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The Impact of Portable HEPA Filtration and Location on Infectious Aerosol Spread in the Dental Operatory

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ABSTRACT

Introduction: Aerosol may harbor infectious microorganisms and are of special concern with the advent of the COVID-19 pandemic (Tran, Cimon, Severn, Pessoa-Silva, & Conly, 2012). Before the pandemic, research on dental aerosol infectious transmission rates is limited and, as a result, standard procedural controls are lacking (Virdi, Durman, & Deacon, 2021). In an attempt to respond to the threats posed by the pandemic, the Army MHS purchased portable air cleaners (PACs) with HEPA filters for each dental operatory. Standards for the use of such controls have not as of yet been established. ***Objective*:** The purpose of this study is to evaluate the effectiveness of PACs with HEPA filters at reducing contaminated aerosol within the dental operatory by comparing colony forming units (CFUs) incubated from aerosols collected directly next to patients' (PATIENT) face and dental hygienists' (RDH) face shield during routine dental cleaning in three different scenarios: 1) with no PAC, 2) PAC used placed at head of PATIENT, 3) PAC placed at foot of PATIENT. ***Methods*:** Aerosol samples were collected onto open blood agar plates (BAP) placed near the PATIENT and in distant to PATIENT. A swab of the RDH face shield was performed before and after each PATIENT encounter: Samples were collected on 3 different days from 4 RDHs. Day 1 no PAC was used. Day 2 PAC placed at PATIENT's head. Day 3 PAC placed at PATIENT's foot. Samples incubated for 48 hours then CFUs counted and analyzed statistically. ***Results*:** There was no statistical difference between aerosol collected without the use of PACs and with PACs placed at different locations in reducing contamination from patients. Environmental contamination (or that emanating from the surroundings) was significantly greater ($p<0.05$) when PAC was placed at head of patient than when no PAC used. There was an average n=22 per test group. CFUs phenotypical to the environment were observed in both patient and environmental samples. ***Conclusion*:** Although the use of PACs did not impact contaminated aerosol spread from the PATIENT, the results suggest that airflow and filtration have a significant impact on spread of environmental contamination. Qualitatively observations also suggest that much of the exposure to contamination was environmental. Transmission from the PATIENT seemed to occur more via splatter than aerosol. More data and further studies are needed in order to suggest a standard of care for use of PACs in the dental setting.

INTRODUCTION

Anyone that has been to the dentist to receive a dental cleaning or restorative treatment has experienced the cloud of liquid vapor that is created around the face and near vicinity of the dental chair. Exposure to this vapor by the dental operator and staff is also noticeable. In today's pandemic state with COVID-19 it's reasonable to ask if this dental vapor is a risk to patients and staff. The aerosol nature of many dental procedures place the dental office as a potential high risk environment for transmission of respiratory infection.

Procedures that generate vast amount of aerosolized liquid vapor such as those that utilize ultrasonic instruments used for prophylactic dental cleanings or powered rotary instruments used in most dental restorative, as well as other procedures, are categorized as Aerosol Generating Procedures (AGPs). Aerosols are defined as droplets (Szymańska, 2007). Airborne droplets greater than this size are termed splatter and are also produced during dental AGPs. Unlike aerosols, splatter follows a projectile path from its source to a hard surface and do not remain suspended in the air. Both aerosols and splatter may contain various other substances to include bacteria, fungi, and viruses which have potential to be infectious. Aerosols 0.5-10um in diameter are of specific concern as they can harbor infective particles and be inhaled and transported to the terminal bronchiole and alveoli of the lung (Szymańska, 2007). Infectious zones of space between individuals have been defined by Hall as intimate (0-45cm), personal (60-120cm), social (1.2-3m), and public (over 3m) (Micik, Miller, Mazzarella, & Ryge, 1969). Because dental operators are working in the intimate and personal zones from the patient, it makes sense that the highest contaminated areas found are the operator's torso, arm, as well as the patient's body (Innes, Johnson et al. 2021). The highest risk activities include ultra-sonic scaling, high-speed air-rotary instrumentation, use of the air-water syringe, air polishing, and extractions using motorized hand pieces (Innes et al., 2021). Although these activities are the highest risk, aerosol contamination was detected for all activities as found in a recent systemic review (Innes, Johnson et al. 2021). Therefore it is difficult for a dental office to draw the line between AGPs and non-AGPs when determine appropriate infection control protocol (Innes, Johnson et al. 2021).

Potential harboring sites of infective pathogens that can then be transmitted through aerosols and splatter during dental treatment include 1) dental/surgical instruments 2) operative site and 3) the saliva, oropharynx, and respiratory tract of the patient (Harrel & Molinari, 2004). The first two sources are effectively managed through proper sterilization and infection control protocols. The later source, however, is more difficult to manage (Harrel & Molinari, 2004). The CDC recommends a number of methods to reduce the risk of contamination from the patient such as proper PPE, chlorohexidine pre-procedural mouth rinses, high-volume evacuation (HVE) systems, rubber dams, and ventilation, filtration, and irradiation systems (Prevention, 2020). Various other suggestions have been made in the literature such as hydrogen peroxide, cinnamon extract, or iodine in the irrigation solution may also help reduce the amount of infectious aerosol to include

specifically CoV-2 virus when 0.5 vol% hydrogen peroxide was used (Ionescu et al., 2021; Kumbargere Nagraj et al., 2020). HVE may be effective at reducing aerosol volume when within 30cm of source but has low efficacy beyond that. However, one study showed there to be no difference between HVE and other lower volume suctions methods (Kumbargere Nagraj et al., 2020). Rubber dam isolation may reduce aerosol up to 2m from the source but there were conflicting results from other studies (Kumbargere Nagraj, Eachempati et al. 2020). HEPA filtration has been shown to reduce aerosol production (Kumbargere Nagraj, Eachempati et al. 2020).

In a pilot study measuring the effects of Portable Air Cleaners (PACs) during dental procedures it was reported that PACs did significantly reduce the bio aerosols during treatment but not to a level equal to that at baseline. Thus with filtration, there will still be presence of bio aerosols regardless (Hallier, Williams et al. 2010). Fruzsina et. al recommends from a simulated experiment intra and inter procedure control of aerosol that a period of at least 15 minutes between procedures with open windows and ventilation be used to reduce concentration. As they mentioned, ventilation units may shorten this amount of time (Kun-Szabó et al., 2021). Another study performed in closed room dental operatories evaluated mechanical ventilation rates via ventilation and PAC with HEPA filtration. HEPA filtration proved to be effective in eliminating aerosols and proved more effective still when combined with adequate ventilation (Ren et al., 2021). Not all dental operatories are in closed rooms, however, and many are in an open bay configuration with open walls and air exchange between adjacent chairs and patients. The capabilities of filtration would presumably be different in this type of environment. In a recent Cochrane systemic review on contaminated aerosol interventions in dentistry, no studies measured disease transmission or viral contamination in aerosols, rather all the studies measured bacterial contamination utilizing CFU (Kumbargere Nagraj, Eachempati et al. 2020). The method of reporting CFUs as a means of assessing contaminated aerosol was used primarily due to ease and affordability. There are many limitations to these studies, however. The transmissibility and infectious nature of these aerosols remains relatively unknown. Rates of transmission of respiratory viruses through aerosol production in the dental setting has not been evaluated in the literature. Also, these studies focus on bacteria as the primary means of assessment. There has not been any published research measuring viral presence in aerosol/splatter production in the dental environment. Thus the risk of

viral transmission due to AGPs can only be assumed based off of the presence of aerosolized bacteria (Harrel & Molinari, 2004; Innes et al., 2021; Kumbargere Nagraj et al., 2020). As it pertains to contaminated dental aerosol management, most of the studies done are of low certainty due to heterogeneity, risk of bias, and small sample sizes (Kumbargere Nagraj, Eachempati et al. 2020).

In attempt to follow the CDCs guidance, the Army spent a considerable amount in purchasing PACs with HEPA filtration for many of the dental clinics throughout the organization. Implement large, wide scale measures such as this is understandable and possibly warranted in such a time as the current pandemic. However, with little precedence, there is a lack of proper standards of procedure (SOP) for their use. For instance, no studies have addressed the difference in location of placement of the PACs in relation to the patient. Also, most studies mentioned, performed testing in closed room operatories but many of the operatories that exist in military dental clinics are open bay. The purpose of this study is to assess the reduction of contaminated aerosol in the open-bay dental operatory utilizing PAC with HEPA filtration and comparing the effect of PAC location on its overall effectiveness in reducing aerosol exposure. Additionally, comparing the effectiveness of the PAC when placed at the foot of the patient versus at the head. These comparisons will be used to suggest a SOP that can be utilized throughout the organization to best reduce spread of infectious aerosols and splatter.

METHODS AND MATERIALS

Setting

The study was conducted in an open bay dental clinic with the sole purpose of providing routine dental hygiene to a continuous load of patient care within the Military Health System. Each operatory area will be cleaned and disinfected per Standard Operating Procedures (SOP) between each patient encounter.

Portable Air Cleaner (PAC)

Each open bay operatory was equipped with a single stand-alone Omniaire 600V HEPA Portable Air Cleaners (PAC). These were purchased for the purpose of COVID-19 response. The filters are

rated MERV 9 with 99.97% filtration at 0.3u and a flow rate of 150-550 CFM. They are floor standing units that were placed either at the head or foot of the patient and ran during patient treatment at a "max" rate as labeled on the variable fan speed control during the study. The filtered air was exited from the exhaust port of the PAC into the open surroundings.

Bioaerosol Sampling

TSA II W/5% Sheep Blood CS100 agar plates, Catalog num. 90001-282, were used as growth medium plates for aerosol collection. A trial phase was performed to test optimal interval periods for aerosol sampling and identify approximate CFU counts that will be expected during the experimental phase. The trial phase was performed by placing plates in a variety of locations and collected at a variety of time. Data from this phase was used to determine the standardized interval and frequency used.

Samples were collected from four different locations:

1. A1: An open agar plate approximately 20cm from Patient's face at the same level as the Patient's face.
2. A2: An open agar plate placed distant to aerosol treatment within the same operatory to act as a control.
3. M1: 4"x4" swab of the outside center area of the RDH's plastic face shield before treatment and after it had been cleaned per SOP chosen by the RDH
4. M2: 4"x4" swab of the outside center area of the RDH's plastic face shield after Patient treatment.

The open agar plates were simply opened during the entire length of the procedure and the closed when the procedure was completed. The masks were swabbed with sterile cotton tip applicators moistened with treated water (from the dental lines – treated with Stericile per SOPs) and then transferred by swabbing across a new agar plate.

Intervals for collection were per patient encounter. RDH's were scheduled a consistent 6 Patients each day with an average of 1 hour 20 minutes per patient. Included in this appointment time was time allotted for cleaning and resetting the operatory for the next patient. This takes an average of

20 minutes. The remaining hour would be presumably Patient treatment. Some Patients may have taken longer or shorter than this depending on the difficulty of the dental cleaning and if it involved Scaling and Root Planning (SRP) or not.

Aerosol sampling was performed in 3 different scenarios:

1. During routine patient dental care treatment in an open bay operatory where no PAC was used
2. During routine patient dental care treatment in an open bay operatory where a PAC was placed at the head of the patient
3. During routine patient dental care treatment in an open bay operatory where a PAC was placed at the foot of the patient

The procedure for all bioaerosol sampling was a standard dental prophylaxis with ultrasonic cavitron instrumentation and selective hand scaling per the RDH's discretion and needs of the Patient.

Quantification of Isolated Microorganisms

Each growth medium plate was identified by location, procedure, time, and position of PAC. The plates were incubated for 48 hours for their final count, but were observed at both 24 and 48 hours. Total CFUs were be counted for each plate and recorded. Colony Forming Units were counted manually by a Keith Fong, microbiologist. Any CFU count over 100 were considered too many to count (TMTC) and labeled as such. All incubation and quantification were performed at DCI, Tripler, Hawaii.

Statistical Analysis

Descriptive statistics for CFU levels (mean standard deviation, median, interquartile range) were summarized. To compare samples to themselves across the 3 days, the ANOVA post-hoc-student's t-test was used. To compare different samples on the same day, also the ANOVA post hoc student's t-test was used. A significance level of 0.05 were used for all analyses.

RESULTS

After samples were collected and incubated they were initially assessed at 24 hours. The data from 24 hours will not be reported here as the numbers were low enough to allow for 48 hour incubation for ease of counting without leading to an increase in too many to count (TMTC) data points. *Table 1* lists the CFU counts after 48 hours. Note that in this study, any CFU count above 100 was deemed TMTC.

Statistical analysis was performed on data from Table 1 using ANOVA post hoc student's t-test, $p < 0.05$. Comparisons were made between the different samples on each day which are depicted in the graphs found in *Figure 1*.

Figure 1. Comparison of samples between different days. Day 1: no PAC was used. Day 2: PAC was placed at head of Patient. Day 3: PAC was placed at foot of Patient. A1: agar plate placed beside Patient's face. A2: agar plate placed distant to dental AGP. M1: swab of face shield before treatment and after cleaned per SOP. M2: swab of face shield after treatment

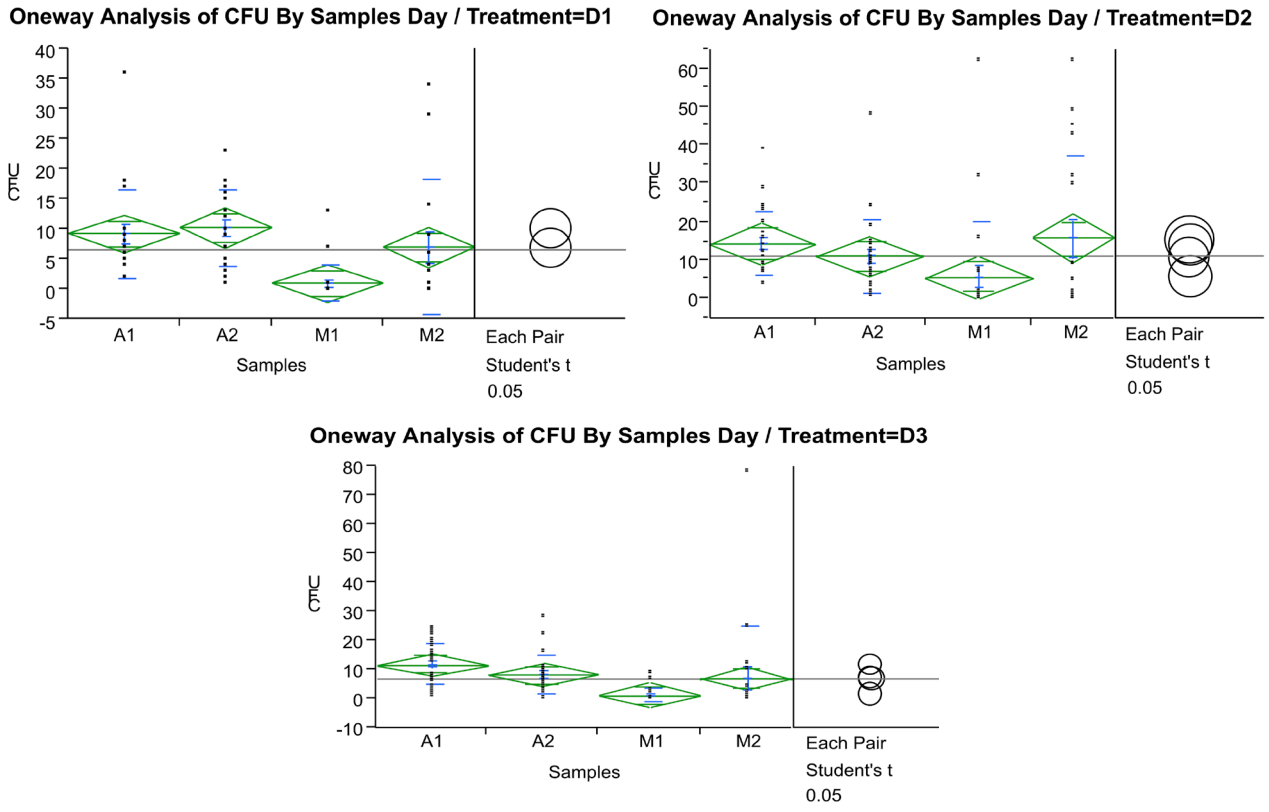

Table 1. The results of the CFU count after 48 hours of incubation.

CFU		D1 48hr					D2 48hr					D3 48hr				
Patient	Room	A1	A2	M1	M2	Time	A1	A2	M1	M2	Time	A1	A2	M1	M2	Time
P1	131	7		0	0	0740-0803	8	8	0	45	0732-0818	15	11	9	12	0719-0809
	132	5		0	0	0742-0756					No show	2	11	2	0	0719-0807
	134	2			9	0741-0802	8	2	0	0	0730-0804	7	7	0		0718-0758
	140	7		0	6	0740-0805	11	3		0	0738-0810					no show
	116											7	4	7	0	0726-0834
P2	131	7	9	0	100	0806-0814	24	11	0	100	0819-0934					no show
	132	8	7	0	1	0839-0856	7	9	7	100	0816-0930					no show
	134	4	23	0	1	0810-0849	17	8	0	0	0808-0946	20	16	0	0	0801-0913
	140					no show	16	19	0	5	0812-0925	13	11	0	0	0750-0849
	116															no show
P3	131	9	12	0	0	0916-1017	9	9	0	100	0936-1041	16	6	0	100	0813-1045
	132	18	15	0	14	0900-1015	9	12	0	1	0931-1030	7	8	0	0	0812-1042
	134	2	10	1	0	0952-1012	16	4	0	9	0946-1024	13	2	0	0	0914-1037
	140	6	5	0	100	0951-1023	29	9	0	49	0928-1033	8	5			no show
	116											16	9	0	1	0835-1054
P4	131	6	18	13	29	1227-1338	11	10	1	30	1222-1327	15	22	0	2	1225-1341
	132	10	16	0	3	1229-1321	16	14	8	100	1223-1330	18	28	3	10	1223-1331
	134	8	1	0	0	1222-1258	8	8	0	43	1220-1322	1	2	0	0	1221-1320
	140	36	16	7	34	1225-1345	20	15	0	0	1218-1335					no show
	116											22	7	2	0	1220-1325
P5	131	18	12	0	0	1323-1432					no show					no show
	132	5	7	0	4	1340-1432	9	13	1	1	1329-1441	23	10	0	78	1331-1441
	134	9	3	0	1	1302-1411	9	1	0	0	1323-1435	6	4	0	0	1324-1429
	140	17	17	0	100	1348-1421		11	2	2	1336-1450	14	7	2	25	1218-1437
	116											19	7	0	0	1325-1434
P6	131	9	13	0	0	1440-1520	14	24	62	62	1446-1527	24	3			no show
	132	7	4	0	29	1437-1528	39	48	32	32	1442-1526	3	7	0	4	1441-1538
	134	5	2	0	0	1416-1515	7	6	0	0	1437-1524	4	2	0	0	1429-1528
	140	5	3	0	100	1423-1522	23	7	0	0	1452-1529	7	3	0	2	1437-1538
	116											2	0	0	0	1434-1536

M1 is lower than M2 on all 3 days, ANOVA post hoc student's t-test, $p<0.05$. M2 is significantly higher than A2 on D1 and D2, but not D3. It is assumed that the face shield gathered the highest amount of aerosol due to its proximity to the AGP. There is no difference between A1 and A2 each day.

Test groups were A1 (agar plate placed beside Patient face) and M2 (swab of face shield after treatment). These were compared to themselves across the 3 treatment days to determine if the PAC use/placement was different. For M2, there was no difference between treatments. For A1, D2 was greater than D1, NOVA post hoc student's t-test, $p<0.05$. These comparisons are illustrated in the graphs of *Figure 2*.

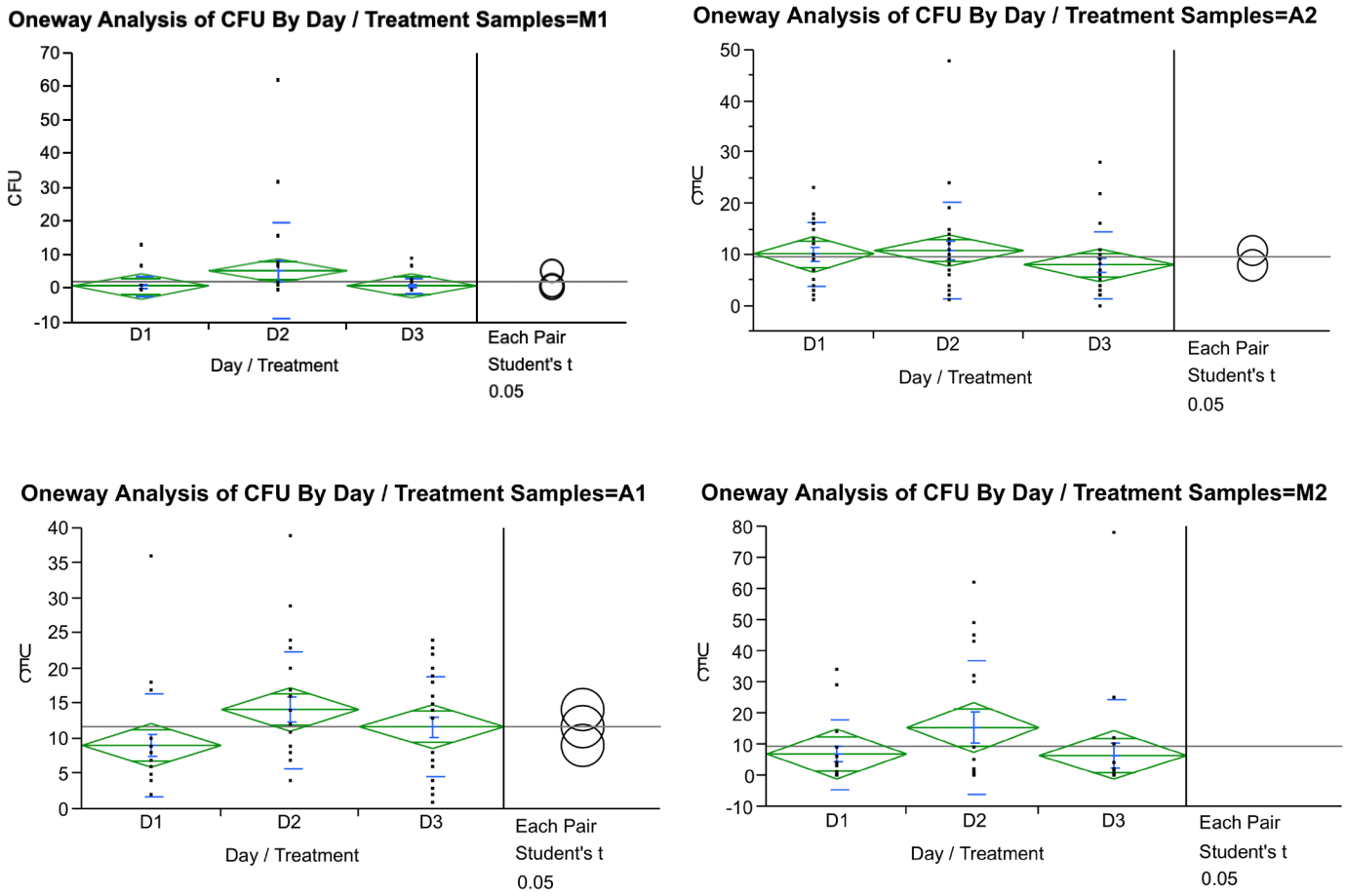

Figure 2. Comparison of sample groups across treatments. Day 1: no PAC was used. Day 2: PAC was placed at head of Patient. Day 3: PAC was placed at foot of Patient. A1: agar plate placed beside Patient's face. A2: agar plate placed distant to dental AGP. M1: swab of face shield before treatment and after cleaned per SOP. M2: swab of face shield after treatment.

In addition to quantitative data in the form of CFU counts, qualitative observations were also noted. Trends in phenotypic expression were observed of the different sample groups. *Figures 3* and *Figure 4* illustrate some of these trends. Most notably, consistency between each group can be seen. For example, A2, the samples placed distant to the AGP, tended to have fewer of the small white CFUs that were observed in more abundance in A1 and M2 sample groups while having an increased variety of different phenotypes with some with a very distinctive, destructive appearance. Meanwhile, A1 and M2 both had similar phenotypical presentation of small white colonies and with only the occasional distinctively different colony. M1 tended to be absent of CFU or with only a small few.

Figure 3. Representation of a typical sample set for a single Patient encounter. Clockwise from upper left: A1, plate placed directly next to patient, A2, plate placed in distant area of operatory, M2, swab of face shield after treatment, M1, swab of cleaned face shield before treatment. A1 and M2 generally shared similar phenotype with generally a high number of homogenous small white/gray colonies. A2 was visually different from A1 and M2 which presented with greater variety in color, size, and hemolytic activity.

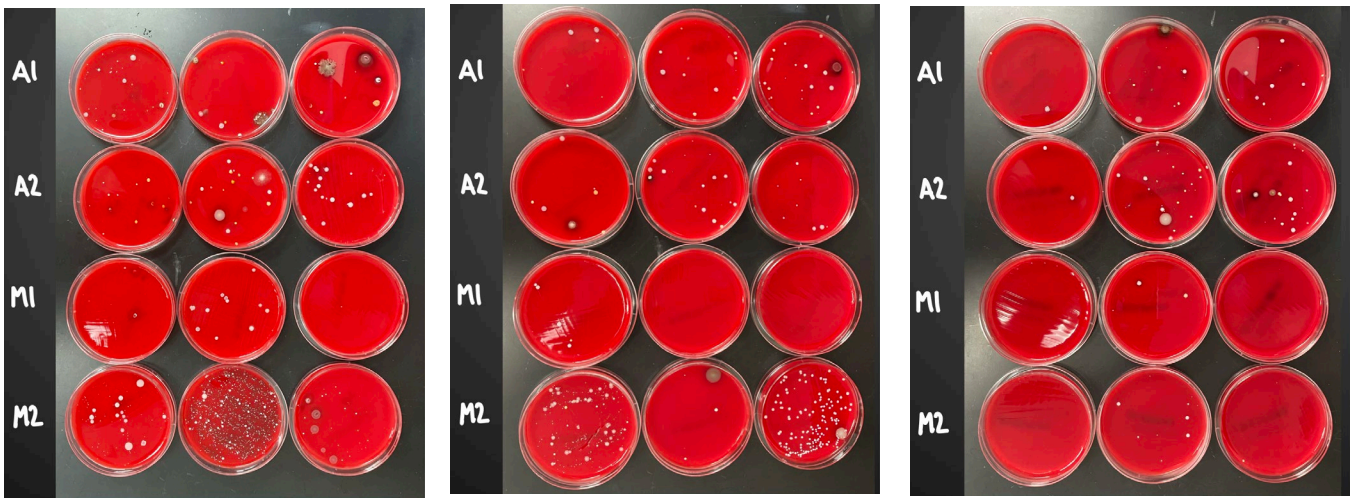

Figure 3. Phenotype comparison of sample groups across treatment days. Left: Day 1, no PAC was used. Center: Day 2, PAC was placed at head of Patient. Right: Day 3, PAC was placed at foot of Patient. A1: agar plate placed beside Patient's face. A2: agar plate placed distant to dental AGP. M1: swab of face shield before treatment and after cleaned per SOP. M2: swab of face shield after treatment. Note the consistency in trends across sample groups. A2 was more sporadic and varied in phenotype but very consistent in CFU count across samples and days. A1 and M2 were similar phenotypes across the different days. M2 notably had the highest CFU counts and also the highest amount of sporadic TMTC. A2 also had a small number of TMTC while A1 did not have any. M1 consistently was less than all others.

DISCUSSION

Dental healthcare is clearly brimming with aerosol (Kun-Szabó et al., 2021). The unknown is whether the obvious aerosol emitting from dental procedures is high risk for infectious transmission. Respiratory infections such as COVID-19, have awakened the awareness that dental healthcare has been left behind in research dedicated to infection control specific to its unique environment and procedures. This places a prudent need for infection control standards of procedure (SOPs) for dentistry relating to aerosol control and risk (Ashtiani, Tehrani, Revilla-León, & Zandinejad, 2020). Due to this lack of knowledge, individuals within small clinics and organizational leaders, such as the Army, have been forced to make decisions for their practices without evidence to support them. This study aimed to test one of these decisions and validate its true impact on improving infection control from aerosols. Portable air cleaners (PACs) purchased by the Army were tested for effectiveness in reducing aerosols during a routine dental cleaning with ultrasonics. It has been shown that airflow strongly impacts the spread and distribution of aerosols, but this has not been applied in a clinically applicable way in the research (Ren et al., 2021). To attempt to answer this unknown, the PACs were also placed in different locations to

evaluate the effect of placement in impacting aerosols. Infectious aerosol was measured via colony forming units (CFUs) collected onto agar plates. Statistical analysis was performed to evaluate if the PACs made a difference and if the placement was important.

The question of most significance to the audience of this study is 'what is the actual risk to the dental practitioner or dental patient from dental aerosols?' Studies have shown that PACs can reduce overall aerosol concentration (Hallier, Williams, Potts, & Lewis, 2010; Ren et al., 2021). There is little evidence, however, regarding the impact PACs have on *infectious* aerosols. This distinction is important as not all aerosols are infectious. Most all of the studies on aerosols in the dental setting have used CFUs to quantify "infectious" aerosols. Few have isolated these colonies to determine true infectious nature of the aerosols that were being collected and none evaluated the actual rate of transmission of respiratory pathogens from the dental setting (Innes et al., 2021; Kumbargere Nagraj et al., 2020). One advantage of this study in comparison with other studies on the same topic is the use of the RDH's face shields as a method of gathering aerosol. The face shield is presumed to be a good representation of the real exposure to the practitioner since it is aerosol that would have otherwise collided with the practitioner's face and potentially entered the respiratory airway. Past studies have mostly focused on agar plates or air pumps, some with swabbing inanimate objects (Kumbargere Nagraj et al., 2020). There was not enough statistical power to derive significance between the 3 different treatment variables and exposure of aerosol on the face shields but there was statistically significant difference between the control (cleaned face shield) and the treatment (face shield swabbed after the patient encounter). This speaks more to the fact that there were aerosols generated during the procedure. This was important to verify we were collecting real data. Phenotypically, this was helpful also because we could assume mostly all of these CFUs collected from the face shield were from the oral cavity. This allowed us to compare oral and environmental phenotypes better. Isolation of these colonies could in the future help validate these assumptions. Future studies could benefit from using the face shield as a source for collecting aerosols to assess exposure. However, this study can only offer a presumption of possible risk of infectious transmission and cannot provide a true rate of transmission. Studies are needed to quantify the real risk of infectious transmission of respiratory pathogens in the dental setting.

The open bay operatory design that exists in many dental clinics presents a unique challenge to airflow and aerosol control. In the context of the PACs that were obtained for the Army clinics throughout the enterprise, this study aimed to address that unknown by assessing placement of the PAC to obtain the best results. As discussed by Ren, Huang et al., airflow has a significant impact on the spread of aerosols (Ren et al., 2021). In this study, the only statistically different outcome was placement of the PAC by the head of the patient yielded greater CFU counts directly by the patient than at the same location when no PAC was used at all. This is contrary to assumption that filtering the air would reduce the amount of aerosol not increase it. Possible explanations are the fact that the filter was placed at the head of the patient and behind the agar plate thus directing flow of aerosol across the patient and across the agar plate thus contributing to the increased numbers. Although this finding doesn't support the use of air filtration it does support the concept that air flow matters. How the filtration generates airflow may be of greater importance and possible detriment than the use of filtration alone. More investigation is needed to evaluate more collection sites to see if a particular airflow pattern would impact other areas of the operatory and ultimately alter exposure of both the practitioner and the patient.

The primary objective of this study was to assess the effectiveness of PACs in reducing dental aerosol in general and, in addition, identify if there is a difference in placement of the PAC in enhancing or reducing its effectiveness. Previous studies have shown that aerosols can be reduced in quantity by PACs (Hallier et al., 2010; Kun-Szabó et al., 2021; Ren et al., 2021) as well as other adjunctive methods such as high speed suctions and barriers such as rubber dams (Harrel & Molinari, 2004; Kumbargere Nagraj et al., 2020). This study was the first of its kind to incorporate the placement of PACs as a variable in assessing aerosol control in the dental operatories. Our findings in this pilot study show no difference between treatments (PAC use/location) for samples collected near patient or on hygienists face shields. The limitation of this study was the limited data points that were collected. Despite the lack of statistical power, trends were identified in the data that could stimulate further investigation. These trends include a distinctive difference in both quantitative and qualitative data between different placements of the PAC. Most notably, the plates distant to the aerosol source collected a much more diversified array of CFU phenotypes, many of which had the appearance of being very destructive. These were presumed to originate from the environment of the building and within the established air and ventilation system. Also the

statistically significant finding that more aerosol was present beside the Patient's face when the PAC was placed at the Patient's head then when no PAC was used at all emphasized the impact of airflow direction. Also the observational finding that aerosolized bacteria in the dental room were different depending on the location in the room with greater variety present the further from the patient source one goes. In summary, more research is needed to determine if there is a statistically significant difference when air filter systems are placed in different locations in the dental operators and to generate ways to control environmental sources of aerosol.

Aerosol is defined as a particle that is suspended in air and usually defined as 50 microns or less (Micik et al., 1969; Szymańska, 2007). Aerosols have been at the forefront of the news due to the risk of them containing infectious respiratory microorganisms and transmitting illness. Despite aerosol being the focus, in a closed space with encounters that are more direct, transmission may occur through more direct routes. Some water droplets generated from dental procedures are too large to be suspended in air. These are called splatter are defined generally as having a size of greater than 50 microns (Szymańska, 2007). One interesting and unexpected finding of this study is that in comparison to the relatively constant CFU counts near the patient and on face shields and the environmental controls, occasionally the face shields and plates next to the patient would have an exceptionally high CFU count. These sporadic high CFU counts weren't observed in the plates distant to treatment. The assumption was made that these high counts were likely due to splatter collected and not aerosol. Two facts supported this assumption. First, the plates with sporadic high counts were isolated from the face shields and in the vicinity of aerosol treatment and not in the distantly placed growth mediums. Second, the phenotypes of the high counts were similar to that found predominately in samples that were near the patient. These appeared as small white CFUs which were assumed to be from the patient which were in contrast to the varied and more destructive colonies found more dominant in the environmental sample. This suggests that the real risk in dental may be due to splatter more so than from aerosol and means of targeting splatter may be more fruitful than focusing on aerosol alone.

The primary limitation of this study was the lack of data to derive statistical power. This study was considered a pilot and acts as a primer to investigate the issues deeper. More samples are needed. A more standardized placement of agar plates (the placement varied between each operatory

depending on the exact layout of the operatory and preferences of the RDH) would help eliminate variation due to changes in location. Also standardizing the interval periods would make the data more meaningful as this study used a single patient encounter that, although, was similar in length on the schedules, varied Patient to Patient based off difficulty and also speed of the RDH. This, however, could also be considered a strength as this variation is true to actual clinical proceedings. Isolating the organisms could help verify the origins of the CFUs and provide more information to analyze especially as it related to the impact of the environment. Although another strength of the study in the real-world-applicability, this study took place in open bay operatories which means there was no control of air flow and disturbances such as people walking by. Controlling these factors in closed rooms, perhaps even with negative air pressure, can also give a more accurate idea of the effects of airflow and PAC placement. A limitation with the specific PACs that were purchased is that they are floor standing units and thus the airflow is below the patient and may be more effective at a higher level. This is another variable that could be tested. One study placed a PAC at the level of the Patient (Hallier et al., 2010). One advantage of the Hallier study is they also used air pumps to collect aerosols onto the agar plates which allows for them to test a larger volume of the room which could also be beneficial in future studies. Finally, finding innovative ways to test other infectious aerosols other than via CFU counts to mimic or replicate viral transmission would be more specific and applicable especially in the current pandemic environment.

As already stated, there is much work to be done to understand the risks that come specific to the dental setting. Because most the policies currently used in dentistry are a derivation from the larger medical community and hospitals (Tran et al., 2012), there lacks a common consensus on how dental procedures fit it to the schema of other health fields. Aerosol generating procedures (AGPs), for example, are clearly defined by the CDC for the hospital setting, but there is no clear consensus on what dental procedures are AGPs or if they are at all ("Clinical Questions about COVID-19: Questions and Answers | CDC," 2022; Innes et al., 2021; Jackson et al., 2020; Prevention, 2020; Virdi et al., 2021). Furthermore, the research performed on aerosols have been all similar in nature, generally utilizing CFUs to quantify infectious aerosols which is far from generalizable to viral spread through aerosols. To the author's understanding at the date of writing this, there have been no studies on viral transmission through aerosols in the dental office (Kumbargere Nagraj et al.,

2020). These and more questions remain that leave the dental community vulnerable during this and the next pandemic. Evaluating the true risk that exists in the dental office is essential to allow dental professionals and team members to make informed decisions that will best protect themselves and their patients.

CONCLUSION

Although no statistical correlation could be made for the effectiveness or placement of PACs in dental operatories, qualitative observation provided evidence that there are differences in aerosol type and maybe quantity depending on location and airflow direction. Total exposure to contaminated aerosol may be greater from the environment than from the actual patient, therefore further investigation into environmental controls and protective measures may be warranted. Isolating organisms in future studies may help identify what is transmitted from the patient versus what is originating from the environment. The real occupational risk during dental procedures might be more from splatter than from aerosol. This might also challenge the inclusion of dental procedures as AGPs. Further studies needed to investigate true nature of infectious risk during dental procedures.

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