Infection Control & Hospital Epidemiology (2024), 1–3
doi:10.1017/ice.2024.109

SHEA

Concise Communication

Evaluation of a wall-mounted far ultraviolet-C light device used for continuous air and surface decontamination in a dental office during routine patient care

Andrew O. Osborne BS[1], Samir Memic BS[2], Jennifer L. Cadnum BS[2] and Curtis J. Donskey MD[2,3]

[1]Case Western Reserve University School of Medicine, Cleveland, OH, USA, [2]Research Service, Louis Stokes Cleveland VA Medical Center, Cleveland, OH, USA and [3]Geriatric Research, Education, and Clinical Center, Louis Stokes Cleveland VA Medical Center, Cleveland, OH, USA

Abstract

A wall-mounted far ultraviolet-C light device used for continuous air and surface decontamination in a dental office reduced aerosolized bacteriophage MS2 and methicillin-resistant *Staphylococcus aureus* on steel disks by >3 $\log_{10}$ in 2 hours in unshaded areas in a procedure room. Far ultraviolet-C delivery was substantially reduced in shaded areas.

(Received 29 November 2023; accepted 29 May 2024)

Introduction

Far ultraviolet-C (UV-C) light (200 to 230 nm) has been proposed as a technology for continuous surface and air decontamination in occupied spaces.[1,2] Far UV-C is purported to be safe for use while people are present because it is strongly absorbed by proteins and other biomolecules and therefore penetrates minimally into skin and eye tissues.[2,3] There is some evidence that 222 nm far UV-C doses within threshold limit values proposed by the American Conference of Governmental Industrial Hygienists (ACGIH) and the International Commission on Non-Ionizing Radiation Protection may be safe.[4–7] However, there is a need for more evidence regarding safety and efficacy in real-world settings.[3]

Dental procedures pose a risk for transmission of bacterial and viral pathogens.[8] The risk can be minimized by following standard precautions.[8] As an adjunctive measure, a private dental office installed far UV-C lamps in 5 dental procedure rooms in 2020 in response to the coronavirus disease 2019 pandemic. The lamps have been operated during care of patients for more than 3 years. Here, we interviewed dental staff regarding their experience with the technology and evaluated the efficacy of the device in a dental procedure room.

Methods

Description of the far UV-C technology

The 250-Watt GermBuster Channel (Sterilray, Inc.) far UV-C technology uses a 45.7 cm krypton-chloride excimer lamp that emits 222 nm light. A picture of the device is shown in the supplementary material. The device includes a high (240 Watts) and low (99 Watts) setting.

Use of the far UV-C technology in the dental office

GermBuster Channel far UV lamps (Sterilray, Inc., Somersworth, NH) were installed in 5 dental treatment rooms ranging from 16.6 to 24.9 m3. The lamps are positioned near the ceiling ∼1.52 meters from patient's head with the patient facing away from the lamp and are operated on the low setting during patient care up to 7 hours per day. Each of the lamps had been operated for more than 2,500 hours by August 2023. One person interviewed the dentist and a dental hygienist regarding their experience using the technology, acceptance by patients, and adverse effects. The interview questions are shown in the supplementary material.

Evaluation of the far UV technology in a dental treatment room

Testing was conducted in a 31.2 m3 dental treatment room with ∼12 air changes per hour at the Cleveland VA Medical Center like the private dental office rooms but larger. The far UV-C device was positioned 2 m from the floor angled toward the patient's chair. Far UV-C delivery to 20 test sites classified as unshaded (i.e., in direct line of UV-C exposure), partially shaded (i.e., not in direct line of exposure), or fully shaded was assessed using a radiometer (UIT2400 Handheld Light Meter for 222 nm (Ushio America, Cypress, CA) and 222UVC Dots colorimetric indicators (Intellego Technologies, AB Gothenburg, Sweden) detecting doses ranging from 5 to 150 mJ/cm^2. For the 20 sites, efficacy against methicillin-resistant *Staphylococcus aureus* (MRSA) in 5% fetal calf serum was tested using a modification of the American Society for Testing and Materials (ASTM) standard quantitative disk carrier test method (ASTM E 2197-02).[9] The concentration of MRSA on the disks was ∼3.5 $\log_{10}$ colony-forming units. The exposure time was 2 hours. Experiments were completed in triplicate. A 3-$\log_{10}$ or greater

Corresponding author: Curtis J. Donskey; Email: Curtis.Donskey@va.gov
Andrew O. Osborne and Samir Memic contributed equally.
Cite this article: Osborne AO, Memic S, Cadnum JL, Donskey CJ. Evaluation of a wall-mounted far ultraviolet-C light device used for continuous air and surface decontamination in a dental office during routine patient care. *Infect Control Hosp Epidemiol* 2024. doi: 10.1017/ice.2024.109

Table 1. Far ultraviolet-C delivery to unshaded, partially shaded, and shaded sites in a dental treatment room and reductions in methicillin-resistant *Staphylococcus aureus* at the test sites

Site	Distance (m)	Irradiance (μW/cm^2)	Dosage 2 hours/ 7 hours (mJ/cm^2)	Colorimetric indicator dose (mJ/cm^2) (2 hours)	Mean (SE) $\log_{10}$ MRSA reduction (2 hours)
Unshaded					
1	1.6	3.8	27.4/95.8	50	>3.5 (0)
2	1.9	3.2	23.0/80.6	No data	>3.5 (0)
3	2.0	1.7	12.2/42.8	20	>3.5 (0)
4	2.3	1.7	12.2/42.8	5	>3.5 (0)
5	2.2	1.4	10.1/35.3	100	>3.5 (0)
6	1.7	1.0	7.2/25.1	5	>3.5 (0)
7	2.0	0.9	6.5/22.7	50	>3.5 (0)
8	2.0	0.8	5.8/20.2	50	>3.5 (0)
9	3.0	0.5	3.6/12.6	20	>3.5 (0)
Partially shaded					
10	1.6	1.5	10.8/37.8	20	3.2 (0.3)
11	3.0	0.9	6.5/22.7	20	3.0 (0.2)
12	3.1	1.0	7.2/25.2	5	2.6 (0.6)
13	1.6	2.2	15.8/55.4	20	2.6 (0.5)
14	0.5	0.6	4.3/15.1	50	1.7 (0.1)
Shaded					
15	0.9	0.1	0.7/2.5	0	0.5 (0.04)
16	1.4	0.2	1.2/4.0	0	0.5 (0.02)
17	2.2	0.0	0/0	0	0.4 (0.3)
18	1.5	0.0	0/0	0	0.4 (0.1)
19	0.5	0.0	0/0	0	0.3 (0.2)
20	3.1	0.0	0/0	0	0.3 (0.1)

Note. SE, standard error; m, meters.
Dosages were calculated for 2-hour and 7-hour exposure times using irradiance readings obtained using a radiometer.

reduction in comparison to untreated controls was considered effective.[3] The supplementary material provides an illustration of the dental room with numbers indicating the test sites and pictures of the room and the colorimetric indicators.

Reduction in aerosolized bacteriophage MS2

The efficacy of the far UV-C technology in reducing aerosolized bacteriophage MS2 was tested in a 23.5 m^3 room with ∼4 air changes per hour.[3] After release of aerosol containing 10^8 plaque-forming units (PFU) of bacteriophage MS2, air samples were collected using National Institute for Occupational Safety and Health two-stage bio-aerosol samplers (Tisch Environmental) over 5-minute periods 0–5 (baseline) and 40–45 minutes after release. $\log_{10}$ reductions were calculated in comparison to control experiments with no far UV-C exposure.

Results

Based on interviews with the dentist and dental hygienist, the technology has been received positively by patients and staff with no reports of adverse health effects, damage to equipment, or discoloration of surfaces. All patients receive an information sheet describing the technology. Staff wear standard dental protective equipment including eye protection.

As shown in Table 1, far UV-C delivery to sites in the treatment room varied considerably, with substantially higher irradiance readings in unshaded or partially shaded (range, .6–3.8 μW/cm2) versus shaded (0–.2 μW/cm2) locations. For the shaded sites, the colorimetric indicators read unexposed and reductions in MRSA were ≤.5 $\log_{10}$ after 2 hours of exposure. In contrast, all unshaded and partially shaded sites had positive colorimetric indicator readings and MRSA reductions of ≥1.7 $\log_{10}$.

After release, >6 $\log_{10}$ PFU of bacteriophage MS2 was recovered from air at baseline and after 45 minutes for control samples (Figure 1). The far-UV-C exposure resulted in a >5 $\log_{10}$ PFU reduction after 45 minutes.

Discussion

Far UV-C is a promising technology for continuous decontamination of air and surfaces.[1,2] However, the lack of published evidence regarding efficacy and safety in real-world settings has been a major impediment. In the current study, we evaluated the efficacy of a far UV-C technology used in a dental clinic during patient care. In a dental procedure room, a single wall-mounted far UV-C lamp delivered substantial doses of far UV-C to unshaded areas 1.6–3.0 m from the lamp and reduced MRSA in these locations by ≥3.5 $\log_{10}$ within 2 hours. Far UV-C doses and

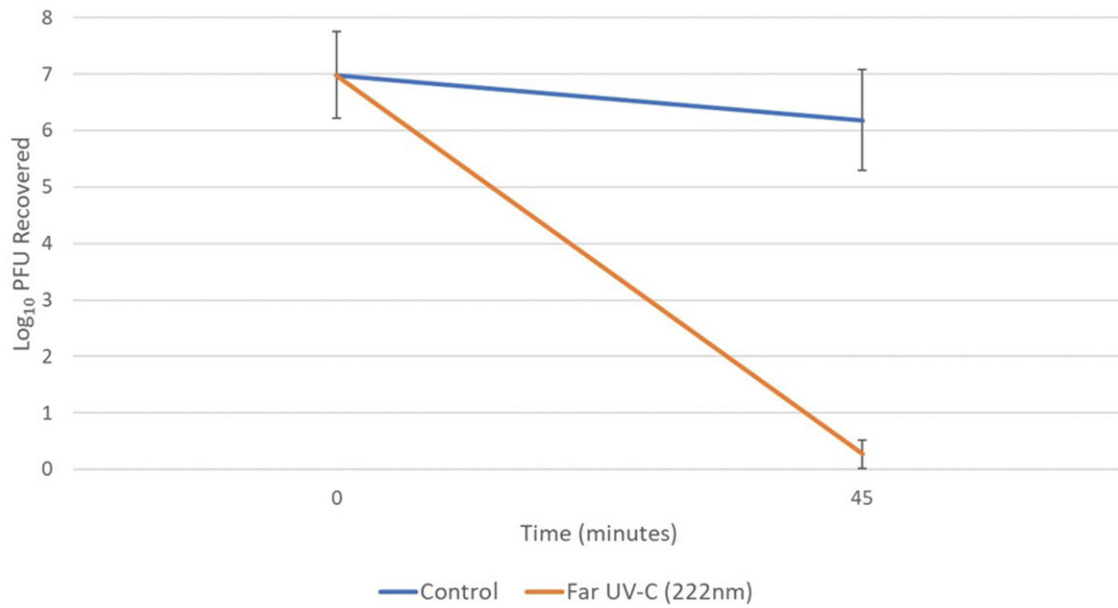

Figure 1. Reduction in aerosolized bacteriophage MS2 over 45 minutes in a test room with and without exposure to far ultraviolet-C light. PFU, plaque-forming units; nm, nanometers. Error bars show standard error.

reductions in MRSA were substantially decreased in fully shaded areas as has been demonstrated for 254 nm UV-C.[10] In a separate test room, aerosolized bacteriophage MS2 was reduced by $>5 \log_{10}$ in 45 minutes.

Safety is a major concern for all UV-C technologies. We did not conduct a formal safety assessment, but dental staff reported no adverse effects during more than 3 years of operation. For those considering implementation of far UV-C technologies in occupied areas, the manufacturer should be asked to provide assurance that personnel and patients will not be exposed to doses exceeding the 8-hour threshold limit values proposed by the ACGIH (161 mJ/cm2 for eyes and 479 mJ/cm2 for skin).[2] In that regard, the calculated doses of far UV-C delivered to 20 sites in a dental office would not exceed the threshold limit value for eye exposure during a 7-hour workday even if personnel were continuously in proximity to the device (Table 1); eye protection would further reduce the risk. Manufacturers must also provide information on the potential for their devices to generate ozone and requirements for adequate ventilation to prevent ozone accumulation.[2]

Our study has some limitations. Although there were no reports of adverse effects, there remains a need for additional studies to assess the safety of far UV-C for long-term use in occupied areas. The testing with aerosolized bacteriophage MS2 was conducted in a small test room (23.5 m3) with ~4 air changes per hour and results might differ in a larger, well-ventilated room. Only one organism was tested in the treatment room. However, in preliminary experiments, vancomycin-resistant *Enterococcus* was reduced by $>3 \log_{10}$ in 45 minutes, and *Clostridioides difficile* spores were reduced by $\sim 1 \log_{10}$ in 24 hours.

Supplementary material. The supplementary material for this article can be found at https://doi.org/10.1017/ice.2024.109.

Acknowledgments. We thank Sterilray, Inc. for providing the far-UV-C device used for testing and the dental office staff for helpful discussions regarding their experience with the technology.

Financial support. Supported by the Department of Veterans Affairs.

Competing interests. C.J.D has received research grants from Clorox and Pfizer. All other authors report no conflicts of interest relevant to this article.

References

1. Donskey CJ. Continuous surface and air decontamination technologies: Current concepts and controversies. *Am J Infect Control* 2023;51: A144–A150.
2. Blatchley ER, Brenner DJ, Claus H, *et al.* Far UV-C radiation: An emerging tool for pandemic control. *Crit Rev Environ Sci Technol* 2022; doi: 10.1080/10643389.2022.2084315.
3. Memic S, Osborne AO, Cadnum JL, Donskey CJ. Efficacy of a far-ultraviolet-C light technology for continuous decontamination of air and surfaces. *Infect Control Hosp Epidemiol* 2023 Aug 2:1–3. doi: 10.1017/ice.2023.159.
4. Eadie E, Hiwar W, Fletcher L, *et al.* Far-UVC (222 nm) efficiently inactivates an airborne pathogen in a room-sized chamber. *Sci Rep* 2022;12:4373.
5. Hessling M, Haag R, Sieber N, Vatter P. The impact of far-UVC radiation (200-230 nm) on pathogens, cells, skin, and eyes - a collection and analysis of a hundred years of data. *GMS Hyg Infect Control* 2021;16: Doc07.
6. Sugihara K, Kaidzu S, Sasaki M, *et al.* One-year ocular safety observation of workers and estimations of microorganism inactivation efficacy in the room irradiated with 222-nm far ultraviolet-C lamps. *Photochem Photobiol* 2022 Sep 8. doi: 10.1111/php.13710.
7. Fukui T, Niikura T, Oda T, *et al.* Exploratory clinical trial on the safety and bactericidal effect of 222-nm ultraviolet C irradiation in healthy humans. *PLoS One* 2020;15:e0235948.
8. Centers for Disease Control and Prevention. Summary of infection prevention practices in dental settings: Basic expectations for safe care. 2016. https://www.cdc.gov/oralhealth/infectioncontrol/summary-infection-prevention-practices/index.html. Accessed January 10 2023.
9. ASTM International, *Designation E2197. Standard Quantitative Disk Carrier Test Method for Determining Bactericidal, Virucidal, Fungicidal, Mycobactericidal, and Sporicidal Activities of Chemicals.* West Conshohocken, PA: ASTM International; 2011.
10. Boyce JM, Donskey CJ. Understanding ultraviolet light surface decontamination in hospital rooms: A primer. *Infect Control Hosp Epidemiol* 2019;40:1030–1035.