Review Article

Historical Evolution and Filtering Characteristics of Masks and Respirators in Dentistry in the Context of COVID-19: A Literature Review

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ABSTRACT

Objectives: At present, it is very important to identify the available literature regarding the use of masks and respirators by analyzing their historical evolution in the medical field. In addition, consideration should be given to the major filtering characteristics of those most used due to the current SARS-CoV-2 pandemic. Therefore, the purpose of this literature review is to describe the qualitative evolution that facemasks and respirators have undergone along with their different characteristics. **Materials and Methods:** This literature review was conducted between September and December 2020. Articles were identified from PubMed Central, Scopus, and Web of Science. The following keywords were used: "COVID-19," "dentistry," and "masks." These MeSH terms were combined with the Boolean operators "AND" and "OR." **Results:** We found 36 articles in PubMed Central, 21 in Scopus, and 17 in Web of Science, which included reviews, clinical, descriptive, and experimental trials. **Conclusion:** The emergence of new pathogens leads to continuous improvement in masks and respirators. It was determined that for the dental field, respirators with filtration characteristics greater than 95%, such as FFP3, N100, N95, and KN95, are indicated in addition to their decontamination and reuse processes.

Keywords: *Covid-19, dentistry, masks, N95 respirators, personal protective equipment (PPE)*

Introduction

Infection with severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), discovered in the city of Wuhan, China, has resulted in high mortality rates worldwide. This pathogen is directly transmitted by small droplet particles found in the air and aerosols.[1]

The first cases of coronavirus disease 2019 (COVID-19), caused by SARS-CoV-2, were reported in December 2019. SARS-CoV-2 is transmitted by direct contact or exposure to symptomatic and asymptomatic patients. Transmission by means of aerosols has also been reported, since this virus remains in an infectious and transmissible state for several days.[2-4]

In the current context of the pandemic, the use of masks and respirators by the population, especially healthcare workers, is essential to reduce the risk of the contagion, since there is currently no vaccine or other specific treatment with worldwide coverage.[4-15] There are significant differences among masks and respirators that will determine their level of protection against microorganisms, as well as their mode of use and possible methods of reuse, which will be important to analyze, especially in the dental field.[2,3]

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For instance, respiratory droplets emitted by people infected with respiratory viruses are an immediate source of infection, and they also descend very quickly, creating barriers less than a meter away from the infected people. On the other hand, the nuclei of the droplets can remain in the air for a prolonged period with the risk of exposure; hence, they may constitute a source of infection at distances >1 m.[5]

Therefore, the purpose of this literature review was to describe the qualitative evolution that masks and respirators have presented together with their different characteristics, as well as to establish a discussion regarding the distribution of these in underdeveloped countries.

Materials and Methods

This literature review was conducted between September 2020 and January 2021. The articles were identified from PubMed Central, Scopus, and Web of Science. The following keywords were used: "COVID-19," "dentistry," and "masks." These MeSH terms were combined with the Boolean operators "AND" and "OR."

Search strategy involved the following formula ("COVID-19" [All Fields] AND "dentistry" [All Fields]) AND "masks" [All Fields]. In addition, for each keyword, the following variations were used:

For COVID-19: "severe acute respiratory syndrome coronavirus 2" [Supplementary Concept] OR "severe acute respiratory syndrome coronavirus 2" [All Fields] OR "ncov" [All Fields] OR "2019-nCoV" [All Fields] OR "COVID-19" [All Fields] OR "SARS-CoV-2" [All Fields] OR (coronavirus [All Fields] OR "cov" [All Fields])

For dentistry: "dentistry" [MeSH Terms] OR "dentistry" [All Fields] OR "dentistry's" [All Fields]

For masks: "mask's" [All Fields] OR "masked" [All Fields] OR "masking" [All Fields] OR "masks" [MeSH Terms] OR "masks" [All Fields].

Results

We found 36 articles in PubMed Central, 21 in Scopus, and 17 in Web of Science, which included reviews, clinical, descriptive, and experimental trials.

Evolution of masks over time

The appearance of the first masks dates back to the middle of the Middle Ages with the emergence of the bubonic plague in the years 1347 to 1353. It was mentioned that the physicians of the time wore black capes and hats, as well as beak masks, to care for patients who contracted the disease.[16] These protective devices were likely filled with cloves, cinnamon, or other substances and thus were better protected from the "miasma," contaminated air from the East, which was considered to be the cause of the pandemic.[16,17] However, it is also noted that there is no strong evidence of the actual existence of physicians wearing spike masks in this context. Although two of such masks are recorded in German museums, they are suspected to be forgeries of a younger era, which could suggest that "beak doctors" served another function.[16,18]

The best-known introduction of nose and mouth protectors was made in surgical rooms during the 20th century. This is because in the late 1800s, research into the transmission of germs increased. Carl Flügge (1847–1923), a bacterial hygienist from Kochian, found that "droplet infection" from the mouth and nose of surgeons was a major source of germs. He even mentioned that speech alone spread a large number of oral bacteria into the environment.[19-21] On this basis, Johann von Mikulicz (1850–1905) made a publication that pointed out the use of mouth dressings during a surgical operation, describing a mask made of a layer of gauze.[21,22] His assistants, Hübner *et al.,* extended their research by mentioning that such mouthguards should be made of two layers of gauze.[21-24]

During the First World War, more research related to masks of variable thickness emerged. Their use gradually became more accepted within the medical and nursing community, who began to use cloth or gauze masks more continuously. It was not until 1920 that surgical masks began to be used more frequently in operating rooms in the United States and Germany for small surgeries. Sixteen years later, Martin Kirschner, director of surgery in Heidelberg, wrote a book in which the chapter "measures to combat infection" mentioned the need to wear a face mask during surgery.[16,25] However, many surgeons and health workers of the time were still reluctant to wear masks during their clinical activities, expressing discomfort in their use.[16]

It was in the year 1940 that washable and sterilizable masks were introduced, which gained special popularity in surgical rooms in the country of Germany.[16,26] Then, in the middle of the year 1960, the United States began to manufacture disposable masks, implementing its trade worldwide. However, 30 years later, it was again put on trial if infections in the surgical field could be reduced with the use of masks and face shields. This issue was resolved by the German Institute for Hygiene "Robert Koch" who presented truthful data indicating that surgical face masks reduce indoor air pollution.[16,27]

Over time, European standards have considered surgical mask as a medical device. Thus, they designated it the official nomenclature of EN 14683 and established its classification as Type I, Type II, and IIR, differentiating between them by their filtration capacity.[8] Later, the same European Committee for Standardization (EN) 149:2001 established three categories for respirators. This classification was also based on their filtering capacity. These respirators are called filtering facepiece parts (FFP) and are divided into FFP1, FFP2, and FFP3.[8,28,29]

In addition, the U.S. federal agency, the National Institute for Occupational Safety and Health (NIOSH), established nine classifications for respirators by their filtering capacity and effectiveness level. The classification is based on groups N, R, and P. As an example of the first group, we can talk about N95 respirators, which are considered the U.S. standard according to the NIOSH.[8] On the other hand, there is a group of respirators of Chinese origin, the KN95. Some authors refer to this group of respirators as having the same characteristics as the N group of the NIOSH.[8,15]

Types and characteristics

The diameter of the particles of the COVID-19 virus ranges from 250 to 500 nm, and these values are extremely important in determining which respirators or masks are the most appropriate and effective for use in the hospital environment, dental practice, and for the general population.[30] For this purpose, the characteristics and filtering capacities of some of these are presented in Table 1.[2,3,31-42]

Among the masks presented in the market, the filtration efficiency of the F, N, and KN types is achieved by the combination of a polypropylene network and electrostatic charge produced by the aerosols generated.[3,28,33]

Masks or respirators in the COVID-19 context?

In the current context of the COVID-19 pandemic, healthcare workers are even more exposed to cross-infection. Hence, the importance of responsible use of personal protective equipment (PPE), which includes both facemasks and respirators, is paramount, and it is important to differentiate between the two.[7] The design of respirators is bidirectional; that is, it is based on preventing the user from inhaling the small particles dissipated in the air and at the same time from emitting contaminating fluids; in addition, they must comply with filtration provisions and must also firmly seal the user's face. Medical masks, also called surgical masks, are unidirectional and are intended to prevent transmission from the user to the patient. They do not present a correct seal and do not reliably prevent inhalation of particles; however, they prevent contact with droplets and hands with the face. It should be noted that whether they are respirators or surgical masks, both are disposable protective equipment [Table 2].[7]

Biosafety protocols described in dentistry

Aerosol-generating medical procedures pose a challenge in dentistry because of the large number of aerosols they generate in clinical practice. In addition, the dentist's work area involves direct contact with saliva, blood, and the tongue, in which are

Table 1: Characteristics of the most common respirators and masks

	Category		Particulate filtration capacity of:	Lifetime	Characteristic
Respirators	FFFP Group	FFP1	<0.3 µm at 80%	Use of maximum 5 times for 8 h of continuous use	2-way protection, peripheral sealing
		FFP2	<0.3 µm at 95%		
		FFP3	<0.3 µm at 99%		
	N Group	N95	<0.3 µm at 95%. Not oil resistant		
		N99	<0.3 µm at 99%. Not oil resistant		
		N100	<0.3 µm at 99.7%. Not oil resistant		
	K Group	KN95	<0.3 µm at 94–95%		
Masks	Surgical	Type I	0.5 µm at 95%.	Disposable, 1 use only, not to exceed 4 h	Avoid the spread of microorganisms only from the inside out (unidirectional) It has no peripheral seal.
		Type II	0.5 µm at 99%.		
		IIR	2.7 microns spray and moisture resistance		
	Cloth		Variable must have 3 layers of fabric between (polyester, nylon, cotton, and cellulose regenerative fibers)	Reusable, daily washing with soap and water.	

Table 2: Studies on respirators and/or masks

Authors	Study design	Conclusion
Umer *et al.* 2020[15]	Review	The N95 disposable respirator is the most widely used and has an efficiency of 95% for an average particle size of 0.3 µm.
Beesoon *et al.* 2020[57]	Review	They mention that recommendations should be made to improve the quality and safety of cloth masks for the general public.
Arellano-Cotrina *et al.* 2020[3]	Review	They recommend prolonged use in combination with a disposable surgical mask over the cloth mask. Although for health personnel, N95 or FFP2 respirators should be used.
Cotrin *et al*. 2020[58]	Cross-sectional	All the subjects wore masks to go to public and crowded places and that the participants felt more protected with the use of masks.

concentrated the largest number of viral particles in patients who have tested positive for SARS-CoV-2.[8,9] Despite the health emergency in China, the demand for emergency dental treatment was reduced by only 38%.[10,11] This provides evidence that emergency dental clinical care is essential even during a pandemic,[11] and dentists should ensure compliance with strict biosafety protocols in each work environment. These protocols include the use of disinfectants, sterilizers, and PPE, which are crucial for the development of dental clinical practice.[12]

Previously, the PPE used during clinical care were gloves, masks, and aprons. However, with the emergence of SARS-CoV-2 and the knowledge of its spread through the air, the World Health Organization recommended implementing more PPE to reduce cross-infection between patients and health care workers[9,13] Therefore, the use of face shields, protective eyewear, aprons or hooded overalls, and disposable boots have been implemented.[13,14]

It should be noted that Umer *et al.* established a special emphasis on the placement of each PPE. They pointed out that carrying out a determined sequence of placing the protective equipment guarantees the maintenance and control of biosafety. These are focused on ensuring adequate protection of the nose and mouth by covering the entrance of the airways of medical personnel. There is a debate over which one would be the most recommended for use. Therefore, it is important to conduct a review that compares the protective effectiveness of surgical masks, N and FFR respirators, among others.[15]

Discussion

For this virus (SARS-CoV-2), several methods of transmission have been studied, including aerosols, surface contamination, and fecal routes. Aerosol transmission has a spread of more than 1 m. This finding suggests that SARS-CoV-2 is an opportunistic infection that is transmitted through the air. Something similar occurs with the infectious virions of this virus that have not been isolated, but it has been possible to discover viral RNA in the air from areas in hospitals to which COVID-19 patients have been admitted. In addition, the deposition of aerosols with viral loads could contaminate objects through fomites, and thus lead to human transmission. Finally, there is also fecal–oral transmission, which is a human transmission route still under study despite the existence of RNA-loaded aerosols found near toilets, in addition to the SARS-CoV-2 RNA detected in rectal swabs during the COVID-19 pandemic in China.[6]

In summary, Harrison *et al.* pointed out that droplet dispersal above 5 µm is the most relevant mode of transmission. Transmission by direct contact takes <1 s from person to person, especially in households where members are in constant interaction. On the other hand, cases of airborne and fecal–oral transmission from person to person have not yet been reported. The symbol of the virus in the patient indicates the places where the presence of RNA/infectious virus has been confirmed.[6]

How to use them, placement and removal, adjustment and adherence as for the mode of use, it must be done with responsibility and care, since the prevention and reduction of the risk of infection will depend on it. For placement, first take the bands with both hands and place them just halfway behind the head and at the neck level, then adjust the band to the bridge of the nose and seal the chin and face contour. Finally, ensure that there is an adequate seal to the face to prevent any microorganism from leaking from the outside and/or escaping from the body. After the application, hand washing with soap should be performed for at least 20 s.[3,43]

Once the respirator is in place, it should not be handled at any time, because when in contact with people we should sense that it has already been contaminated.[2] To remove the respirator, avoid handling the front of the respirator because it is contaminated; to do this,

hold the elastic bands and remove them in an upward direction to avoid touching the front. Then, the mask should be discarded in the trash can; finally, hands should be washed with soap for at least 20 s.[3,43]

How effective are tissue masks in absorbing particles that cause respiratory infections? As a result of the pandemic, the use of respirators or face masks by health care workers and the general public has been mandated to prevent airborne transmission of SARS-CoV-2 by inhaling contaminated aerosols or droplets of the virus.[44] Previous studies on fiber spacing demonstrated that fabric masks had large holes; hence, it would be possible to transpose more than 680 million droplets (5.75 µm),[30] and that if fabric masks were multilayered, they could offer greater protection against nanometric-sized aerosols.[45] To date, the FFP2 respirator and surgical mask continue to provide greater blockage to SARS-CoV-2 particles due to the interposition of the different layers they present.[30] Silk, like an FFP2 respirator, has properties that may provide a protective barrier against respiratory infection particles such as SARS-CoV-2, but its effectiveness for the respective function remains to be evaluated.[46] Dentists are the health professionals most at risk for exposure to respiratory infections, and a fabric mask would not provide the necessary protection in a clinical setting.[45,47]

The high demand for face masks to prevent SARS-CoV-2 infection has led to a shortage of this product.[48] For this reason, studies have been conducted using ultraviolet germicidal irradiation (UVGI) in N95 and SN95 surgical masks. The application of a UVGI cycle did not affect the performance of the masks with respect to aerosol penetration and airflow filtration, but it was able to decontaminate the surfaces of the masks that had been exposed to the virus in a laboratory. However, the assessments were conducted in a laboratory setting and do not represent real-world conditions, as multiple mask removal and placement reduces the ability to fit the mask.[49] Another promising method is hydrogen peroxide (H_2O_2) vapor decontamination, which has been shown to maintain aerosol filtration efficiency and airflow in N95 masks.[40]

On the contrary, the filtration efficiency of aerosols from gauze masks decreased with wet heat decontamination (autoclave), in dry heat at 160°, and isopropyl alcohol at 70–75%, being more significant the filtration efficiency decreased when using the chemical agent sodium hypochlorite (bleach).[3,38,48] Previous studies have shown that face mask exposure to radiation doses (10–30 kGy) degrades the performance of standard N95 respirator.[50,51] It should be noted that surgical masks should not be worn for more than 4 h, and FFP should not be worn for more than 8 h according to provider recommendations.[35,52,53]

Several authors have reported that the pressure and force exerted by mask elastics is likely to be a cause of headaches and stress in the current pandemic situation manifested by healthcare workers.[41]

There is rapid adaptation of new biosafety protocols and implementation in dental clinical practice due to the continuity of work and closeness to the patient. It is noted that the percentage of emergency dental treatment has been maintained.[8] Despite this, Uguru *et al.* pointed out that the public sector does not have the necessary economic resources or sufficient political guidelines for the acquisition of PPE.[54] This information probably coincides with the reality that is emerging in Peru; however, there are few studies on this, and research on the subject is suggested.

The use of appropriate respirators that guarantee the highest percentage of protection is indispensable; therefore, the use of FFP3, N100, and KN95 is suggested in different parts of the world. On the other hand, a review by Arellano *et al.* recommends that N95, FFP2, FFP3, and KN95 respirators should be used in the dental office because of their filtration capacity and protection against aerosols.[3,36,38] It should be noted that these types of respirators are more widely available in the South American and Peruvian markets. In addition, surgical masks and those made from fabrics have low filtration and protection efficiency due to the lack of an airtight seal around the face.[41]

The cost of respirators during this COVID-19 pandemic has risen considerably, with their acquisition and scarcity being a disadvantage. Consequently, methods have been developed that have proven effective in maintaining necessary protection through the reuse of respirators. This is based on their sterilization by minimizing their deterioration, ensuring the prolongation of their useful life, and preventing the transmission of the virus. Therefore, the use of exposure to UVGI, ethylene oxide, and vaporized hydrogen peroxide is proposed, which requires further studies to assess their effectiveness in a clinical environment.[3,38,40,48,49]

Recent studies indicate that the copper surface has an effective capacity for inactivation of SARS-Cov-2 virus in a short period of time. Warnes *et al.* also established the same conclusions because in their study in the year 2015, they indicated that a higher percentage of copper increased the inhibition of CoV-229E. It should be noted that the inactivation of the coronavirus is due to the release of copper ions and generation of reactive oxygen species.[55] Therefore, it is suggested to evaluate

the possibility of using nanoparticles based on copper or copper salt for the preparation of EPP. This would help prevent and limit the spread of the virus.

Although the respirators are designed for a determined number of times of use and with a duration of 8 continuous hours at most, this varies according to the direct contact and direct exposure to aerosols in consultation with COVID-19 patients. In such cases, their reuse can be allowed, thus saving economic resources.[15] This has an impact on the recommendation for use of a face shield and a second mask, which will be discarded immediately after the consultation. This reduces the risk of contamination and preserves the main respiratory mask.[2]

As a result of the pandemic, dental care, like hospital care, requires prolonged use of respirators, involving more than 4 h of work without rest. This has led to the presentation of adverse manifestations such as headaches, overheating, lack of concentration, pressure areas, extreme exhaustion, and even fainting.[41,53] Therefore, it is suggested that the necessary management should have more human resources in health facilities, and thus reduce the time of use of the respirator. On the other hand, to manage cross-contamination, it is important to have knowledge of the sanitary strategies to counteract the SARS-CoV-2 infection. It is essential that the dental staff be up to date to protect the oral health of these patients.[47]

Research is suggested on the management of biosafety protocols in rural areas of Peru.[56] Due to the country's socioeconomic condition and the precarious health system in the regions, we can extrapolate that access to materials in these areas is very scarce. On the other hand, we state that there is little information about the appearance of respirators in a given historical context.

Conclusions

With the passage of time and the emergence of new pathogens, humans have implemented continuous improvement of respirators to avoid cross-infection during clinical care. In the current context of the SARS-CoV-2 pandemic, respirators with filtration characteristics greater than 95%, such as FFP3, N100, N95, and KN95, are indicated for use in the dental setting. This has generated a greater demand for their use; therefore, their cost has risen. From this, several authors recommend the decontamination process and that it be evaluated in *in vivo* studies to confirm its use for the benefit of society.

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The authors declare that this review was carried out with our own resources.

Conflicts of interest

The authors declare that they have no conflicts of interest.

Author contributions

AR, DO, GL, BT, RW, DAT, and FMT: conception. FMT and RW: design of the manuscript, review for relevant intellectual content, writing-review and editing, and final approval of the version to be published. AR, DO, BR, and FMT: writing original draft.

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