Review Article

JRAD Journal of Research and Advancement in Dentistry

J Res Adv Dent 2020;10:3:107-116.

Demystifying the Facts About Respirators and Masks and Their Re-Use in Pandemic Crisis: A Review

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ABSTRACT

Background: Face masks and respirators plays a crucial role in reducing the biohazard to which healthcare personnel are exposed during the pandemics like recent novel coronavirus (COVID 19). In this scenario, there is shortage of supplies worldwide, leading to occupational infections. Proper knowledge about respirators and masks and their reuse is necessary to prevent contraction of the disease in this pandemic crisis. This review aims to summarize the available evidence on identifying right type and choosing proper fit of facemask/respirator with emphasis on their extended use/re-use in the scenario of pandemic crisis.

Keywords: Masks, Respirators, Re-use.

INTRODUCTION

The recent outbreak of coronavirus disease 2019 (COVID-19), highlighted the risk of disease transmission among health care workers (HCWs). COVID 19 is thought to be transmitted primarily by respiratory droplet (<0.5 μm in diameter) and direct contact. However airborne transmission may also be possible during procedures that generates aerosols. These procedures place HCWs at increased risk for COVID 19 infection. HCWs were infected during some of these aerosol-generating procedures, despite the use of accepted universal precautions (i.e, gowns, caps, gloves, eye protection, masks etc).[1] Protecting the health and safety of HCWs is important for welfare of the society. Hence preparing for and tackling this outbreak of COVID-19 requires a high-level commitment to respiratory protection for HCWs.[2]

Face masks and respirators are used regularly for respiratory protection of HCWs.[3] Face masks were designed to prevent the spread of infection from wearers to others. They can protect the wearer from splashes or sprays of blood or body fluids, but do not provide respiratory protection as they have lower filtration efficiency than respirators. They do not provide a proper seal around the face, and vary widely in type and quality.[4] Respirators are designed to protect the wearer against inhalation of

Received: June 16, 2020: **Accepted**: June. 27, 2020

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pISSN 2278-0076
eISSN 2321-9270

small and large airborne particles. Thus, it protects the wearer from others who might be infected. They provide a seal around the face and is defined and regulated by its filtration capacity.[5]

No consensus exists around the choice between facemasks and respirators for respiratory protection.[6] World Health Organisation (WHO) recommends the use of a mask in low-risk settings and a respirator in high-risk settings (aerosol generating procedures) Whereas Centre for Disease Control (CDC) guidelines recommend the use of respirator in both low-risk settings and a high-risk settings to protect healthcare workers (HCWs) in cases of pandemics. [2,7] Availability of Mask/respirator is also crucial in the context of COVID 19 which has no vaccine or treatment available, leaving non pharmaceutical measures as the only available protection for HCWs.[8] Unfortunately, during this pandemic, the supply of masks/respirators may not meet the demands due to insufficient production, lack of stockpiles or heavy usage.[9] In such scenario, optimisation of usage of masks and other alternatives for respiratory protection of HCWs should be considered. The aim of this review to summarize the available evidence on identifying right type and choosing proper fit of facemask/respirator with emphasis on their extended use/re-use in the scenario of pandemic crisis.

Face masks

These are disposable and loose-fitting, which reduce the spread of the respiratory droplets from wearer to other people and the environment. They afford protection to wearer from large droplets and sprays.[10] Type I medical masks are used for patients with the aim of controlling the source, and Type II or Type IIR(R stands for 'resistant') by HCWs while performing operatory procedures. The main difference among the types is based on their bacterial filtration efficiency. Type IIR face masks provides protection from the splashes, unlike Type I. [11]

Fig 1: Masks and N95 Respirator.

A lack of consistency was identified in regards to the nomenclature. The WHO frequently uses the term "medical masks", while the CDC uses the term "facemask".[3]

Respirators

Respirators are personal protective devices that cover the nose and mouth (or in some cases, more of the face and head) and operate either by purifying the air inhaled by the wearer through filtering materials or by independently supplying breathable air to the wearer (table 1) To be optimally effective, most types of respirators require a tight facial seal, thus individual fit testing is required.[12]

Filtering facepiece respirators **(**FFRs) have been used in industrial settings since the 1970s. In the 1990s, these devices found new applications in health care settings. Initially, they were advocated as the minimum level of protection to reduce exposure to infectious aerosols from patients with tuberculosis. Later, they were recommended for outbreaks and pandemics involving pathogens with potential for aerosol transmission.[13]

However, most commonly used respirators in health care are :

A) Disposable filtering facepiece respirators
B) Reusable elastomeric respirators
C) Powered air-purifying respirators (PAPRs)

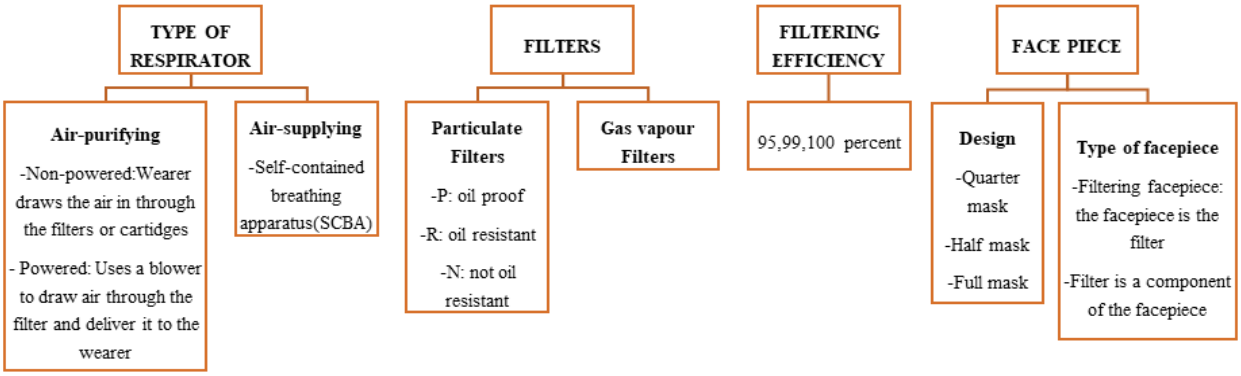
All three of these types are air-purifying respirators.[14]

Respirators can be disposable or reusable and are advised to be used during high-risk activities such as aerosol generating procedures in healthcare settings.[15]

Disposable filtering facepiece respirators (FFRs)

These are tight-fitting devices, designed to filter airborne particles.[16] They are inhalational protective devices. They are labelled based on their filtration properties and national regulations defining the standard conditions they were tested at. The National Institute for Occupational Safety and Health (NIOSH),U.S. agency regulates the testing and certification of respiratory protection equipment.[1]

Table 1: Respirators can be categorised generally based on [14]



The most common respirators utilized by HCWs is N95 filtering facepiece respirators (N95FFR). To be approved by the NIOSH, FFRs must pass a number of tests. Letter designations (eg, N, R, P) reflect the respirator's resistance to oil particles and numerical designations (95, 99, and 100) reflect the minimum filtration efficiency of the respirator filter to a challenge aerosol consisting of particles in the most penetrating particle size range (approximately 0.3 mm test particles) delivered at a flow rate of 85 L/min (table 3). [18]

Thus, N95FFR has 95% filtration efficiency and they have an assigned protection factor (APF) of 10. It indicates that with properly fitted FFR, trained users do not inhale more than one-tenth of the airborne contaminant present.[19] APFs are generally based on laboratory and workplace studies and measures the ratio of the ambient contaminant concentration to the contaminant concentration inside a respirator. [20, 21] However, as opposed to particulates and chemicals, governmental regulatory agencies have not established safe exposure levels for biological aerosols; thus, there is no assurance that any respirator will completely eliminate the inhalation of pathogens. However, it is assumed that the higher the APF, the more protection afforded to the wearer.[1]

Filtering performance strongly depends on fitting, and HCWs should test different devices to find the best fitting model for their face. This is because one size doesn't fit all. Also, presence of facial hair or beard can alter the sealing. [22] This is disadvantage of these disposable FFRs. Thus, fit test with an indicator aerosol should be used to evaluate the presence of leakages and to confirm the choice of the respirator model and size. Inhalation and exhalation seal checks should be performed before every use, to tighten the device properly and confirm that it was put on properly.[11]

There is concern regarding FFR moisture accumulation due to ambient humidity, retained moisture from the exhaled breath, and facial sweat accumulation resulting in loosening of the seal of the FFR to the face and a potential increase in breathing resistance as a result of blockage of pores in the FFR filter that could increase the work of breathing. Disruption of seal results in ingress of contaminants increasing the chances of biohazard.[23]

Though they provide better protection than masks, the direct costs of buying respirators and indirect costs of certification, training, and fit testing are high compared to masks. This is one of the reason as to why these respirators are not commonly used. [4,24]

Table 2: National Institute for Occupational respirators: Safety and Health's (NIOSH's) approved list of comparable respirators.

Country	Acceptable product classifications
Australia	P3 P2
Brazil	PFF3 PFF2
China	KN 100, KP100 KN95,KP95
Europe	FFP3 FFP2
Japan	DS/DL3 DS/DL2
Korea	Special 1st
Mexico	N100,P100,R100 N99,P99,R99 N95,P95,R95
US NIOSH	N100,P100,R100 N99,P99,R99 N95,P95,R95

Table 3- US, European and Australian standards and their filtration efficiency and Health's (NIOSH's) approved list of comparable respirators.

■ RESPIRATOR STANDARDS	■ FILTRATION EFFICIENCY
■ FFP1 & P1	■ 80 %
■ FFP2 & P2	■ 94%
■ N 95	■ 95 %
■ N 99 & FFP3	■ 99 %
■ P3	■ 99.95%
■ N100	■ 99.97%

Fig 2: US Standards equivalents.

Fig 3: Valved respirator

Valved versus Valveless respirators

FFRs are also available with an expiratory valve, which make them more comfortable for long-time wearing (Figure 3). The valve opens during the expiratory phase of the wearer's breathing, allowing the exhaled air to flow-out. The protection from body fluids and splashes is not guaranteed by valved FFR, and has to be confirmed by the label ''Type IIR'', as for face masks. It also reduces fogging of the goggles. Not ideal for health care settings as they can contaminate sterile environment.[25,26]

Table 4: Difference between Mask and N95 Respirator[27]

Surgical Mask	N95 Respirator
Cleared by the U.S. Food and Drug Administration (FDA)	Evaluated, tested, and approved by NIOSH as per the requirements in 42 CFR Part 84
Fluid resistant and provides the wearer protection against large droplets, splashes, or sprays of bodily or other hazardous fluids. Protects the patient from the wearer's respiratory emissions.	Reduces wearer's exposure to particles including small particle aerosols and large droplets (only non-oil aerosols)
Loose-fitting	Tight-fitting
Fit testing is not required	Fit testing is required
Seal check is not required	Seal check required each time the respirator is donned (put on)
Does NOT provide the wearer with a reliable level of protection from inhaling smaller airborne particles and is not considered respiratory protection	Filters out at least 95% of airborne particles including large and small particles
Leakage occurs around the edge of the mask when user inhales	When properly fitted and donned, minimal leakage occurs around edges of the respirator when user inhales
Disposable. Discard after each patient encounter.	Ideally should be discarded after each patient encounter and after aerosol generating procedures. It should also be discarded if it no longer forms an effective seal to the face; or if breathing becomes difficult; or if it becomes contaminated with blood, respiratory or nasal secretions, or other bodily fluids from patients.

Reusable elastomeric respirators

These respirators are made from elastomeric materials, which can withstand high elastic deformation without rupture . The respirator can be cleaned, disinfected, and reused. In health care, the half-mask configuration is frequently used (figure 4).These respirators have replaceable filters or cartridges and inhalation and exhalation valves. Fit testing is required for usage of these respirators. [14]

A prerequisite for use of these reusable respirators, is an accurate cleaning/disinfection procedure. They are procurable alternatives to disposable FFRs, for augmenting the total supply of respirators especially in case of pandemics like COVID 19. While elastomeric respirators are not cleared by FDA for fluid resistance, based on their NIOSH approval, they can provide at least equivalent protection to N95 FFRs. Some types of elastomeric respirators can offer APF than N95 FFRs.[28]

They require maintenance and a supply of replaceable components such as inhalation and exhalation valves, straps ,valve covers, and filters or canisters. Hard outer casing of filters can be decontaminated, but the filter material cannot be cleaned or disinfected for reuse. Instead, filter components should be discarded when they become damaged, soiled, or clogged. Elastomeric respirators with exhalation valves should not be used in surgical settings as they can contaminate the sterile field. [14]

However there is lack of consensus regarding best practices for cleaning, disinfection and maintenance which can lead to disease transmission through fomite contamination from surfaces of reusable respirator including straps.[14]

Fig 4: Half and full face reusable respirators.

Fig 5: Powered air purifying respirators

Powered air purifying respirators

The PAPR is an air-purifying respirator with a powered blower with interchangeable and disposable filters, such as high-efficiency particulate air filters (HEPA) [Figure 5].The PAPR's assigned protection factor is 25 for devices equipped with a loose fitting face piece and 1,000 for tight-fitting face piece models. This means that the PAPR offers greater respiratory protection than a disposable FFR.[29]

Loose-fitting PAPR with a hood is preferred in health care settings over a tight-fitting mask that

are used in industrial settings. Advantage of loose-fitting PAPRs is that they do not require fit testing or other user characteristics such as a clean shaven face. However, they require charged batteries to maintain equipment operation.[30]

HEPA filters have similar filtration as P100 and are the filters of choice for disease control. The use of HEPA filters in PAPRs provide greater level of respiratory protection than N95 masks. PAPRs have the advantage of providing head and neck protection. In spite of providing superior respiratory protection compared to disposable FFRs and reusable elastomeric respirators, these battery-powered respirators may have physiologic and ergonomic impacts from the weight and noise of the devices. Other drawbacks include difficulties in communication due to their bulk and noise, the inability to use a stethoscope and a requirement for batteries to ensure proper airflow rates into the hood. Also, they are highly expensive than reusable elastomeric respirators. PAPR also does not filter particles from exhaled breath like reusable respirators. After use, filters are considered to be contaminated with infectious material; therefore, they pose a potential risk to individuals reprocessing reusable respirators.[31,32]

Concurrent use of PAPR and N95

Although the use of a concurrent N95FFR could potentially decrease the in-PAPR exposure by 90%, no studies have yet evaluated the efficacy of an N95FFR/PAPR combination. It may provide greater respiratory protection over that of PAPR alone, but it is unproven. Hence, no firm conclusions can be drawn. There can also be risk of self-contamination or dissemination of pathogens to nearby HCWs or patients.[33]

The Extended use and limited reuse of disposable N95 masks

In the scenario of COVID 19, shortages of disposable N95 filtering facepiece respirators are inevitable. Hence greater emphasis is laid on their extended use and limited reuse.

Extended use refers to the practice of wearing the same N95 respirator for repeated close contact encounters with several patients, without removing the respirator in between patients. It is well suited to situations wherein multiple patients are infected with the same respiratory pathogen. Extended use has been recommended as an option for conserving respirators during outbreaks and pandemics.[34]

The CDC reports that prolonged N95 mask use (including between patients) can be safe for up to 8 hours. Current guidelines encourage wearing a face shield over the N95 to decrease the chances of soiling the mask.

Reuse refers to the practice of using the same N95 respirator for multiple encounters with patients but doffing after each encounter. The respirator is stored in between encounters to be donned prior to the next encounter with a patient. Even when N95 respirator reuse is practiced or recommended, restrictions are in place which limit the number of times the same FFR is reused. Thus, N95 respirator reuse is often referred to as "limited reuse". Limited reuse has been recommended and widely used as an option for conserving respirators during outbreaks and pandemics.[13]

Because coronaviruses(COVID 19) lose their viability significantly after 72 hours it promoted a rotation and re-use strategy.[35] Assuming there is no soiling and minimal to no viral contamination to the mask, the CDC suggests that masks can be re-used up to 5 times with the following strategy:

Mask Rotation

Set of N95 masks are acquired (at least 5 per the CDC), and rotated their use each day, allowing them to dry for long enough that the virus is no longer viable (> 72 hours). Proper storage for this technique requires either hanging the respirators to dry, or keeping them in a clean, breathable container like a paper bag between uses .A user seal check should be performed before each use. Fastidious donning/doffing should be done to avoid contamination of the inside or outside of the mask at all times.If the mask is damaged or significantly contaminated from aerosol generating procedures or bodily fluids, the CDC recommends discarding it.[36]

Givi et al stated that N95 masks may be re-used after aerosol generating medical procedures (AGMP) performed on patients at low risk of having COVID-19.[37] The CDC has provided statement that decontamination with either UVC, vaporized hydrogen peroxide, or moist heat could be

considered by health care institutions in an emergency.[38,39]

Difficulties associated with usuage of respirators

Respirator usage may appear to be easy, but they can interfere with respiration, thermal equilibrium, vision, communication, physical and psychological factors.[40,41] Work cannot be performed for longer times while wearing a respirator compared to when respirators are not worn. This necessitates more time for a particular task or more workers to complete the same task. It also exhibits wearer variability. Some wearers can tolerate respirators high inspiratory or expiratory resistance levels, while others cannot. Some wearers can tolerate hot, humid conditions inside respirators, whereas others cannot.[42]

Prolonged usage of N95 can lead to increased frequency of headaches,[43] nasal resistance, physical discomfort, decreased blood oxygen saturation level due to increased CO_2 content of inspired air which could possibly lead to giddiness, loss of judgement, loss of co-ordination, weakness,nausea,fainting, loss of consciousness and even death in severe cases.[44,45]

CONCLUSION

Knowledge of various available masks and respirators are essential to apply it in appropriate clinical settings. In case of airborne hazard, respirators are effective compared to mask. However, there is no consensus on the use of respirators. Use of appropriate respiratory protective equipment is crucial for the healthcare workers especially while treating viral infections, such as the current pandemic, COVID-19. With limited supplies of these FFR, knowledge about alternatives play a major role in assuring protection to health care personnel. Scientific evidence on the effectiveness of respirators in the combatting COVID-19 is low. There should be a more constant research effort regarding use of properly fitted respirators and periodical training of healthcare workers for the usage of these respirators.

CONFLICTS OF INTEREST

The authors declare they have no potential conflict of interests regarding this article.

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