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Pragmatic Evaluation of an Augment to the Dental Operatory Disinfection Bundle

Cayouette MJ[1†], Hil BM[1,†], Klingler KT[1,†], Cayouette SR[1,2], Marshall JL[3], and Schmidt MG[3*]

[1,†]Department of Oral Rehabilitation, James B. Edwards College of Dental Medicine, Medical University of South Carolina, Charleston, SC. 29425, USA

[2]Charleston Restorative & Cosmetic Dentistry, LLC, Charleston, SC 29407, USA

[3*]Department of Stomatology, James B. Edwards College of Dental Medicine, Medical University of South Carolina, Charleston, SC. 29425, USA

RESEARCH ARTICLE

ABSTRACT

Background: Dental care generates microbially ladened aerosols that remain aloft for upwards of 41 hours, fugitively settling onto surfaces. In 2020, OSHA recognized the risk such aerosols could present to patients and providers classifying dentistry as a ‘very high-risk occupation’ for transmission of the agent responsible for the COVID-19 pandemic, SARS-CoV-2. Here we measured the effectiveness of an electrostatic application of US-EPA-N-List-disinfectant, sodium dichloroisocyanurate-US-EPA-Reg-71847-6-91524 to disinfect surfaces.

Methods: A pragmatic trial design evaluated the effectiveness of the electrostatic application of an US-EPA-N-List-disinfectant to five high-touch surfaces, in ten dental operatories, on three separate occasions, measuring effectiveness as a reduction in surface microbial burden. Five high-touch surfaces were sampled pre/post application of the disinfectant: light-handle, dental-hand-piece air-hose, air-water-syringe holder, arm-of-the-dental chair, and operatory floor. Samples were characterized for total aerobic-colony–forming-units of bacteria recovered from each surface. A positive outcome was scored as a reduction in microbial burden observed post-application of the disinfectant.

Results: Evaluating 410 surfaces found a significant reduction to surface microbial-burden post-electrostatic fogging, lowering the overall risk of encountering microbes two-fold, from a median pre-electrostatic fogging concentration of 160 to a post-fogging concentration of 80 ACC•100 cm^2 ($p=0.0002$).

Conclusion: Electrostatic deposition of an US-EPA-N-List-disinfectant has an opportunity to conveniently augment the dental infection control bundle and aid in substantially reducing the associated microbial risk of surfaces within the dental operatory.

KEYWORDS

Antimicrobial agents, Bacteria, Biofilm(s), Infection control, Anti-Viral disinfectant, SARS-CoV-2 mitigation, Electrostatic deposition

Correspondence to: Dr. Schmidt MG, Department of Stomatology, James B. Edwards College of Dental Medicine, Medical University of South Carolina, Charleston, SC. 29425, USA, Email: schmidtm@musc.edu

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INTRODUCTION

Since the emergence of the SARS-CoV-2 virus in the central Chinese city of Wuhan in late 2019, this virus, and its variants, have quickly spread across the globe, reaching pandemic status in March 2020, resulting in significant global levels of morbidity and mortality [1]. Transmission of SARS-CoV-2 occurs principally by human-to-human contact through multiple modalities. Respiratory droplets, aerosols, and fomites all have been implicated in the transmission of this virus [2-4]. The aerosol nature of transmission has resulted in public health agencies recommending that the general population wear properly fitted cloth and/or medical masks to reduce the fugitive transmission of SARS-CoV-2 to slow its spread [5]. With the advent of the availability of highly effective vaccines, public health advisories have tempered the need for masking among those individuals fully vaccinated and boosted against SARS-CoV-2. It is unlikely that vaccination alone can address the risks associated with the liberation of potentially infectious aerosol emissions resulting from routine dental care. To date, there have been no documented cases of transmission of SARS-CoV-2 within the confines of a dental healthcare setting.

Consultative and infection control standard setting bodies, including the CDC, the WHO, and the ADA have offered interventions and best practice recommendations to limit the risk of contracting SARS-CoV-2 resulting from routine and restorative dental care. However, the United States Occupational Safety and Health Administration (OSHA) has classified dentistry as one of the 'very high-risk occupations' for the transmission of the SARS-CoV-2, principally because of the generation of aerosols during the conduct of normal restorative and preventive dental procedures facilitated by dental instruments [6].

Operationally, an aerosol results in the dispersion of solid and liquid particles where the offending particulate matter generated ranges in size between 0.001 to 100 µm [7]. Restorative dental procedures employing high-speed handpieces routinely result in the generation of microbially ladened aerosols. These dispersed droplets or aerosol particles may range in size between 5µm and 300 µm in diameter, with escape velocities varying in speed between 1.3 m s-1 and 2.6 m s-1 [8].

Previous studies have validated distances microbes travel to approximately 1.5 to 2 meters from the field of care surrounding the patient [9]. Such dispersion measurement secondary to dental care have recovered concentrations of bacteria at a mean concentration of 1,119 CFUm-2 hr-1at distances greater than 1.5 m from the patient [9]. Santarpia and colleagues have recently offered that infectious forms of SARS-CoV-2 are able to be recovered from size-fractionated aerosol samples from within a hospitalized patient care setting [10].

While the dental operatory is routinely disinfected between patients, the indoor airspace and floors are not. Aerosol particles less than 0.5µm in diameter can take upwards of 41 hours to settle, while particles greater than 10µm can settle within 8.2 minutes [11]. Newly generated aerosolized particles may collide with previously generated aerosol droplets creating the potential for them to coalescence with subsequent settling onto surfaces within the built dental operatory environment. Santarpia and others found aerosol particles with a mean diameter of 0.6 µm to 0.8 µm, termed "fined mode aerosol particles" contained infectious SARS-CoV-2 particles and were resident in the built clinical environment [10]. It is logical to assume that these smaller aerosol particles will eventually settle, generating a possibility of creating a virally contaminated surface, despite routine disinfection between patients.

This study assessed the ability of an electrostatic sprayer to deliver a sufficient concentration of a US-EPA-Grade-N registered disinfectant-ladened fog onto surfaces within the built dental operatory environment. We surmise this will lower the incident microbial burden, thereby reducing the risk that frequently contacted surfaces within the dental operatory might serve as fomites of infectious transfer, secondary to their aerosol deposition. We evaluated the hypothesis that the electrostatic application of the active agent, sodium dichloroisocyanurate ((NADCC) /C3Cl2N3NaO3 (US-EPA Reg. No. 71847-6-91524)) would be sufficient in its spectrum of activity to significantly reduce the risk that surfaces might pose, offering an additional mitigative step in the prevention of the fugitive transmission of bacteria, viruses, and fungi to dental care providers and their patients.

RESEARCH METHODS

Study design, setting, and rationale

The study was conducted in the restorative clinic of dental school in the USA. This clinic has forty-three fully equipped and partially partitioned operatories, of which ten were pragmatically sampled on three separate occasions. Samples from five different surfaces within each operatory were collected before and after the application of a final concentration 2,153 ppm of an US-EPA registered disinfectant, sodium dichloroisocyanurate ((NADCC) / $C_3Cl_2N_3NaO_3$ (US-EPA Reg. No. 71847-6-91524)). This disinfectant class is on the US-EPA List N agents. The US-EPA expects all products Graded N to inactivate the coronavirus, SARS-CoV-2 when used according to the label directions [12].

Each dental operatory was equipped with a RabbitAir-MINUSA2-UltraQuietAirPurifier that was responsible for the continuous filtration of the incident air from each operatory. The addition of this device within each operatory when combined with the inherent filtration effect provided for by the air-filtration system of the clinic building offered each operatory an effective air-exchange rate of approximately ten Air Exchanges per Hour (ACH). This rate of exchange achieved approximately 99% to 99.9% removal efficiency between 28 and 41 minutes, which is recommended for preventing the transmission of the air-borne pathogen *Mycobacterium tuberculosis* within health-care facilities [13].

The interventional disinfectant was applied to the surfaces by using a Protexus electrostatic sprayer at the rate recommended by the manufacturer. The active agent was supplied as an effervescent tablet, diluted with tap water. Upon suspension, the organic chlorine donor forms a mildly acidic to neutral solution that provides an appropriate concentration of hypochlorous acid (HOCl) to inactivate a variety of microorganisms found on surfaces within the built dental operatory.

A sufficient number of tablets were dissolved in tap-water to yield a final concentration of 2,153 ppm of HOCl. The dry mist generated by the electrostatic sprayer deposited a concentration of hypochlorous acid, sufficient to warrant a Grade N, US-EPA public health claim, that upon application the disinfectant will inactivate Norovirus (ATCC VR-782) within 1 minute of contact and a variety of Gram-negative and Gram-positive bacteria within 5 minutes on surfaces. This product also offered an emerging pathogen claim that when applied according to the manufacturer's specification, the disinfectant met the criteria for use against emerging enveloped viral pathogens, e.g., SARS-CoV-2. Per the guidance to registrants, the US-EPA offers that these statements will only be permitted as non-label claims when emerging viral pathogen conditions are met, which is the case for the SARS-CoV-2 pandemic [12].

Patients were treated in the student-served restorative clinic at the dental school following the College's established SARS-CoV-2 pandemic-informed infection control guidelines. Patients were temperature screened prior to treatment and surveyed as to any COVID-19 contacts and date from a positive SARS-CoV-2 diagnostic test. Patients were required to conduct a 30 second, 20 ml, oral antiseptic rinse (Colgate®Peroxyl® (1.5% w/v) hydrogen peroxide) immediately prior to the provision care.

At no time were patients exposed directly to the Grade N vapor phase disinfectant. Samples were collected between 5 minutes and 1 hour of a patient occupying the dental operatory. For the purposes of this study only, the dental operatory was not sanitized after the provision of care. The study was reviewed by the Institutional Review Board and deemed exempt with microbiology work in the laboratory and monitored according to established and approved protocols of the Institutional Biosafety Committee.

Sampling Collection and burden evaluation

Total aerobic colony–forming units within an area of 100 cm^2 (ACC/100cm^2) were measured from five distinct locations from within each of the four high-touch areas (the light handle, the dental hand piece air-hose, the air water syringe jet holster, and the arm of the dental chair) located within the patient dental operatory and the adjacent floor surface (Figure 1). Measurements were taken prior to the application of the effervescent disinfectant and 5 minutes subsequent application. To ensure the act of sampling would not skew the results, a different location was sampled subsequent the application of the disinfectant.

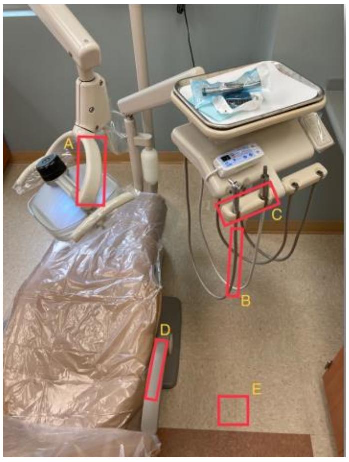

Figure 1: Sampling locations within the dental operatory assessed to evaluate the effectiveness of an electrostatically applied US-EPA N List effervescent disinfectant, (2,153 ppm: 5 minutes contact time), sodium dichloroisocyanurate ((NADCC) / C3Cl2N3NaO3 (US-EPA Reg. No. 71847-6-91524)).

Total aerobic colony forming units per 100 cm^2 (ACC/100 cm^2) were measured as described on 4 separate occasions from each of 5 areas associated with 10 distinct dental operatories of the restorative clinic of a college of dental medicine. A 100 cm^2 area was sampled using a Teflon template using a premoistened swab before and 5 minutes subsequent electrostatic application of an N class disinfectant. A, light handle B, dental hand piece air-hose, C, the air water syringe jet holster, D, the arm of the dental chair, and E, the floor surrounding the operatory. Each of the five surfaces were sampled using the ESK®.

Environmental Sampling Kit comprised of 4 ml of sterile neutralizing buffer and polyester swab. The kit was manufactured by Puritan Medical Products Co, LLC; each template-assisted area was sampled by rolling the swab over each surface five repetitions up and down and five repetitions left and right. Samples were immediately returned to the lab for enumeration of the total aerobic colony forming units of bacteria present by vortexing each sample for 30 seconds whereupon 100 µl from each sample was plated onto Blood Agar (Thermo Scientific). The plates were incubated inverted at 37°C for 48 hours. The number of colonies were counted and the concentration per area sampled was computed and expressed as total aerobic colony–forming units within an area of 100 cm^2 (ACC/100cm^2).

POWER AND STATISTICAL CALCULATIONS

The efficacy of the electrostatic disinfection in reducing the microbial burden was determined by comparing the distributions of the total microbial burden (ACC/100 cm^2) pre- and post- application of disinfectant using the Mann-Whitney test, where $p < 0.05$ was considered significant. All statistical analyses were conducted with Prism 9.2 software. Median values along with other descriptive statistics were calculated to assess the total microbial burden for each of the operatories sampled. At no time did the team attempt to recover virus from the samples evaluated. Therefore, the total microbial burden recovered was used as a surrogate to assess the effectiveness of the effervescent tablet based electrostatic disinfectant fogging; as a List N agent it was anticipated that should any SARS-CoV-2 be present, its risk of remaining infectious would be reduced.

Given that each frequently touched dental operatory contact surface is disinfected subsequent each patient encounter, we anticipated that the intrinsic microbial burden associated with those surfaces subsequent care would be low, potentially limiting our ability to reproducibly measure the effect of the intervention without substantially disrupting the workflow of the clinic. In order to overcome this limitation of a stochastically low concentration of microbes within the operatory, we included the operatory floor, a surface not routinely disinfected between cases. We posit the operatory floor contains sufficient microbial concentrations to determine the number of samples required to detect the effectiveness of the intervention. The effect size used in the sample size estimate calculation was based on the published US-EPA activity for the N-class disinfectant employed and consideration of the stochastic distribution of microbes on the floor secondary to aerosol deposition. Assuming α=0.05 and 1-β=0.8, 88 samples were deemed sufficient for a two-tailed Mann-Whitney test. We elected to oversample by approximately 59% for a total of 140 floor samples, 70 pre-intervention and 70 post-intervention in order to determine the effectiveness of the intervention.

DATA AVAILABILITY

The raw data associated with the recovery of microbes from the surfaces samples are available upon request.

RESULTS

Application of an effervescent disinfectant significantly reduced the concentration of microbes within the built dental operatory environment.

The application of an electrostatically applied effervescent disinfectant, with a contact time of five minutes was able to significantly lower the total concentration of aerobic colony–forming microbes found associated with two of the five surfaces evaluated (Figure 2). The other surfaces also had lower median concentrations of microbes within the allotted 5-minute contact time but failed to reach significance. When all the surfaces sampled were considered, the difference in the burden was significantly lower post electrostatic-fogging, reducing the risk of encountering a microbe two-fold, from a median pre-electrostatic fogging concentration of 160 ACC/100 cm^2 to 80 ACC/100 cm^2 post-application, ($p = 0.0002$; N=410 surfaces evaluated). The results from the sampling of the floor suggest that electrostatic spraying of the surfaces within the dental operatory can significantly reduce the median microbial burden on the floor by almost five-fold. The pre-intervention and post-intervention median concentrations recovered from the sampling of the floor surfaces were 580 ACC/100 cm^2 and 120 ACC/100 cm^2, respectively, ($p < 0.0001$; N=70) (Figure 2).

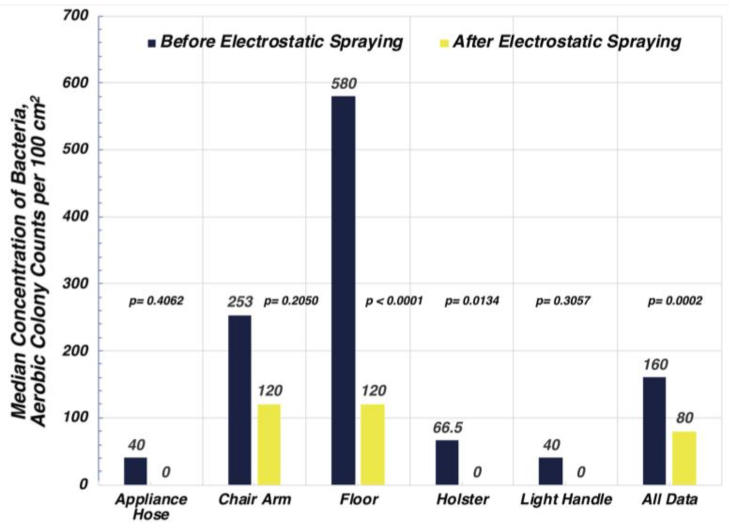

Figure 2: Application of an effervescent disinfectant significantly reduced the concentration of microbes within the built dental operatory environment.

Five surfaces each, from ten operatories within a forty-three operatory student clinic were pragmatically sampled before and after the application of a fogged based effervescent disinfectant, sodium dichloro-s-traizinetrhione, at a final effective concentration of 2,153 ppm with five minutes of contact time. In total 410 surfaces were evaluated over the course of 3 months. Significance was assessed by comparing the before and after total aerobic colony forming unit concentrations recovered, (ACC/100 cm^2), from sampling using a non-parametric pairwise comparison using the Mann-Whitney test. A value of 0 indicates that the value was below the limit of detection (<40 ACC/cm^2) of the sampling protocol. Significance level (p) was assessed as less than 5% ($p < 0.05$) using Prism 9.2 software.

For all surfaces evaluated, the microbes recovered on the plates were principally bacteria and fungi, with bacteria outnumbering the fungal species. As the total concentration of microbes was the sole outcome measured, further characterization of the microbes was not conducted. The microbes recovered from the positive control sample, the floor, had the greatest degree of colony morphology of the microbes recovered. At no time did the investigators attempt to recover SARS-CoV-2 virus from any of the samples, but as the N-class disinfectant was applied according to the manufacturers recommendations and with the contact time exceeding that required to inactivate the facsimile virus, Norovirus (1 minute) by five-fold, it was assumed that if the total aerobic concentration of bacteria were significantly reduced then the risk from the fugitive emission of the SARS-CoV-2 virus from an infected patient or dental team member would be similarly minimized.

DISCUSSION

Dentistry has addressed the safety and effectiveness limitations of commonly employed infection control protocols during the Covid-19 pandemic to better control its fugitive spread. Several additional mitigative steps have been introduced to reduce the risk to providers and patients. They range from screening and triaging all who enter their practice for signs and symptoms associated with SARS-CoV-2, to the continuous use of N-95 masks, the coincident use of other PPE (impervious gowns, face shields, eye protection) by care team members during the conduct of care, and employing preprocedural mouth rinses (PPMR) to lessen the risk to both patients and care-team providers from an aerosol release of active virus [6]**.** In the pragmatic trial, we evaluated an additional mitigative step to address the issue of procedural-derived aerosols that could not be formally a1ddressed by external high-volume extraction devices (HVE), [14] as well as other risks normally not anticipated by the current OSHA-CDC guidance for dental operatories [6]. Here, the application of an electrostatically enhanced disinfectant fog was found effective in reducing the bioburden within the confines of each dental operatory. The floor showed the largest decrease in microbial burden, illustrating the utility of applying an N List disinfectant via an electrostatic sprayer. Current standard of care for dentistry requires only that floor be cleaned on a daily basis, absent a spill. Given that there was no formal spraying of the floor, these results suggest that the electrostatic distribution of the disinfectant was likely sufficient to cover critical areas, in that sufficient vapor settled and significantly disinfected the floor. Consequently, we are confident that should any of the other mitigative steps have failed in their ability to address fugitive emissions of SARS-CoV-2 during care, the subsequent electrostatic-fogging of the operatory with an N-List disinfectant would contribute to an enhanced reduction in the risk of infection acquisition from microbes resident in the built dental environment.

The low burden associated with pre-application sampling of the high-touch surfaces within the operatories suggests compliance with the infection control protocols requiring their disinfection subsequent care within this student clinic was good. Absent adherence, we would have expected higher burden rates on these surfaces. The failure of inherent burden resident on these surfaces to achieve significant reductions subsequent electrostatic fogging was likely a result of the stochastic nature of aerosol burden deposition onto surfaces, as well inherent to the sampling process itself.

While it is understood that the techniques employed in dentistry generate aerosols and that masking, the most effective mitigative step for controlling the transmission of SARS-CoV-2, is not available during the provision of dental care, the addition of an electrostatic-fogging mitigative step within the dental operatory may serve to improve the clinical efficacy of the infection control in dentistry. There is an increasing body of literature offering that the success of a clinically effective infection control program is dependent on an effective systematic approach that considers the risks introduced in the provision of care [15]**.** Adherence to the protocol or bundle helps to offer consistent and safe patient care. Each step within the dental infection control bundle attempts to address limitations or gaps associated with the other steps to better control the spread of viruses, bacteria, and fungi. Here, the additional application of an N-List disinfectant electrostatic fog facilitated the droplet-ladened disinfectant attraction to the surfaces within the operatory rather than simply floating in the air as generally happens with spray mist applications or other foggers. The agent used, PureTab, passed rigorous independent testing by OSHA and NIOSH offering that when applied using the Protexus Electrostatic sprayer, there are no safety concerns from acute or long-term exposure to the disinfectant as its levels fall below Permissible Exposure Levels (PEL) [16]. Finally, when considered with the other steps introduced into the dental infection control bundle to reducing the risk of fugitive aerosol transmission of SARS-CoV-2 (use of HVE, oral-antiseptic rinses, 10 ACH), this additional mitigative step has an added advantage of quickly disinfecting a dental operatory without fear that the active agent will harm the hard or soft surfaces or pose a health hazard to dental personnel.

The limitations associated with this study were that no attempt was made to characterize the decrease in human viruses resident on the surfaces within the dental operatory, there was variability in the burden recovered from the surfaces sampled due to the stochastic nature of aerosol generation and deposition, and the limit of sensitivity of the sampling was less than 40 ACC/cm^2.

A further limitation of the study was that the effectiveness of the intervention was assessed principally through the measurement of the reduction in the concentration of microbes present on the floor. We believe this was reasonable considering the low concentration of microbes recovered from the high-touch surfaces pre-intervention and that separate surfaces were assessed subsequent the application of the intervention in order to eliminate the bias introduced by the removal of microbes as a consequence of sampling. The greater burden resident on the floor afforded an opportunity to assess the effectiveness of this augment as an additional intervention in the standard infection control dentistry bundle and may offer insight into its use as an augment to existing infection control methods used in other outpatient healthcare settings.

CONCLUSION

The electrostatic application of an effervescent disinfectant immediately after patient care was found to significantly reduce the concentration of microbes within the built dental operatory environment. The disinfectant used had broad spectrum activity against a variety of bacteria, viruses, and fungi, and, coupled with the convenience of its rapid electrostatic deposition offers the opportunity to significantly reduce the microbial risk that surfaces within the dental operatory represent to patients and providers by mitigating the inherent and stochastic risk associated with the settling of aerosols within the dental operatory.

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