Original Article

pISSN, eISSN 0125-5614
M Dent J 2022; 42 (1) : 47-54

A novel negative airflow aerosol chamber minimized aerosol transmission during ultrasonic scaling: A laboratory investigation

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Objective: The purpose of this study was to evaluate the effectiveness of a novel negative airflow aerosol chamber in reducing aerosols and droplets during ultrasonic scaling.

Materials and Methods: We created a new protective chamber for minimizing the bioaerosols generated during dental treatment. The negative airflow aerosol chamber comprised a hexagonal-steel frame with a reusable plastic drape connected to an air-purifier to create negative air flow. The effectiveness of the negative airflow aerosol chamber was evaluated using a dental manikin model fixed on a dental chair head rest. Ultrasonic scaling was performed for 10 minutes using an ultrasonic scaler supplied with a *L. acidophilus* suspension to evaluate the dissemination of dental aerosols generated during scaling with or without the negative airflow aerosol chamber. Culture plates containing De Man, Rogosa, and Sharpe agar were placed at 5 positions in the dental operating room. Scaling was performed and the plates were left exposed for 20 minutes after scaling was completed. The plates were incubated at 37±0.5°C for 48 hours in an anaerobic environment. The bacterial colonies were counted and reported as colony forming units per plate (CFU/plate).

Results: The bacterial colonies were detected at all positions. The negative airflow aerosol chamber significantly decreased the number of bacterial colonies at all sampling sites ($p<0.05$). Moreover, when using the negative airflow aerosol chamber, the total colonies were reduced by 86.63±9.86%.

Conclusion: The negative airflow aerosol chamber is effective in reducing the dental bioaerosols created during ultrasonic scaling.

Keywords: aerosol dissemination, infection control, *L. acidophilus*, negative airflow aerosol chamber, ultrasonic scaling

How to cite: Lertsooksawat W, Horsophonphong S, Chestsuttayangkul Y. The effectiveness of negative airflow aerosol chamber for minimizing aerosol transmission during ultrasonic scaling: A laboratory investigation. M Dent J 2022; 42: 47-54.

Introduction

Providing dental care entails a degree of risk. Cross-infection can occur during dental treatment when infectious agents are transmitted between patients and dental personnel in a clinical setting. Infectious agents in the patient's mouth can be transmitted by infected air droplets, blood splatter, aerosols, saliva, and equipment contaminated with secretions [1]. There are numerous pathogens that can be present in the oral cavity and respiratory tract, such as cytomegalovirus (CMV), hepatitis C virus (HCV), hepatitis B virus (HBV), herpes simplex virus, human immunodeficiency virus (HIV), Mycobacterium tuberculosis, staphylococci, and streptococci, that might cause cross-infection in dentistry [1, 2]. Therefore, cross-infection in the dental office has emerged as a serious public health issue. Furthermore, we are currently

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Received : 31 December 2021 Revised : 23 February 2022 Accepted : 25 February 2022

experiencing the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2)/COVID-19 pandemic. SARS-CoV-2 transmission can potentially occur during dental treatments by inhaling aerosols/droplets from infected persons or direct contact with mucosal membranes, oral secretions, and contaminated tools and surfaces [3-6]. This has increased the concern about cross infection and the transmission of infectious diseases in the dental office.

Most dental treatments produce aerosols and airborne droplets containing microorganisms from the oral cavity [7] that can raise the risk of infection and disease transmission. Scaling is the most commonly performed procedure in the dental clinic and ultrasonic scalers are the greatest source of aerosols [8]. The aerosols from an ultrasonic scaler can carry infectious bacteria and viruses from patients to the dental personnel [9-10], leading to disease transmission. Many guidelines have recommended the use of personal protective equipment, such as gloves, masks and face shields, and high-velocity suction devices to avoid aerosol transfer during dental treatment [7, 11]. However, Infectious materials can enter the respiratory tract via leaks in masks and contact mucus membranes by passing around protective devices, such as safety glasses [7]. Moreover, after a dental procedure, the aerosols can be retained in the operating room air for up to 30 min [12]. This implies that when after a dental procedure is finished, if the operator removes a protective barrier, such as a face mask, to speak with the patient, the risk of contact with airborne contaminated material persists [7].

During the COVID-19 pandemic, various types of barrier enclosure systems, such as aerosol boxes, protective shields, plastic drapes, and disposable plastic covers, have been invented and recommended for use during medical aerosol-generating procedures to limit the transmission of respiratory tract disease [13-14]. Furthermore, the current optimum method for managing suspected or confirmed COVID-19 patients is personal protective equipment and airborne isolation in negative pressure rooms [15-16]. These concepts inspired us to create a new negative airflow aerosol chamber for minimizing the bioaerosols generated during dental treatment. Thus, the purpose of this study was to determine the efficiency of this novel negative airflow aerosol chamber in reducing bacterial aerosols during ultrasonic scaling.

Materials and Methods

The negative airflow aerosol chamber comprised a plastic enclosure (AI technology Co., Ltd., Pathumthani, Thailand) and an air purifier (IQ Air Healthpro 250, Throbotics Co., Ltd., Bangkok, Thailand) with a HEPA filter. The chamber is a hexagonal-steel frame with reusable plastic that encloses half of the dental chair with 5 arm openings for the dental operator's hands, for the dental assistant's hands and for the circulating assistant's hand to transfer materials or instruments, and an additional opening at the bottom to connect with the air purifier (Figure 1).

Dental scaling was performed on a dental manikin model fixed on the dental chair head rest using an ultrasonic scaler (Superson Merk III, Thai Dental Products Co., Ltd., 25 kHz power, Bangkok, Thailand) as previously described [17-18]. Briefly, bioaerosols were created by an ultrasonic scaler with a suspension of *Lactobacillus acidophilus* (*L. acidophilus)* at a concentration of 10^7 colony forming units (CFU)/ml. *L. acidophilus* was isolated from acidophilus probiotic (Nature's Bounty Inc., Bohemia, NY, USA) and grown on de Man, Rogosa, and Sharpe (MRS) agar culture plates (Difco, Sparks, MD, USA),

a Lactobacillus spp. selective medium [19]. The dental scaling was performed with the air conditioner and exhaust air system turned off to eliminate airflow disturbance. Prior to scaling, culture plates containing MRS agar were placed at 5 positions (Table 1): the instrument tray, assistant's tray, operator's head, assistant's head, and 150 cm away from the dental chair (Figure 2), for 30 min to detect the background bacterial contamination in the room. New culture plates were then placed at the same positions. Ultrasonic scaling was performed for 10 min using a high-power evacuator (HVE) and a saliva ejector with or without the use of the negative airflow aerosol chamber (Figure 3). After scaling was completed, the plates remained in place for 20 min. The MRS agar plates were incubated at 37±0.5°C for 48 h in an anaerobic environment. The bacterial colonies were counted and reported as colony forming units per plate (CFU/plate).

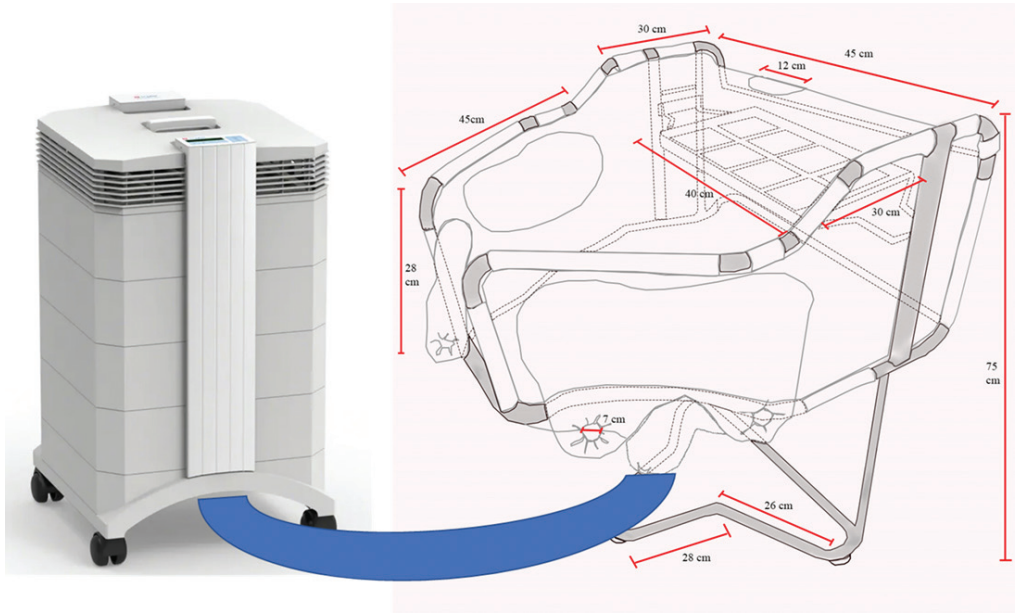


Figure 1 Negative Airflow Aerosol Chamber. The chamber comprised a hexagonal-steel frame with reusable plastic, with 5 arm openings and an additional opening at the bottom to connect with the air purifier (Airflow 310 m^3/h).

Table 1 The MRS agar culture plate positions

Position	Horizontal distance from oral cavity of the manikin model (cm)	Vertical distance from the floor (cm)
Oral cavity of manikin model		60
1. Instrument tray	60	85
2. Assistant's tray	60	75
3. Operator's head	40	135
4. Assistant's head	50	137
5. Away (150 cm) from the dental chair	150	180

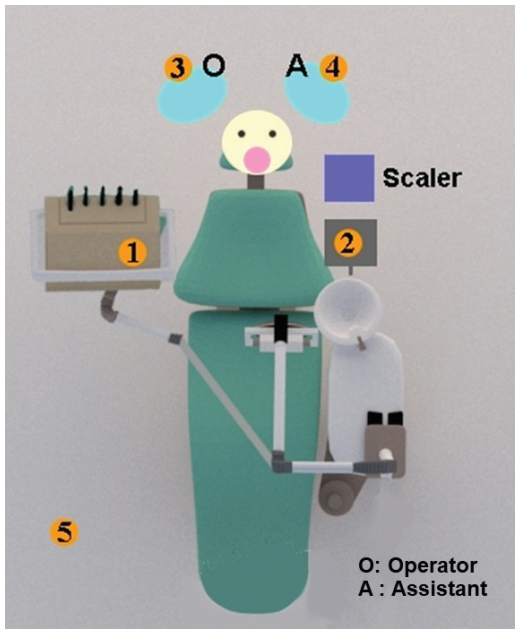
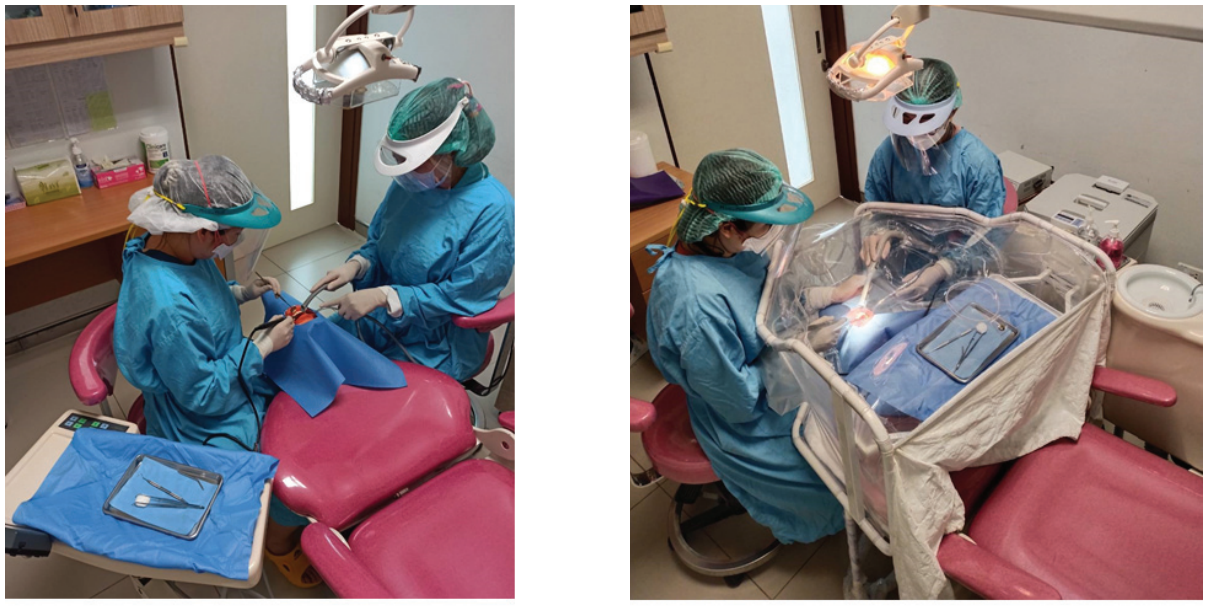


Figure 2 The sampling sites for placing the MRS agar culture plates. 1) Instrument tray, 2) Assistant's tray, 3) Operator's head, 4) Assistant's head, and 5) 150 cm away from dental chair.

After each procedure, the operation area and the negative airflow aerosol chamber were cleaned using CaviWipes™ (Metrex, Orange, USA). The operating room was decontaminated by UVC radiation (G36T8, Philips, Amsterdam, Netherlands) for 30 min accompanied by turning on the air conditioner. After the UVC radiation was completed, the air conditioner was left on for an additional 30 minutes.

Statistical analysis

The data are presented as the mean with standard deviation (SD) of four independent experiments. Statistical differences between groups were analyzed by the independent sample t-test using SPSS software version 18 (IBM, Armonk, NY, USA). Statistical significance was considered at $p<0.05$.



No Negative Airflow Aerosol Chamber

With Negative Airflow Aerosol Chamber

Figure 3 The ultrasonic scaling was performed using a high-power evacuator (HVE) and a saliva ejector with or without using the negative airflow aerosol chamber.

Results

The number of background air bacterial colonies on the culture medium plates and the number of bacterial colonies after the scaling procedures on the culture medium plates in each position were determined (Table 2). The background CFUs at all positions were ≤1. Scaling with and without using negative airflow aerosol chamber resulted in increased bacterial colonies on the MRS plates in the room compared with the background data. Furthermore, the negative airflow aerosol chamber significantly reduced bacterial air contamination at all indicated positions (range 1.5–3.75 CFUs) compared with no negative airflow aerosol chamber use (range 11.0–25.33 CFUs). The bacterial contamination at the head of the operator and assistant was reduced by ~90%.

With using the negative airflow aerosol chamber during dental scaling, the total number of bacterial colonies, the sum of the bacterial colonies in all sampling sites, in the experimental group was significantly decreased compared with the control group (p value <0.005) (Figure 4). Moreover, when using the negative airflow aerosol chamber, the total colonies were reduced by 86.63±9.86% (Table 3).

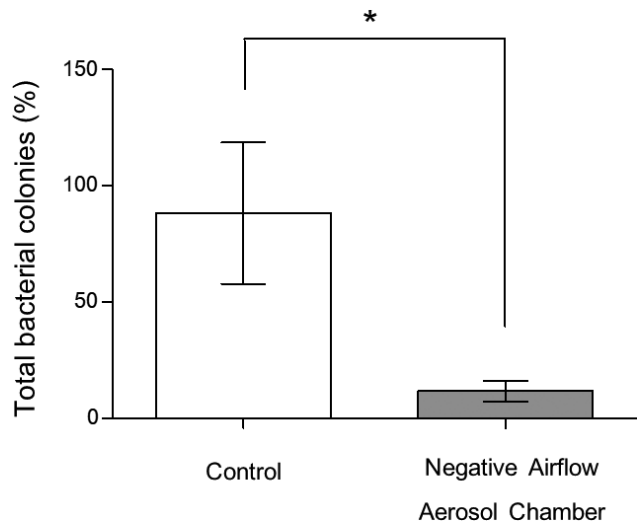


Figure 4 The total number of bacterial colonies compared with control (no negative airflow aerosol chamber), * p<0.005.

Table 2 Number of bacterial colonies (CFU/plate) detected at each sampling site

Positions	Description	Background	No Negative Airflow Aerosol Chamber	Negative Airflow Aerosol Chamber	*P* value*
1	On the instrument tray	0.22 (0.44)	22.33 (6.03)	3.75* (0.96)	0.002
2	On the assistant's tray	0.50 (0.58)	20.67 (9.61)	3.00* (2.31)	0.031
3	On the head of the operator	0.86 (0.69)	25.33 (12.50)	2.50* (2.38)	0.014
4	On the head of the assistant	1.00 (1.00)	18.67 (12.22)	2.25* (1.26)	0.040
5	Away (150 cm) from the dental chair	0.29 (0.49)	11.00 (1.00)	1.5* (1.91)	0.001

Data are presented as mean (SD), *p<0.05 compared between the control (no negative airflow aerosol chamber) and the negative airflow aerosol chamber.

Table 3 Percentage reduction in detected colonies at each sampling site

Positions	1	2	3	4	5	Total
Negative Airflow Aerosol Chamber	83.21 (4.29)	85.48 (11.17)	90.13 (9.40)	87.95 (6.74)	86.36 (17.41)	86.63 (9.86)

Data were presented as mean (SD).

Discussion

The dissemination of microorganism is an important issue in dental clinics because dental treatments frequently create aerosols and splatters, raising the potential for cross contamination between the dental practitioners and patients. When performing dental procedures, such as using a high-speed handpiece, an ultrasonic scaler, or a three-way syringe, special precautions must be taken to minimize the risk of disease transmission [20]. HVE and intraoral suction have been demonstrated to greatly minimize bacterial aerosols [17, 21]. In the medical field, barrier enclosure systems have been established as a means of reducing the transmission and dissemination of airborne particles [8-9, 13] and have been demonstrated to be beneficial during dental treatments. However, there were still drawbacks, including a lack of confinement and efficient aerosol removal, as well as limited space.

We created a new negative airflow aerosol chamber that is composed of a hexagonal-steel frame with a reusable plastic drape connected to an air purifier to create a negative air flow. To maximize the benefits of our device, we designed a number of features that expand its capabilities. These include the following: (1) a chamber volume of ~90 L, (2) produces a negative pressure (-4 to -16 Pa), (3) an air purifier with a HEPA filter that efficiently captures bacterial and viral particles, (4) a shelf for the operator tray, (5) the device is constructed of a medical-grade stainless steel frame and a clear, plastic exterior resulting in increased durability, mobility, decontamination, and visibility, and (6) the chamber is reusable.

In this study, we examined the efficiency of the negative airflow aerosol chamber in minimizing bacterial (*L. acidophilus)* aerosols during dental scaling treatment. Our results demonstrated that when the negative airflow aerosol chamber was used, the *L. acidophilus* colonies were dramatically and significantly decreased at all tested locations and the total colonies were reduced by 86.63±9.86%. These results confirmed the effectiveness of the barrier in minimizing bacterial aerosols generated during ultrasonic scaling.

Notably, the greatest reduction in CFUs when using the negative airflow chamber was seen at the head of the operator and the assistant (~90%). Their head locations were the highest in the present study and well above the level of the mouth, thus the airflow due to the air pump opening location likely drew the aerosols away from the heads. These results indicate that the safety of the dental personnel from cross-infection was markedly increased when using the chamber. In contrast, a slightly lower reduction was seen at the instrument trays (~85%). The tray levels were located below those of the heads, and the airflow thus may have caused some of the aerosols to flow over the tray locations, rather than completely away from them.

Furthermore, the reduction in CFUs in the plate 150cm away from the chair (from 11.0 to 1.5) indicate that the HEPA filter kept the aerosols being drawn away from the operating field from disseminating into the rest of the room, maintaining the safety of other personnel in the clinic.

An interesting aspect of our methodology was that the experiment was conducted without the use of air conditioning or an exhaust system. Although the use of a ventilation system is common in dental clinics, when performing dental procedures in the field/rural settings it is not. Our results indicate that our novel negative airflow chamber might be well suited for use in these conditions to increase the safety of the dental personnel when providing treatment in a less than ideal environment.

The transmission of air-borne disease experiment required using a recognized, noninfectious test organism with which infections may coexist in the respiratory system and that could be predicted to spread in the same manner as the pathogens. *L. acidophilus* was chosen in the present study to represent the aerosol or splatter generated during ultrasonic scaling because it is a nonpathogenic organism that naturally exists in the respiratory system. Although *L. acidophilus* is not defined as an airborne organism according to Du Buy H *et al*. (1947), *L. acidophilus* can be suspended in the air from a liquid media with the suspension containing 10^5–10^7 organisms per milliliter [22].

The negative airflow aerosol chamber is simple to assemble, customizable, affordable, and portable. However, several aspects of the design may require adjustment in the future to facilitate access during dental treatments, such as the height of the chamber at the operation area to allow for greater operator hand movement.

The limitation of the study is that it only determined bacterial contamination, and not that of viruses that are smaller and likely to disperse over a wider distance. Therefore, additional studies are needed to investigate whether the negative airflow aerosol chamber can reduce viral contamination during dental scaling.

Conclusion

The negative airflow aerosol chamber was effective in minimizing the dental bacterial aerosols created during ultrasonic scaling.

Acknowledgements

Not applicable

Funding resources: Not applicable

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