Mekanika: Majalah Ilmiah Mekanika

Design Evaluations of Aerosol Suction Machine for Dental Treatment Practices In the COVID-19 Era

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Abstract
This paper aims to demonstrate the evaluation process to select the Aerosol Suction Machine (ASM) design to be implemented in a dental treatment practice to prevent the spread of Coronavirus Disease (COVID-19). There are two designs evaluated, the movable ASM and the fixed mounting ASM. The evaluation process involved four criteria: flexibility, safety level, manufacturability, andmaintenance. The evaluation is conducted based on a specific requirement of a small dental clinic located in Surakarta, Indonesia. The evaluation results show that the fixed mounting is more suitable for implementation in a small dental clinic with many natural ventilation openings.

1 Introduction

The first COVID-19 was reported in Indonesia on March 2, 2020 [1], and in less than four months, the reported cases have been increased to more than 50 thousand, with more than 2,000 deaths [2]. The mortality rate for COVID-19 in Indonesia is also the highest in Southeast Asia [1]. According to the Guidelines for Prevention and Control of Coronavirus Disease (COVID-19) published in March 2020 [3], the characteristics of a person infected with the Severe Acute Respiratory Syndrome (SARS)-CoV-2 virus can be divided into three groups, namelyPeople Without Symptoms (*Orang Tanpa Gejala*-OTG), marked if a person has a history of close contact with someone who hasconfirmed COVID-19, has no symptoms but has a risk of contracting and transmitting. People Under Monitoring (*Orang Dalam Pengawasan*-ODP) who experience symptoms of respiratory system disorders such as runny nose/sore throat/cough AND in the last 14 days before the onset of symptoms have a history of contact with confirmed cases of COVID-19. Lastly, Patients Under Monitoring (*Pasien Dalam Pengawasan*-PDP) with fever (>38 ℃) or a history of fever or Acute Respiratory Infection and in the last 14 days before the onset of symptoms had a history of contact with a confirmed case of COVID-19.

Based on the results of the study reported in China, the highest prevalence was in the OTG group, which was 86%, followed by ODP (11.4%), PDP (1.93%), and critical care (0.36%), and death (0.3%). 32%) [4]. In Indonesia, based on data as of June 28, 2020, the highest prevalence was in the ODP group (46.8%), followed by OTG (35.9%), PDP (14.7%), and death (2.7%) [5]. However, out of a total of 273,517,000 Indonesians [6], not all Indonesians have tested for COVID-19. Therefore, the potential for spreading the virus in the family and work environments needs to be mitigated.

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Most of the treatments and procedures in dentistry are in the close distance category. In addition to the relatively close distance between the dentist and the patient, dental procedures can also produce aerosol formation in massive quantities. Thus, dentistry is one of the high-risk professions for transmitting and spreading the SARS-CoV-2 virus [7]. Most of the risk of transmission occurs when splashes (splatters, droplets, and aerosols) spray onto the body or face of dentists, assistants, and patients [8]. Transmission is through non-surgical procedures that produce aerosol particles, including ultrasonic/sonic scalers, handpieces, or three-way syringes [9]. In addition, Asadi et al. reported that even speaking activity in the consultation process can emit 1-50 aerosol particles/second [10].

Therefore, additional protection is vital as a new standard for preventing COVID-19 transmission during dental practice management in the new average era. An Aerosol Suction Machine (ASM) can be one of the protection devices as it provides intense vacuum pressure to evacuate potentially infectious aerosol from spreading into the room. However, among several ASM designs available in the market, studies need to be carried out to evaluate the compliance of the design to the guidelines of COVID-19 prevention in dental practice. This paper executes the design consideration studies to assess the compliance of various designs to the guidelines and discuss the key factors that need to be addressed when designing the ASM for a dental practice in the COVID-19 era.

Dentistry belongs to the category of the profession who are at high risk for transmission of the SARS-CoV-2 virus. Risk level assessment in dentistry management is based on the potential for exposure from known or suspected COVID-19 patients. The dentistry treatments naturally can generate aerosols, such as high-speed handpieces, ultrasonic scalers, three-way syringes, and polishing tools. The Occupational Safety and Health Administration (OSHA) then stipulates risk levels, as shown in Figure 1 [7,11-17].

Low Risk No contact with patients, assistants, or actions involving aerosols **Actions:** 1. Preventive: Verbal consultations in dental and mouth care and style of diet. 2. Diagnostic: Observations through radiography results	**Moderate Risk** Short-period and close-contact, with no aerosol-generating actions. **Actions:** 1. Preventive: Fluoride applications. 2. Diagnostic: Clinical check, Intra-oral radiography 3. Curative: Abcess drainage, Atraumatic restorative technique, Simple tooth extraction, Post-surgery check, Orthodontic check, Dental mold making
High Risk Involving controlled aerosol-generating actions. **Actions:** 1. Preventive: Manual scalings, controlled polishings with minimum paste, sealings involving rubber dams. 2. Curative: Insertions of endodontic implants, Tooth restoration with rubber dam assistance, Manual scalings and root plannings, Gingival curettage, extra-oral handpiece grinding actions.	**Very High Risk** We involve uncontrolled aerosol-generating actions. **Actions:** 1. Preventive: Scalings using sonic/ultrasonic technique. 2. Curative: Contact point restorations, Occlusal adjustments, Use of high/low-speed handpiece, Preparations of tooth restorations, Three-way syringe. Note: Without any rubber dam assistance

Figure 1. The risk categories of COVID-19 in dentistry

Given the risk, the division of space zoning in dentistry's healthcare facilities is also indispensable in the new average era. Apart from zoning, it is necessary to pay attention to the direction of the flow of patient movement. The movement of medical personnel must be identified and arranged with unique signs that can be understood well. The flow of patients entering the health care facility must be regulated to maintain a safe distance and control the population density. The flow of medical personnel, dentists, and assistants' activities in the practice room must be prominent. There is a path to the room dressing or decontamination made not to meet the staff or waiting room the patient directly. The dentist's practice roomarrangement also needs to pay attention to airflow in the room.

The World Health Organization (WHO) recommendations relating to ventilation requirements are as follows:

1) The strong recommendation of adequate ventilation in all areas of health care facilities to help prevent airborne infections is using clean airflow materials to enter the room, following the circulation model set to release air circulation using a vacuum has exhauster.

2) The use of natural ventilation obtains conditional recommendations from WHO, with a minimum hourlyaverage ventilation flow as follows:

a) 160 L/sec/patient (average ventilation rate per hour) for room precautions by air (note that this only applies to new health care facilities and those that perform major renovation);

b) 80 L/sec/patient for non-aerosol outpatient rooms; and

c) 2.5 L/sec/m^3 for the corridor and temporary waiting room with a small number of patients; However, when patient care is carried out in corridors during emergencies or other situations, level requirementsof the same ventilation for air prevention rooms or general wards will apply.

Note: Design must take into account ventilation rate fluctuations (= turnover airflow), and when natural ventilation alone cannot meet the recommended ventilation requirements, alternative ventilation systems, such as ventilation systems natural hybrid (mixed mode), should be considered, and then ifthat is not sufficient, mechanical ventilation should be used.

3) When designing health care facilities using the natural ventilation system, the overall airflow must bring air from the sources from clean areas where the volume of clean airflow will be mixed quite well with the air in the room.

4) For procedure rooms where the transmission pathogens generate aerosols, the natural ventilation requirements should follow the recommendations for airflow at point 1. If it is airborne, then the recommendation of points 1, 2, and 3 must be followed.

2 Experimental Methods

2.1 Design Criteria

Dental Exhaust Aerosol Suction Machine is aerosol disposal equipment that functions as an air circulator in a dental practice. This tool sucks air from around the patient's mouth, then circulates it to finally be disposed of in an environment far from touchable from objects susceptible to Covid-19 transmission. This tool helps minimize the spread of droplets that come out of the patient's mouth because all aerosols that come out of the patient's mouth, along with aerosols around the patient's mouth, will be directly sucked up through this tool. The risk of droplets coming out of the patient's mouth will be spread into the surrounding air, or the dentist's equipment can be minimized. Several requirements or standards need to be followed to ensure that the device can effectively mitigate the risk of COVID-19 infections.

1. The laminar flow air velocity is 0.43 m/s.
2. The direction of the flow of clean air from behind the officer to the patient
3. Use of Hepa Filter 99.97%
4. The room has a negative pressure between 2.5-15 Pa.
5. Leakage tolerance Room 0.046 m^2
6. Have at least 12 Air Changes/Hour (ACH) in the room
7. Exhaust air must be at least 3 m higher than the clinic building
8. Exhaust air must be far from the intake air radius of 10 m
9. Ultraviolet (UV) lamps must use type C with a minimum wavelength of 254 nm

2.2 Design Options

Two design options will be evaluated in this study. The first design is the movable ASM with pivot wheels, an embedded filtration system, and a UV system. In contrast, the second design option is the ASM with fixed mounting with a dedicated exhaust conduit and embedded filtration system, and UV system. The evaluation will be scored based on flexibility, safety level, manufacturability, and maintenance.

2.2.1 Movable ASM design

The illustration of the portable ASM design is shown in Figure 2. The main feature of a portable ASM design is its pivot wheels which allow it to be freely moved around. The only limitation in the movement is the length of the power cord which can also be improved if the ASM is equipped with internal batteries. The movability provides it with the flexibility to move according to the dentist's needs. However, the movability also has drawbacks in integrating the air filters and UV light in its carriage. The nature of this flexibility makes the design and maintenance complex. The movable feature also means that the exhaust air will need to be recirculated in the room after being filtered. Such arrangement will require strict maintenance in the filtering system as the risk of contamination is high.

Figure 2. Movable ASM design

2.2.2 Fixed mounting ASM

The fixed mounting ASM design shown in Figure 3 has almost everything contrary to the portable ASM design. The apparent difference is that the fixed mounting ASM installation is fixed so that it cannot be moved flexibly using wheels like the first variation. Therefore, the user needs to make sure that their dental hair is installed close to a wall or a rigid structure that can be mounted with the ASM. The installation plan also needs to be carefully prepared initially, as moving the ASM will require some labor. However,the design is more straightforward, and the risk of contamination is lower as the fixed mounting allows the exhaust conduit to be directed outside the room.

Figure 3. Fixed mounting ASM design

2.3 Evaluation criteria

Due to the existence of two designs with their respective properties and advantages, it is necessary to determine the criteria of evaluation that can be used to compare which variation is more suitable for dental practice application in a specific location. The simple evaluation assessment (Table 1) proposed in this paper is as follows:

Table 1. Evaluation criteria

No	Criteria	Remarks	Weight
1	Flexibility	Measures the ease of moving the devicefrom one place to another	*W1*
2	Safety Level	Measures the risk level of the virus spreading in the room	*W2*
3	Manufacturability	Measures the complexity of the deviceto be manufactured	*W3*
4	Maintenance	Measures the ease of maintaining the the device, including filter replacement and cleaning.	*W4*
		TOTAL (*W1+W2+W3+W4*)	**10**

The evaluation criteria shown in Table 1 divide the scoring into four categories, flexibility, safety level, manufacturability, and maintenance. Each criterion addresses specific design characteristics and can be assigned a specific weight depending on the dental practice location and the users' preference. For example, in this paper, the evaluation is made for ASM application in a dental clinic located in Surakarta, Indonesia. The clinic only consists of one treatment room with no separation between the consultationand treatment rooms. The clinic also has few immediate openings to the outdoor environment, and the dental chair is also located very close to one of the openings. Therefore, the weight for *W1*, *W2*, *W3*, and *W2* are assigned as 2, 4, 2, and 2, respectively, where the safety is put as the highest importance considering the size of the clinic is small, and no separation between the consultation room and the treatment room has madethe contamination risk higher.

3 Results and Discussion

With the evaluation criteria explained in Section 3 and the weight assigned based on the case study in one of the dental clinics in Surakarta, the scoring of each criterion can be explained as follows:

3.1 Flexibility

In terms of flexibility, it is clear that the movable ASM is more capable than the Fixed Mounting ASM. As explained earlier, the movable ASM benefits from the attached pivot wheels, which allow it to be moved freely and positioned in the room. This feature will benefit large or emergency clinics where the equipment setup might require dynamic equipment arrangement. However, for the case study taken in this paper, flexibility might not add many advantages as the clinic's size is relatively small and has many openings.

3.2 Safety level

Both movable ASM and fixed mounting ASM could offer considerable safety as long as the device is used with proper care and maintenance. However, to some extent, the tolerance level of the fixed mounting ASM to poor maintenance and cleaning is higher than the movable ASM. The main reason is the dedicated exhaust conduit that can be prepared in the fixed mounting ASM. Due to the flexibility required in the movable ASM, the dedicated exhaust conduit is not applicable.

3.3 Manufacturability

The manufacturability of both designs is highly dependent on the designers and the additional features added to the ASM. Such additional features can be the adjustability of the suction power, the thermal safety switch, the maintenance and cleaning reminder, the internal battery as backup power, etc. The more additional features provided, the device's complexity will also be increased. However, in the same features, the movable ASM's manufacturability will generally require more process than the fixed mounting ASM as the flexibility demands carriages and consideration of weight distribution. Fixed mounting ASM, on the other hand, is more straightforward as there are no requirements to move the device, and therefore the design consideration is more relaxed, and fewer components are involved.

3.4 Maintenance

As a consequence of the safety level, the maintenance is less stringent in the Fixed Mounting ASM than in the movable ASM. The routine maintenance required is generally related to the filter cleaning and visual inspections, which are more or less similar between the movable ASM and the fixed mounting ASM. However, the tolerance of the fixed mounting ASM to poor maintenance is higher than the movable ASM as the risk of contamination due to filter clogging or rupture is minor in the fixed mounting ASM since the exhaust is released in the open air outside the room.

Table 2. Evaluation Results for Small Clinic ASM Design

Criteria	Flexibility	Safety Level	Manufacturability	Maintenance	Overall Score
Weight	2	4	2	*2*	10
Movable ASM	1	0	0	0	2
Fixed Mounting ASM	0	1	1	1	8

According to the evaluation results shown in Table 2, it is clear that the fixed mounting ASM is more suitable to be implemented in a small dental clinic application. The advantages of safety level, manufacturability, and maintenance in small dental clinic applications have made the fixed mounting ASM preferable. These results, however, do not imply that the movable ASM is a less superior design to the fixed mounting ASM. In the specific applications that require more flexibility and are capable of strict maintenance, the weight distribution might be shifted to prioritize the flexibility criterion more than others. In this case, the movable ASM might have a higher score than the fixed mounting ASM.

To some extent, combining the benefit of each design is possible, which makes a hybrid design for example, a movable ASM with the capability to extend the exhaust conduit into an outdoor environment. However, in this case, the flexibility feature will be deemed inactive. Alternatively, fixed mounting ASM with unique accessories allows it to be detached easily from the walls. Nevertheless, the mounting accessories need to be specially added and installed in a few mounting points inside the clinic. Overall, as a general rule, no design will be superior in any situation. Therefore, the specific requirements and preferences need to be defined before deciding which design to implement or make in the first place. A good understanding of a particular user requirement is the key to successful design implementations.

4 Conclusions

The Covid-19 pandemic has changed the implementation of health protocols in everyday life, one of which is dentists' practice. One of the protocols required is the existence of an Aerosol Suction Machine (ASM) that can evacuate and filter aerosols around the patient's mouth to prevent the spread of Covid-19 contaminations around the dental treatment room and dental clinics. There are two main designs available, the portable ASM design and the fixed mounting ASM design. For the case of a small dental clinic that requires no frequent change of equipment arrangement and has many openings, the fixed mounting ASM design is shown to score higher in the design evaluation results. The movable ASM could be superior for different applications, such as the application requiring frequent ASM movement. The proper selection of the ASM for particular clinic characteristics, user requirements, and preference is significant to ensure the device's effectiveness in preventing the spread of COVID-19 and shortening the pandemic.

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