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Original Article

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Comparative study on the relationship between the use of a polymethyl methacrylate dome and the aerosol dispersion distance for contamination prevention in dentistry

Estudo comparativo sobre a relação entre o uso de domo de polimetilmetacrilato e a distância de dispersão de aerossóis para prevenção de contaminação em odontologia

Marcelo VILLACIS[a]*, **Estefano CORNEJO[a]**, **Yajaira VÁSQUEZ-TENORIO[a]**, **Maurício Andres TINAJERO ARONI[a]**

[a]UIDE – Universidad Internacional del Ecuador, Quito, Ecuador

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Resumo

Introdução: Diante da pandemia de COVID-19, os protocolos de biossegurança em odontologia foram intensificados devido ao alto risco de contaminação por aerossóis. Este estudo visa avaliar a distribuição espacial de aerossóis e a eficácia do Prime Protector (domo protetor) em procedimentos odontológicos simulados, buscando melhorar as medidas de proteção nos consultórios dentários. **Objetivo:** Este estudo avaliou a distribuição espacial de aerossóis e a eficácia do Prime Protector (domo protetor) durante procedimentos odontológicos geradores de aerossóis. **Material e método:** Foi utilizada uma unidade de simulação equipada com um simulador dentário e de posição de trabalho. Discos de papel filtro de celulose de algodão (12,5 cm de diâmetro) e fita adesiva foram colocados a distâncias de 0,5, 1, 1,5 e 2 metros em duas direções diferentes correspondentes às posições 12 e 2 das horas do relógio. Os procedimentos incluíram raspagem e profilaxia dentária na incisão superior, realizados com ou sem cúpula. **Resultado:** Ao final do procedimento, foram coletados os papéis de filtro e contadas as gotas depositadas. Identificaram-se diferenças significativas nos procedimentos aplicados (p=0,000), nas distâncias (p=0,000) e no momento da coleta (p=0,000). Maior distância, menor tempo após o procedimento e o uso da cúpula diminuíram as gotículas do aerossol. **Conclusão:** O Prime Protector neutraliza a propagação espacial de aerossóis durante procedimentos odontológicos simulados e aumenta a biossegurança, proporcionando maior proteção à equipe dos consultórios odontológicos.

Descritores: Aerossóis; contenção de riscos biológicos; odontologia.

Abstract

Introduction : In light of the COVID-19 pandemic, biosafety protocols in dentistry have been intensified due to the high risk of aerosol contamination. This study aims to evaluate the spatial distribution of aerosols and the effectiveness of Prime Protector (protective dome) in simulated dental procedures, aiming to enhance protective measures in dental offices. **Objective:** This study evaluated the spatial distribution of aerosols and the effectiveness of Prime Protector (protective dome) during aerosol-generating dental procedures. **Material and method:** A simulation unit equipped with a dental simulator and working position was used. Cotton cellulose filter paper discs (12.5 cm in diameter) and adhesive tape were placed at distances of 0.5, 1, 1.5 and 2 meters in two different directions corresponding to the 12 and 2 o'clock positions on the clock. The procedures included scaling and dental prophylaxis in the upper incision, performed with or without a dome. **Result:** At the end of the procedure, the filter papers were collected and the deposited droplets were counted. Significant differences were identified in the procedures applied (p=0.000), in the distances (p=0.000) and in the time of collection (p=0.000). Greater distance, shorter time after the procedure and the use of the dome reduced the aerosol droplets. **Conclusion:** Prime Protector neutralizes the spatial propagation of aerosols during simulated dental procedures and increases biosafety, providing greater protection to dental office staff.

Descriptors: Aerosols; biological risk containment; dentistry.

INTRODUCTION

Since the emergence of coronavirus disease (COVID-19) in December 2019. a series of changes and adjustments have been made to healthcare protocols[1,2]. Dentists are considered to be the healthcare workers with the highest exposure to infections and diseases such as severe acute respiratory syndrome caused by Coronavirus (SARS-CoV-2). leading to an increased state of alert regarding biosafety measures. making the use of personal protective equipment (PPE) in dental offices essential and strictly required[3]. It has been proposed that a large amount of aerosols are produced during dental treatments; therefore. dental procedures continuously pose a risk to both clinicians. staff. and even patients. as the oropharynx is the primary site of colonization for potential respiratory pathogens that can be found in the oral biofilm[4,5].

Aerosols are defined as several solid and liquid particles. smaller than 50 micrometers in diameter. with the potential ability to remain suspended in the air until it settles on environmental surfaces or enter in the respiratory tract[6,7]. Saliva. dental instruments. the oral cavity. and the operative field are major sources of aerosols. which may also be contaminated with blood. dental biofilm. viruses. and bacteria. Once emitted. it can contaminate the clinical environment and surfaces adjacent to the work area[4,8].

It is known that aerosol contamination pathways can occur directly through the nose and mouth when coughing. sneezing. or even speaking. and indirectly when in contact with surfaces contaminated with secretions or droplets invisible to the naked eye[9,10]. Within dental procedures. the use of rotary instruments and triple syringes is common. and these generate aerosols mainly composed of water. saliva. blood. microorganisms. and other waste[11,12]. These bioaerosols have the potential to remain suspended in the clinical environment and on nearby surfaces for minutes or hours. posing a potential risk to all healthcare staff providing care and patients. as it can be inhaled. leading to the development of various pathologies[13,14].

Due to the impact on biosafety caused by the recent pandemic. there has been a need to improve barriers and personal protective equipment (PPE). leading to new ideas on how to contain contamination and the dispersion of bioaerosols. New instruments have been implemented in dental offices. ranging from high-power suction systems to aerosol containment capsules. In Ecuador. a prototype of a microbial protective dome called Prime Protector was designed to protect dentists and reduce aerosol emissions within the dental office. This aims to reduce the spread of bioaerosols and decrease the daily exposure of clinicians and their work teams.

The objective of this study was to determine the spatial distribution of aerosols and the effectiveness of Prime Protector by simulating dental aerosol-generating procedures. such as the use of a scaler and a high-speed handpiece. The goal is for the study results to contribute to improving biosafety and personal protective measures taken within dental offices.

MATERIAL AND METHOD

This study was conducted in the preclinical laboratory of the School of Dentistry at the International University of Ecuador (UIDE) (6.14m x 10.23m x 8.21m). using one of its simulation units equipped with a dental phantom (OM-860-1) and simulating the working position commonly used in dental consultations. Using the simulation unit's head as a reference. cotton cellulose filter paper discs (12.5 cm diameter) and adhesive tape were placed at distances of 0.5. 1. 1.5. and 2 meters. each in two different directions corresponding to the clock hour positions 12 and 2 (Figure 1). Additionally. paper was placed on the chest of both the operator and the assistant. The use of cotton cellulose filter paper was chosen because this material has a smooth surface. normal hardness. and can retain large crystalline particles and gelatinous precipitates. Each of the discs was assigned an identification code depending on its location. distance. and time to enable identification and interpretation of the results. Moreover. the following experimental groups were identified: Carving without dome (C); Carving with dome (CD); Prophylaxis without dome (P); and Prophylaxis with dome (PD). It is important to note that while each test was conducted. the windows and doors of the laboratory remained fully closed to counteract air flow and prevent bias in data collection. All procedures were performed by a single operator that was a researcher of this study.

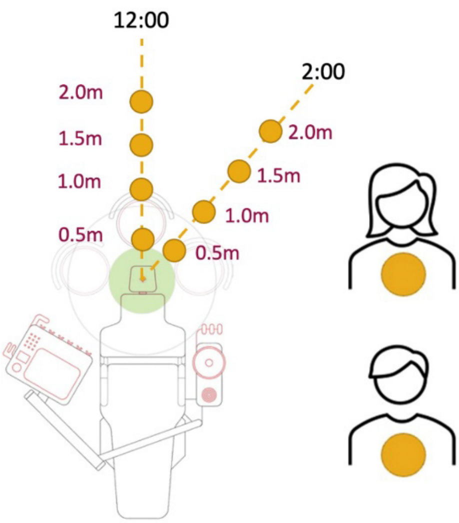

Figure 1. Schematic diagram of the filter paper distribution.

Protective Dome for Microbial Agents

The aerosol protective dome. called Prime Protector (PP). is a protective device with free mobility and easy operation. which allows for total asepsis of its surfaces because it does not have any formed angles in its structure (Figure 2). This device was designed as a biosafety complement because it enables the encapsulation of microbial agents. providing protection to the operator. assistant. patient. and even the clinical environment. One of the main advantages of the device is its morphology and the material it is made of. a thermoformed PMMA (Polymethyl Methacrylate). This material prevents fogging. effectively encapsulating any microorganism without altering or distorting the operator's visibility. PP features a mobilization mechanism through three wheels connected to a central axis. The device also allows for adjustment of the height and angle of the dome according to the operator's comfort (Figure 3). The entire PMMA structure is supported by a stainless steel AISI 304 base. which is commonly used in equipment within the healthcare field.

Figure 2. Its shape facilitates the cleaning of the device.

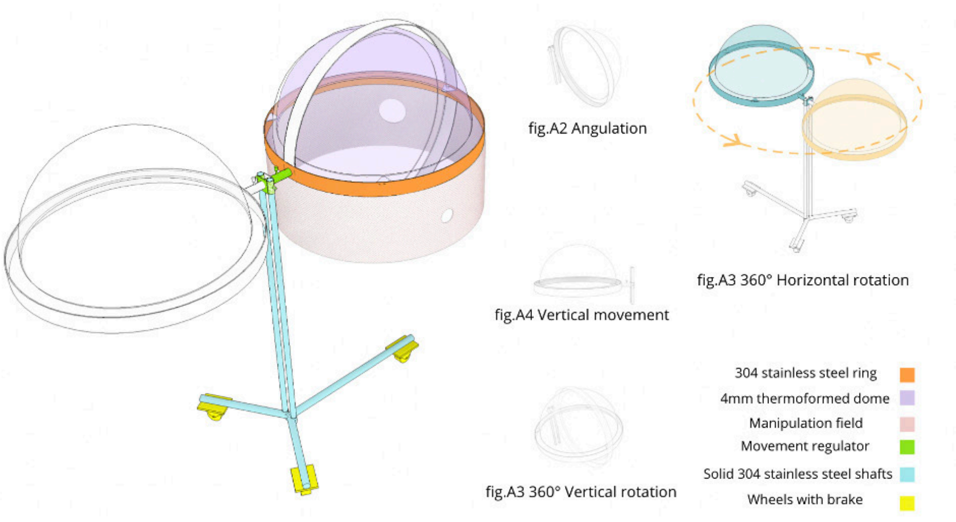

Figure 3. Description of movements and versatility.

Experimental Phase

This phase was carried out in two stages. The first phase was conducted without a protective dome. performing two different dental procedures: first. a crown preparation of an upper central incisor tooth. and finally. a dental prophylaxis. The second phase consisted of performing the same procedures with the protective dome. For the dental preparation. a turbine with three water outlets (NSK SGMS-ER20i) was used; in the case of the prophylaxis. an ultrasonic scaler (Dentflex Cavflex 600) with water output was used for a period of 10 minutes. Additionally. for each procedure. an assistant and low-power suction were used.

All simulation equipment. face shields. domes. and simulators were previously disinfected with 70% alcohol 10 minutes before starting the experiment. Each filter paper was placed in the initial position (clock hands at 12 and 2 o'clock. at distances of 0.5. 1. 1.5. and 2 meters). Once the procedure was completed. the filter papers were collected and placed in a Ziplock bag labeled with the identification codes for each paper (example: PF12H1M10m). After all the papers were removed. new ones were placed in the same positions for 30 and 60 minutes. After the filter papers corresponding to the 60-minute mark were removed. a total of 2 hours were waited between each test to clean the simulation equipment. rotary instruments. the preclinical lab. and prepare everything for the next test. The door and windows were opened after the 2-hour period of each test was completed.

In this study. sodium fluorescein ($C_{20}H_{10}Na_2O_5$) 1g dissolved in 1L of distilled water and filtered was used. This solution was placed in the water tank of the simulation equipment. To collect the final data. the papers were placed on a black background between two milimetric acetate sheets. with halogen dental lamps placed on top to count the droplets deposited on the surface of the filter papers. allowing interpretation of the contamination level generated by the aerosols. Finally. the data were collected in an Excel database. and statistical analysis and information correlation were performed using the Statistical Package for Social Sciences (SPSS). allowing interpretation of the previously collected data.

Statistical Analysis

The collected data were analyzed using the Shapiro-Wilk test to assess their normality. Once normality was verified. the data were compared using the non-parametric Kruskal-Wallis test. Post hoc analyses used the Mann-Whitney U test for multiple comparisons of distances and axes. with significance set at 95%. All statistical analyses were performed using the Statistical Package for Social Sciences (SPSS).

RESULT

In the present study. the contaminated filter paper cells were analyzed. considering the different established variables: data collection (repetitions up to 5), location of the filter papers (at 12 hours and 2 hours on the clock), filter paper collection time (0 minutes. 30 minutes. and 60 minutes), distance (0.5m; 1m; 1.5m; and 2.0m), as well as the operator and assistant's chest. and procedure (Carving CD. Carving without dome C. Prophylaxis PD. Prophylaxis without dome P). The highest number of contaminated cells was on the professional's chest (127.18 ± 166.42), followed by the C procedure (21.88 ± 86.64); likewise, the lowest number of contaminated cells was in the filter papers collected after 60 minutes (0.59 ± 1.24). (Table 1)

Table 1. Descriptive data of the droplets deposited on the surface of the filter papers

Groups	Categories	Median	95% confidence interval		Standard deviation
			Inferior limit	Superior limit	
Procedure	Carving without dome	21.88	6.84	36.91	86.64
	Carving	13.64	6.01	31.26	72.75
	Prophylaxis without dome	20.54	0.49	4.58	11.79
	Prophylaxis	12.01	2.81	21.21	53.01
Distance	Profesional chest	127.18	73.95	180.40	166.42
	0.5m of distance	10.10	1.19	19.01	49.30
	1.0m of distance	4.60	-1.26	10.46	32.40
	1.5m of distance	1.22	0.66	1.78	3.10
	2.0m of distance	1.34	0.83	1.85	2.81
Time	Immediate	34.33	20.63	48.03	98.26
	30 min	1.24	0.84	1.63	2.54
	60 min	0.59	0.39	0.78	1.24
Position	12 h	24.16	13.51	34.81	87.21
	2 h	3.37	1.97	4.77	11.43

To identify the statistical difference in the number of contaminated cells in each established variable. A mean difference analysis is conducted using the non-parametric kruskal-wallis test with a 95% confidence significance level. It is identified that there are significant differences between the applied procedures (p=0.000); between the distances at which the filter papers were placed (p=0.000); and between the time when the filter papers were collected (p=0.000). As shown in Table 2.

Table 2. Difference in means between the groups defined to measure the number of contaminated cells

Group	N	p
Procedure	520	0.000
Distance	520	0.000
Time	520	0.000
Position	520	0.566

The post hoc analyses that used the Mann-Whitney U multiple comparison criterion for significance revealed that there are significant differences in contaminated cells between: C and the other groups, and between CD and P and PD groups (p <0.0001). There were no significant difference found between prophylaxis and with and the dome. Significant differences in contaminated cells were found between all collection times of the filter papers (p=0.00). When comparing the distances at which the filter papers were placed, significant differences were found between distances of less than 1 meter (p=0.00). The highest mean differences. i.e. more than 92%. were found between the distances where the filter papers were placed on the professional's chest up to 2 meters. as well as the time when the papers were collected immediately and 30 or 60 minutes later. As shown in Table 3.

Table 3. Differences in means in categories of each analysis group

Group	Categories	N	p
Procedure	C – CD	130	0.0038
	C – P	130	0.0000
	T – PD	130	0.0000
	CD – P	130	0.0002
	CD – PD	130	0.0049
	P – PD	130	0.3825
Distance	Professional chest – 0.5m	120	0.0000
	Professional chest – 1.0m	120	0.0000
	Professional chest – 1.5m	120	0.0000
	Professional chest – 2.0m	120	0.0000
	0.5m – 1.0m	120	0.0141
	0.5m – 1.5m	120	0.0002
	0.5m – 2.0m	120	0.0030
	1.0m – 1.5m	120	0.1905
	1.0m – 2.0m	120	0.5926
	1.5m – 2.0m	120	0.4398
Time	Immediate– 30 min	200	0.0000
	Immediate – 60 min	200	0.0000
	30 min – 60 min	200	0.0034

C: Carving without dome; CD: Carving; P: Prophylaxis without dome; PD: Prophylaxis.

DISCUSSION

Control over the generation of aerosols in dental consultations is truly complex, especially considering that they can potentially be pathogenic for the operator, their staff, and even the patients themselves[15,16]. Additionally, in the context of the pandemic, dentistry is one of the professions with a high risk of transmission[17]. For this reason. it is essential to consider various measures and options that can assist in reducing aerosol dispersion, such as the high-power oral evacuator[18] or the aerosol containment capsule as in this research. It is important to emphasize that these measures are only complementary to achieving the main goal[19,20].

A study investigating the effectiveness of barriers in reducing aerosols mentions that these can travel up to 1.5–2 meters from the oral cavity and can contaminate the clinical environment for an extended period of time[21]. Another study mentions that the distances where there is greater aerosol contamination are 0.7 meters from the patient's mouth[22]. Once the results of the research were established, it was found that the distance at which the filter paper had the highest number of contaminated cells was on the operator's chest. compared to 0.5. 1. 1.5. and 2 meters away. This aligns with a study stating that the distance with the highest contamination deposit is at 0.5 meters or shorter distances[23].

The procedure with the highest cell contamination was C. which was performed with a turbine (NSK SGMS-ER20i) with three water outlets. Another study evaluating aerosols and splashes after dental procedures reported higher levels of contamination when a high-speed handpiece was used[8], which concurs with our results.

Regarding the collection time. it was concluded that the filter papers showing the most contamination were those collected immediately after each procedure, while those collected at 60 minutes had the lowest number of contaminated cells. In this regard, a study published in Paraguay mentions that the periods with the highest contamination were recorded immediately after the procedures and at nearby distances, justifying that this may be because larger aerosol particles do not reach very long distances because of gravity[24].

In the distribution of contamination related to the 12 and 2 o'clock axes, the results indicated that there was a higher presence of aerosols associated with the 12 o'clock axis. Authors of studies evaluating aerosol dispersion during the use of a turbine and scaler state that in both studies. the distribution of contamination was similar. which suggests that the operator's body is mostly exposed to aerosol emission. an important factor to consider for the application of biosafety measures[24.25].

According to the results obtained in this study, it should be mentioned that, although it was a simulation of commonly performed dental procedures, a large number of aerosols are exposed to the environment and nearby surfaces. which constitute a risk for the operator. their staff. and the patients[25]. It is essential for dentists to have guidance on biosafety measures, barriers, equipment, and devices that help reduce the spread of bioaerosols within the clinical environment, as it is known that there is a large number and variety of microorganisms in the oral environment.

Our research studies the functionality of the Prime Protector dome to contain and reduce the spread of aerosols into the environment. However, it should be noted that further studies are needed to determine more accurate and concrete solutions.

CONCLUSION

This study shows that the procedure with the highest aerosol contamination. according to the interpretation of marked cells on the filter papers. was TSC. followed by PSC. while T and P did not present statistically significant differences. This allows us to conclude that the microbial agent protective dome. Prime Protector. counters the spatial spread of aerosols generated during simulated dental procedures using a scaler and a high-speed handpiece. Additionally. it can be stated that Prime Protector enhances biosafety and provides greater protection to the staff within dental offices.

AUTHORS' CONTRIBUTIONS

Marcelo Villacis: Conceptualization, Data analysis, Validation of data and experiments, Writing of the original manuscript, Proofreading and editing, Approve of the final version.

Estefano CORNEJO: Research, Methodology, Approve of the final version.

Yajaira Vásquez-Tenorio: Research, Methodology, Approve of the final version.

Maurício Andres Tinajero Aroni: Writing of the original manuscript, Proofreading and editing, Approve of the final version.

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CONFLICTS OF INTERESTS

The authors declare that there is no conflict of interest related to this study.

*CORRESPONDING AUTHOR

Marcelo Villacis, UIDE – Universidad Internacional del Ecuador, Jorge Fernández s/n, 170411 Quito, Ecuador, e-mail: mavillacisva@uide.edu.ec

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