment of the studies was performed independently in an unblinded standardized manner by three investigators (KR, HR, and PS). After initial search and duplicate removal, titles of the identified studies were reviewed for relevance to the review question. Further, the abstracts and full texts of the eligible studies were evaluated independently and the articles addressing review questions specifically were selected for the review. If any disagreements between reviewers occurred regarding the inclusion of studies they were resolved by consensus and discussion with the fourth reviewer (PK).

SOURCE OF AEROSOL GENERATION

Aerosols generated during routine activities
During this COVID-19 pandemic, all of us have remained incredibly focused on aerosol-generating procedures (AGPs), but it is crucial to recognize that aerosols are additionally generated via routine human activities (e.g., respiration). Papineni and Rosenthal have revealed that around 90% of the particles produced by human expiration are <1 µm. Table 1 shows the outcome of an experiment performed by Duguid, who concluded that 95% particles were lesser than 100 µm, and the greater number were between 4 and 8 µm. The majority of small droplets emerge from the front of the mouth and a few, from the nose or from the throat.

Aerosol-generating procedures in dentistry
AGPs can be defined as “any medical or patient care procedure that results in the production of airborne particles (aerosols)”[11] Table 2. According to a review, use of high-speed handpieces and 3-in-1 syringes account for 56% of the AGPs, powered (sonic/ultrasonic) scalers for 43%, slow-speed handpieces for 29%, and surgical handpieces account for 22% AGPs. In spite of the fact that the aerosols do not have a dominant role in the transference of SARS-CoV-2 in the usual everyday functions, the status is dissimilar within the dental operatory. This is because many dental devices need a water splash to cool the operating tip and to restrict heat generation.
The water, when combined with compressed air, is used as a coolant, and spraying generates aerosols that become infected with microbes from mouth.[18] A water sprayer is also utilized to lavage the operating site to increase the operator’s vision.[12] A COVID-positive patient bears several viruses in his saliva and on tongue.[19] If aerosols generated procedures are performed on these individuals, they are likely to transfer the virus to the dentist.[20] The mean level of bioaerosols generated depends on the procedures; greater levels of aerosol are produced during cavity preparation (24–105 CFU/m³) and for ultrasonic scaling (42–71 CFU/m³), and lower levels for extraction (9–66 CFU/m³) and for clinical examination of oral cavity (24–62 CFU/m³).[21] Most studies have reached the conclusion that bioaerosols return to baseline 2 h after the dental procedure.[22] The sites displaying the greatest microbial contamination due to splatter and aerosol are masks of the operator and assistant, a unit lamp, areas close to spittoons, and mobile instruments. A dental surgeon operates from about ≤60 cm from the patient’s mouth. Recent research shows that the greatest amount of microbial contamination in the dental operatory takes place not beyond 1 m from the mouth, through both aerosols and splashes.[23]

**MODES OF TRANSMISSION OF AEROSOL**

**Direct and indirect contact**
Cross-transmission of the pathogen [Table 3] in dental setups via direct contact can occur through hands, improperly sterilized instruments, or needle stick mishaps.[24] The prime contagion route includes inhalation of those pathogens that remain suspended in environment and later descend upon surfaces.[25] This happens because even after the treatment is completed, aerosols hover within the dental clinic air, with
heavier and bigger particulates descending sooner.\cite{20} Settling occurs in almost all areas, after which these can possibly act as a medium for transference of the SARS-CoV-2 virus via indirect contact. Researches prove that the viable virus was still present on plastic surfaces even after 72 h for up to 7 days.\cite{26} Recent research has revealed that the COVID causing coronavirus can persist on some surfaces for up to 9 days.\cite{27} Indirect transmission is through a fomite, “an object that has been in contact with an infected person and can thus spread the infection to another person.” Irrespective of the route of transference, the minimum dose of SARS-CoV-2 dose that can be contagious has not yet been confirmed. Hence, regardless of the level of infection, all areas that are potentially aerosol contaminated or touched by patients must be considered as a potential source of infection [Figure 1].

**Blood contact**

The greatest incidents of transmission in clinic happen if microbes are transferred directly from blood (e.g., of the patient) to blood (e.g., of the dental health-care personal). These mishaps occur throughout the medical fraternity, but dental surgeons are comparatively at a greater risk. The possibility of transference of blood-borne pathogens is consequently an occupational health hazard, as dental health-care personal regularly handle sharp equipments and needles and many times, they work under indirect vision, hence injuring their fingers.\cite{29}

**Airborne route**

Airborne transference is distinct from droplet transference because it indicates the existence of microorganisms in droplet nuclei, which are commonly recognized as particles <5 μm in diameter. These particles can hover in environment for a prolonged time and may transmit to other individuals over distances more than 1 m [Figure 1]. Three probable sources of airborne infection amid dental procedure are saliva and respiratory sources, dental instrumentation, and from the treatment site.\cite{29}

**Dental unit waterlines**

The water from dental unit waterlines (DUWLs) is utilized amid procedures to cool the operating unit; this is required for a safe dental procedure. At the same time, this coolant could be a potential source of transference of virulent microbe. Water in the DUWLs can be contaminated from water coming back from the patients’ side into the DUWLs as well as from the microbes from the incoming water.\cite{30} Shortly after the first use of the DUWLs, a multispecies biofilm develops within the inner surface of the waterlines.\cite{31} The various factors responsible for adherence and flourishment of biofilms are damp environment of the DUWLs at room temperature and the used fabrics of the DUWLs. Both dental health workers and patients are risked of infected water from the DUWLs directly or indirectly (through aerosols, generated via dental handpiece).\cite{32}

**RISKS OF COVID-19 TRANSMISSION IN DENTAL HEALTH CARE**

The transference of SARS-CoV-2 primarily happens via aerosol and droplets. SARS-CoV-2 can stay in aerosol for up to 3 h and has a comparatively longer half-life of almost 1.1–1.2 h.\cite{26} Meng et al.\cite{33} revealed the incidence of nine COVID-19 cases amid 169 dental professionals, emphasizing the significant hazard of contagion to professionals.

**Saliva as a source of aerosol transmission**

WHO has claimed that the novel coronavirus (2019-nCoV) transmits principally through saliva droplets or discharge from the nose.\cite{4} SARS-CoV-2 has the three different courses to show in saliva: 1. Infection from the higher and upper respiratory tract; 2. Infection from the buccal mucosa; 3. Infection via mucosae of the digestive tract.
may infiltrate the oral cavity through the gingival crevicular fluid; the salivary gland can be infected by this virus, with the particle discharge into the saliva via salivary ducts.\[34\] As SARS-CoV-2 can be identified in saliva,\[19\] the hazard of transference of viruses that cause respiratory diseases via saliva cannot be overlooked within the dental setup; hence, the transference-based protections ought to be taken within the dental operatory.\[33\] COVID-19-positive patients without any symptoms may show up for the emergency in dental clinics. These patients are assumed to have infected saliva and are confirmed sources of contamination. Also, the nasolacrimal duct is associated with the conjunctival mucosa and the upper respiratory tract, and they share ACE2 on their cell membranes,\[35\] this endangers the dentist to the possibility of contamination through direct exposure of conjunctiva to splatter/droplets from patients amid the various dental procedures.

ACE2 is the prime host cell receptor of SARS-CoV-2 and plays an integral part in the access of virus into the cell.\[36\] The research laboratory results prove that angiotensin-converting enzyme-2 is expressed highly on oral mucosa epithelial cells, advocating that the mouth is at more risk for SARS-CoV-2 infection.\[37\]

**Role of particle size in transmission**

Aerosols are assorted mostly depending on their particle size [Table 4]\[25,38,39\]: Spatter is more than 50 µm, droplet is <50 µm, and a droplet nucleus is <10 µm. In dental environments, 90% of the aerosols generated are usually <5 µm.\[40\] There is continuing

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**Figure 1:** Modes aerosol transmission in dental clinics.

| Aerosols                      | Splatters                              |
|-------------------------------|----------------------------------------|
| Size – particles less than 50 µm in diameter | Size – airborne particles more than 50 µm in size |
| Cannot be seen with naked eyes  | Seen with naked eyes                   |
| Particles of this size are small enough to stay in the air for a long time even after the completion of the dental procedure | Particles of this size are ejected forcibly from the operating site and arc in a trajectory similar to that of a bullet until they contact a surface. Splatter evaporates, leaving smaller particles called droplet nuclei |
| The aerosol particle of size ranging between 0.5 and 10 µm in diameter can easily enter and lodge in the smaller tracts of the lungs | As these particles are too large to become suspended in the air and are airborne only briefly, shows limited penetration into the respiratory system |
| Carried in air currents for great distances | Unaffected by air currents, travel in ballistic manner |
| Subsizes – particulate matter 2.5 µm – reach alvelous | No subsizes, grossly contaminate surfaces such as the skin, hair, clothing, and operatory |
| Particulate matter 10 µm reach higher respiratory tree | Possible mode of transmission – direct contact or from dust |
| Possible mode of transmission – inhalation | Possible mode of transmission – inhalation |
debate about how to segregate them, the World Health Organization defines that “the particles of more than 5 μm as droplets, and those <5 μm as aerosols or droplet nuclei.” Particles of sizes between 0.5 and 10 μm have the highest potentiality to enter the lungs and respiratory tract, acquiring the probability to spread the infection. Segregating aerosols by their basic size is relevant in relationship to their dispersion patterns. Outcomes from some research have exhibited that aerosols from microbes such as SARS-CoV-2 can migrate >6 feet.

Table 5: Summary of aerosol-generating procedures

| Country                  | AGP details                                                                 | PPE                                                                      | Procedural mitigation                                                                 | Environmental mitigation                                                   |
|--------------------------|------------------------------------------------------------------------------|----------------------------------------------------------------------------|-------------------------------------------------------------------------------------|---------------------------------------------------------------------------|
| Country-Ireland          | Source-Irish Dental Association                                                | Not reported                                                              | Face mask - FFP2, Fit test required, eye protection, disposable apron, surgical cap/hat, and shoe covers not recommended | Mouthwash not recommended, rubber dam, high-volume suction               |
| Updated on May 15, 2020  |                                                                               |                                                                            | Rubber dam – High-level evacuation, preprocedural mouthwash 1% hydrogen peroxide        | Dentaloperatory cleaning immediately after AGP is not required unless a patient has known or suspected COVID-19 |
| Country-Australia        | Source-Australian Dental Association                                           | High-speed handpieces, 3-in-1 syringe, powered scalers, lasers             | Face mask - Level 2/3 surgical mask or P2/N95 respirator, Fit-test required, Protective eye wear, Face shields in conjunction with surgical mask, Surgical gown, Disposable apron | A negative pressure room, Social distancing in the waiting room. Keep minimum items in dental clinic |
| Updated on May 31, 2020  |                                                                               |                                                                            | Must avoid AGPs, use lowest aerosol-generating options if necessary. Moutwash - 1% - 1.5% hydrogen peroxide or 1% povidone-iodine (60 s), rubber dam, high-volume suction | The operatory must be left empty (with the door closed) to permit the clearance and/or settling of aerosols |
| Country-Canada           | Source-Royal College of Dental Surgeons of Ontario                            | High-speed, low-speed, other rotary handpieces, powered scalers, 3-in-1 syringes | Face mask – Level 2 or 3 surgical mask or N95 respirator, Fit-test required, eye protection OR face shield, protective gown | Rubber dam, high-volume suction                                            |
| Updated on July 05, 2020 |                                                                               |                                                                            |                                                                                     | Not reported                                                               |
| Country-India            | Source-Dental Council of India                                                | Not reported                                                              | Face mask – three layered surgical mask and N95 respirator, Goggles/face visor, disposable apron, head caps, shoe covers | Mouthwash - preoperative 1% hydrogen peroxide, use-rubber dams. High-volume saliva ejectors, high-volume suction, do not use a spittoon |
| Published on July 05, 2020 |                                                                               |                                                                            |                                                                                     | General ventilation – Fumigation is done daily at end of the day in clinical or high contact areas; biweekly in nonclinical or low contact areas |
| Country - Malta          | Source-Office for the Deputy Prime Minister. Ministry for Health              | 3-in-1 syringe                                                            | Double gloving, face masks – N95 for hospital staff, face shield, disposable apron, waterproof footwear | Ruber dam, high-volume suction                                              |
| Published on Jun-20      |                                                                               |                                                                            |                                                                                     |                                                                           |
| Country - USA            | Source-ADA                                                                   | Not reported                                                              | Face mask – if N95 or other respirators is available, use both surgical mask and full face shield Goggles/ full face visor surgical cap/ hat disposable apron shoes or disposable shoe covers should be worn | Mouthwash-Pretreatment rinsing with1% H₂O₂, 0.2% Povidone or a combination of Chlorhexidine (0.5%– 0.12%) + CPC (0.01%– 1%), Rubber dam, high-volume suction |
| Updated on September 06, 2020 |                                                                               |                                                                            |                                                                                     | Keep windows open during procedure if no other means of General ventilation is done. Windows should be closed if there is an air purification system. Use of upper-room UV irradiation should be considered as an adjunct to higher general ventilation | Not reported |
| Country-USA              | Source-CDC                                                                   | Avoid use of dental handpieces, 3-in-1 syringe, powered scalers           | Face mask - surgical face mask, N95 or KN95, fit test required, goggles/face visor, surgical gown, surgical cap/ hat, shoe covers | Rubber dam, high-volume suction, use hand scaling instead of ultrasonic scaling |
| Updated on June 17, 2020 |                                                                               |                                                                            |                                                                                     | Systems that provide air movement in a clean-to-less clean flow direction are better, HEPA air filtration unit, use upper-room ultraviolet germicidal irradiation as an adjunct |

ADA: American Dental Association, CDC: Centers for Disease Control and Prevention, AGP: Aerosol-generating procedures, COVID-19: Coronavirus disease-2019, UV: Ultraviolet, CPC: Cetylpyridinium chloride, HEPA: High efficiency particulate air.
METHODS OF REDUCING AEROSOL

As per the present epidemiological research, 2019-nCoV has greater transmissivity as compared to SARS-CoV and MERS-CoV. Hence, modification of standard safety measure disease control regime focused on 2019-nCoV is indispensable amid this flare-up [Table 2]. Various dental AGPs as defined in international dental guidelines and the mitigation procedures suggested by them are tabulated in Table 5.

CONCLUSION

A direct co-relationship between bioaerosols generated during dental procedures and the transference of highly contagious infections not only to the dental professionals but additionally to patients has been confirmed. The probability of SARS-CoV-2 spreading through aerosols even in the absence of aerosol-generating procedures has also been supported by some studies.

Recommendations

The COVID-19 pandemic has had a startling effect on clinical practice. There is a huge gap in our knowledge regarding the role of aerosol in the spreading of COVID-19 and to prevent its transmission. Indeed, it is the appropriate time for dental surgeons to update themselves and be dynamic members of health-care organizations dealing with the pandemic. It is indispensable that in the current scenario, the necessary salience should be given to dental procedures that the WHO labeled as emergencies. This would be a suitable step in an attempt to abridge any transference of COVID-19. Dentists who treat amid the coronavirus pandemic should assume “every” person is potentially infected and mandatorily follows universal infection control protocol, as discussed in the current article.

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Conflicts of interest

The authors of this manuscript declare that they have no conflicts of interest, real or perceived, financial or nonfinancial in this article.

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**SUPPLEMENTARY FILE**

**Supplementary 1: Information sources and search strategy**

Three search strings were run in PubMed from inception to April 01, 2021. In PubMed the following strings were combined: (("aerosols"[MeSH Terms] OR (“aerosol s”[All Fields] OR “aerosolization”[All Fields] OR (“bioaerosol”[All Fields] OR “bioaerosols”[All Fields]) OR “Aerosol generating procedures”[All Fields]) AND (“covid 19”[All Fields] OR “covid 19”[MeSH Terms] OR “sars cov 2”[All Fields] OR “sars cov 2”[MeSH Terms] OR “severe acute respiratory syndrome coronavirus 2”[All Fields] OR “ncov”[All Fields] OR “2019 ncov”[All Fields] OR ((“coronavirus”[MeSH Terms] OR “coronavirus”[All Fields] OR “cov”[All Fields]))).

**PRISMA flow chart**

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Flow diagram of literature searches according to the PRISMA statement.