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Research Article

Effect of moisture on filtration effectiveness of dental face masks against pathogenic bacteria

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Abstract

Background/Objectives: This study aimed to compare the effectiveness of dental mask filters for pathogenic bacterial protection with and without the moisture for a proper standard for replacing dental masks.

Methods/Statistical analysis: A ventilator was attached to a manikin wearing a dental mask. An aerosol application 100 μl of bacterial inoculation solution cultured in a brain heart infusion (BHI) broth for one day was performed on the external surface of the mask, and a ventilator then attached without additional humidification. After four hours, both surfaces of the dental masks were sampled using sterile swabs.

Findings: One ml of the sample was dispensed on Petrifilm Staph Express plates, then grown for 24 hours at 37 degrees. The same process was used for an additional test, but with samples taken from both surfaces after eight hours.

In the test model with no humidification, no bacteria were found after four or eight hours on the inside surface of the mask. With humidification, no bacteria were found after two hours, but after four hours of ventilation bacteria

were found on the inner surface.

Improvements/Applications: The use of dental masks for pathogenic bacterial filtration should not exceed four hours, and dental masks over two hours could be reused after being dried thoroughly.

Keywords: Surgical mask, Duration on filter function, Humidifying effect, Pandemic, Pathogenic bacteria

1. Introduction

With the world engulfed in the COVID-19 pandemic, the WHO and the Korea Disease Control and Prevention Agency (KDCA) recommend the use of masks for infection control [1,2]. Consumers select masks from a variety of products available in the market based on descriptions of filter functions. While KF 94-rated masks have superior filters compared to dental masks, the latter are also sometimes recommended due to better comfort and easier breathing [3,4]. Many experts in public health recommend the importance of mask wearing in respiratory infection prevention. In December, 2020, coronavirus outbreak was reported in Wuhan, China. On January 31, 2020, WHO declared the coronavirus pandemic and the outbreak was named coronavirus disease-19 (COVID-19). 0n March 11, 2020, COVID-19 was officially recognized as the pandemic condition [5,6]. As a result, Tokyo Olympic Games were put off indefinitely. There are three pandemics by WHO; Hong Kong flu (A/H3N2) in 1968, pandemic influenza (A/H1N1) in 2009, and COVID-19 in 2020.

The first COVID-19 patient in Korea was reported in January 20, 2020. COVID-19 is transmitted via respiratory route and it has the highest transmission in the initial stage of infection. COVID-19 symptoms include sore throat, high fever, cough, respiratory distress, and pneumonia. On August 11, 2020, the cumulative worldwide infections were over 20 million. COVID-19 is caused by the same agent of severe acute respiratory syndrome (SARS) and middle east respiratory syndrome (MERS). The virus is SARS CoV-2. Coronavirus is a single stranded RNA virus and has spike proteins which has an important role in cross species infections of SARS CoV which has angiotensin converting enzyme 2(ACE 2).

In order to prevent COVID-19, the best method is wearing masks. In this study, the researchers tried to reveal the mask filtration effectiveness.

A study has shown that a person's hands come into contact with the face an average of 23 times per hour [7]. Similar frequency would be expected while wearing a mask. Touching a mask with unwashed hands would leave pathogenic organisms including COVID-19 on the surface of the mask, leading to a possible pathogen infection via the mask even if there is no aerosol contact [8,9]. Care should be taken while wearing a mask, and masks should be frequently replaced. Mask filters are also affected by moisture absorption rates [8], and experts recommend that wet masks should be replaced or dried immediately [10,11]. Masks, except cotton masks, are single-use; however with COVID-19 straining mask supplies, there is a general perception that masks can be used as long as there's no soiling. However, there is no clear standard for replacing masks among members of the general public, and the WHO, KCDC, the Korean Medial Association (KMA) and other healthcare authorities offer different guidelines. This study aims to examine how long dental mask filters remain effective against pathogenic bacterial to determine if a standard can be established for replacing dental masks.

2. Materials and Methods

To simulate a dental mask being worn in everyday life, a ventilator was affixed to a manikin wearing a dental

mask. The presence or absence of moisture caused by breathing was determined to be the standard for functional effectiveness; for the test, a ventilator without a humidifier (non-humidification model) and a ventilator with the humidifier enabled (humidification model) were selected, with all other conditions remaining equal.

2.1. Non-humidification model

An aerosol application 100 μl of bacterial culture solution grown in a brain heart infusion (BHI) broth for 24 hours was performed on the external surface of the mask, and a ventilator then attached without additional humidification. After four hours, both surfaces of the dental masks were sampled using sterile swabs (3M pipette swab, 3M Korea Ltd.). One ml of the sample was dispensed on Petrifilm Staph Express plates, then grown for 24 hours at 37 degrees. The same process was used for an additional test, but with samples taken from both surfaces after eight hours instead of four.

2.2. Humidification model

For the humidification model, the same setup was used with the addition of a ventilator with a humidifier attachment. After one hour, samples were taken with sterile swabs from the inner and outer surfaces of the dental masks. Additional samples were taken using the same method after two, four and eight hours.

2.3. Reusing a dental mask

With the humidification model, an additional test was performed after verifying the threshold when bacteria were not found on the inner surface. After the mask was fully dried, filter functionality was tested.

2.4. Study instrument of dental mask

Dental masks manufactured by “Y” Company that complies with Ministry of Food and Drug Safety and FDA standards were used.

2.5. Study instrument of ventilator

CareFusion’s LTV®1200 was used, with a Laerdal pocket mask attached to the ventilator hose to be affixed on to the face of the manikin wearing a dental mask.

To ensure that the manikin’s lungs expand fully to supply sufficient tidal volume, the ventilator was set to CMV(control mandatory volume) mode with tidal volume at 600ml, twelve breaths per minute, 1:2 inhalation/exhalation ratio, and CPAP(continuous positive airway pressure) at 20 ㎝/H_2O.

2.6. Study instrument of manikin

An intubation manikin with observable lung inflation was used (Airway Management Trainer® by Laerdal).

2.7. Study instrument of pathogenic bacteria

To check the dental mask’s pathogenic bacteria filtration effect, Staphylococcus aureus that cause pyogenic infection on dermal and soft tissue as well as pneumonia, food position and toxic shock syndrome was used [8].

3. Results

3.1. Elapsed time comparison for bacteria discovery, non-humidification and humidification models

For the model without humidification, bacteria were not found on the inner surface of the mask after four or eight hours of ventilation. For the humidification model, bacteria were not found after two hours, but were discovered on the inner surface after four hours (fig. 1).

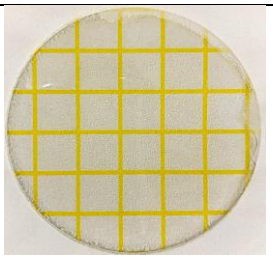
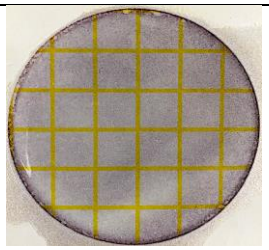
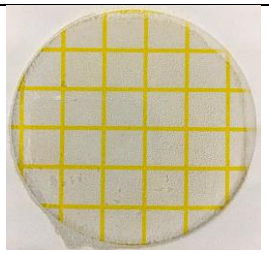
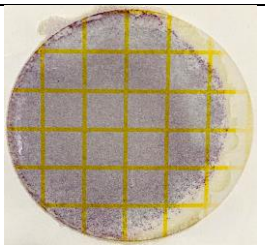
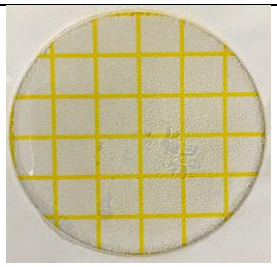
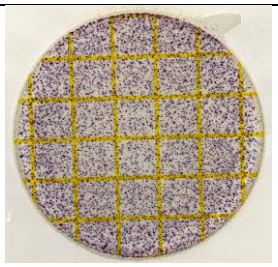
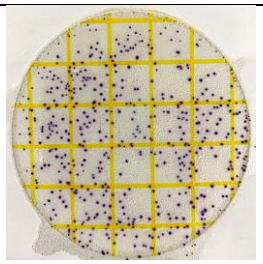
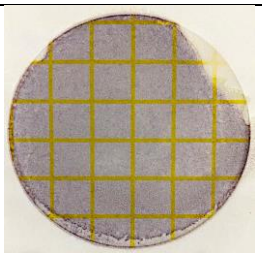
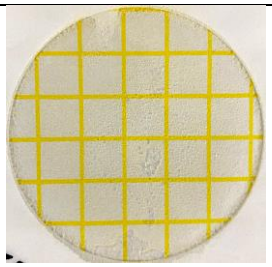
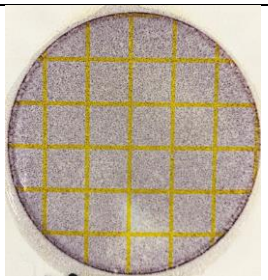
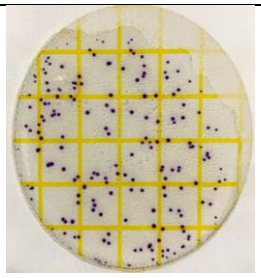
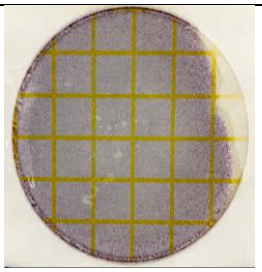
	non-humidification model		Humidification model	
	Inner layer	Outer surface	Inner layer	Outer surface
1h				
2h				
4h				
8h				

Figure 1. Incubated result of the collected samples from the inner layer and outer surface of the surgical mask.

3.2. Elapsed time for bacteria discovery for a re-used mask

No bacteria were sampled after a mask that was ventilator applied in the humidification model was completely dried then exposed to ventilation for an additional two hours (fig. 2).

inner layer	outer surface

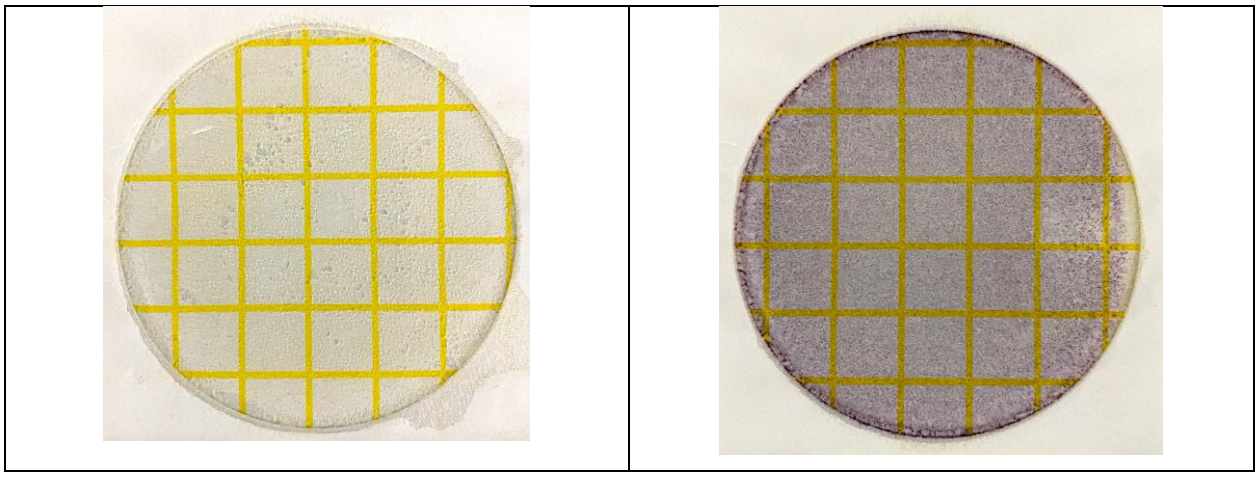


Figure 2. Result of the ventilator connected to a humidifying device applied for 2 hours and completely dried and then applied again for another 2 hours

4. Discussion

The WHO and the Korea Center for Disease Control and Prevention recommend the use of face masks for preventing COVID-19 infection, but only offer recommendations regarding mask ratings by occupation, wearing method and precautions without specific standards for how long a mask can be worn or whether it can be reused safely [12, 13].

Mask filters lose effectiveness when they absorb moisture [14], and experts recommend that wet masks should be replaced or dried immediately [15].

According to Rebeiro et al.[16] revealed that the importance of mandatory use of masks in preventing and mitigating nationwide COVID-19 pandemic.

Leung et al.[8] revealed the following experiments. Those who had symptomatic respiratory virus infection were selected in exhalation virus study. A total of two hundred forty six persons were recruited and fifty % of them had no face mask during the first exhalation. The rest 50% of them had a face mask. Each of the virus was sampled and quantified. The symptoms at presentation were fever, cough, sore throat, runny nose, headache, myalgia, phlegm, chest tightness, shortness of breath, chill, sweating, fatigue, vomiting, and diarrhea. Nasal swab, throat swab, and respiratory droplets and aerosols were tested by RT-PCR for coronavirus, influenza virus, and rhinovirus. The experiments showed that viral RNA quantity increased in nasal swabs in comparison to throat swabs in each virus. So wearing face masks is very important to prevent the respiratory infections including coronaviruses, influenza viruses, and rhinoviruses.

Some experts recommend dental masks, which are easier to wear and are resistant to moisture absorption, over KF 94-rated masks [4]. However, other reports state that moisture absorption does not affect the effectiveness of HEPA filters [17], indicating that while moisture absorption cannot be used as a definite standard for mask selection, it could be used as a standard indicator for how long a mask should be used.

This study showed that in the non-humidification model, bacteria did not penetrate the dental mask's filter after four or eight hours of use. For the humidification model, the bacteria did not compromise the mask after two hours, but did after four hours. When the mask used for two hours was dried completely and reused, the bacteria did not pass through the filter. Thus to ensure proper filtration of pathogenic bacteria, dental masks should not be used for more than four hours, and dental masks used for two hours can be reused after being dried completely. While dental masks are meant to be single-use only, reusing them can thus be an option when supplies are dire due to viral outbreaks such as the current pandemic[18,19].

However, this study only provides an optimal duration of dental mask use for filtration of pathogenic bacteria; further study would be required for other factors that cause respiratory infection (i.e. virus), and additional research on similar masks such as cotton masks and medical-grade (i.e. KF 94) masks are recommended as well.

4. Conclusion

This study showed the results to compare the effectiveness of dental mask filters for pathogenic bacterial protection with and without the moisture. In the test model with no humidification, no bacteria were found after four or eight hours on the inside surface of the mask. With humidification, no bacteria were found after two hours, but after four hours of ventilation bacteria were found on the inner surface.

So the use of dental masks for pathogenic bacterial filtration should not exceed four hours, and dental masks over two hours could be reused after being dried thoroughly.

Further study would be required for other factors that cause respiratory infection (i.e. virus), and additional research on similar masks such as cotton masks and medical-grade (i.e. KF 94 in Korea) masks are recommended as well.

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