Facial Mask and Plexiglass Box: a critical overview on the current strategies to protect patients from COVID-19 infection

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The route of transmission of SARS-CoV-2 has been understood thanks to the knowledge of previously identified human coronaviruses. According to these studies, the transmission of the virus occurs mainly between humans at close range, through respiratory droplets produced during conversation or coughing, as well as through direct contact of the hands then placed on the mucous membranes or mouth. From the final analysis of studies carried out on protective systems, the validity of plexiglass as a material to be used for the construction of protective devices could be affirmed. The plexiglass, in fact, would seem able to isolate the diffusion of aerosol particles dispersed by infected subjects and in different environments.

The SARS CoronaVirus-2 (SARS-CoV-2) is highly contagious and has its main location within the epithelial cells of the respiratory tract, where its spike proteins bind to ACE-2 receptors (1).

The transmission pathway of SARS-CoV-2 has been understood thanks to the knowledge on the previously identified human coronaviruses. According to these studies, the virus transmission occurs mainly among humans at close distance, through the respiratory droplets produced during the talking or coughing, as well as through direct contacts of hands then placed on mucouses or mouth (2). Droplets can have a diameter greater than 10 microns; they may be found on several surfaces or linked to other microscopic particles, spreaded in the air for a long time and able to be displaced in wide distances (3). It is commonly believed that the saliva droplets, due to their large size, quickly settle on the surrounding surfaces, and can therefore transmit the infection only within a radius of 1-2 meters by directly impacting the mucous membranes of the mouth, nose, eyes of a subject. Hence, a kind of "safety distance" may be no less than 2 meters (1-3). On the other hand, the aerosol particles are enough small (<5 μm) to remains in the air for long time: they can penetrate deep into the respiratory mucosa, easily reaching the lung and promoting a severe inflammation (4).

To protect against COVID-19 contagion, several protective measures are required: World Health Organization (WHO) strongly and primarily recommends the use of personal protective equipment (6, 7).

Face masks: main studies and outcomes

Among the different devices recently circulating among general population, it has been reported the

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presence of several face masks not reporting the CE certificate: such masks do not protect the airways and cannot be considered protective devices, especially against a highly contagious virus such as COVID-19. Commonly, certified protective face masks are available in 4 types: I, IR, II and IIR; these types are characterized by different levels of protection, depending on the filters used, resulting in different bacterial filtration efficiency (BFE) (typically, from 95% to 98%, for microorganisms measuring from 3 to 1μ). The only protective equipment (PPE) that ensure safety against COVID-19 is indicated with the abbreviations FF, and it has protective levels from P1 to P3 (Filtering Face Piece):

- FFP1 indicates a minimum filtering efficiency against solid particles of 78%;
- FFP2 indicates a minimum effectiveness of 92% against solid and liquid particles;
- FFP3 indicates an effectiveness that reaches 98%.

The disposable N95 masks (the mask ensuring the same protection of the FFP2 mask) are the most worldwide used ones (6).

The FFP2 and FFP3 masks can be equipped with an exhalation valve: it has no effect on the filtering ability, as it only allows humidified air to be expelled from the mask. Since the exhalation is not filtered at the exit but only at the entrance, these devices protect the wearer but not those around, therefore, especially in the healthcare sector, it is advisable to overlay this with a simple disposable surgical mask for the protection of the patient and / or the rigid visor. These masks should be replaced after 4-6 hours, not reused, and disposed of properly. Of great importance is the way in which the templates are handled both in the positioning and removal phases (1-4) movement caused by the displacement of air mass but also due to the collision between gaseous and aerosol particles. Since this cloud of particles persists and is fed above all in environments where patients and procedures follow one another and overlap, the use of protective devices by the operators and above all the targeted choice of the appropriate mask to use is of fundamental importance. In a study carried out by Checchi et al. the differences between masks and oral respirators were illustrated but practical support was also provided in choosing the suitable device to choose for each clinical situation. The surgical mask and respirator are individual devices that meet specific standards, the use of which must always be combined with other PPE such as protective screens and goggles, headgear, gloves, disposable gowns. There are many conflicting opinions on the type of respirator to be used to prevent Sars-CoV-2 infection; in fact, those without valve / filter provide high protection for both the patient and the operator but make breathing difficult if used for prolonged periods. For this purpose, to improve respiratory capacity, the use of a highly filtered respirator with valve to be used together with a surgical mask positioned above was hypothesized. To date, surgical masks remain valid safeguards for all those services that do not lead to the creation of infected aerosols (7).

Recently, the "Smart Air" company that produces air purifiers has carried out several studies to draw up a list of the most performing materials for making masks. The list included two-ply paper cloths which in the test filtered 96% of large particles (droplets) and 33% of small particles (aerosols) and cotton (100%) which was shown to have capacity 90% filtering for droplets and 24% for small particles. In this study, the cloth was also tested but the masks that had an efficiency greater than 95% in both directions of suction were made with 3 layers of fabric of which 2 were layers of non-woven fabric (TNT). Most of the filter materials for masks are synthetic non-woven fabrics, mainly of polypropylene (PP), and polyethylene terephthalate (PET), these being the most easily spun polymers together with polyamide (PA). Synthetic TNT-based masks are made up of two or three layers of TNT made up of polypropylene or polyester fibers. Typically, the layer exposed to the outside is made of spunbond (S) type TNT with possible hydrophobic treatment, economic and light, and confers mechanical resistance and functional properties to the mask, but has limited filtering properties for fine particles, given the size of the fibers. The intermediate layer, made with meltblown (M) type non-woven fabric, is made up of microfibres with a diameter of 1-3 μm and performs the main filtering function.

Meltblown type fibers are different from spunbond type fibers, but it is above all the felt that is

produced that has a different structure and therefore different filtering characteristics. A possible third layer, typically also of the spunbond type, is in contact with the subject's face and protects the skin from the filtering layer. For economic reasons and / or the availability of meltblown TNT, SM or SMS composites have been made directly in the production phase, which are sufficiently resistant, and at the same time highly filtering (8).

In a work of 2013, studies were conducted on the filtering properties and pressure drops of some commonly known materials such as 100% cotton, linen, and silk but also scarves, antimicrobial pillowcases and bags for vacuum cleaners compared to surgical masks. Tests to evaluate filtration efficiency were carried out using an aerosol containing bacteria and one virus. These fabrics had high filtration efficiency, similar to surgical masks, but increasing the number of filtering layers greatly decreased breathability. In conclusion, it was deduced that using "home made" masks created with these materials should only be a last and extreme condition when there is no availability of other masks (9).

In a study by Van der Sande et al. conducted in 2009, pandemic period linked to the A / H1N1 virus, a surgical mask with 95% filtration efficiency for 0.02-1 μm particles and a mask created with pieces of cotton were compared. The results showed that homemade masks ensured almost limited protection compared to surgical masks and FFP2, even if the use of any type of mask reduces both the risk of infection and exposure to the virus, despite the problems of adhesion. and wearability (10).

In 2015, however, the first clinical study was conducted that allowed us to test surgical masks on 1600 people in comparison with masks created with common materials. The tissue masks were evidently less effective than the surgical ones, as the penetration of the particles through the tissue masks was 97% against 44% of the surgical ones. Poor filtering capacity associated with moisture retention and reuse can in fact cause an increased risk of infection. The authors stated that as a precaution they advised against the use of these masks especially in situations of high risk, as these are commercial products and apparently of poor quality (11).

Plexiglass box: main studies and outcomes

The new coronavirus is a respiratory virus that is spread mainly through close contact with an infected person. The primary route of transmission are the droplets of the breath of infected people for example through:

- saliva, coughing and sneezing
- personal direct contacts
- hands, for example by touching contaminated (not yet washed) hands with your mouth, nose or eyes (12).

Protecting yourself from the transmission of the virus, at the moment, has become an emergency and in the same way unfortunately makes it necessary to take stringent measures in the workplace, both those open to the public and private ones. There is talk of protective barriers, as well as protective devices, developed with innovative and highly sustainable materials that allow the subject maximum safety (13).

The plexiglass barriers may ensure the right protection against the COVID-19 transmission.

Plexiglas is one of the various trade names for polymethylmethacrylate (PMMA), a polymer of the methyl ester of methacrylic acid (MMA). It has excellent properties such as: extreme transparency (even higher than that of glass), high impact resistance, lightness, thermo-formability, ability to filter the UV component of solar radiation and excellent thermal insulation.

A PMMA barrier can minimize contamination between people in the same space. In support of this thesis, numerous experimental studies have been carried out in recent months.

One of the latest studies, dated August 2020, compares the concentration of breath droplets as well as contact contamination using 3 different barrier techniques when intubating a manikin. The health workers enrolled in the study and normally equipped with personal protective equipment simulated intubation on a manikin in three different ways: one without a barrier, the other with a plastic sheet (120 cm wide × 150 cm long). Cover of the mannequin, the other with a plexiglass intubation box above the mannequin. To simulate the diffusion of breath droplets, fluorescein was expelled from inside the mouth of the manikin. Instead, using ultraviolet

light, the authors assessed the location and degree of contamination on the intubator and operator. The severity of the contamination was assessed in a standard way, with a numerical scale: 0 = none; 1 = minor; 2 = greater.

The plexiglass intubation box was created from clear acrylic one eighth of an inch (3.17mm) thick and placed over the manikin's head prior to the start of study procedures. The results of the study showed substantial differences between the three protection methodologies. For the intubator, the total contamination score was higher when the plastic sheet was used, the plastic contaminated the environment and operator (median 29 [interquartile range (IQR) 25-34]) than when the box (median 17 [IQR 15-22]) or when it was not used (median 18 [IQR 13-21]). The plastic therefore increased contact contamination, compromising intubation, however, the use of the Plexiglas box, which is very easy to use, is more difficult to decontaminate (14). A Thai doctor, in March 2020, in order to contain the aerosol particles generated during the coughing or sneezing of people with Covid-19 built a simple device with a transparent plastic box made of methyl methacrylate polymers, with a opening on one side that allows it to adapt to the patient's chest and neck, while the opposite side has two small holes through which doctors can insert their hands.

The device is designed to allow clinicians to intubate a patient while better protecting themselves from any aerosol particles that may be released from the patient's airways during the procedure. The designed box has the following measures: L: 40 cm (16 in) H: 50 cm (20 in) W: 50 cm (20 in) Diameter of the circular opening for insertion of arms: 10 cm (4 in) Position of the circular opening: 25 cm (10 in) from base and 5 cm (2 in) from the side of the box.

DISCUSSION

The experimental tests showed good results to validate the model and put it on the market. For the validation of this prototype, a simulation was carried out in which a laryngoscopist was dressed in standard PPE and a small balloon was placed in the hypopharynx of the manikin to recreate a very strong cough and diffusion of aerosol in latex containing 10 ml of fluorescent dye. The balloon was inflated with compressed oxygen and flowed through the tubes into the cuff until it burst. The burst of the balloon made it possible to simulate a cough. This procedure was done with and without box and the color diffusion was observed through ultraviolet light. With the use of PPE alone, the dye was found

Table I. *Plexiglass box VS other materials*

Experiment Material	Dimensions	Aereosol Dispersion	References
Plastic Sheet VS PMMA box	Plastic Sheet= 120 cm wide × 150 cm long PMMA box= one-eighth of an inch thick (3,17mm).	Plastic sheet: (median 29 [interquartile range (IQR) 25–34]) PMMA box: (median 17 [IQR 15–22]) No barrier: (median 18 [IQR 13–21]).	Dalton et al. 2020
Methyl Methacrylate Polymers VS No barrier with normal PPE	Methyl Methacrylate Polymers Box L: 40 cm (16 in) H: 50 cm (20 in) W: 50 cm (20 in)	No barrier with normal PPE: contamination gown, gloves, face and eye mask, hair, neck, ears. Floor contamination occurred within approximately 1m of the head of the bed and also on a monitor located more than 2m away. Methyl Methacrylate Polymers Box: No macroscopic contamination (only the inner surface of the box).	Canelli et al. 2020
Plexiglass box	Plexiglass box: Length 90 cm, Width 70 cm, Height 60 cm	Plexiglass box : No macroscopic contamination (only the inner surface of the box).	Ljubicic et al. 2020
CubeDV plexiglass VS No barrier	CubeDV: 5 mm polymethylmethacrylate	No barrier: 1.2 meters away from both the right and left sides, 1 meter in the air, the patient's upper plane 1.1 meters in the coronal plane and 1 meter in the distal plane. CubeDV Plexiglass: the aerosol particles was concentrated only on the inside of the box and on the operator's covered hands and forearms.	Mijares et al. 2020
Acrylic Box VS Plastic Sheet	Acrylic Box A: height of 47 cm behind and 37 on the side of the "curtain", width 50 cm and thickness of 35 cm Acrylic Box B: height of 60 cm, width 55 cm and thickness 35 Acrylic Box C: height of 47, width 50 cm and thickness of 35 cm Plastic sheet: 115 ×100 cm	The overall dispersion difference: Boxes (ABC) : 3.3% -19.0% Plastic sheet : 2.8% No Barrier: 26%	Laosuwan et al. 2020
Plexiglass Box	Height 80 cm, Total width 60 cm and Thickness of 35 cm	The presence of aerosol was observated on the surgical gloves, apron (fists), inside the tubing system and on the inner walls of the acrylic chamber.	Teichert-Filho et al. 2020

on the gown, gloves, face and eye mask, hair, neck, ears, and shoes of the laryngoscopist. Floor contamination occurred within approximately 1m of the head of the bed and on a monitor located more than 2m away. Subsequently, when the simulation was done with the box, the simulated cough resulted in the contamination of only the inner surface of the box and the laryngoscopist's gloves and forearms. And no mascoscopic contamination was shown either on the operator or in the room. This simulation was then not associated with studies on real subjects or on the speed of real coughs, plus this method did not allow to detect very small amounts of potentially infectious material. However, this box can be considered an addition to standard PPE, acting as an additional barrier. The limit highlighted was in the movement of the operator inside the box, operators should be ready to abandon the use of the box if airway management proves difficult (15).

Similarly, to reduce the risk of contracting the COVID-19 virus during gastrointestinal endoscopic procedures, a plexiglass box was designed, with the aim of minimizing the spread of aerosols during endoscopy. The box built in transparent plexiglass has the following characteristics: length 90 cm, width 70 cm and height 60 cm with a side opening for the endoscope with a diameter of 60 mm and 2 openings for the anesthetist and the passage of the cables of the various equipment (diameter 150 mm each).

During the Endoscopic Retrograde CholangioPancreatography (ERCP), the patient was sedated in a prone position with the arms extended near the head in order to help the anesthetist. The box limited neither the procedure to be performed nor the quality of the diascopy visualization. In this study it was not specifically studied how this box model could limit the diffusion of the aerosol, also because the model was very similar to that of Canelli et al studied for endotracheal intubation (16).

Moreno et al., In June they redesigned a new model of protection device and called it CubeDV, made entirely of 5 mm polymethylmethacrylate (PMMA). The authors explained the reason for which the choice fell on PMMA: it is a plastic transparent material, and it is also resistant to degradation due to UV rays; it has a low density (1190 kg / m) and is easy to carry. In addition, PMMA, the authors themselves confirm, is a washable material and is not affected by detergents commonly used in hospitals for cleaning and disinfecting medical equipment that could be infected. Dispersal of the virus was carried out by simulating a sneeze with a fluorescent liquid aerosol device.

The test was carried out in two phases, with and without CubeDV. In both cases, the expansion of the aerosol particles was recorded with the addition of ultraviolet light through photographs, footage and even testimony from operating room operators. The results of the experiment without CubeDV showed that the distribution of the fluorescent aerosol particles from the patient's position (where the spray was activated), was: 1.2 meters away from both the right and left sides, 1 meter in the air, the patient's upper plane 1.1 meters in the coronal plane and 1 meter in the distal plane. Furthermore, the presence of particles in the operator's face masks was evident. Subsequently, the second phase of the investigation with the CubeDV was performed: the results showed that the distribution of the aerosol particles was concentrated only on the inside of the box and on the operator's covered hands and forearms. The use of CubeDV has also been tested in other medical procedures such as: bronchoscopy, upper digestive endoscopy and induction of inhalation anesthesia in pediatric patients. This work has demonstrated the validity of the plexiglass box (17).

In a study from May 2020, the effectiveness of acrylic glass boxes and plastic sheets as protective barriers was compared with the absence of coverage under fluorescence conditions. To simulate coughing during tracheal extubation, the investigators intubated the airways of a manikin with a 7.0 size endotracheal tube, 21 cm deep. To simulate cough, they designed a device capable of simulating drops with an estimated speed of 4-10 m / s. A tube was connected to the pressure generator and the nozzle tip was fixed in the midline in the oral cavity, subsequently injecting fluorescent alcohol thus simulating droplets and mucous secretions. The plastic sheet used had dimensions of 115 × 100 cm, while 3 different box configurations were used. Box A had an open door on the right side and the front

part of the "curtain" with a height of 47 cm behind and 37 on the side of the "curtain", width 50 cm and thickness of 35 cm; box B with a sloping motif at the top and a small "curtain" in front, with a height of 60 cm, width 55 cm and thickness 35; the last C box of simple square shape with two opening channels for manual insertion. The size was similar to box A but no slope in front. To evaluate the dispersion of the droplets, the area of the boxes was divided into 300 squares measuring 5 × 5 cm, taking into account the colored squares. Instead, to count the dispersion outside the boxes, the room was divided into columns and rows. The overall dispersion difference between the 3 different possibilities was approximately 3.3% -19.0% for boxes (ABC), 2.8% for the plastic sheet and 26% for the total absence of coverage, 3% during tracheal extubation. All the acrylic boxes showed no contamination on the medical staff, however, the sheet caused contamination of both the chest and abdomen of the staff.

The use of different models led to different protective results; this is because each box had a different design. The disadvantages and concerns are manifold, such as for example the still inconclusive cleaning methods, or the slits in the hands that limit the movement of the hand for more complicated airway procedures if not also the uncooperative or agitated patient, with possible risk of trauma. The use of the plastic sheet also resulted in less contamination of the manikin. The advantages of the plastic sheet are single use, lower cost and fewer restrictions on hand movement. By evaluating the self-contamination, it was found that using 1 mL of fluorescent fluid, the cough flow spread under the plastic sheet and towards the opposite side of the extubator. Furthermore, improper disposal of the plastic cover sheet can lead to cross-contamination of healthcare workers. Of considerable importance is the consideration of all aspects, including limitations, in fact these barriers can be used as an additional element to the standard personal protective equipment (PPE) but cannot totally replace them (18).

Among the healthcare professions heavily influenced by COVID-19, dentists and professionals are highly exposed to risks of infection during clinical work, due to exposure to saliva. è R. Teichert - Filho et al, described the use of a device capable of reducing the dispersion of aerosols in dental clinics by isolating the patient in an 'internal environment' through which the operator can have access to perform dental procedures protected by a physical barrier. This physical barrier was constructed using plexiglass as the primary material and designed to fit the dental chair, covering the patient's head, neck and chest. The dimensions of the box were as follows: total height 80 cm, total width 60 cm and the thickness of 35 cm. The box also featured an air filtering system with a 2% NaOCl solution, which aimed to neutralize circulating microorganisms.

At this point the authors investigated the validity of this device by mimicking dental care with and without barrier. The results showed that in the absence of the device the dye, a dye consisting of a reflective fluorescent solution added to the water system of the dental unit, was observed on the manikin's face, surgical gloves, apron (chest, legs, fists) and visor, as well as on the dental chair (backrest, light reflector) and on the floor. In contrast, in the simulated dental procedure using the device, the dye was observed only on the surgical gloves, apron (fists), inside the tubing system and on the inner walls of the acrylic chamber. According to the authors themselves, the device they use represents a low-cost complementary resource to be used together with standard PPE in the dental field (19-26).

From the final analysis of these studies carried out, could be affirmed the validity of plexiglass as a material to be used for the construction of protective devices. In fact, the plexiglass would seem able to isolate the diffusion of aerosol particles dispersed by infected subjects and in different environments.

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