

Protective device to reduce aerosol dispersion in dental clinics during the COVID-19 pandemic

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Abstract

Teichert-Filho R, Baldasso CN, Campos MM, Gomes MS. Protective device to reduce aerosol dispersion in dental clinics during the COVID-19 pandemic. *International Endodontic Journal*, 53, 1588–1597, 2020.

Aim To describe the use of a new protective device to reduce aerosol dispersion in dental clinics during the COVID-19 pandemic.

Methodology The device consists of a rigid translucent acrylic structure (methyl polymethacrylate), adjusted to the dental chair, involving the patient's head, neck and chest. There is also a piping system to generate negative pressure, for aspiration and filtering of the air inside the device chamber. The operator works through small holes in the acrylic structure, to reduce contact with the microparticles arising from aerosols during dental procedures. Simulated dental procedures using a fluorescent dye in the water of the dental equipment were carried out, with and without the use of the device. The presence of the dye was analysed at various locations, such as on personal protective equipment (PPE), the dental chair and on the clinic floor.

Results In the simulated dental procedure without the device, the dye was obvious on surgical gloves, aprons (waist, chest, legs, fists) and face shields, as well as on the dental chair (backrest, light reflector) and clinic floor. In the simulated dental procedure using the device, the dye was observed only on surgical gloves, apron (fists), inside the pipe system and internal walls of the acrylic chamber. There was a certain limitation of movement and visualization by the dentist whilst using the device.

Conclusions The present device is a low-cost complementary resource for use in conjunction with standard PPE, to reduce the transmission of SARS-CoV-2 in the dental setting. Further clinical trials should be carried out to test the efficacy of this device to reduce aerosol dispersion and the consequent vector of contamination, as well as the ergonomic impacts related to its use.

Keywords: dental care, infection control, personal protective equipment, public health, SARS-CoV-2.

Received 25 May 2020; accepted 24 July 2020

Introduction

Healthcare professions have been strongly impacted by the COVID-19 pandemic, a disease caused by the coronavirus (SARS-CoV-2) (World Health Organization 2020a), which challenges the capacity and structure of existing health systems (Haines *et al.* 2020, World

Health Organization 2020b). Dental professionals are exposed to very high risks of infection by SARS-CoV-2 during clinical work, due to exposure to saliva, blood and other body fluids, combined with the handling of sharp instruments and procedures that generate aerosols (Bentley *et al.* 1994, Rivera-Hidalgo *et al.* 1999, Toroğlu *et al.* 2001, Kohn *et al.* 2003, Timmerman

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et al. 2004, Feres *et al.* 2010, Nejatidanesh *et al.* 2013, Gupta *et al.* 2014, Veena *et al.* 2015). Additional infection control measures in dental practice are necessary and have been recommended to prevent the spread of the virus and help control the pandemic (Meng *et al.* 2020).

One of the most concerning characteristics related to the nature of dental procedures during the pandemic is the use of high-speed handpieces and ultrasonic tips, which generate aerosols of saliva particles, blood and other fluids (Bentley *et al.* 1994, Rivera-Hidalgo *et al.* 1999, Toroğlu *et al.* 2001, Kohn *et al.* 2003, Timmerman *et al.* 2004, Feres *et al.* 2010, Nejatidanesh *et al.* 2013, Gupta *et al.* 2014, Veena *et al.* 2015). Special attention should be paid to the role of saliva as a significant source of SARS-CoV-2 transmission, since the angiotensin-converting enzyme 2 (ACE2) is present in the epithelial cells of the ducts of salivary glands. ACE2 is the main host cell receptor of SARS-CoV-2 and plays a central function in the entry of viruses into the cell to cause infection (Wang *et al.* 2020, Xu *et al.* 2020a, b). Due to the unique characteristics of dental practices, standard protective measures in daily clinical work may not be effective enough to prevent the spread of SARS-CoV-2, especially when patients are in the incubation period and may ignore or even deny they are infected (Meng *et al.* 2020).

Current protocols recommend preventive measures to limit SARS-CoV-2 contagion in dentistry, such as patient triage, prescription of mouth rinses before dental treatment, hand hygiene, the use of personal protective equipment (PPE) (including gloves, N95 or FFP2 masks, protective outerwear, protective surgical glasses and face shields) for dental practitioners and the oral health team, use of rubber dam isolation, limitation of aerosol-producing procedures and cleaning of potentially contaminated surfaces (Izzetti *et al.* 2020, Meng *et al.* 2020, Peng *et al.* 2020, Prati *et al.* 2020, Umer *et al.* 2020). Significantly, none of the present oral healthcare protocols suggest a specific device to reduce aerosol dispersion, even though the current gold standard to manage COVID-19 is to enhance PPE and airborne isolation in negative pressure rooms (Cubillos *et al.* 2020).

Recent studies from medical fields suggested using devices to reduce aerosol dispersion (Canelli *et al.* 2020, Cubillos *et al.* 2020, Francom *et al.* 2020), but those did not consider the peculiarities of dentistry, such as the need for constant suction and good visualization of the operative field, since dental procedures require gentle and precise movements. Thus, this study

aimed to describe the use of a new protective device to reduce aerosol dispersion in dental clinics during the COVID-19 pandemic, to be used as a low-cost complementary resource in conjunction with standard PPE.

Methodology

The device with the aspiration and filtering system

The main purpose of the device is to reduce aerosol dispersion in dental clinics, isolating the patient in an 'internal environment' through which the operator (in the 'external environment') can have access to perform the dental procedures whilst protected by a physical barrier. The prototype of the device consists of a rigid translucent acrylic structure (methyl polymethacrylate) designed to fit on the dental chair, covering the patient's head, neck and chest. The shape and dimensions of the acrylic structure are shown in Figures 1, 2a,b. The device is propped up on the dental chair, positioned simultaneously when the patient sits (Fig. 2b). Access for the operator's hands is provided through three oval-shaped holes in the acrylic chamber, which allow dental procedures be performed whilst seated in the 9 to 3 o'clock ergonomic positions. These orifices are covered by translucent flexible polyvinyl chloride (PVC) films, in which small incisions are made, allowing the hands and arms of the operator to reach inside the device, whilst keeping the operator as close as possible to the patient. The back of the device is open (no rigid acrylic structure) and should be sealed with flexible PVC films, so the patients can comfortably support themselves in the chair, whilst the PVC film protects the chair from contamination. The working position with the device is shown in Figure 3.

Within the acrylic structure, there is a piping system (Fig. 2c) for the aspiration and filtering of air, which provides a negative pressure inside the chamber. The aspiration system is composed of two hoses strategically positioned in the chamber (Fig. 2c) and a suction unit. The aspiration system forces the air to pass through an external box containing an antiseptic solution (2% NaOCl), aimed at neutralizing circulating microorganisms and toxic particles before the air returns to the external environment (Fig. 4).

Simulations of the dental procedures

Standardized simulated dental procedures were carried out, with and without the use of the device. For

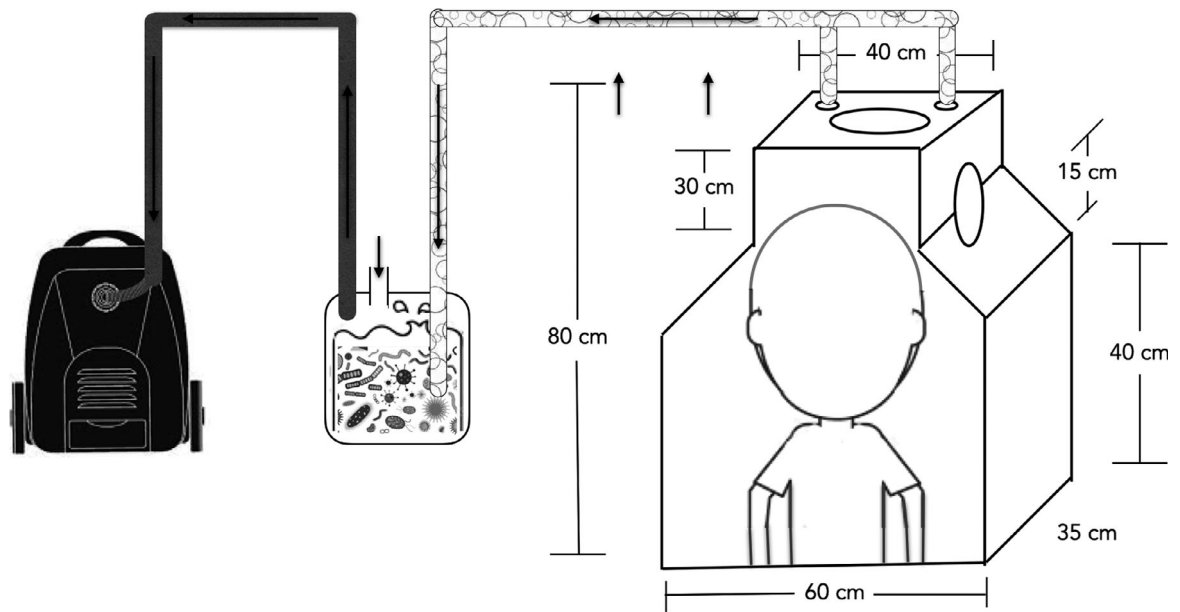


Figure 1 Schematic representation of the protective device to reduce aerosol dispersion in dental clinics during the COVID-19 pandemic. The equipment consists of a rigid translucent acrylic structure designed to fit on the dental chair, covering the patient's head, neck and chest regions. Within the acrylic structure, there is a piping system for the aspiration and filtering of air, which provides a negative pressure inside the chamber. Dimensions are expressed in centimetres (cm).

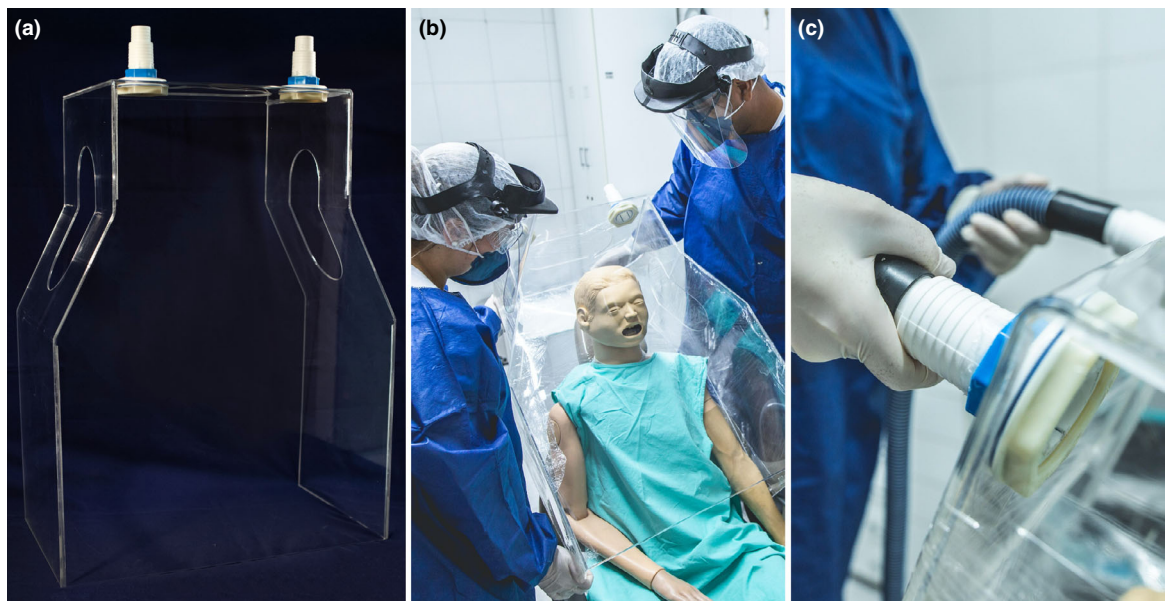


Figure 2 Detailed images of the device: translucent acrylic chamber (a); positioning of the acrylic chamber (b); and positioning of the aspiration piping (c).

illustration purposes, a dye (fluorescent reflective solution-Color Fluor; Bio Technology, City of Amparo, São Paulo, Brazil) was added to the water system of the dental unit. According to the manufacturer, the

composition of the dye was glycerine, methylparaben, aqua, magnesium silicate, calcium carbonate, PEG-7 glyceryl cocoate, hydroxyethylcellulose, parfum, butyl-phenyl methylpropional, hexyl cinnamal and linalool.

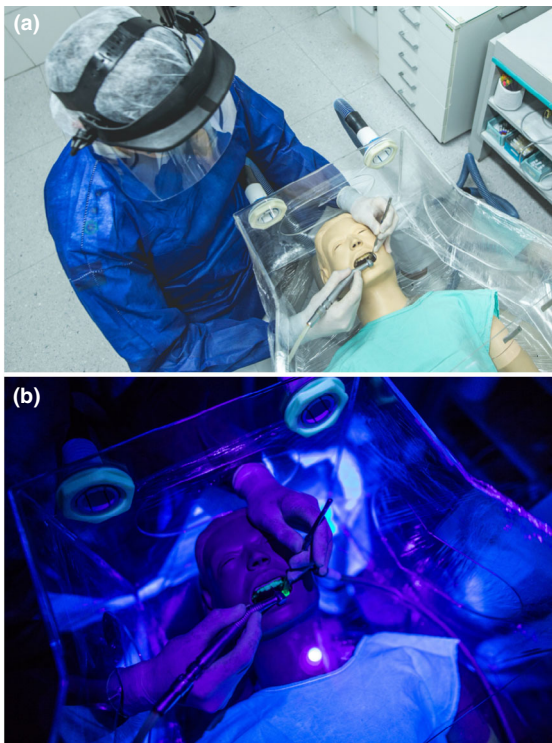


Figure 3 Images showing the work position of the operator (a,b). Ambient lights off and ultraviolet lights on to start the simulated dental procedure (b).

For both simulations, a human mannequin was positioned in the dental chair (Fig. 2b). The dentist worked in the 11 o'clock position (Fig. 3a). A high-speed handpiece was activated towards the maxillary incisors for a period of 60 s. Due to the use of the fluorescent dye, the simulations were carried out using an ultraviolet flashlight illumination in the working field (Fig. 3b). Images of the simulations were registered through photographs and videos. The presence and spreading of the dye were analysed in different locations, such as personal protective equipment (PPE), dental chair and floor of the operatory room. Descriptive results were reported.

Results

In the simulated dental procedure without the device, the dye was observed on the face of the mannequin, surgical gloves, apron (chest, legs, fists) and face shield, as well as on the dental chair (backrest, light reflector) and floor. The dye was found on the operator's clothes under the apron, revealing the possibility



Figure 4 Image of the aspiration and filtering system in operation.

of contamination. The presence of dye on the operator's cap and mask was not observed. Figure 5 illustrates the results of the simulation without the device.

In contrast, in the simulated dental procedure using the device, the dye was observed only on the surgical gloves, apron (fists), inside the pipe system and internal walls of the acrylic chamber. Figure 6 illustrates the results of the simulation with the device. Additional details of the device and the simulation results can be observed in the Video S1. A certain limitation of movements and visualization by the dentist during the operative procedures with the use of the device was observed. The Figure S1 shows a series of images of a clinical case illustrating an emergency dental procedure using the device, in a patient presenting with symptomatic apical periodontitis in a maxillary left second molar.

Discussion

This report describes a novel low-cost device that can be integrated into dental practice, in conjunction with standard PPE, during the COVID-19 pandemic. Although previous studies suggested strategies to

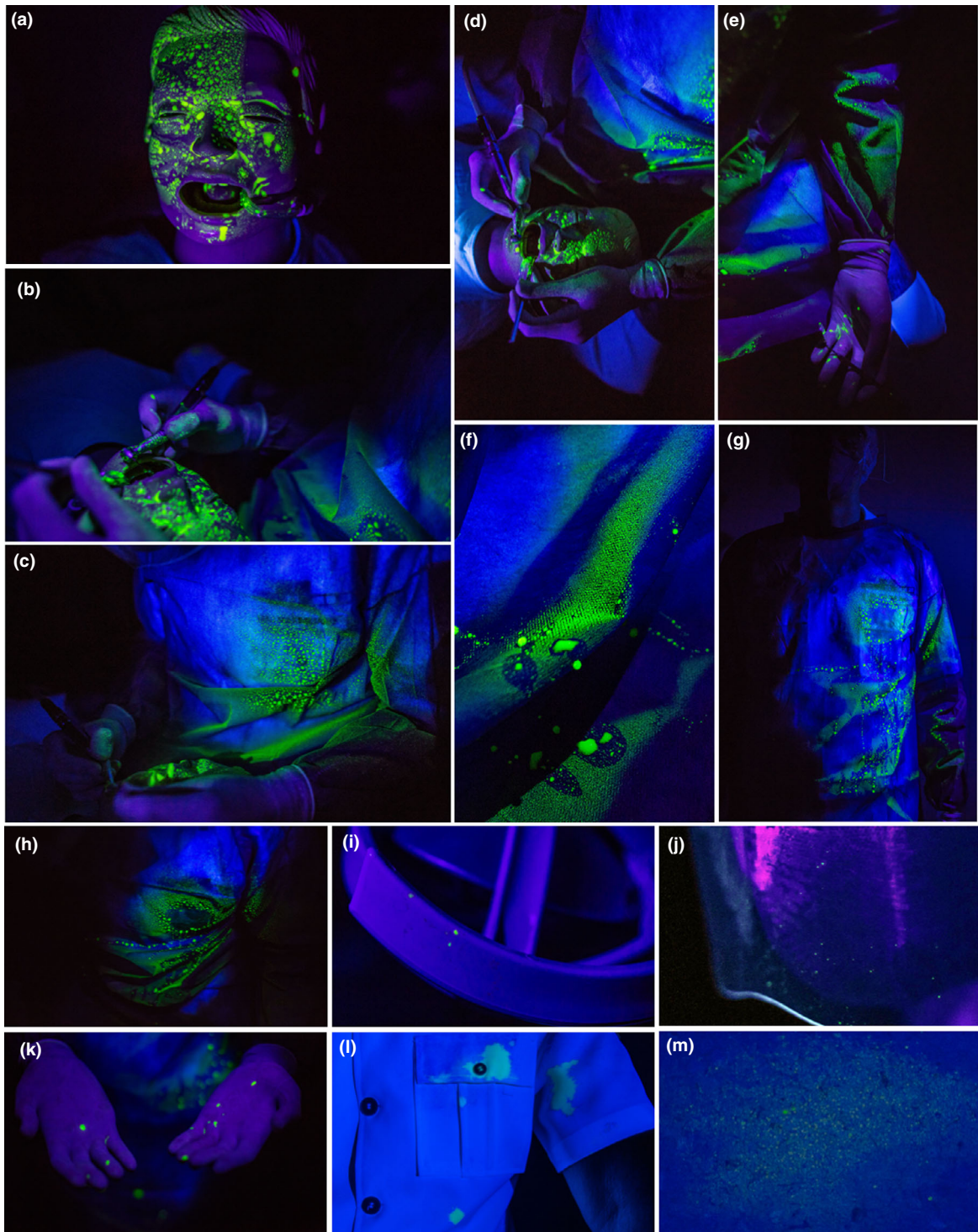


Figure 5 Series of detailed images resulting from the simulation without the device. The fluorescent dye can be observed on the mannequin's face (a, b, c, d), operator's gloves (b, c, d, e, k), forearms (c, d, e, g), chest (c, d, g, h), waist region on the apron (e, f), light reflector (i) face shield (j), operator's clothes under the apron (l) and operating room floor (m).

reduce aerosol dispersion in various medical areas (Canelli *et al.* 2020, Cubillos *et al.* 2020, Francom *et al.* 2020), the present device seems to be the first aerosol box designed for the dental setting. Of note, considering the remarkably high risks of infection by SARS-CoV-2 during dental practice, the use of this device may contribute to preventing the spread of the virus and help to control the pandemic.

The role of saliva as a significant source of SARS-CoV-2 transmission has been studied. ACE2 is a protein widely distributed in the upper respiratory tract and epithelial cells of the ducts of salivary glands in monkeys and humans (Liu *et al.* 2011), and it has been demonstrated that SARS-CoV-2 protein S has a significant binding affinity for human ACE2 (Xu *et al.* 2020a, b). Thus, ACE2 is the main host cell receptor of SARS-CoV-2 and plays a pivotal role in host cell infection (Wang *et al.* 2020, Xu *et al.* 2020a, b). ACE2 is present in several organs of the human body, such as small intestine, testicles, adipose tissue, thyroid gland, kidneys, heart muscle, colon, ovaries and salivary glands. The expression of the ACE2 protein varies in each organ, and as the salivary glands are in the tenth position in the expression level (<https://gtexportal.org>), there is robust evidence for the establishment of careful preventive SARS-CoV-2 infection control protocols in dental clinics (Xu *et al.* 2020a, b).

The World Health Organization recommends the use of a particulate respirator at least as protective as a US National Institute for Occupational Safety and Health (NIOSH) – certified N95, European Union (EU) standard FFP2 or equivalent, when performing aerosol-generating procedures such as tracheal intubation, noninvasive ventilation, tracheotomy, cardiopulmonary resuscitation, manual ventilation before intubation and bronchoscopy (World Health Organization 2020c). Surprisingly, aerosol-generating dental procedures are not mentioned in that recommendation, but the use of N95 or FFP2 respirators are highly recommended (Meng *et al.* 2020).

The simulated dental procedure carried out in the present study followed a standardized protocol, aiming to illustrate the dispersion of aerosol particles using a fluorescent dye. The time of activation of the high-speed handpiece was standardized and limited to 60 s, which is usually much shorter in relation to the activation time in a regular dental visit. Moreover, no ultrasonic tips were used in the simulations. Thus, it is possible to infer that the results of aerosol-spreading in this simulation study are underestimated, and this raises the alert for risks of aerolization in clinical practice.

The results from the simulation using the device revealed a number of dye particles inside the aspiration system piping. The negative pressure inside the apparatus seems to be of great value, preventing the dispersion of the aerosol. In the simulation using the device, the dye was observed in considerably fewer areas of the PPE (only in the surgical gloves and fists of the apron), compared to the simulation without the device, where gloves, apron (chest, legs, fists) and face shields were marked. Thus, it is possible to infer that the use of the device may help to reduce the infection of health professionals during unbundling (disrobing) procedures, where the risk is significantly increased (Driggin *et al.* 2020).

In addition, without the device, the dye was observed in distant areas of the dental surgery, such as the light reflector and floor. These findings reinforce that standard protective measures in daily clinical work may not be effective enough to prevent the spread of SARS-CoV-2 and suggest that the use of the device may contribute in reducing the dissemination of infection during and after the dental visit, contributing to control cross-infection between patient professional and between patients. The device may also help to reduce the viral load exposure of the dental team, a relevant factor which may influence the evolution and prognosis of COVID-19 (Coulthard 2020).

Various aerosol boxes have been proposed in the medical field (Canelli *et al.* 2020, Cubillos *et al.* 2020, Francom *et al.* 2020). Previous extra-oral dental suction systems have been proposed and commercialized, but none using an aerosol box. Some devices include a large clear cup-shaped acrylic plate to capture the aerosols under high negative pressure, but with no physical barriers to limit the dispersion of aerosol particles. Thus, pre-existing devices may likely reduce but not prevent the aerosol dispersion in the air room and consequently may not completely prevent the contact of aerosol particles with the dentists and their staff.

The device described in the present study has a filtering system of the air inside the chamber, before it returns to the environment. The filtering system presented in this prototype used a 2% NaOCl solution, which aimed to neutralize circulating microorganisms, mainly SARS-CoV-2. However, the antimicrobial action of NaOCl is highly dependent on the duration of contact of the air with the solution, and at this time, there is no scientific evidence of the antimicrobial efficacy of the present method.



Figure 6 Series of detailed images resulting from the simulation with the device. The fluorescent dye can be observed on the mannequin's face (a, b, c, d, f, g), internal walls of the acrylic chamber (a, b, d, f, g, j, k), internal walls the piping system (i), operator's gloves (c, d, f, g). The dye was not observed in the operator's waist, chest and head regions (e), nor in the light reflector (h) or operating room floor (l).

Previous extra-oral dental suction devices included several filtering systems using high efficiency particulate arrestance (HEPA) filters or ultraviolet light. Future prototypes of the present device may include the addition of HEPA filters along with ultraviolet light, which may present a greater antimicrobial efficiency. Nevertheless, all these variances should be tested under clinical use. The circulation of microorganisms in the ambient air may reach the respiratory tract of the health team and patients or even be deposited in the clothes or object surfaces inside the room. Thus, a highly efficient aspiration and filtering system seems to be important to reduce the risks of transmission to the health team, patients and society.

Using the device, the dye was observed on all the internal walls of the apparatus, which emphasizes the importance of a physical barrier to prevent aerosol dissemination. On the other hand, it highlights the need for a complementary system to frequently clean and dry the acrylic walls during the dental procedure, to allow the proper visualization of the operative field. For that purpose, the prototype described in the present study used an aquarium cleaner with a magnet, but this system should be improved for future versions of the device.

The costs to build the device prototype were relatively low, and if produced on large scale, the costs may be further reduced. Economically viable alternatives are particularly important, to allow the broad dissemination of this protective option which may help dental professionals to safely return to their activities. Moreover, the device was built to be reused several times, considering the actual scarcity and consequent increased costs of standard PPE in face of the current pandemic.

Several limitations of the present device were observed. The disinfection of the internal walls of the apparatus between patients may be time-consuming, and the disinfection of the aspiration system piping is challenging. Currently, a 0.2% quaternary ammonium compound solution has been used in the service where the device is being tested, for disinfection of the acrylic surfaces of the device. In addition, the internal walls of the piping system are being disinfected by aspiration of a 2% NaOCl solution. Alternative disinfection techniques of the device should be proposed and tested in the near future.

Additionally, with the device there is a restriction of movement for the patients, who cannot spit, and some may experience anxiety and a claustrophobic

sensation which may hinder the use of the device. Limitations regarding the communication between dentist and patient may occur as well. Moreover, there was a certain limitation of movements and visualization of the operative field by the dentist using the device, compared to the standard clinical protocol. Nevertheless, at this point, the device is being tested under clinical conditions in a public dental service, and it is being accepted by most patients and operators, and it does not preclude real dental procedures. For illustration purposes, the report of a clinical case using the device in a dental emergency visit is included (Figure S1), in which a symptomatic apical periodontitis in a maxillary left second molar was treated, and all necessary procedures were performed such as rubber dam isolation, coronal access, root canal access, irrigation and root canal debridement, intracanal dressing and temporary coronary sealing. Furthermore, the device described in this study has three oval-shaped holes which allow four-hand procedures, so the dentist can work with an assistant. The ergonomic impact of the use of the device should be tested in future clinical investigations.

The present study was restricted to the detailed description of the device, illustrating its usage with a simulation using a fluorescent solution. Importantly, further clinical trials are recommended and should be carried out to test the efficacy of this device to reduce microbial aerosol dispersion and the consequent vector of contamination. A clinical trial is underway in Brazil, aiming to evaluate both the microbial efficacy and ergonomic implications of the present device. In the meantime, considering the unprecedented pandemic scenario, this low-cost device may be improved and used in different dental settings, possibly reducing the risks of contamination and helping dental professionals to act decisively to prevent the transmission of SARS-CoV-2 and other infectious diseases.

Finally, the present device may be adapted to other health services, and not just used for dental purposes. It may be used at both ambulatory or hospital levels, for medical procedures that involve aerolization, aiming to reduce the spread of particles, thus contributing to control the cross-infection during the COVID-19 pandemic and also in the prevention of future epidemics.

Conclusion

The present device represents a low-cost complementary resource to be used in conjunction with standard

PPE, to contribute to the prevention of transmission of SARS-CoV-2 in the dental settings. Further clinical trials should be carried out to test the efficacy of this device to reduce aerosol dispersion and the consequent vector of contamination, as well as the ergonomic impacts related to the use of the device.

Acknowledgements

This study was financed in part by the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior – Brazil (CAPES), Finance Code 001; and in part by the Research Support Foundation of the State of Rio Grande do Sul (FAPERGS) – grant #06/2020. Support of the Director and staff of the Medical and Dental Centre of the Military Police of Rio Grande do Sul is highly acknowledged. The authors thank for the support of Prof. Janete Urbanetto, head of the Laboratory of Realistic Simulation on Nursing of the Pontifical Catholic University of Rio Grande do Sul (PUCRS).

Conflict of interest

Teichert-Filho R owns a pending patent of the device described in the study. The other authors have stated explicitly that there are no conflicts of interest in connection with this article.

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Supporting Information

Additional Supporting Information may be found in the online version of this article:

Video S1. Video illustrating details of the device and a summary of the main findings of the simulated dental procedures with and without the device.

Figure S1. Series of images of a clinical case illustrating an emergency dental procedure using the device: (a) initial digital periapical radiography of a symptomatic apical periodontitis in a maxillary left second molar; (b) initial intraoral aspect, showing the maxillary left second molar with a deep caries lesion and a fractured restoration; (c) rubber dam isolation with the patient inside the device; (d) use of

the high-speed handpiece for caries removal and coronal access; (e) professional at the work position and protected by the device; (f) root canal irrigation and aspiration, a four-hands procedure; (g) open view of a four-hands procedure, revealing the possibility to work with a dental assistant; (h) mechanical debridement of the root canals with a hand #10 K-file; (i) details of four root canal orifices into the pulp chamber (mesiobuccal, mesiopalatal, distobuccal and palatal root canals); (j) application of the intracanal dressing and a cotton pellet; (k) temporary coronary sealing with light-curing glass ionomer cement; (l) photopolymerization carried out by the dental assistant; (m) open view of the finishing procedure of the temporary restoration using a high-speed handpiece; (n) removal of the rubber dam isolation; (o) detail of the droplets from aerolization produced during the finishing of the restoration; (p) detail of the clinical aspect of the final temporary coronary sealing; (q,r) details of the lateral lower support of the device, which can be fixed by passing outside (q) or inside (r) the arm of the chair; (s) detail of the upper support of the device, which can be propped up on the head support of the dental chair, and detail of the four-hands work inside the device; (t) open view of the course of care with professional, dental assistant and patient positioned; (u,v) sequence of the removal process of the device, starting by removing the suction tubes (u) and the acrylic box (v) of the device; (w) detail of the back part of the device after use, showing the flexible PVC film which is removed and discarded, so the rigid part of the acrylic can be disinfected; (x) detail of the interior of the device after use, showing the aggregation of humid particles (droplets) as a result of the aerolization process – without the device, these droplets could reach the legs, waist and chest of the professional and assistant, or could be deposited in the dental chair surfaces and in the room floor.