ORIGINAL ARTICLE

The effectiveness of using local exhaust ventilation, HEPA filter, and dental aerosol suction on indoor air quality

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ABSTRACT

Introduction: The emergence of COVID-19 pandemic that occurred at the end of December 2019 in Wuhan, China, was a health crisis that greatly affected the world. Therefore, dentists and dental nurses are professionals who have a very high risk of being exposed to the droplets and aerosol particles generated during dental procedures. Furthermore, they also have a high risk of cross-infection from exposure to microorganisms in blood, saliva, droplets, and instruments contaminated with blood, saliva, and tissue debris. This study aims to analyze the effectiveness of using exhaust fan wall/Local Exhaust Ventilation (LEV), HEPA filter, and dental aerosol suction in the dental clinic of Academic Hospital Gadjah Mada University. **Methods:** The type of the research is analytical observational study. This study measured temperature, humidity, ACH and the microbial load in the 3 dental clinic rooms of Sadewa 1 RSA UGM in September 2020, using an analytical observational method with ANOVA to determine the effect of using a LEV, HEPA filter and dental aerosol suction in the dental clinic. **Results:** Dental clinic equipped with a LEV, HEPA filter, and dental aerosol suction, was negatively associated with room humidity levels, with a Pearson correlation of (p value -0.777), air humidity correlated with microbial load ((p value 0.242), but the correlation was not large.The ANOVA results, the use of LEV, HEPA filter and dental aerosol suction against humidity has a significant effect on reducing the humidity in the dental clinic with p value 0.05. **Conclusion:** The use of an oral LEV, HEPA filter, and dental aerosol suction has an effect on reducing air humidity and decreasing the microbial load, affects the number of particles or droplets in dental clinics, and affects ACH.

KEYWORDS
local exhaust ventilation, HEPA filter and dental aerosol suction, microbial load, humidity

INTRODUCTION

The extraordinary occurrence of the COVID-19 pandemic that happened at the end of December 2019 in Wuhan, China, led to a world crisis, especially the health crisis. There were 12 million positive confirmed cases, and around 570 thousand cases died (4.4% of the death rate) with 215 countries affected and 163 local transmission countries.[1]

Dentistry is considered a high-risk profession during a transmissible period of pandemic due to the close proximity of dental care providers (DCPs) to the patient's respiratory tract openings during dental examinations and treatments.[2] Therefore, dentists and dental nurses are professions that have a very high risk of being exposed to droplets and aerosol particles that are generated during patient treatment. Furthermore, they also have a high risk of cross-infection from exposure to microorganisms in blood, saliva, droplets and instruments contaminated with blood, saliva, and tissue debris.[4]

Those microorganisms consist of pathogenic bacteria, viruses, and fungi.[3] The transmission of infection in dental or surgical procedures can occur in several routes as follows: direct contact with blood, saliva, or tissue debris; Indirect contact with instruments or surfaces that are contaminated and haven't been sterilized properly; Contact with an infective agent in droplets or aerosol particles from saliva and other respiratory fluids; During the dental procedure, saliva becomes aerosol and microorganisms from the oral cavity greatly contribute to the spread of infection[3]; Dental drill and ultrasonic scaler, combined with air spray, produces droplets/aerosol particles containing body fluids (saliva, blood, dental plaque) and microbes; Aerosol/droplet particles can move from the patient's mouth to the body surface or the respiratory area of the dentist. Therefore, it is important to reduce the risks of COVID-19 spread in dental clinics.[4]

Although the policy regarding restrictions on dental practice services during the COVID-9 Pandemic has been issued by the Indonesian Dental Association (PDGI) in the form of Circular Number: 2776/PB PDGI/III-3/2020 regarding guidelines for dental services, emergency services are not avoided. Based on the PDGI's data, as of the end of April 2020, there were six dentists in Indonesia who died from infection with SARS-CoV-2 and as of March 2021, there were 396 dentists who were exposed to COVID-19 in 199 health centers. Efforts are needed to reduce the risk of transmitting COVID-19 to the dentist and dental hygienist. Engineering controls, such as mechanical ventilation and air filtration, are important tools for reducing the risks of the transmission of airborne diseases in enclosed spaces like dental treatment rooms. These controls are regarded as a higher level of a precaution than personal protective equipment (PPE).[2]

Ventilation is crucial to minimize exposure in cases when possibly contaminated aerosols do escape.[5] Ventilation is the process of changing or replacing air from any space by mechanical or natural means. The key elements defining ventilation of any building include the rate of ventilation, the direction of airflow, and the pattern of airflow. However, this is frequently determined by building configuration, and changing it could be expensive or complex.[6] Filtration is a different strategy that can be used to boost the effectiveness of air-exchange rate. Increased ventilation by mobile high-efficiency particulate air (HEPA-filtration) units or similar methods, seems to be an effective way to reduce SARS-CoV-2 in the surrounding air.[7] This can be done by employing freestanding HEPA filtration systems, although the impact of these will probably depend on how far the source is from the room and how much airflow is present there.[2]

Although naturally influenced by elements present both indoors and outdoors, indoor air contributes more to population exposures than outdoor air does. The likelihood of COVID-19 airborne transmission is higher in dry indoor environments, or locations with reduced humidity (40%). According to an indoor experiment conducted in cities in China from January to March 2020, boosting RH (relative humidity) from 23.33% to 82.67% was effective in reducing the airborne spread of SARS-CoV-2.[8]

Other research shows both the kinematics of evaporation and particle development are impacted by humidity. The likelihood of airborne SARS-CoV-2 transmission is higher in dry indoor environments (i.e., lower humidity, 40% RH) than in humid environments (i.e., greater than 90% RH). According to past research, interior environments should have a relative humidity of between 40 and 60 percent to be healthy for people. In order to limit the spread of SARS-CoV-2 through the air, it is crucial to establish a minimum relative humidity norm for interior locations like hospitals and public transportation.[9]

Friendly and Caring Hospital (RSA UGM) as a health service provider and a referral hospital for COVID-19 patients, since May 2020 has separated the covid and non-covid inpatient rooms to eliminate the spread of the COVID-19 infection. RSA UGM is also using local exhaust ventilation, HEPA filters and dental aerosol suction in their dental clinic. To determine the effectiveness of these three tools, microbiological parameters are used, namely the number of airborne germs and physical parameters, namely temperature, humidity and ventilation rate as stipulated in the Regulation of the Minister of Health of the Republic of Indonesia Number 7 of 2019 concerning Hospital Environmental Health [10].

Personal Protective Equipment (PPE) such as using N95 masks, protective goggles with shields and full-length face shields is recommended for the protection and reducing the airborne disease transmission. The other mechanism to reduce the risk of airborne disease transmission is engineering control. The risk of air borne disease transmission reduction can be achieved by utilizing engineering control.[2] An adequate ventilation is necessary to reduce the infection risk in confined spaces such as offices, residential areas, public buildings like malls, restaurant, museum and public vehicles.[11]

Devices can be used for improving ventilation system are: Local Exhaust Ventilation (LEV) is an extract ventilation system that takes air borne contaminant such as dusts, mists, gasses, vapor or fumes out the workplace air, so that they can't be breathed in. Properly designed LEV will collect the air contains the contaminants, make sure they are contained and taken away from people, clean the air (if necessary) and get rid of the contaminants safety EPA (High Efficiency Particulate Air) filter is a device for filtering dirty air that enters and releases clean air and is specially designed to capture pollutants and particles which are very fine and much smaller. Therefore, by using HEPA filters, we can get clean air with low pollutant content. The evaluation of air purifiers effectiveness to reduce droplet and aerosol contamination by positioning the device in 4 different locations has been conducted.[12]

Research on the effectiveness of using exhaust fan wall, HEPA filter and dental aerosol suction to air quality in dental clinics during the COVID-19 pandemic has never been done before. This research is expected to provide benefits to Dentist/ related health personnel; Provides information on the effectiveness of using exhaust fan wall, HEPA filter and dental aerosol suction in the dental clinics; Education; as a comparison that can be used for further research; For Hospital: evaluating the effectiveness of using these 3 equipment in the dental clinic. The purpose of this study was to analyze the effectiveness of using exhaust fan wall/LEV, HEPA filter and dental aerosol suction on air quality in the dental clinic academic hospital UGM.

METHODS

The type of the research is analytical observational study. Study setting, the study was conducted in the dental clinic Academic Hospital UGM at September 2020, where the study located on first floor (Sadewa room) with characteristic the space: First dental clinic room with an area of 19.1 m2 equipped with local exhaust ventilation, HEPA filter (FASS™ Hazmat 1000), suitable for $64m^2$ and dental aerosol suction (COXO®) as well as direct lighting; second dental clinic room, with an area of 11.29 m^2, equipped with an local exhaust ventilation, dental aerosol suction (COXO®) and direct lighting; Third dental clinic, with an area of 10.93 m2, equipped with an exhaust fan wall/LEV, dental aerosol suction and indirect lighting.

The temperature and humidity measured using a thermo hygrometer which is installed in the dental room when doing dental procedure. Recording of temperature and humidity is carried out twice a day, namely at 08.00 am before dental procedure and at 14.00 pm after dental procedure and service hours are completed. Air change per Hour (ACH) measured using a vane anemometer. Step 1 determines the surface area of the ventilation plane, step 2 determines the approximate air velocity through the ventilation, step 3 determines the room volume capacity (VR) and then calculates the rate of air exchange per hour.

Microbial load is the number of microbial in the air from a certain place being examined, and the number of bacteria in the sample was to be determined. Principle of this examination counts the number of colonies that grow on Plate Count Agar. This research is an analytic observational research type by measuring temperature, humidity, ACH, and microbial load in 3 rooms of Sadewa 1 dental clinic at RSA UGM. The data were analyzed using an ANOVA test to determine the effectiveness of using exhaust fan wall/LEV, HEPA filter and dental aerosol suction in 3 dental clinics, and Pearson correlation to determine the correlation between all of the variables.

RESULTS

The temperature, humidity and the microbial load were measured twice at 08.00 am and 14.00 pm. Based on the measurement of the temperature and humidity in all of the dental clinics room, the result shows there was a decrease in temperature after dental procedure.

In the first dental clinic room, there was a decrease in humidity with the average humidity before dental procedure, from 76% to 64%, the temperature increasing from 23.40^0 C to 25^{0}C, with a total number of 72 patients. In the second dental clinic room, there was a decrease in air humidity with an average humidity before dental procedure from 75 to 71%, the temperature's room increasing from 24.70^{0}C to 25.10^{0}C with 44 patients. In the third dental clinic, there was a decrease in air humidity with an average humidity before the dental procedure from 71 to 69%, and the temperature's room decreasing from 24.30^{0}C to 23.80 ^{0}C with 2 patients. From the measurement results all of the 3 dental clinics room, first dental clinic tend to decrease humidity and temperature as increasing the number of patients

Table 1. Correlations between variables

		Exhaust	Temperature	Microbial load	Humidity
Exhaust	Pearson Correlation	1	0.396	0.147	-0.777
	Sig. (2-tailed)		0.437	0.782	0.069
	Sum of Squares and Cross-products	1.500	0.745	28.750	-0.093
	Covariance	0.300	0.149	5.750	-0.019
	N	6	6	6	6
Temp	Pearson Correlation	0.396	1	0.456	-0.510
	Sig. (2-tailed)	0.437		0.363	0.301
	Sum of Squares and Cross-products	0.745	2.363	112.354	-0.076
	Covariance	0.149	0.473	22.471	-0.015
	N	6	6	6	6
Mic.load	Pearson Correlation	0.147	0.456	1	0.242
	Sig. (2-tailed)	0.782	0.363		0.644

Table 1 shows that the dental clinic equipped an exhaust fan wall, a HEPA filter and dental aerosol suction, which is significantly related to the humidity level in the dental clinic room, analyzed with the Pearson correlation at (-0.777). Furthermore, the negative correlation between the installation of the tools and humidity implies that the presence of this equipment can reduce the humidity level in the dental clinic room. Based on table 1, the result indicates that air humidity is correlated with the microbial load (0.242). However, the correlation is not strong, because there are several variables that haven't been measured, including the number of patients, the area of the room, and the room's lighting. The effect of using LEV, HEPA filter and dental aerosol suction on the humidity is described in Table 2, while the use of a HEPA filter in particular and its effect on humidity, temperature and microbial load are shown in Table 3.

Tabel 2. ANOVA the use of LEV, HEPA filter and dental aerosol suction on humidity

	Humidity				
	Sum of squares	df	Mean square	F	P value
Between groups	0.006	1	0.006	7.663	0.050
Within goups	0.003	4	0.001		
Total	**0.010**	**5**			

By utilizing the ANOVA analysis in Table 2, the result shows that the use of the equipment has a significant impact on reducing the humidity in the dental clinic room.

Tabel 3. The influence of The use of HEPA filter

	Humidity (%)			Temperature (^{0}C)			Microbial load (CFU/m^3)		
	Before	After	Margin	Before	after	Margin	Before	After	margin
Poli 1	76.62%	64.67%	11.95%	23.44	25.14	1.70	450	425	-25
Poli 2	75.89%	71.15%	4.74%	24.79	25.09	0.30	475	555	80
Poli 3	71.56%	69.81%	1.74%	24.38	23.87	-0.52	365	367.5	2.5

Table 3 presents dental clinic I, and shows that the use of a HEPA filter has the highest reduction in humidity and microbial load. This is in line with the results of Table 1 regarding the correlation between variables, where the microbial load is positively correlated with humidity. The correlation also explains that the more effective the reduction in humidity, the more likely it is to reduce the microbial load. Moreover, the results of table 3 also indicate that the installation of a HEPA filter is recommended to reduce humidity and reduce the number of microbial loads.

In determining the effect of utilizing a HEPA filter on humidity, and the microbial load, we conduct the ANOVA analysis, and the results are shown in table 4.

Table 4. ANOVA the use of HEPA filter on the humidity and the microbial load

		Sum of squares	df	Mean square	F	P value
Humidity	**Between groups**	0.005	1	0.005	11.213	0.185
	Within groups	0.000	1	0.000		
	Total	0.005	2			
Micro.load	**Between groups**	2926.042	1	2926.042	0.974	0.504
	Within groups	3003.125	1	3003.125		
	Total	5929.167	2			

In table 4, the result shows that the influence of the factor variables on the dependent variable is not significant with a significance of 0.185 (humidity) and 0.504 (microbial load) which is higher than 0.05. This is more due to the lack of data, namely only 1 data for the HEPA filter group, and 2 data for the without HEPA filter group. Therefore, this research will be continued by adding data and designing a good Design of Experiment (DOE). Based on the data in table 8, with the addition of data, it is possible that the results of the analysis will show that the addition of a HEPA filter will significantly affect humidity and decrease the microbial load.

DISCUSSION

In this study, we measure temperature, humidity, ACH, and the microbial load in three dental clinic rooms. The microbial load and the three factors of the physical environment are part of the Hospital Environmental Health requirements regulated by the Minister of Health No.7 of 2019.[13] Based on the measurement of the ACH value in each dental clinic I, II, III with a number of 24.79; 43.24; 15.20 has met the recommended airflow standards for infectious red zones, which larger than 12 for the prevention of infection in the action room that generates aerosols which is equivalent to 160 L/s/ patient in a 4x2x3 m3 room.[14]

According to WHO standard, several procedures that produce aerosols are associated with an increased risk of infection transmission, therefore the number of air ventilation plays a very important role in preventing infection transmission. Rooms with high mechanical ventilation would have less accumulation of aerosol particles than rooms with poor mechanical ventilation.[2]

From the measurement of the microbial load, the result shows that the microbial load did not meet the standards, especially for the number of airborne germs. On the other hand, the result also shows that the number of floor swabs and wall swabs had met the standards.

The standard microbial load (in the air) based on health ministry regulation was 200-500 CFU/m^3.[10] Furthermore, the paper indicates that the number of airborne germs that did not meet the standards may be influenced by the number of patients, the occupants in the room who have an on room temperature and the spread of bacteria in the room. In that case, the bacteria will spread to the air around the room and contaminate air quality. The use of Portable Air Cleaner (PAC) with HEPA filter can reduce aerosol accumulation and accelerate aerosol removal in rooms with low ventilation.[2]

The effect of using local exhaust ventilation, HEPA filters and dental aerosol suction can be seen in the table 2, which indicates the use of these equipment has a significant effect on reducing room humidity. Previous research shows that the use of mechanical ventilation during all working shifts played in an Academic Dentistry Clinic in Greece, retaining good indoor air quality levels. In this research, researchers using HEPA units and four portable Tongdy TSP-18 & the mechanical ventilation system without vacuum extraoral suction such as in our study.

Parameters in this study were relative humidity, temperature, TVOC (total volatile organic compound), CO_2 (carbon dioxide), PM 10 (Particulate matter <10 micrometers), Pm2 (Particulate matter <2,5 micrometers). But in our study, besides using HEPA and mechanical ventilation, we use dental aerosol suction, and parameters of our research were relative humidity, temperature and microbial load.[15] The use of powerful dental aerosol suction has proved effective in preventing pollution caused by dispersed contaminant.[16]

The dental aerosol suction and air purification system could provide highest possible air quality control and mitigation of disease transmission.[17] Pathway controls are, in general, more difficult to design and implement correctly. For example, increasing the number of air changes per hour (dilution ventilation) can lower the overall concentration of particles in a space, but may not be effective at lowering particle concentrations near the source.[18] HEPA filters, ionizers and UVGI filters are the filters suggested for removing contaminants from the surrounding. [19]

While the use of a HEPA filter in particular and its effect on humidity, temperature and microbial load is shown in table 3, the first dental clinic, as the only dental clinic room that uses a HEPA filter, has the highest reduction in humidity and a decrease in the microbial load. This is in accordance with the results in table 1 regarding the correlation between variables, where the number of germs is positively correlated with humidity. Microbial growth may depend on many parameters such as temperature and relative humidity. The evaporation creates hydric stress (loss of water) within the microorganism which can lead to cell lethality. One of the studies showed that the virus survived well at an RH lower than 33 and at 100%, while the viability is reduced at medium RH (relative humidity).[20] This correlation also explains that the more effective the reduction in humidity, the more likely it is to reduce the microbial load. The results of table 8 also indicate that the installation of a HEPA filter is recommended to reduce humidity and reduce the microbial load and use of an air cleaner may be effective to reduce aerosol particles.[12]

Table 4 shows that the influence of the factor variables on the dependent variable is not significant with a significance of 0.185 (humidity) and 0.504 (microbial load) which is >0.05. Previous research emphasized that indoor humidity is a thermal parameter as important as room temperature and ventilation in controlling the indoor air quality, health, comfort and working performance.[21] With the same spirit with previous research [], this research using LEV, HEPA filter and dental aerosol suction for reducing microbial contaminants. This is more due to the lack of data, namely only 1 data for the HEPA filter group, and 2 data for the without HEPA filter group. Therefore, this research will be continued by adding data and designing a good Design of Experiment (DOE). Based on the data in table 3, with the addition of data, it is possible that the results of the analysis will show that the addition of a HEPA filter will significantly affect humidity and decrease the number of germs.

In this study, researchers have not taken into account the area of space between different dental clinics, different lighting and the number and types of dental procedure in the dental clinic. In this study also, researchers have not compared the use of each tool with the number and type of dental procedure in the same dental clinic.

CONCLUSION

The use of an exhaust fan wall, HEPA filter and dental aerosol suction has an effect on decreasing air humidity and decreasing the number of germs (microbial load), and affects the number of particles or droplets in the dental clinic room and affects ACH.

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