Dental Clinic Aerosol Management

Redirecting and trapping airborne particles of dental procedure aerosol for a targeted suction and prevention of clinicians' direct exposure

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Abstract

Aerosol clouds carry airborne particles including SARS-CoV-2, the virus that causes COVID-19. Dental clinicians are recommended to use heavy duty protective equipment (i.e. level 3 personal protective equipment (PPE)). Current supply shortage, and difficulties with fitting and wearing, remain problematic for dental practices to have a sustainable and long-term work plan. As droplet can stay airborne for a long time after a procedure, dental practices are also recommended to leave sufficient time gap (~60 min.) between each procedure. This makes their operations economically not viable.

As dental clinics are opening post COVID-19, there are still confusions around measures need to be taken to have a safe operational environment. Because of inadequate access to suitable PPE, as well as insufficient guideline and regulations, healthcare clinicians are improvising protective barriers to reduce risks associated to the aerosol spread. In such uncertain time therefore, clinicians must take common sense measures, above and beyond the formal guidelines issued by different authorities.

We are introducing a new design for a barrier to increase protection measures for dental clinicians. By redirecting and trapping the aerosol cloud into a more concentrated area, this barrier enables, 1: a targeted suction, and, 2: reduces time required for the airborne particles to land on a specific surfaces so they can be cleaned faster. The measures that reduces the time gap between procedures.

1. Introduction

Dental procedures produce airborne particles (aerosols) including SARS-CoV-2, the virus that causes COVID-19 [(1)]. COVID-19 is a new disease and we are still learning about how it may spread in dental practices and what measures need to be taken [(2)].

As dental practices are beginning to open post COVID-19, there are growing confusions around the use of personal protective equipment (PPE) to create safe operational environments. In such uncertain time, and in the absence of clear guidelines and standards, dental practices must take common sense measures to increase the protection levels.

In the Guidance for Dental Setting issued by CDC (Centre of Disease Control and Prevention) [(2)], and NHS's new guidelines [(3, 4)], dental practices are recommended to *"avoid aerosol-generating procedures whenever possible"* and if it is not possible, they are asked to take several protective measures during and after AGPs including but not limited to:

- using level 3 PPE to prevent clinicians from exposure to the aerosol cloud during AGP procedure [(3, 4)].
- Leaving sufficient time gap (~60 min.) between each procedure (i.e. patient) to leave time for droplets to be landed in a surface.

Current inadequate access to PPEs due to supply shortage, and difficulties with fitting and wearing level 3 PPEs, as well as inefficiency of work operation as the result of long gaps between procedures remain problematic for dental practices as they are re-opening. Dental clinicians therefore are improvising the use of different barriers and suctions to make a safer environment[(5)]. We have designed a new barrier with specific shape and size to address these issues without creating additional need for motorised machines (high-power suction motors) that require high energy consumption and regular maintenance procedures including regular change of contaminated filters on site.

2. Aerosol

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Aerosol (airborne particles), defined as particles less than 50 micrometres (µm) in diameter [6] [7] [8, 9]. The greatest airborne infection threat in dentistry comes from aerosols because they are small enough to stay airborne for an extended period of time before they settle on a surface or enter the respiratory tract [7, 10, 11].

The larger and heavier particles (> 5µm) are droplets that can travel up to 1 meter from the source and contaminate surfaces within that range [12-14]. The smaller particles (1-5µm) are called droplet nuclei that can stay airborne for long periods of time before landing and contaminating surfaces. Both types of particle are relevant to SARS-CoV-2 transmission since this may occur via both direct air-borne infection and indirect spread via contact with contaminated surfaces [7].

3. Our Proposed Barrier

3.1. Objective

Dental clinicians are exposed to aerosol cloud generated, more specifically during AGP procedures as shown in Figure 4. Clinicians are therefore recommended to use level 3 PPEs to prevent direct contact. In a recent experimental research, a similar approach used during a simulated endotracheal intubation. With PPE only, the paper reports that *"dye was found on the laryngoscopist's gown, gloves, face mask, eye shield, hair, neck, ears, and shoes"* [5] and *"contamination of the floor occurred within approximately 1 m from the head of the bed and also on a monitor located more than 2 m away"* (5). This is a very similar approach to the aerosol contact with the dental clinicians. In the test with aerosol box on the other hand, the paper reports that *"the simulated cough resulted in contamination of only the inner surface of the box and the laryngoscopist's gloves and gowned forearms"* [5] and*. " Examination of the laryngoscopist and the room with ultraviolet light showed no macroscopic contamination outside the box".*[5]

Smaller / lighter airborne particles travel around the room for an extended period. Depends on several factors such as room size, air conditioning, and locations of windows and doors, particles float until they reach a surface to land. Therefore, a longer time required for the room to go back to a normal and safe operational condition. For this reason, clinicians are recommended to leave time gap (~60 min) between each procedure.

The main objectives for our design are to create a barrier that,

- protects clinicians from direct contact with aerosol cloud without any compromise for clinicians' access to the patient, line of sight, and ergonomic posture.
- directs aerosol cloud to a more concentrated area for a targeted suction
- reduces time for the airborne particles to land on a surface
- reduce time gap required between procedures (patients)

3.2. Design

This barrier is designed as a one-piece quarter hemisphere shape made from cast acrylic sheet, Polymethyl methacrylate (PMMA). The unit is sitting on a set of rolling legs to provide flexibility. Two circular ports are created for the access to the patient. A removable and wipeable plastic cover is designed to be hooked to the unit to seal the unit during procedures (Figure 1, Figure 2, Figure 3).

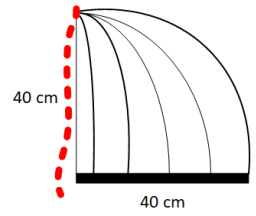

Figure 1: Quarter hemisphere design (dome shape) directs particles to the centre

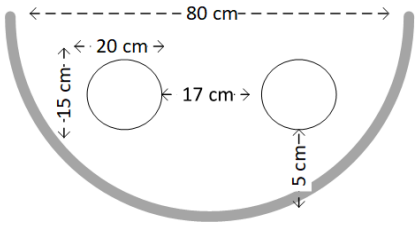

Figure 2: Flange with protective edge and access holes

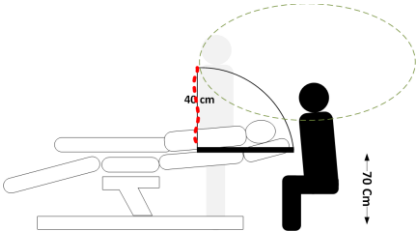

Figure 3: Typical set arrangement

3.3. Advantages

The one-piece barrier sitting on a set of rolling legs, provide following advantages:

- Line of sight - the edge less design, and rounded shape creates a full line of sight with no obstacle
- Assess - there are 2 ports designed to create access to the patients. During prototype tests, they were appeared to be perfectly used as armrests for dentists conducting the experiment

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- Flexibility - the rolling legs enables clinicians to move in different direction with moving shield creating full flexibility during procedures
- Sanitising - the unit is designed as a one-piece acrylic unit with no edge and joint. This makes sanitizing simple and straightforward after each procedure. The cast acrylic is a hard surface material with low absorbency and hence is suitable for treatment with any anti-COVID antibacterial surface treatment.
- Claustrophobia – the see-through material used, as well as circular shape with no edge, creates a safe and comfortable environment for the patient during procedures
- Aerosol flow - the quarter hemisphere shape barrier redirects and traps the flow of the aerosol to a more concentrated point. The removable cover, shown in Red in Figure 4, seals the unit during procedures, enabling targeted suctions. Also, within the hemisphere, airborne particles reach a surface to land much quicker, resulting in having less particle floating, reducing the time required between each procedure.

3.4. Disadvantages

Using a barrier in a clinical procedure requires work style adjustment. It is impossible to impose additional safety measures of any type with no complication in working condition. The proposed barrier is not an exception and certainly add some level of discomfort mainly for the clinicians to adjust, which is inevitable.

4. Experiment

We built a prototype unit based on the design. We used high speed cameras and particle counter machine to visualise and assess different scenarios during and after a typical AGP.

4.1. Equipment

We worked in a dental clinic with standard equipment such as dental chair, suction, handpieces, and manikin to simulate typical AGP procedures. In addition, we used following equipment to visualise and gather data:

- Heavy duty lighting – to produce lighting required to capture images of the aerosol cloud generated during a simulated AGP
- High Speed Camera – to capture and record images of the aerosol cloud and its journey
- Particle counter - measuring particulates generated during a simulated AGP (TSI DustTrak 8533 DRX Dust & Aerosol Monitor.)

4.2. Scenarios

We simulated similar conditions for two types of scenarios (with and without shield) to be able to compare and assess the impact of the designed barrier. We simulated the worst-case scenario to generate the maximum level of aerosol (i.e. much higher than a typical AGP operation). We run the simulations over 7 continuous slots as follow:

- Slot 1 (15 min) – leaving the room in a standstill condition with no operation
- Slot 2 (15 min) – simulating AGP operation with barrier
- Slot 3 (45 min) – stopping the operation and moving around the room for cleaning and sanitising the equipment
- Slot 4 (15 min) – leaving the room in a standstill condition with no operation.
- Slot 5 (15 min) – simulating AGP operation with no barrier
- Slot 6 (45 min) – stopping the operation and moving around the room and cleaning and sanitising the equipment
- Slot 7 (15 min) – Leaving the room in a standstill condition with no operation.

4.3. Results

Real time image

Figure 4 shows the aerosol flow. In the scenario without barrier, the thick aerosol cloud first contacts with clinicians and then continues to float around the room. In the scenario with the proposed barrier, aerosol cloud appears to be running toward the centre of the hemisphere with nearly zero visible contact with clinicians. For the imaging purpose, we did not use cover so we can see the cloud path.

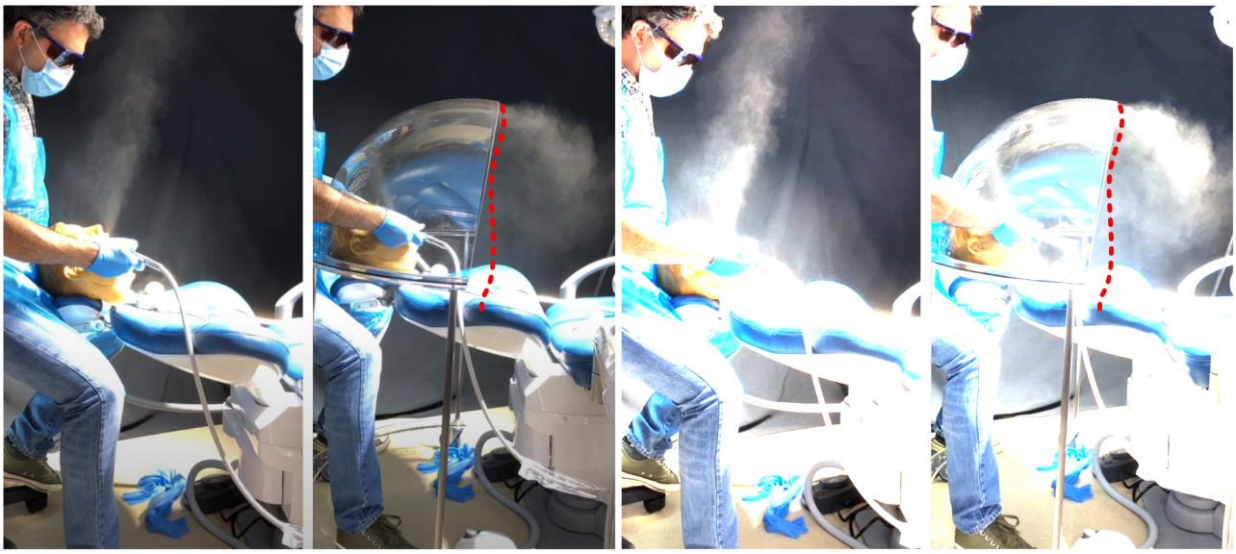

Figure 4: Dentist exposure to the aerosol cloud (with and without barrier)

Aerosol Counting

The TSI DustTrak 8533 DRX Dust & Aerosol Monitor, measures particulate and aerosol contaminants and simultaneously measure size-segregated mass fraction concentrations corresponding to PM1, PM2.5, PM10, Respirable and Total PM size fractions. We set the machine behind the dentist closer to the upper side of the bodies. Figure 5, shows the results gathered over the nearly 180 minutes experiment over the above 7 slots. The data gathered provides two main conclusions:

- In the 15 minutes of AGP operations, the aerosol particle concentration in the room (floating particles) is nearly double in size in compare to the results with our barrier
- It takes nearly 45 min until the aerosol particle concentration size in the scenario without barrier reduces and reaches the size achieved in the scenario with our proposed barrier after 15 min.

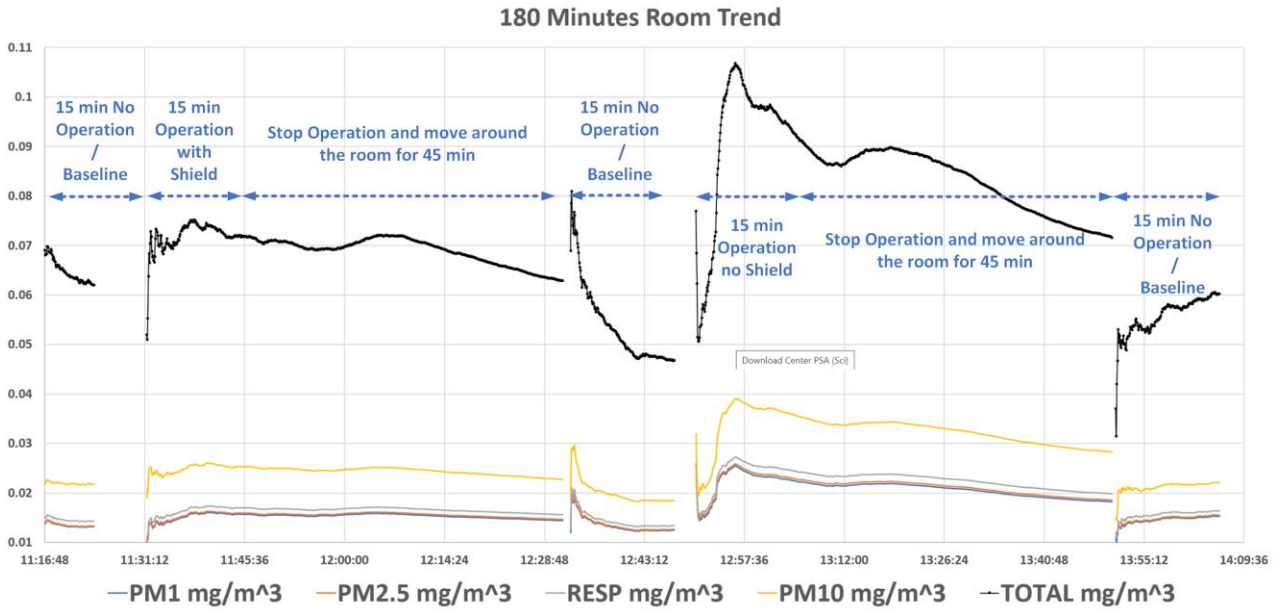

Figure 5: Running experiments in a clinic over nearly 180 continuous minutes with 7 slots

For a direct comparison, we overlapped the results of the 60-minutes operations of two scenarios. Figure 6, Figure 7, Figure 8, and Figure 9 respectively present results of the size-segregated mass fraction concentrations corresponding to PM1, PM2.5, PM10 and Total.

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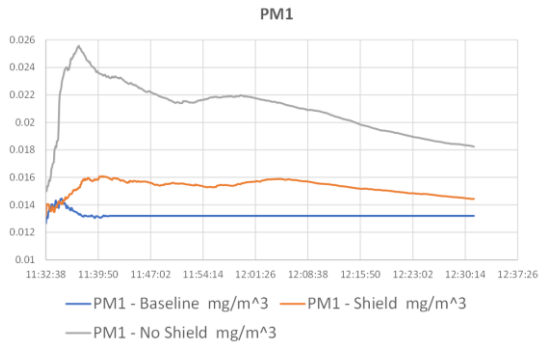

Figure 6: PM1 trend (60 min. experiment)

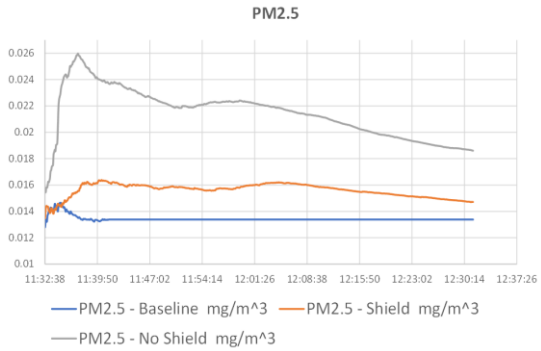

Figure 7: PM2.5 trend (60 min. experiment)

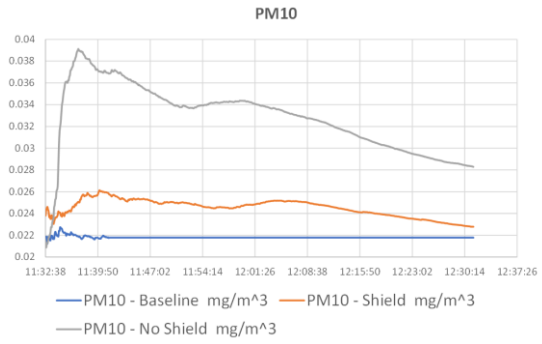

Figure 8: PM10 trend (60 min. experiment)

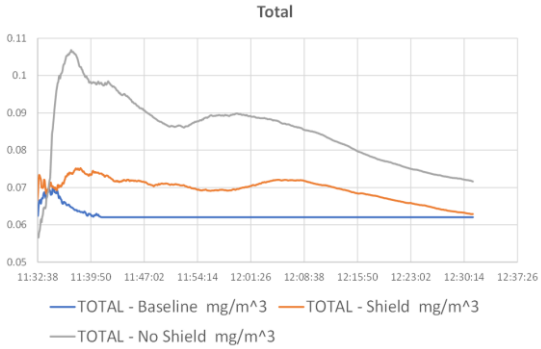

Figure 9: Total trend (60 min. experiment)

5. Conclusion

The results illustrate two distinctive conclusions:

1. Our proposed barrier reduces the level of aerosol particle concentration (floating airborne particles) significantly, protecting clinicians from direct exposure. This could potentially result in a review on the necessity of the use of level 3 protective PPE in a long run.
2. Our proposed barrier redirects airborne particles to a much more concentrated area. Using the protective cover as well as suctions inside the hemisphere, resulted in a much shorter time for the particles to reach a surface. The results show a 45-min time difference between the two scenarios until they reach the same level of floating particles. This could potentially result in a review on the necessity of 60-min time gap between procedures.

As caveat in our experiment, in our simulation droplets are produced much more than a real scenario. Also, we are not counting the materials of less than 1 micrometres (µm) in diameter that could potentially be infectious. We are suggesting that the use of such barrier in conjunction with standard PPEs reduces the exposure to the aerosol significantly, a measure that will create a safer working environment.

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