REVIEW

Role of respirators in controlling the spread of novel coronavirus (COVID-19) amongst dental healthcare providers: a review

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Abstract

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During the ongoing COVID-19 pandemic, healthcare professionals are at the forefront of managing the highly infectious coronavirus. As the most common route of transmission is via aerosols and droplet inhalation, it is critical for healthcare workers to have the correct personal protective equipment (PPE) including gowns, masks and goggles. Surgical masks are not effective in preventing the influenza and SARS, so they are unlikely to be able to resist contaminated aerosols from entering the respiratory system. Therefore, it is vital to use respirators which have been proven to offer better protection against droplets, aerosols and fluid penetration and which form a tight seal around the mouth and nose. Various types of respirators are used in healthcare settings, such as half-mask filtering facepiece respirators (FFRs) and powered air-purifying respirators (PAPRs). The most commonly used FFR is the N95 disposable respirator, which is tight fitting and has a 95% or above particle filtering efficiency for a median particle size of 0.3 μm. This review discusses respirators, their purpose, types, clinical efficiency and proper donning and doffing techniques.

Keywords: COVID-19, masks, pandemic, respirators.

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Introduction

With the emerging outbreak of the coronavirus pandemic, millions of people throughout the world are staying at home to contain the spread of disease and contribute to flattening the curve associated with the rapid rise in the number of cases. However, healthcare professionals will not be staying home. Indeed, they belong to a group of individuals who will be particularly vulnerable to contracting the infection (Dave *et al.* 2020), which has been reported to be as high as 29% in Wuhan, China (Wang *et al.* 2020). In this context, the Occupational Safety and Health Administration (OSHA) within the Department of Labor, USA, has developed an occupational risk pyramid which defines the risk of healthcare providers based on exposure (https://www.osha.gov/Publications/OSHA3990.pdf; United States, Department of Labour). According to the OSHA, dental healthcare providers (DHCPs) are classified as 'very high risk'. For this reason, the personal protective equipment (PPE) requirements for DHCPs have been modified to include the wearing of impermeable gowns, goggles or face shields and N95 or better respirators in addition to standard precautions (Meng *et al.* 2020).

The recommendation for a N95 respirator is unique for dentistry and requires a detailed discussion on, its

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types, alternatives, donning and doffing techniques and fit testing.

Why is a respirator required?

According to the information available, the most common transmission routes for severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) or COVID-19 are through droplet transmission via direct face-to-face contact between patients and dental healthcare providers (DHCPs), coughing or sneezing and indirect transmission by touching surfaces that were contaminated by the virus and then touching face, nose or eyes and through coarse or small droplets of saliva whilst performing aerosol generating procedures such as laryngoscopy or dental treatments (Peng *et al.* 2020, Prati *et al.* 2020). The SARS-CoV-2 virus has an affinity for the angiotensin-converting enzyme 2 (ACE-2) receptor, which is in abundance in the respiratory tract and salivary gland duct epithelium, and therefore, the saliva is very likely to contain a high viral load (Liu *et al.* 2011). Micik and colleagues were the first to define aerosols in dentistry as particles of size less than 50 μm which were able to stay airborne for extended periods of time before eventually settling in the environment and or inhaled into the respiratory system (Micik *et al.* 1969). The particle size of 0.5–10 μm is of distinct importance as they are most likely to transmit infection (Micik *et al.* 1969). This has been validated by numerous studies, and there is strong evidence which indicates that severe acute respiratory distress syndrome virus (SARS) spreads through aerosol transmission. It would be completely logical to assume that COVID-19, which is similar to SARS, can likewise spread through aerosols (Jones & Brosseau 2015, Centers for Disease Control and Prevention: https://www.cdc.gov/sars/guidance/i-infection/healthcare.html (accessed 21 April 2020)).

Do surgical masks offer protection from COVID-19?

Since the outbreak, there is a lack of data comparing the efficacy of surgical mask versus respirators in mitigating the spread of COVID-19 virus; however, there is an abundance of published data comparing the two against the influenza virus and SARS (Seto *et al.* 2003, Teleman *et al.* 2004).

Wen and colleagues tested the performance of various respirators and surgical masks against viral aerosols and demonstrated that the protection factor of N95 was thirty times greater than normal surgical masks (Wen *et al.* 2013). Likewise, the superiority of N95 over surgical masks has also been demonstrated against SARS in a number of case–control studies (Seto *et al.* 2003, Teleman *et al.* 2004).

Conversely, a recent systematic review and meta-analysis failed to demonstrate the superiority of N95 respirators over surgical masks during influenza pandemics (Long *et al.* 2020). The reasons suggested by the authors for the conflicting results were the high risk of bias in the randomized control trials, low compliance of wearing the N95 respirator and frequent doffing as the respirator was uncomfortable to wear for longer periods of time (Long *et al.* 2020). To sum up, faced with the emergence of a virulent disease such as COVID-19 it would be logical to use a respirator as it offers resistance to fluid penetration and forms a seal around the mouth and nose in contrast to surgical masks that provide barrier protection only against droplets including large respiratory particles. Most surgical masks lack an adequate face seal and do not effectively filter small particles from the air or aerosols, allowing for leakage around the mask and subsequent exposure (Wen *et al.* 2013). Furthermore, the American Dental Association (ADA) recommends an isolation of 14 days for both the DHCP and the patient if an aerosol generating procedure was performed using only a surgical mask and/or a COVID test be performed on the patient (https://www.ada.org/en/member-center/coronavirus-resource-toolkit-for-ada-members).

What are the different types of respirators?

There is a range of respirators including full- and half-mask types. The common types of respirators that are used in healthcare settings include half-mask filtering facepiece respirators (FFRs) and powered air-purifying respirators (PAPRs). Since all dental guidelines recommend using FFRs, they are discussed in greater detail (Chughtai *et al.* 2020). The most widely used FFRs are the N95 respirators, which are disposable filtering facepiece respirators (FFRs) that tightly fit to provide optimum face seal and have a 95% or above particle filtering efficiency for a median particle size of 0.3 μm (Bergman *et al.* 2015).

The prefix N is a description of the filter material (N = oil nonresistant, R = some resistance to oil and P = oil proof) and suffix 95 describes its protective

properties (95 would filter 95% particles whilst 99 filters 99% particles) (Bollinger 2004).

They come in a variety of shapes, for example cup-shaped 1860 (3M™, St. Paul, MN, United States), flat-fold 1870 (3M™) and duckbill PFR95-270 (Kimberly Clark Corp., Dallas, TX, United States). These variations allow for better fit and comfort for different face types. Some masks have exhalation valves that tend to keep the face cooler and prevent moisture build-up. The masks with an exhalation valve should not be used when working under sterile conditions (Bollinger 2004).

The respirators mentioned below according to 3M™ are equivalent in performance to N95 (United States NIOSH-42CFR84) and may be considered as viable alternatives to N95 (https://multimedia.3m.com/mws/media/9577300/respirators-and-surgical-masks-contrast-technical-bulletin.pdf).

- FFP2 (Europe EN 149-2001)
- KN95 (China GB2626-2006)
- P2 Particulate respirator (1716:2012; 3M ™ Australia/New Zealand)
- Korea 1st class (Korea KMOEL-2017-64)
- DS (Japan JMHLW-Notification 214, 2018)

Which model should i choose?

Fit testing is needed to determine whether a particular size and model of respirator provide an acceptable fit. The benefit of the FFR will be negated if it does not form a tight seal around the face and nose; therefore, a process of individual fit testing is required (OSHA Respiratory Protection standard 29 CFR 1910.134) and this should be repeated periodically (Bergman *et al.* 2015). There are two types of fit tests available, which include qualitative and quantitative tests.

The qualitative test is graded as adequate if the test subject does not detect the sweet or bitter taste of saccharin or Bitrex (a solution containing 95% water, 5% sodium chloride and < 0.1% denatonium benzoate), respectively, whilst performing a series of test exercises. Whilst the quantitative fit test is done by using ambient aerosols to numerically estimate how well the N95 fits the user by measuring the aerosol particle ratio outside (C_o) and inside (C_i) the device. Nonetheless, studies demonstrate that fit testing with either method provides the expected levels of protection (Shaffer & Janssen 2015). Studies have shown that varying pass rates for fit tests range from 10% to 80% indicating that one size does not fit all

(McMahon *et al.* 2008, Winter *et al.* 2010, Huh *et al.* 2018).

To date, there have been hundreds of approved N95 models that are available and it is difficult to predict which type of respirator will be the best fit in a given population. A fit testing programme is recommended for dental healthcare providers, in which the selection of the most suitable model should be made by an experienced fit tester who would determine the best fit based on facial dimensions, ethnicity and appearance of fit. These recommendations have proven to be useful in the past (McMahon *et al.* 2008, Wilkinson *et al.* 2010, Danyluk & Hon 2011).

Donning and doffing of FFRs

Correct donning and doffing procedures are the key to use of PPE, and all efforts should be made to prevent contamination during wearing and removal of respirators. Therefore, stringent surveillance on proper PPE use is critical for preventing disease transmission to healthcare workers. Previous studies show poor adherence with donning and doffing protocols lead to self-contamination (Beam *et al.* 2011, Casanova *et al.* 2016). There are no universally accepted donning and doffing sequences but having a check list or instructions (Figs 1 and 2) are useful. Having full body mirrors for self-assessment and external observers have also proven to be helpful in preventing self-contamination (Aguilar & Linsuwanont 2011).

Reuse and decontamination of FFRs

Respirators are meant for single use only; however, reuse may be allowed in a crisis situation to conserve resources. The COVID-19 virus is able to survive on plastic, stainless steel and cardboard for up to 72 h (van Doremalen *et al.* 2020). Therefore, there is a chance that the outer surface of respirators could become contaminated with aerosol, which can later be transferred to the user during donning and doffing procedures. Ultraviolet germicidal irradiation (UVGI), vaporous hydrogen peroxide (VHP) and moist heat are the most promising decontamination procedures, but there are is no literature which supports their efficacy against COVID-19. Nevertheless, caution is advised as decontamination procedures can have negative impact on the respirator performance as well as the fit of the respirator. It is also recommended to contact the vendor for best decontamination practices
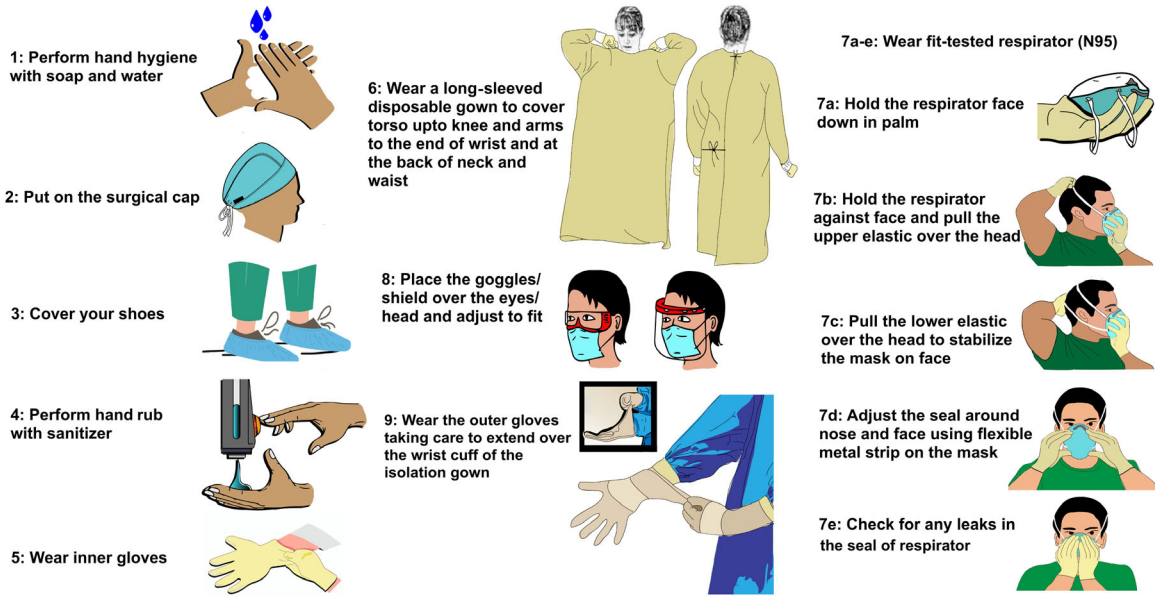
1: Perform hand hygiene with soap and water

2: Put on the surgical cap

3: Cover your shoes

4: Perform hand rub with sanitizer

5: Wear inner gloves

6: Wear a long-sleeved disposable gown to cover torso upto knee and arms to the end of wrist and at the back of neck and waist

8: Place the goggles/shield over the eyes/head and adjust to fit

9: Wear the outer gloves taking care to extend over the wrist cuff of the isolation gown

7a-e: Wear fit-tested respirator (N95)

7a: Hold the respirator face down in palm

7b: Hold the respirator against face and pull the upper elastic over the head

7c: Pull the lower elastic over the head to stabilize the mask on face

7d: Adjust the seal around nose and face using flexible metal strip on the mask

7e: Check for any leaks in the seal of respirator

Figure 1 Donning of PPE.

1a-c: De-gloving

1a: Use gloved hand to grasp the palm area of other gloved hand to peel off first glove

1b: Hold contaminated outer glove in gloved hand and slide fingers of with inner glove under other outer glove at wrist to peel off second glove over first one

1c: Carefully discard gloves at designated place

2a-c: Remove the gown

2a: Untie the gown taking care not to touch your body with contaminated sleeves

2b: Pull the gown away inside out from neck and shoulders

2c: Fold or roll into a bundle and discard in designated container

3: Remove shoe covers

4: Perform hand rub with sanitizer

5: Untie goggles/shield and extend it to pull over head

6a-c: Remove the respirator (N95)

6a: With slight forward bent head, remove the lower tie/elastic over the head.

6b: Remove the upper tie/elastic over the head taking care not to touch the contaminated surface

6c: Pull it away from the face by holding the tie/elastic and discard where designated

7: Remove the surgical cap

8: Remove inner gloves in the same order as outer gloves were removed

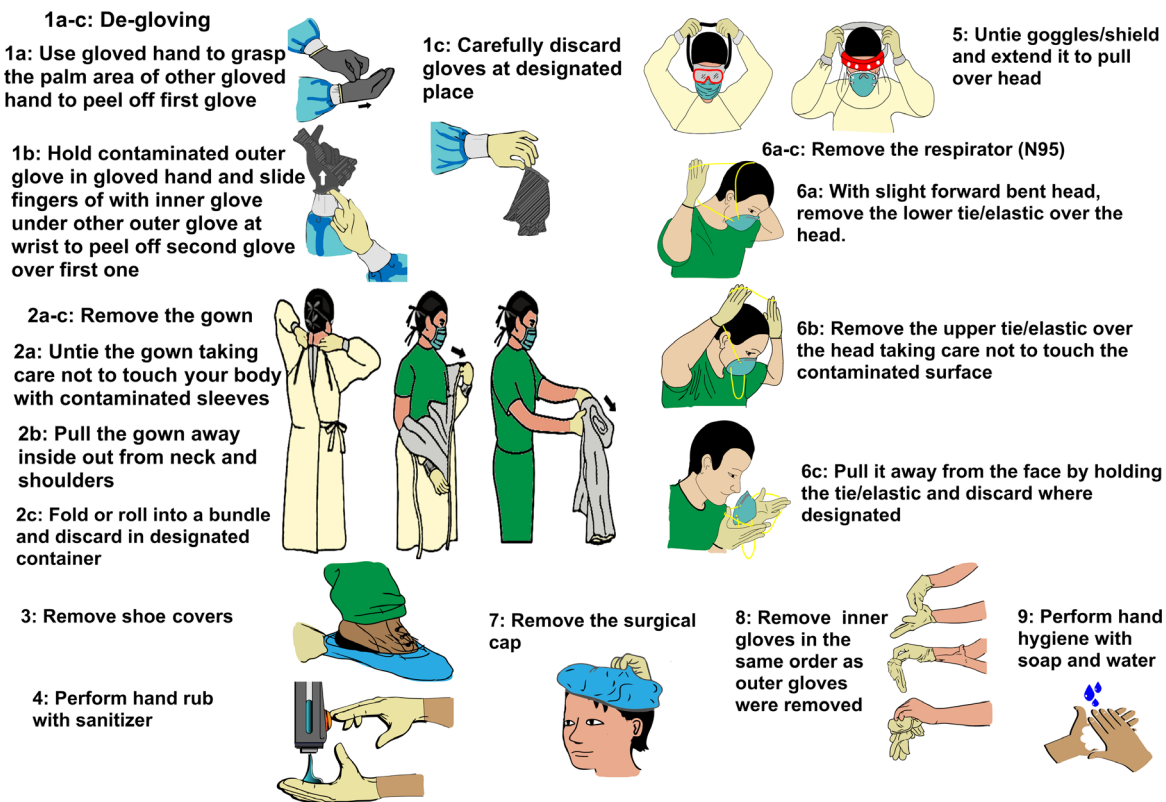9: Perform hand hygiene with soap and water

Figure 2 Doffing of PPE.

(Bergman *et al.* 2010, Aguilar & Linsuwanont 2011, van Straten *et al.* 2020).

Conclusion

It is essential to use FFRs during the pandemic of COVID-19 to prevent aerosol and droplet transmission as they are proven to offer resistance against fluid penetration and forms a seal around the mouth and nose better than surgical masks. The success of any FFR in preventing the inhalation of contaminant particles is also subject to an acceptable fit test and proper donning and doffing. The most commonly used FFR is the N95 respirator to prevent the transmission of disease.

Conflict of interest

The authors have stated explicitly that there are no conflicts of interest in connection with this article.

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