Original Article

Assessment of dental personal protective equipment (PPE) and the relationship between manual dexterity and dissemination of aerosol and splatter during the COVID-19 pandemic

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KEYWORDS
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Abstract  Background/purpose: Asymptomatic COVID-19 patients visit the dental clinic for routine treatment, during which, high-speed handpieces, and third-use sprayers can produce aerosols. We focused on the effect and possible inadequacy of personal protective equipment (PPE) while cleaning teeth and assessed whether doctors’ proficiency was related to the range of spraying droplets.

Materials and methods: Doctors were divided into three different groups: attending physicians, residents, and intern respectively. Each doctor treated 15 patients; each group comprised 30 patients. The dentists wore leg covers, shoe covers, medical masks, haircaps, full masks, waterproof barrier gowns, and gloves. Each patient was covered with a waterproof hole towel, and the upper edge was fixed to the patient’s nose with a medical tape. After cleaning the teeth with water contained red pigment, the spattering distance and range of droplets

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Introduction

In December 2019, a wild animal-derived pneumonia breakout was suspected in Wuhan, China. In January 2020, the COVID-19 infection spread was limited to China and Asia, which was still an “epidemic” under the definition of WHO. However, in March 2020, the number of cases increased 19-fold, expanding to nearly 120,000 people infected in more than 110 countries in only two weeks. Considering the outbreaks in Italy, Iran, South Korea and other countries, the World Health Organization declared a global pandemic. Thus far, nearly 200 million people in 194 countries/regions around the world have been diagnosed with the COVID-19 infection. The WHO reported that 80% of patients infected with COVID-19 presented with mild symptoms, and nearly 50% presented with no obvious symptoms. Current research shows that one of the characteristics of COVID-19 infection is that the clinical symptoms were not directly related to the viral load, and those with mild symptoms were almost the same as those diagnosed with obvious respiratory diseases.

The COVID-19 virus is transmitted directly or indirectly through droplets between people and animals or people to people. Asymptomatic patients may go to the dentist for treatment; however, in routine dental treatment, the infection may spread through instruments (e.g., ultrasonic scaling, high-speed handpiece, and third-way sprayer), which generate water mist and aerosols. These water mist and aerosols mix with the blood and bodily fluids of patients, and can easily spread to dental personnel and cause environmental pollution; the spread is mostly attributable to scaling machines. An appropriate safe distance was not maintained between the medical staff and patient during the dental treatment, leading to a direct spray of aerosols and droplets at close distances (less than 1 m), and exposing the dental staff to the risk of infection.

According to the guidelines of national dental infection control measures, when dental personnel were exposed to mucosa, blood and saliva, the recommended personal protective equipment (PPE) was masks, gloves, isolation clothes, facial protective gear (goggles or masks) and hair-caps. The current research did not have any shortcomings in clinical inspection of doctors’ protection, so it was one of the goals of this article. The hole towel covered by the patient’s face when washing his teeth was 72 cm × 67 cm, but there was no standard specification at present. In addition to the knowledge and professionalism of dentists, the flexibility of the hand is also an indispensable part. Generally, the more senior doctors had higher hand flexibility than junior doctors due to longer-term training, so they wanted to know whether the range of spraying in the patient’s body will be assessed because of differences in doctor proficiency during the routine scaling process.

This study aimed to assess the protection effect and possible shortcomings of dental PPE at present and assess the coverage of the hole towel used by patients. In addition, we aimed to determine the correlation between the subjective and objective perceptions of participants. Measure whether the range of aerosol spread during dental cleanings vary among doctors with varying proficiencies.

Materials and methods

The study was reviewed and approved by the ethics committee of Kaohsiung Medical University Hospital (KMUHIRB-E(I)-20200145). The subjects were divided into dentists and patients. The inclusion criteria of entrance dentists were 1) age twenty to fifty-nine years, and 2) no physical disability; the exclusion criterion was people with eye diseases (e.g., old eyes, cataracts). The inclusion criteria of patients were: 1) people aged twenty to fifty-nine years; 2) people having more than 20 permanent teeth (excluding corrective braces and implants) 3) people with gingivitis; the exclusion criteria were: 1) patients with HIV, HBV and HCV and those at risk of infection; 2) patients with dry mouth syndrome; 3) patients with a mouth opening of less than 35 mm.

According to the previous dental pneumatic research, fluorescence was added to distilled water to identify the existence of pneumatic glue and evaluate the environment. Fluorescence was found to be harmful to the human body. Therefore, we used a red No. 40 food pigment (Fig. 1) in the proportion of 1.5 g dissolved in 1L distilled water, and used this dyed water in the water outlet pipe of the dental chair, so that the droplets could be easily identified by the naked eye. The Densply® P-10 (Australia) was used throughout the experimental process, and the water output was the same.

The dentists were divided into three groups: attending physician, resident and intern. Each dentist treated 15
patients, and each group comprised 30 patients. The dentist and assistant wore leg covers, shoe covers, general medical masks, and cloth hats before placing haircaps, full cover mask, waterproof barrier gowns, and gloves. In addition, the outer layer of the full cover mask was covered with rice paper, leaving a rectangular opening on the eye to avoid interference to the line of sight (Fig. 2). Each patient received a full mouth scaling session with the assistance of the same professional assistant, and the other personnel recorded the time taken for the procedure.

The patient covered his or her face with a waterproof hole-towel, which was covered with a 1.5 × 1.5 cm mesh on a 30 × 60 cm rice paper for droplet detection, with a portion left open to expose the mouth and nostrils. The upper edge of the hole-towel opening was fixed to the patient’s nose with a medical tape. The personnel recorded the position of the tip of the nose for reference (Fig. 3).

The data of splash distance, size of the droplet distribution and presence of droplet contamination on the PPE of dentists and assistants were measured and calculated by the same researcher.

The splash distance is the distance between the tip of the nose and the farthest point on the paper.

There were 180 1.5 × 1.5 cm meshes on the 30 × 60 cm paper, and the red droplets that appeared in the grid (with edges), no matter how large, were recorded as a grid. The size of the droplet distribution is recorded. The presence of droplet contamination on the PPE of dentists and assistants is also investigated. The range of contamination was found on the outer side of the mask, medical surgical mask, the upper half of the waterproof isolation clothing, the lower half of the waterproof isolation clothing, the leg cover, shoe cover, gloves and haircap.

Results

According to the results presented in Table 1, regardless of the protective equipment worn by the dentist or medical assistant, traces of pigment splash could be identified, except on the shoe covers and medical surgical masks. Furthermore, parts of the protective mask extending to the neck region also demonstrated traces of pigment splashing. Therefore, it was recommended that the length of the protective mask be extended to cover the neck of the doctor to effectively achieve complete protection.

According to the results presented in Table 2, in terms of the duration of scaling, the intern took significantly longer (332.8 ± 81.6 s) than the residents (191.4 ± 44.9 s) and the attending dentist (208.9 ± 47.8 s), and the difference was statistically significant (P = 0.001). In terms of grid numbers, there was no significant statistical difference between the three groups. The farthest splash distance for the intern group was 64.5 ± 13.8 cm, for the inpatient group was 54.9 ± 16.9 cm, and for the attending dentist group was 60.6 ± 13.7 cm, and the spatter distance of the intern group was significantly larger than that of the inpatient group (P = 0.0064).

Discussion

Dental high-speed handpiece and third-way sprayers both produced aerosols, which were divided into spatter (spatter >50 my) and droplets (droplet ≤50 mm) according to their...
particle size. Aerosols were more likely to stay in the air for a longer time before entering the human nasal channel or even into the respiratory system. Therefore, the larger spatter (spatter >50 me) evaporates first, leaving a droplet nuclei, and most likely became the carrier of Mycobacterium tuberculosis. Both large or small particles might carry microorganisms (e.g. human immunodeficiency virus or hepatitis B virus) and pose a risk of infection. The spatter from ultrasonic scaling, whether large or small, contains blood and bacteria. In addition, few studies have found that the aerosols produced during ultrasonic scaling mainly contained Gram-positive coccus (e.g. Staphylococcus epidermidis). Therefore, self-protection was more important for clinicians that were exposed to droplets from patients that were exposed to (direct or indirect) airborne diseases, such as influenza or COVID-19. Of all dental procedures, ultrasonic scaling was the easiest to produce aerosols. Therefore, this study mainly evaluates the current protective effect and possible shortcomings of dental protective equipment. As shown in Table 1, the whole equipment provided protection to the dentist or a medical assistant all have aerosol spread, except for shoe covers, haircaps, and medical surgical mask. Traces of pigment splashes were identified outside the therapeutic surgical mask. In addition, part of the protective mask extending to the dentist’s neck also had traces of splashing pigments. Therefore, it was recommended that the length of the protective mask should be extended to the neck area to effectively provide complete protection. According to the recommendation in the guidelines of the Disease Control Department of Disease Control of the Ministry of Health and Welfare, when directly exposed to the patient’s mucosa, blood, and saliva (e.g. ultrasonic scaling or high-speed handpiece), the recommended PPE should include masks, gloves, isolation clothes, and facial protective equipment (e.g. masks, goggles). The suggestion involving hair hats was almost similar to that stated in our study; however, in our study, traces could still be found in the neck region and the part below the knee of the operator; both of these were commonly neglected areas. Therefore,
these findings could help clinicians to re-examine whether there is a need to strengthen the existing protective equipment. Notably, no traces of pigment splash were found in the haircaps; however, according to the guidelines for dental infection control measures of the Disease Control Department of the Ministry of Health and Welfare,6 clinical dentists are still recommended to wear haircaps to protect against the splashing of droplets while operating. Owing to the minimal splash, it was considered impossible to directly identify traces of pigments with the naked eye. However, based on safety considerations, it was still recommended to wear haircaps when performing procedures with risk of aerosol spread. In addition, there was no clinical study in the literature that reported the need for shoe covers. Herein, no pigment splash marks had been found in the shoe covers, and the use of shoe covers was also not recommended in the guidelines for dental infection control measures of the Disease Control Department of the Ministry of Health and Welfare. It may be due to the distance between infectious area and the foot, thus the shoe cover was not necessary for protection equipment.

It was thought that the distance of stain transmission might be different from that of the actual virus. However, it was not feasible to perform experiments with actual virus on the human body, not to mention of getting the consent of the IRB. Thus, we designed our study refer to the study of Veena et al., 2015,9 which have used fluorescence and dyes of the IRB. Thus, we designed our study refer to the study of Veena et al., 2015,9 which have used fluorescence and dyes to see the size of the droplet. It was also noted that the droplets of ultrasonic scaling may contain pathogens. In conclusion, it is possible that some pathogens cannot be fully manifested by dyes, but if there is staining, it could be regarded as having a larger amount of pathogens and more infectious. Therefore, the stained part should still have reference value.

In our study, the proportion of men was higher (62.22%), and the subjects enrolled in this study were diagnosed as gingivitis and having at least 20 teeth in the mouth. The spattering distance observed when the procedure was performed by the interns was significantly higher than that of the residents. As a result, doctors with less clinical experience were observed to spend more time performing complete scaling, and the spattering distances were also further away. Therefore, for doctors and assistants with less clinical experience, the protective equipment should be effectively implemented to prevent the spread of pathogens. In addition, the splash distance between the different grades was between 54.9 and 64.5 cm, all of which were in the range of vulnerability to infection. Therefore, the infectious area including the dental chairs and diagnostic instruments should be thoroughly disinfected at the end of the procedure to prevent cross-infection to the next patient. In addition, our findings could act as a future reference for the evaluation of the coverage area of the hole towel.

A study by Veena et al., 2015 found that the most contaminated area during ultrasonic scaling was the right arm of the doctor and the left arm of the assistant.9 In addition, aerosols could remain in the air for up to 30 min after scaling. In addition to the importance of protective equipment, experts suggested that letting patients gargle and using a strong suction device can effectively reduce the possibility of cross-infection before performing any treatment.7,20 Therefore, in addition to the protective equipment of dentists and assistants, regular disinfection and monitoring of the ventilation equipment, strong suction devices, and dental treatment chairs can also reduce aerosols or sputter, thus reducing the potential harm to dental practitioners and patients themselves. Otherwise, strengthening the proficiency of doctors will also help in reducing the splash of droplets.

In conclusion, it is recommended to wear a general medical surgical mask and hair cap, a full mask (recommended coverage should include the doctor’s neck), and waterproof isolation clothing (recommended coverage should exceed the knee). Otherwise, the length and width of the hole towel should be centered at the tip of the patient’s nose, and the radius should measure at least more than 54.9 ~ 64.5 cm. Finally, the proficiency of doctors will indeed cause differences in the tooth cleaning time, and further affect the distance of droplets. In another words, it is recommended that the protective equipment for interns should be improvised accordingly.

### Table 2 Time of scaling in interns, residents and attending physicians, the number of grids splashed during teeth washing and the spatter distance.

| Number of patients | Time of scaling (mean ± Standard deviation) second | Numbers of grids (mean ± Standard deviation) | Spatter distance (mean ± Standard deviation) cm |
|--------------------|-----------------------------------------------------|---------------------------------------------|---------------------------------------------|
| Intern             | 332.8 ± 81.6 *#                                    | 912.8 ± 243.9                               | 64.5 ± 13.8 #                               |
| Resident           | 191.4 ± 44.9                                       | 814.4 ± 309.2                               | 54.9 ± 16.9                                 |
| Attending physician | 208.9 ± 47.8                                       | 800.2 ± 290.8                               | 60.6 ± 13.7                                 |

*Represents significant difference between interns and attending physicians groups.
# Represents significant difference between interns and residents groups.
Declaration of competing interest

The authors have no conflicts of interest relevant to this article.

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