Use of the AIIR Portable Device on Containment and Removal of Aerosols and Droplets in a Dental Practice

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Abstract

The US Department of Labour places air quality in dental practices in the highest risk category. Furthermore, Occupational Safety and Health Administration (OSHA) defines the four professions most at risk of contracting COVID-19 on the job as dental hygienists, dental surgeons, dental assistants and dentists [1].

This white paper builds on previous research and further examines the Airborne Infection Isolation and Removal (AIIR) device, manufactured by Kelowna-based Care Health Meditech, and reports on its efficacy in the containment and elimination of aerosols and droplets created in a dental practice during aerosol generating procedures (AGP). Furthermore, it examines aerosol movement within a dental practice, during and shortly after AGP, within a natural experimental setting and through advanced Computational Fluid Dynamics Modelling. Finally, it provides comment on the use of high-volume evacuation (HVE) as a tool to control aerosols and droplets created in a dental practice during AGP.

I. Objective

Many dental procedures generate aerosols, or small droplets of saliva and blood, that are ejected into the air. These aerosols remain suspended in the room for an extended period of time and can contain dangerous particles that contain viruses, including SARS-COV2, influenza, tuberculosis, HPV and aerosolized mercury [2, 3].

The objective of this white paper is to test how the AIIR device can affect aerosol motion and droplet trajectory and to further define if the use of AIIR device during AGP could make a dental office safer for dental care workers.

II. Methodology

A natural experiment was carried out by the UBC research team in an actual dental office. Simulated dental treatment was performed on a mannequin by Dr. Dionysius David, DDS, Alberta Health Services Department of Dentistry, a highly experienced general dentist (Figure 1). In the natural test Glo-Germ in both gel lotion and powder forms were applied to a mannequin trainer's teeth and mouth to track the trajectories of potential pathogens. Ultraviolet (UV) light was then used to visualize droplet and aerosol creation, dispersal and potential dental worker exposure to the simulated pathogen.

Glo-Germ™ is a commercially available odorless lotion or powder which glows brightly when exposed to UV light. It contains proven safe ingredients formulated to be a similar size as bacteria, approximately 5 microns in diameter. Glo-Germ is used to safely simulate and allow visualization of a pathogen and is commonly used to demonstrate the efficacy of hand-hygiene, containment, surface-cleaning and aseptic techniques.

Figure 1: A highly experienced dentist performing a routine dental procedure on the trainer mannequin using the AIIR device

A dental mannequin trainer has simulated teeth to provide a look and feel similar to natural teeth. Teeth are positioned into the model to provide dentition with normal contact and occlusal relationships. The natural anatomy and placement of teeth provides a realistic simulation of the embrasure and contours of the gingiva. The teeth are designed to cut like natural tooth structure. Dental mannequins are commonly used for teaching and practicing dental anatomy and Operative Dentistry.

(a) (b)

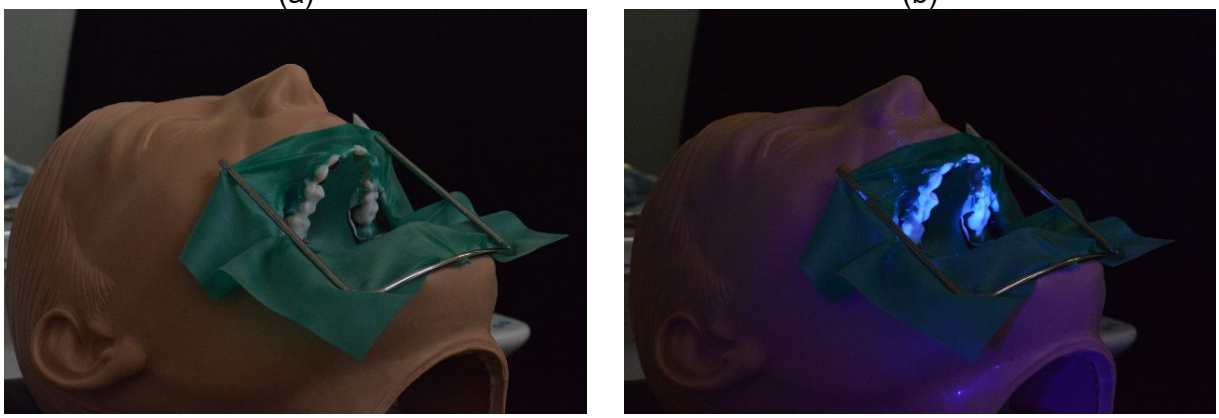

Figure 2: Mannequin and Glo-Germ. (a): Glo-Germ Lotion applied to the mannequin's teeth; (b): mannequin's teeth under UV light after applying Glo-Germ lotion

Three tests are conducted. Test 1: Using Glo-Germ in lotion form without the AIIR device; Test 2: Using Glo-Germ in lotion form with the AIIR device; Test 3: Using Glo-Germ in powder form without the AIIR device. Figure 2 shows the mannequin and Glo-Germ under UV light. The potential contaminated areas and quantity of simulated pathogen spread on the dentist's body were observed after lotion Glo-Germ tests without and with the AIIR device. As the current pandemic standard of practice calls for its use, during both tests a HVE was used to vacuum inside the mannequin's mouth. In a separate experiment particle motion and spread were visualized by applying powder Glo-Germ, which allows for more accurate estimation of aerosol trajectories.

III. Observations

Test 1:

The experiment showed that during AGP conducted without the AIIR device, many areas on the dentist's body including the hands, forearms, upper arms, abdomen and chest, were exposed to the simulated pathogen, creating the potential for exposure for the dental worker. Chest and abdomen were the part of the dentist body most significantly exposed to the droplets produced and the possible contamination area was widespread. Figures 3 shows the exposed parts of dentist's body after the dental treatment without AIIR device.

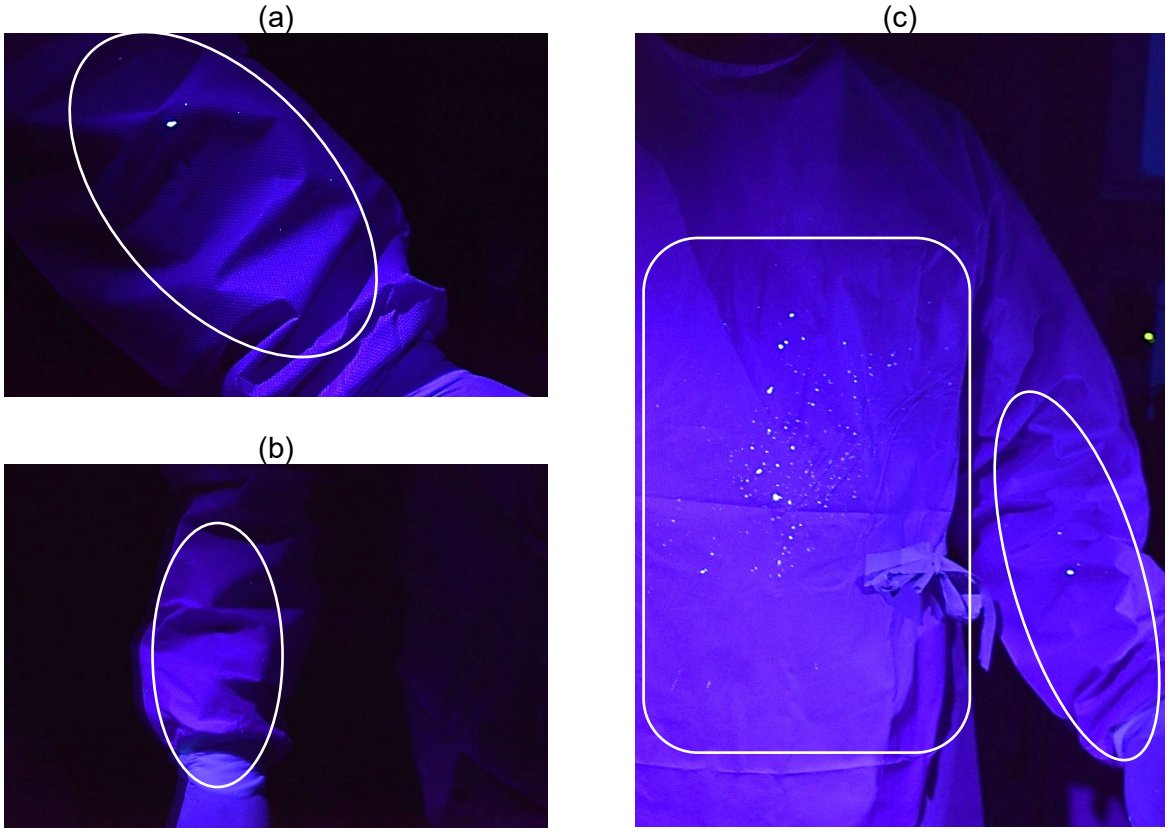

Figure 3: Dentist's body observation after the test without the AIIR device. (a): Left hand; (b): Right hand; (c): Chest, abdomen and left hand

Test 2:

When the AIIR device was used, the dentist's chest was free from contamination and only the hands and lower parts of abdomen were contaminated. Additionally, the intensity and abundance of contamination of these areas was noticeably less than the test without AIIR device. Figures 4 shows the exposed parts of dentist's body after the dental treatment with AIIR device.

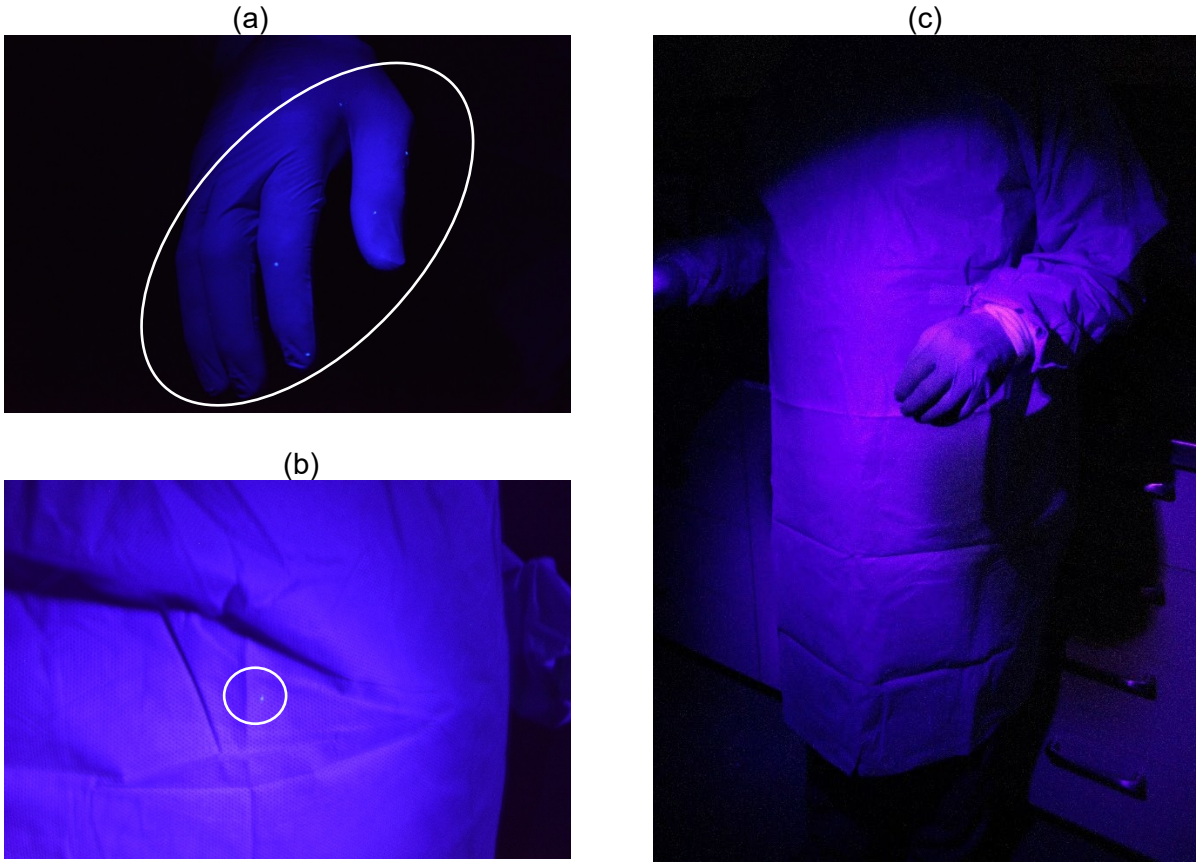

Figure 4: Dentist's body observation after the test with the AIIR device. (a): right hand; (b): abdomen; (c): left hand, chest and abdomen

Test 3:

This test utilised Glo-Germ powder as its properties provide for a better visualization of smaller particle motion (e.g., small droplets and aerosols). Figure 5 illustrates bigger droplets and the plume of smaller ones when the dentist is applying a three-way syringe. The larger droplets depending on their size, location and initial velocity magnitude and direction, fell down on the floor, chair and patient or remained on the dentist body. The contaminated area due to larger droplets was approximately a circle with a radius of one meter. However, for smaller particles, the distribution of particles within the room was different to the droplets. These smaller particles made a plume and within 30-seconds, had spread to almost all areas of the dental operatory.

The observation of the aerosol behaviour, or "spread" supports the literature specific to aerosols created during AGP and further infers the requirement for additional engineering controls to be

used during practice to both contain and eliminate this spread. Future studies are required to optimize the visualization of aerosols and to test the AIIR device in this context.

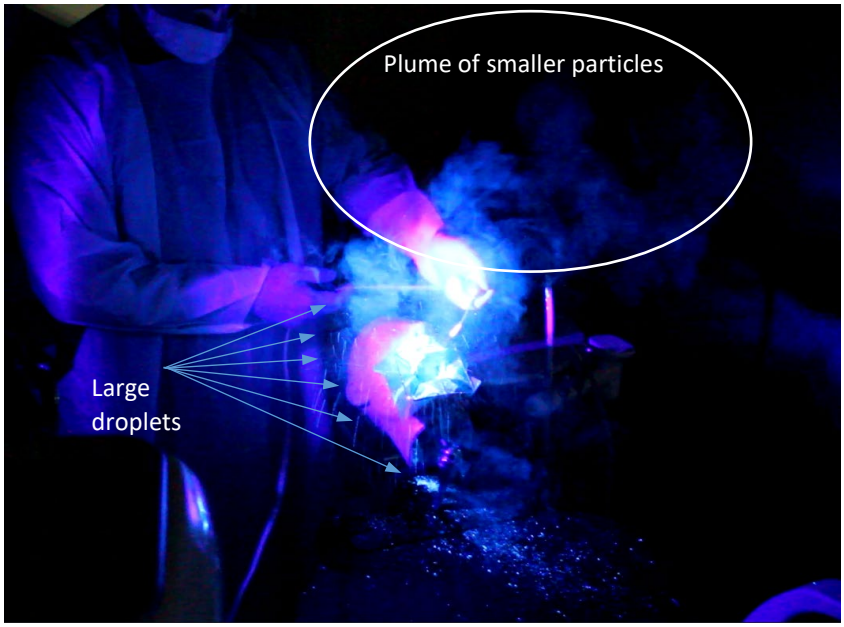

Figure 5: Large droplets and Plume of smaller particles

HVE or AIIR?

Figure 6 shows a qualitative comparison between the HVE and AIIR devices effectiveness using lotion Glo-Germ. Observations showed some large droplets that escaped from the HVE (Figure 6a) subsequently being contained or trapped by the AIIR device (Figure 6b). In case of large droplets the AIIR device acts like a 360 degree transparent shield to prevent large droplets from reaching the dentist and ultimately their respiratory system, thereby reducing the chance of clinician infection. This conclusion is supported by the natural test results, where the upper parts of the dentist's body remained clean and only the lower part of dentist's abdomen were exposed to the Glo-Germ.

The biggest advantage of AIIR device is its capacity to vacuum and remove the smaller particles. Larger droplets, will be stopped by AIIR collection dome and either remain on the dome, or eventually fall back to the patient "bib".

Without AIIR, the large droplets can escape HVE and directly contaminate the clinician while aerosols created during an AGP can remain suspended in the air creating a risk of both airborne or fomite (contact) transmission.

In addition to the natural test, the UBC research team modeled the AIIR device using Computational Fluid Dynamics (CFD). Simulations allow evaluation of the AIIR device's effect on the path of the very small particles (aerosols) in a dental office with a standard Air Conditioning (AC).

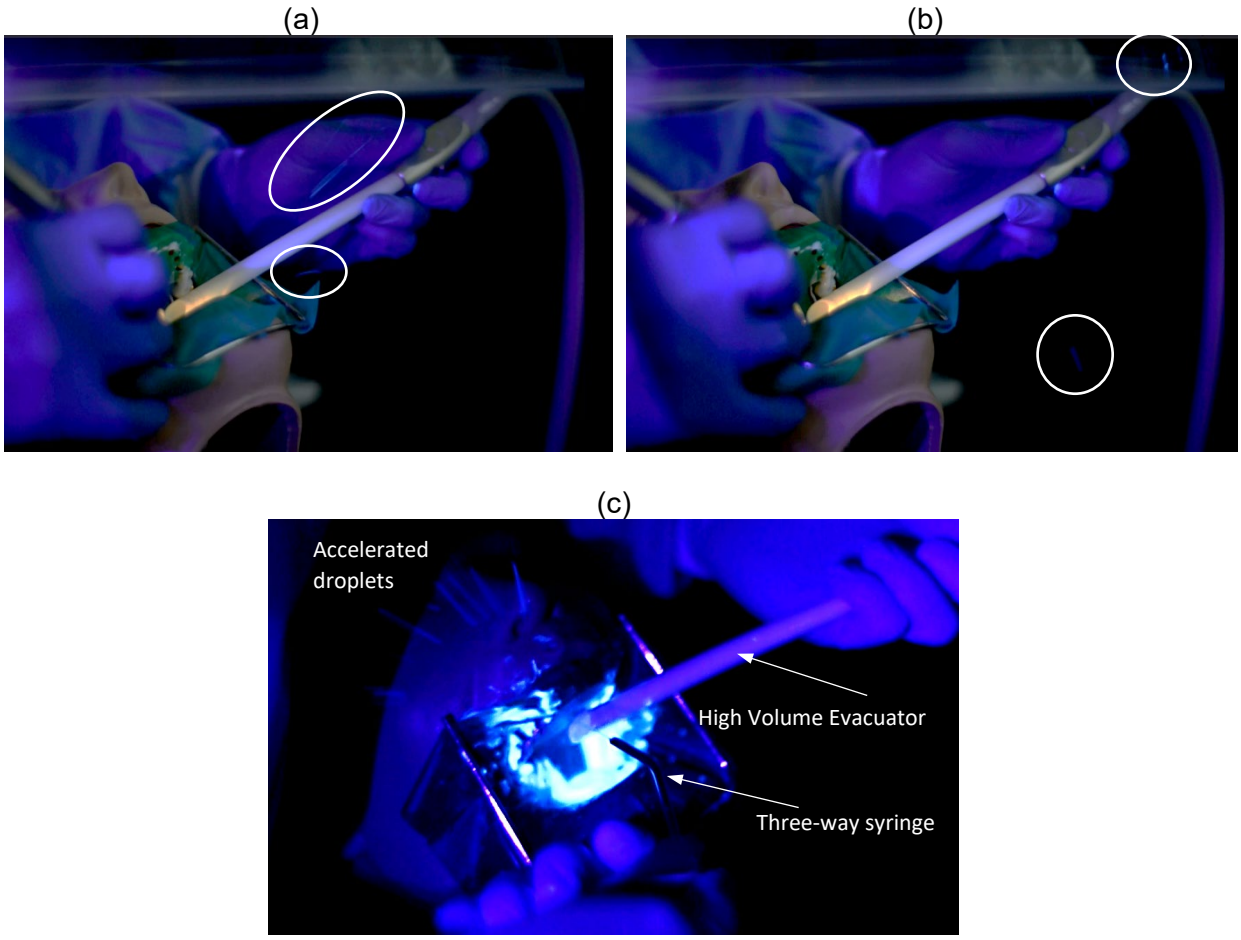

Figure 6: HVE and AIIR devices effectiveness comparison. (a): Droplets have escaped from HVE; (b) The AIIR dome has collected droplets and acts as a shield;
(c): Three-way syringe splashes

Due to their size, the slip rate between the small particles and the air is zero (0) and as such are predicted to follow the air's pathlines. Therefore the pathlines are good indicators of aerosol trajectories for a steady-state fluid flow.

Figure 7 shows the pathlines starting from the patient's mouth in a dental office not equipped with AIIR. The small particles that are released from the patient's mouth have followed the AC flow pattern and become dispersed throughout the room (Figure 7). Test 3 that was conducted with powder Glo-Germ validated the CFD results outlining that aerosols will quickly drift and contaminate the entire operatory if not actively managed.

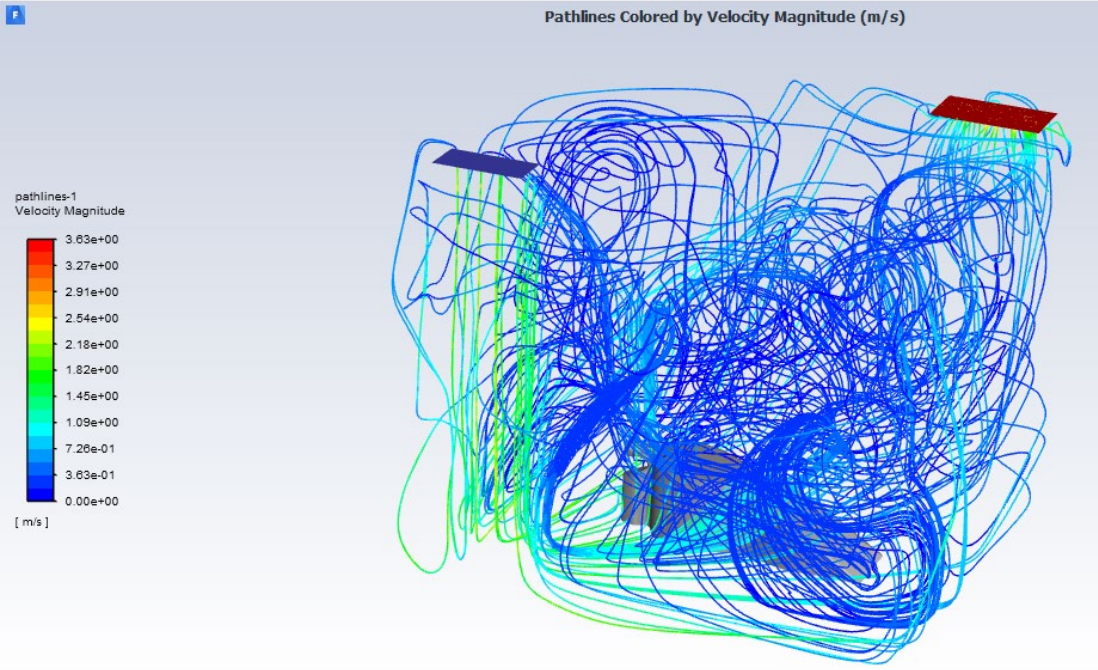

Figure 7: Pathlines starting from patient mouth in a regular dental office

IV. Conclusions

Major findings are:

1- The AIIR device reduces the contaminated areas dramatically in terms of size, intensity and location.
2- The AIIR device is effective not only in blocking exposure to large droplets but also plays an important role in removing aerosols created during an AGP.
3- When used in concert with an existing layered approach to infection control, the AIIR device can reduce risk of exposure to droplets and airborne pathogens in a dental office.
4- Many dentists believe HVE is an absolute protection for aerosols and droplets created during AGP, yet this does not appear to be the case.

References

1. U.S. Department of Labor, Occupational Safety and Health Administration. Guidance on Preparing Workplaces for COVID-19, Classifying Worker Exposure to SARS-CoV-2, OSHA 3990- 03 2020, 18-20.

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