

Low Cost Equipment with Compressor System and Balanced Pressure to Protect the Professional Dentist Against Contaminated Aerosol During COVID-19 Pandemic

Equipo de Bajo Costo con Sistema de Compresor y Presión Equilibrada para Proteger al Dentista Profesional Contra el Aerosol Contaminado Durante la Pandemia COVID-19

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VIEIRA, J. C. F. Low cost equipment with compressor system and balanced pressure to protect the professional dentist against contaminated aerosol during COVID-19 pandemic. *Int. J. Odontostomat.*, 14(4):523-528, 2020.

ABSTRACT: During the current coronavirus epidemic, personal protective equipment has become a vital issue. Depending on the procedure, the generation of aerosols increases the risk of infection for healthcare professionals. However, in dentistry, there is a high risk of contamination from blood or tissue fluids, generated in surgical procedures with ultrasonic and high-speed cutting devices. Thus, the creation of a prototype with a functional respiratory protection system offers filtered air at the entrance and exit of the circuit, also benefiting the patient. This experimental and unprecedented air purification system has 99.9 % high efficiency filters, positive and negative pressure control and also generates an internal balance of air flow; its purpose is to maintain the facial seal of the snorkel mask. The results showed that this air purification system could be an option in environments contaminated by aerosol caused by rotary instruments in dentistry.

KEY WORDS: COVID-19, coronavirus, snorkel, mask, aerosol, dentistry.

INTRODUCTION

During the First World War (1914-1918), aerosols of toxic gases were exposed on the battlefield. This encouraged the search for efficient respiratory filters. One of these filters was developed by N.L. Hansen in 1930, who used animal wool impregnated with resin through electrostatic force (The National Institute for Occupational Safety and Health, 1985). Currently, filters against aerosols use cheaper fibers which have low resistance to breathing and good properties against surface clogging. Thus, industries have developed PPE (Personal Protective Equipment) for professionals with diverse functions. In the health area, PPE helps to diagnose diseases and their origins (Araújo, 2005). Today, personal protective equipment has become a central issue during the current coronavirus epidemic COVID-19. Virus transmission is caused by contact or droplets attributed to relatively large respiratory particles which are subject to gravitational forces. Depending on the procedure, the generation of aerosols increases the risk of infection

for healthcare professionals (Cook, 2020). Aerosols from blood or tissue fluids are generated in surgical procedures with ultrasonic and high-speed cutting devices in dentistry (NHS National Services Scotland, 2020). For the professional's protection, masks must be fluid resistant. Disposable masks with high performance filtration FFP3, FFP2 and N95 are the most used. The three types lose their filtering capacity, unless they fit well to user's face and create a great seal (Danyluk *et al.*, 2011). One disadvantage is that, during the inspiration phase, the amount of air inside the FFP 2 decreases, thus generating a negative pressure which can cause a small amount of contaminated environment air to pass through the sealing zone on the user's face 6 .

A safe line of RPE (Respiratory Protection Equipment) is the non-disposable masks: semi facial and full face. The semi facial has the advantage of presenting a higher level of respiratory protection than

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FFP. The full face, protects the operator's eyes and respiratory tract, and can be supplied with air from an electric compressor, thus generating positive pressure. They are recommended for protection against the inhalation of pathogens transmitted by aerosols in situations of great risk for the user. However, they are contraindicated for work in sterile field once the exhalation valve, which is in the facepiece, allows the escape of expelled particles. As disadvantages: the difficulty of health worker's verbal communication and the need for inspection, cleaning and hygiene (Agencia Nacional de Vigilancia Sanitaria, 2009).

In this context, in order to improve health professional's and patient's protection, due to the COVID-19 pandemic, the need to create respiratory protection equipment with efficient filters to let air in and out arose, thus generating positive and negative pressure not exacerbated with a balanced pressure compressor and reducing the risk of rupture of the face sealing zone of the mask, both during health professional's inhalation and exhalation. Therefore, the need to make a model with such characteristics was born.

Objective: To develop, during COVID-19 pandemic, low-cost respiratory protection equipment, with a motorized, portable air purification circuit that offers balanced pressure of positive and negative air flow sufficient to not break the facial sealing of snorkel mask and, simultaneously, meet the health professional's respiratory need without fogging the viewfinder, thus making it feasible for a possible indication in sterile or contaminated environments by aerosol generated by the high rotation used in dentistry.

In periods of 1, 2 and 3 hours, O₂ saturation and heart rate were measured and the usability of the prototype equipment with a functional respiratory protection system was tested on a mannequin with the use of high-speed aerosol-generating by rotary instrument in the procedures of dental preparation.

MATERIAL AND METHOD

From the creation of the project and its tests of filtered air circuit, during the quarantine of COVID-19 pandemic. Pieces purchased via internet: 1) snorkel mask, 2) PVC hose trachea, 3) mini oil-free air compressor, 4) valve adapters that come with the air pump to fill the mattress and inflatable boats 5) micro-

bubble cup 6) HME breathing filters - mechanic breathing. Material used for the adaptations of the pieces: acrylic resin, bench micro motor, drills for cutting, finishing and polishing. The manual adaptations of the pieces were made at the author's own residence.

RESULTS

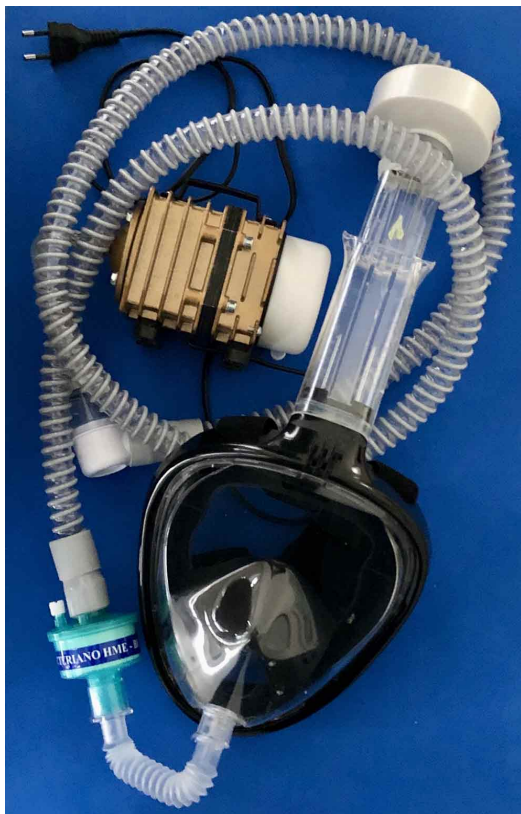
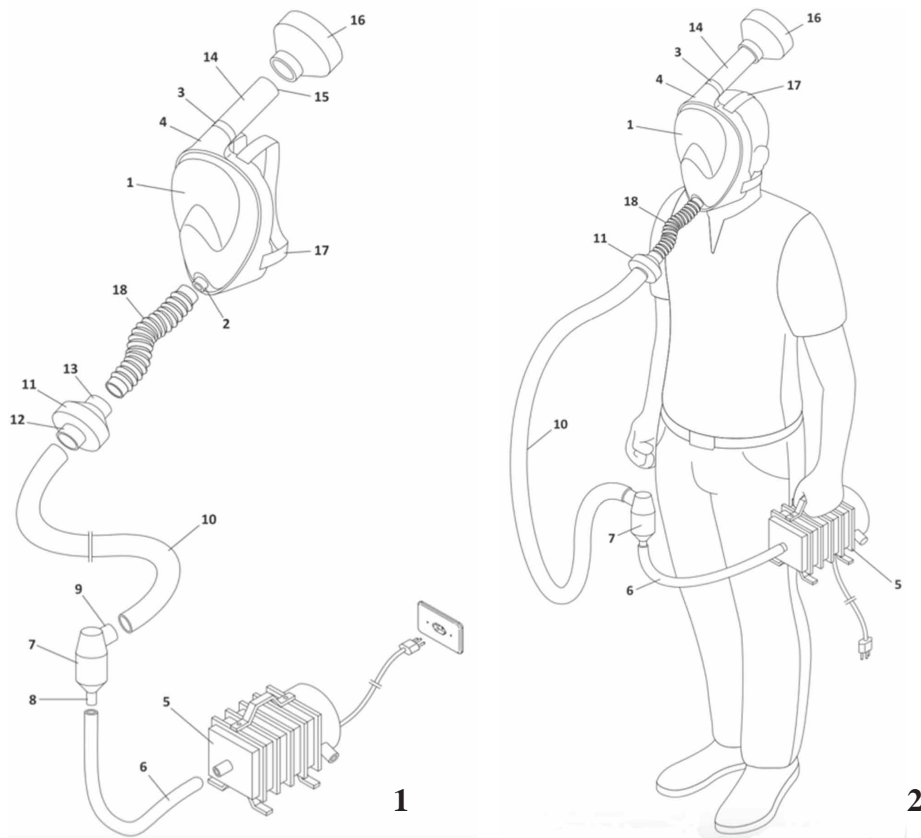
The results show that it is perfectly feasible to create low-cost respiratory protection equipment, with a motorized, portable air purification circuit and without the aid of a 3D printer (Figs. 1 to 5). Powered by a mini compressor, portable, oil-free and with a flow rate of 50 L per minute of air, it brought the best balance in the air flow rate for the operator to breathe comfortably during the cycle. This compressor is commonly used in aquariums, turned on for 24 hours, which proves its resistance in clinical use. Both the mask and the compressor are inexpensive.

Strengths:

- 1) The air exhaled by the operator is filtered, thus increasing the safety of both the patient and the health professional.
- 2) Ease of fitting the mask and operating the system.
- 3) Greater safety in the facial sealing area (Fig. 5).
- 4) The mask display is blurred for the first 3 to 5 minutes of use, until the lung air is replaced by filtered air (Fig. 4). This fact, which is unprecedented, seems to constitute a balanced pressure for breathing.
- 5) Comfort while breathing.
- 6) It allows to perform dental procedures on the mannequin for 1h, 2h and 3 hours continuously.
- 7) During the procedures, it was observed that the operator's breathing was not labored.
- 8) O₂ saturation - 97 % on average, over the entire period.
- 9) Heartbeat - 93 beats per minute on average
- 10) Neck movements were not altered due to the air purification system fitted to the mask.
- 11) Ease of removal which will allow less user contamination.

Negative points:

- 1) Compressor noise.
- 2) Vibration that the compressor transfers to the mask.
- 3) Time for cleaning and disinfecting the equipment.



Figs. 1, 2. Includes a full face facial mask with an air inlet connection (2) in the lower front portion and an air outlet connection (4) in the upper end; face mask (1) characterized by being connected to an electric compressor (5) of compressed air, by means of air hose (6) that extends from the electric compressor (5) to a first filter element (7) unidirectional flow type, connecting through the inlet connector (8) of the filter (7); first filter element (7) has an outlet connection (9) from which an air hose (10) is projected, larger in diameter than the air hose (6), and which extends to a second element filter (11) also of the unidirectional flow type, interconnecting through the inlet connector (12) of filter (11); the outlet connector (13) of the filter (11) is attached to a flexible trachea type pipe (18) which, in turn, is attached to the air inlet connection (2) of the mask (1); mask (1) superiorly an air outlet (4) provided with a connector (3) that is attached to a snorkel extension (14), which receives at its end (15) an air outlet filter (16). This work generated a patent application number BR 20 2020 009809-3.

Fig. 3. Assembled air purifier system.



Fig. 4. Evolution of the display overflow from left to right after 4 minutes with the system on, time for air to be changed.

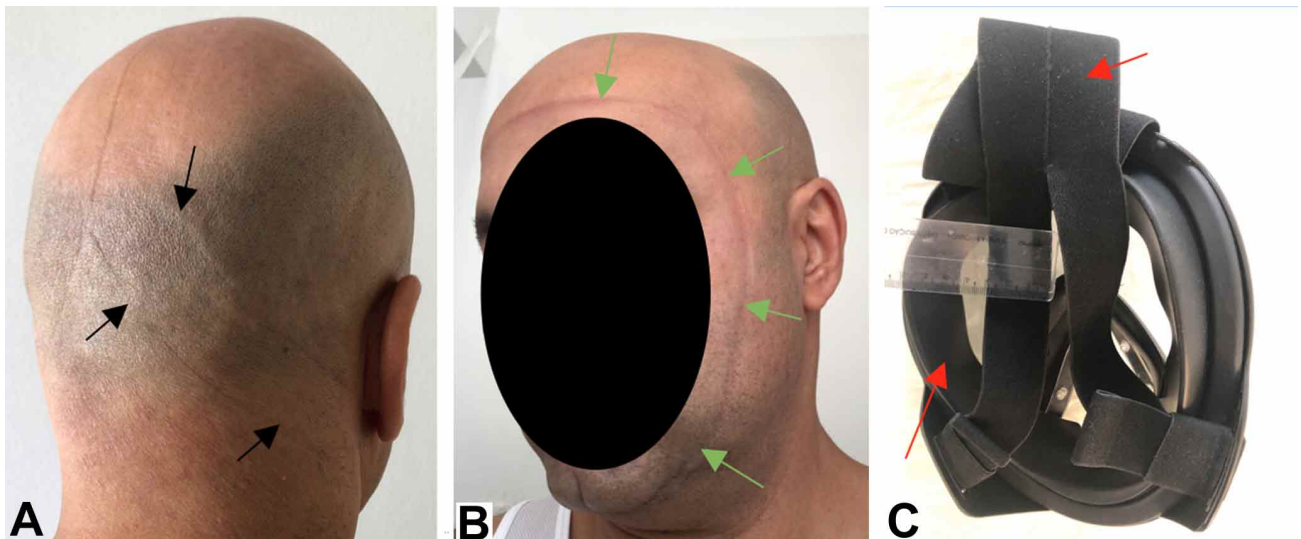


Fig. 5. marks of the safety elastic (black arrow) and facial sealing zone (green arrow). Rubber bands and rubber for sealing the mask with an average diameter of 3.0 cm (red arrow), the marks disappear after a few minutes

DISCUSSION

A Cochrane review of PPE for healthcare professionals exposed to contaminated body fluids shows the lack of robust evidence in this area, classified as very low (Verbeek *et al.*, 2019). PPE recommendations from international organizations are broadly consistent, but the same is not true for the effective use of PPE. The evidence base for the use of a type of mask FFP 2, FFP 3, and N 95, in detriment of another surgical mask, is not as robust, besides showing low evidence of benefit for high filtration masks (Offeddu *et al.*, 2017). The three types of disposable masks do not work unless they fit well to the face and create a sufficient seal (Danyluk *et al.*). In addition, the use of N95 mask, without an exhalation valve, has been associated with greater intolerance than a similar model with a valve which shows the difficulty of professional's expiration after a longer period of use (Radonovich *et al.*, 2009).

Thus, this experimental EPR (Figs. 1 and 2), powered by controlled flow compressed air, where the air outlet is independent of inlet connection, associated with a filtering element that returns treated air to the environment, seeks to assist the professional in the safety of dental clinical environment. Once the snorkell mask is firmly adjusted and fixed on the professional's head, the need for adjustments during use or manual contact is eliminated. Before using the respiratory system with filtered air circuit, it is necessary to choose the right size of the mask, adjust the pressure of the elastic straps behind the head, check, looking in the mirror, if the sealing rubber is correct (Fig. 5) and, with negative pressure test, close the air inlet and outlet to ensure that the sealing is done. After the system is turned on, the mask display will be blurred for the first 3 to 5 minutes of use, until the lung air is replaced by filtered air; after that brief period, it will no longer fog up (Fig. 4.). This unprecedented fact seems to constitute a balanced pressure for breathing.

It is also possible to notice the mask mark on the user's face, after 3 hours of continuous use, in the area where the acrylic part presses the face with elastic strips, in the sealing area (Fig 5). If the strips are loose, the sealing zone is vulnerable. These requirements were not described in a recent article, which identified flaws in the seal (Greig *et al.*, 2020) Another article aimed at assisting health professionals in preventing COVID-19 mentioned the feasibility of a respirator with an improvised engine and an air purifier, but reports that the rate of air flow in the mask needs to be

improved, and that the air expelled by the operator is not filtered. Tests performed on the mask were not specific to the health area (Khoo *et al.*, 2020).

The snorkell mask is already being used in hospitals in Europe, adapted as ventilators for COVID-19 sick patients (Walsh *et al.*, 2020; Willingham *et al.*, 2020). According to Reuters (2020), researchers said tests on adapting the Snorkel mask offered more protection than FFP 3 masks considered one of the highest level filters. A recent project improved the Snorkel mask as a respirator in patients with COVID-19, to be powered by air generated by the BIPAP (Bilevel Positive Pressure Airway) device (Souza, 2020), but it is expensive, compared to the compressor in our study. The snorkel mask is already being used by health professionals as protective equipment in hospitals in Europe. However, some do not invert the expiration valve, which is no longer indicated for COVID-19 pandemic, as the professional himself may be infected. Other experimental tests have shown that the air outlet valve is closed or inverted, but the possibility of aspirating CO₂ increases considerably.

In dentistry, nothing has been described yet about a snorkel mask powered by a low-cost portable compressor and with filters in the air circuit at the entrance and exit (Fig. 3), in which the lung air is exchanged for the air coming from the compressor, after 3 to 5 minutes of use on average. Furthermore, the mask with a filtered air circuit (HME) of 99.99 % efficiency for harmful particles is ready for use. Another advantage of this new air circuit system, with a compressor weighing approximately 2 kg, is that it can be taken anywhere, even if the environment is contaminated by aerosol.

CONCLUSION

This work showed the development of a prototype that aims to supply the need for protection of health professionals and their patients, during the COVID-19 pandemic. The equipment has a functional respiratory protection system, with a filtered air circuit and balanced pressure, seeking to respect the integrity of SNORKEL mask sealing area. The projected equipment was able to meet the respiratory needs of health professional during 3 hours of dental procedures on a mannequin. It is an alternative for use in environments contaminated by aerosol generated by rotary instrument or air abrasion. More tests will be

needed to validate the use of this system in dentistry or other areas of health.

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RESUMEN: Durante la actual epidemia de coronavirus, el equipo de protección personal se ha convertido en un problema vital. Dependiendo del procedimiento, la generación de aerosoles aumenta el riesgo de infección para los profesionales de la salud. Sin embargo, en odontología, existe un alto riesgo de contaminación por sangre o fluidos tisulares, generados en procedimientos quirúrgicos con dispositivos de corte ultrasónicos y de alta velocidad. Por lo tanto, la creación de un prototipo con un sistema funcional de protección respiratoria ofrece aire filtrado a la entrada y salida del circuito, lo que también beneficia al paciente. Este sistema de purificación de aire experimental y sin precedentes tiene 99.9 % de filtros de alta eficiencia, control de presión positiva y negativa y también genera un equilibrio interno del flujo de aire; Su propósito es mantener el sello facial de la máscara de snorkel. Los resultados mostraron que este sistema de purificación de aire podría ser una opción en ambientes contaminados por aerosoles causados por instrumentos rotativos en odontología.

PALABRAS CLAVE: COVID-19, coronavirus, snorkel, mascarilla, aerosol, odontología.

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Received:07-06-2020

Accepted:10-06-2020