Original Article

The Efficiency in Reducing the Dispersion Aerosols by Using Various Types of Intraoral and Extraoral Suctions

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Abstract

Coronavirus disease 2019 (COVID-19) is an emerging disease that puts aerosolized dental treatments at a high risk of transmission; therefore, up-to-date knowledge of aerosol control plays an essential role in determining standard regulation in dental practice. The objective of this study was to compare the efficiency in reducing the dispersion of aerosols by using various types of intraoral and extraoral suctions. The study was conducted in a closed acrylic box. A high-speed handpiece (Airotor) was used to create aerosols. The intraoral and extraoral suctions were divided into six groups (saliva ejector, high-power suction tip, side-wing tip, dome- shaped tip, EasyPrep®, and Extraoral suction). The relative humidity in the box was monitored at 1, 5, and 10 mins with a hygrometer and was repeated three independent times. The videos were also recorded during the experiment. Results showed that the saliva ejector alone had the most aerosol diffusion outside the mouth. The mean of relative humidity was highest and was significantly higher than other groups using a saliva ejector in combination with other suctions. After 1 minute of the procedure, the mean relative humidity in the group using the saliva ejector plus extraoral suction was significantly lower than that of the group using the saliva ejector plus the high-power suction tip at *P*-value = 0.038. When the saliva ejector was used with the extraoral suction, the means relative humidity were not different between groups after 5-10 mins. In conclusion, the present study provided preliminary information for considering instruments as needed and the most effective one in reducing the dispersion of aerosols. The knowledge from this research could be used as a guideline to improve the workflow or regulation in dental practice for safety.

Keywords: Aerosol control, COVID-19, Dental aerosol, Dental aerosol reduction

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Introduction

Dental procedures require various types of dental equipments, whether a high-speed handpiece, ultrasonic scaler, dental polishing tool (air polishers and air abrasion), or other tools that can produce both large droplets and small aerosols which can be smaller than 50 microns.[1] Most dental treatments involve hard tissue and require tools to grind, cut, and drill teeth or bone. A tool is a handheld tool or the tip of a sharp trimming tool connected to the handpiece that rotates at high speed and requires water to reduce the operating temperature and the heat generated. In the operation of these instruments, microscopic droplets of water are contaminated with saliva, blood, or microorganism.[2-4] Small droplets can be dispersed into the air and contaminate the tools, equipment, clothing, and personal protective equipment. In the event of the coronavirus disease 2019 (COVID-19) outbreak, these small droplets can float and stay in the air for a period of time depending on the environment.[5,6]

Aerosols as small as 0.5 to 10 microns can enter the respiratory tract and lungs[7], making them highly susceptible to transmission of infection[1,6,8], especially a risk of infection from patient to dentist and the supporting team.[9] Therefore, it is necessary to have guidelines for dental treatment to control the spread of aerosols and infection effectively and strictly. The dispersion of these aerosols has not yet to be reported how far they can disperse, making disinfection on all surfaces and ventilation systems within the dental clinic imperative. However, the current standard protocol in clinical practice may not be effective enough to prevent the spread of COVID-19, despite tremendous screening efforts to evaluate if the patients are in the latent period without any symptoms or not providing accurate information to screening.

The use of an ultrasonic scaling instrument has been reported to produce aerosol dispersion as far as 18 inches, even with no water and extraoral testing.[8] Using a high-speed handpiece can create a wide diffusion area of aerosols which can deposit around the working area.[10] However, to date, there has been no study comparing the control of aerosol distribution in devices currently used during the COVID-19 outbreak. Based on current knowledge, it is believed that aerosols produced by dental treatments are airborne and may remain for several hours.[7,8] As for the diffusion distance, there has been no definitive research on how far the aerosols spread. During the COVID-19 outbreak, it has been suggested to use aerosol diffusion control equipment plus the tools and equipment regularly used under normal circumstances. A wide variety of additional tools and equipments are available in the market with different features. However, there has been no proper research indicating the comparative efficiency of controlling micro-aerosols' dispersion by these instruments and devices.

Since droplets can remain in the air for up to 30 minutes, there is a high risk of infection if they are contaminated with bacteria or viruses6, especially if the operators immediately remove masks and protective clothing in the working area after performing the treatment. For the control of aerosols in the dental area that aerosols disperse, in some clinics or hospitals, only a saliva ejector or together with a high-power suction attached to the dental chair is used. This can only reduce the dispersion of aerosols to a certain amount. However, if a high-volume evacuator is used with a high-volume evacuator power of 100 cubic feet of air per minute, the aerosols can be reduced by more than 90 percent.[7,9,11] However, high-volume evacuators, both intraoral and extraoral, are not in the standard protocol for dental treatments and are not commonly used in dental clinics or hospitals. Moreover, some types of the high-volume evacuators require additional installation resulting in increased costs. In Thailand, these tools are imported or fabricated for commercial purposes. Nevertheless, it is not widely used because the comparative efficacy has yet to be dicovered. Therefore, in this study, seven different tools available in the market were selected and tested for their effectiveness in reducing aerosol diffusion.

Direct measurement of aerosol concentrations is technically difficult. The aerosol measurement, including Laser scattering technology, has been adopted, with a pump-suction sampling method to real-time detect and calculate the number of suspended particles with different particle sizes in the air. Although the newly developed novel aerosol measurement methods, such as "handheld particle counters", are available in the market, they are expensive.[12] Therefore, the hygrometer was used in this study to measure liquid dental aerosols because of its cost-effectiveness rather than using direct particle aerosol detection.

Materials and Methods

This experiment tested the reduction of dental aerosols by various types of intraoral and extraoral suctions (Free arm forte-S, Tokyo Giken, INC.). A high-speed handpiece (Airotor) (TwinPower Turbine4H® handpieces, J.Morita MFG. CORP.) was used to generate small aerosols by connecting to the water system of the dental treatment unit (Actus 9000, Siamdent). The experiment was conducted in a closed system using a clear acrylic box. The experimental groups were divided into six groups, as shown in Table 1.

Table 1 *Shows the experimental groups on the efficiency in reducing the dispersion of fine aerosols by six different types of intraoral and extraoral devices*

Type of aerosol suction devices	Experimental groups					
	Group 1	Group 2	Group 3	Group 4	Group 5	Group 6
Saliva Ejector	+	+	+	+	+	+
High-power suction + straight tip		+				
High-power suction + side-wing tip			+			
High-power suction + dome- shaped tip				+		
High-power suction + EasyPrep®					+	
Extra oral suction						+

Before testing, the relative humidity in the box was measured. The test was carried out using an aerosol generator in the upper front teeth area. The hygrometer (Humidity Thermometer DT-321S, Eastern energy co.,ltd) and the instruments inside the acrylic were positioned at the same place in all groups. The time required to perform the experiment and collect data was 1, 5, and 10 mins, while the aerosol generator and the tested devices were operated simultaneously. Images and video clips were collected and observed during the experiment (PXW-Z150 4K camcorder, Sony). The relative humidity inside the acrylic box was measured using a hygrometer before every experiment in the acrylic box. The experiments were carried out in triplicate in each group. Statistical analysis was performed using SPSS (IBM SPSS Statistics for Windows, Version 23.0) and statistical significance was set at 0.05. Mean and standard deviation were calculated for the relative humidity. One-way ANOVA and Scheffe's test were used to compare the relative humidity means between the experimental groups.

Results

The results from the simulation using a high-speed handpiece (Airotor) on the upper front teeth adjacent to the lip, where aerosol diffusion occurs most, together with various types of aerosol suction tools. Observation of Images and video clips showed that using a saliva ejector alone in the control group showed a large amount of aerosol diffusion outside the mouth. When using other types of aerosol suction tools with the tip closest to the aerosol source, it was found that high-power suction combined with a straight tip, high-power suction with a side-wing tip, and high-power suction with EasyPrep® were able to reduce the amount of aerosol dispersion significantly. The aerosols were sucked back into the oral cavity when the high-power suction connected with the EasyPrep® inside the oral cavity was used. The use of high-power suction with the dome-shaped tip and the use of extraoral suction, which had the large diameter of the tips, also made it possible to suck the aerosol back into the tools, especially when the tool was placed close to the source of aerosols. However, if the tool's tip was far from the aerosol source, it could not absorb aerosols properly, and aerosols started spreading out of the mouth. Moreover, the large tip size interfered with work and vision more, as shown in Figure 1.

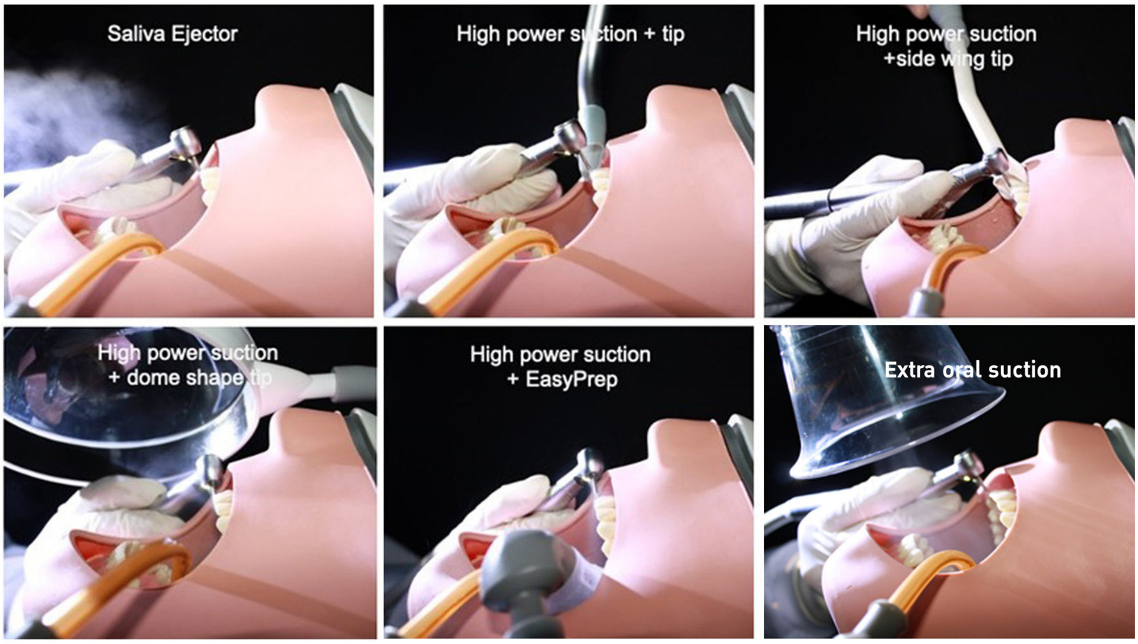

Figure 1 *The reduction of aerosol diffusion caused by a high-speed handpiece (Airotor) by various types of intraoral and extraoral suction tools*

The relative humidity inside the acrylic box measured by a hygrometer at 1, 5, and 10 mins showed that the group of saliva ejector alone had a mean relative humidity at 10 min increased from the mean relative humidity at the beginning of the experiment. For the group using the saliva ejector in combination with other groups of aerosol suctions, the data showed that the mean relative humidity at 10 min decreased from the mean relative humidity at the beginning, as shown in Table 2.

Table 2 *The results of the mean relative humidity (percent) generated by fine aerosols from the high-speed handpiece (Airotor), classified by type of aerosol suction device used and time of use.*

Type of aerosol suction devices	The mean relative humidity (percent)			
	Mean ± SD			
	0 minute	1 minute	5 minutes	10 minutes
Saliva ejector	74.23±0.19	78.28±3.11	77.86±3.48	75.85±3.11
Saliva ejector and High power suction tip	74.23±0.65	68.69±1.28	63.45±1.36	65.17±2.38
Saliva ejector and High power suction side- wing tip	73.75±0.84	67.85±1.36	61.80±2.10	60.68±2.55
Saliva ejector and High power suction dome-shaped tip	74.56±0.80	67.04±0.36	62.65±3.03	61.05±2.74
Saliva ejector and EasyPrep®	74.38±0.60	67.89±1.82	61.22±1.80	59.82±1.86
Saliva ejector and Extra oral suction	74.12±0.82	62.32±2.18	63.15±2.24	63.71±2.28

From the statistical analysis to compare the average relative humidity from the aerosol suction device in each group, it was found that at the start of the experiment (min 0), the means relative humidity of all groups were not different from the group using saliva ejector alone as a control group. In comparing the average relative humidity from each group of aerosol suctions when the experiment was conducted for 1 min, the mean relative humidity of the saliva ejector alone showed the highest value and a statistically significant difference from all groups. In addition, it was found that the mean relative humidity of the group using the saliva ejector combined with the high-power suction was significantly higher than that of the group using the saliva ejector combined with extraoral suction at 1 min (P-value = 0.038). Comparison of the average relative humidity from each group of aerosol suctions at 5, and 10 mins showed that the saliva ejector group had a statistically higher value than that of others as shown in Table 3.

Table 3 *The comparison of the average relative humidity classified by the type of aerosol suction devices and the duration of the experiment. (*Statistically significant differences (P<0.05; ANOVA test and Scheffe's test)*

Duration	Control group	Experimental groups	*P*-value	95% Confidence Interval	
				Lower Bound	Upper Bound
0 minute	Saliva ejector	Saliva ejector and High-power suction tip	1.000	-2.214	2.214
		Saliva ejector and High-power suction side- wing tip	0.977	-1.731	2.698
		Saliva ejector and High-power suction dome- shaped tip	0.996	-2.538	1.891
		Saliva ejector and EasyPrep®	1.000	-2.358	2.071
		Saliva ejector and Extra oral suction	1.000	-2.108	2.321
1 minute	Saliva ejector	Saliva ejector and High-power suction tip	0.002*	3.517	15.656
		Saliva ejector and High-power suction side- wing tip	0.001*	4.360	16.500
		Saliva ejector and High-power suction dome- shaped tip	<0.001*	5.164	17.303
		Saliva ejector and EasyPrep®	0.001*	4.317	16.456
		Saliva ejector and Extra oral suction	<0.001*	9.884	22.023
	Saliva ejector and High-power suction tip	Saliva ejector	0.002*	-15.656	-3.517
		Saliva ejector and High-power suction side- wing tip	0.997	-5.226	6.913
		Saliva ejector and High-power suction dome- shaped tip	0.943	-4.423	7.716
		Saliva ejector and EasyPrep®	0.998	-5.270	6.870
		Saliva ejector and Extra oral suction	0.038*	0.297	12.436
5 minutes	Saliva ejector	Saliva ejector and High-power suction tip	<0.001*	6.550	22.264
		Saliva ejector and High-power suction side- wing tip	<0.001*	8.203	23.917
		Saliva ejector and High-power suction dome- shaped tip	<0.001*	7.357	23.070
		Saliva ejector and EasyPrep®	<0.001*	8.780	24.494
		Saliva ejector and Extra oral suction	<0.001*	6.853	22.567
10 minutes	Saliva ejector	Saliva ejector and High-power suction tip	0.008*	2.575	18.785
		Saliva ejector and High-power suction side- wing tip	<0.001*	7.065	23.275
		Saliva ejector and High-power suction dome- shaped tip	<0.001*	6.695	22.905
		Saliva ejector and EasyPrep®	<0.001*	7.918	24.129
		Saliva ejector and Extra oral suction	0.003*	4.031	20.242

Discussion

The most effective method to select devices for reducing the amount of aerosol dispersion caused by dental treatments is controversial. Currently, manufacturers provide many devices in the market as accessories during the COVID-19 pandemic, with the expectation that the efficiency of aerosol removal can be significantly enhanced. Most of the tools currently used in dental clinics are intraoral suctions, which are small, easy, and quickly mobilized. In addition, there is a tool for reducing the aerosol from outside the mouth to be used as well. Some of these aerosol removal devices are expensive and may be inconvenient. Therefore, it is still being determined whether it is worth using or not. In the present study, various devices widely used to reduce saliva and aerosols during the COVID-19 outbreak were tested.

Relative humidity is a ratio of atmospheric moisture relative to the amount that would be present if the air was saturated. This displays it as a percentage of the total amount needed for the air to be fully saturated at the same temperature. Measuring relative humidity is not complicated by using a hygrometer. Digital humidity hygrometers have a higher degree of accuracy than analog hygrometers, and they do not need to be recalibrated. Absolute humidity measures the weight of water vapor per unit volume of air. The absolute humidity unit is given as g / m^3., units of grams of water vapor per cubic meter of air, since the absolute humidity of the air is calculated by dividing the mass of water contained in the air by the volume occupied by the quantity of air concerned. So, it is rather complicated than the relative humidity measurement. To quantify the aerosol remaining in the air in this study, we decided to use the simple, cheap, but still reliable and acceptable method.

From the results of this study, it was found that at 10 minutes after using the aerosol-generating tool, the decline in relative humidity percentage was consistent with other studies.[7,9-11] When the relative humidity was measured at 5 and 10 mins after the procedure, no tools tested in the present study significantly reduced the relative humidity. However, using the saliva ejector alone is not recommended since this device is ineffective in reducing the aerosols. The Extraoral suction and high-power suction combined with a dome-shaped tip had the same relative humidity reduction efficiency as other types of aerosol reduction tools, and they can reduce aerosols effectively when placed near the aerosol source. However, they have a limitation: the tool's tip is oversized and must be placed as close to the aerosol source as possible, impeding the dentist's work and vision. Therefore, it is difficult to use effectively compared with the High-power suction with a straight tip, high-power suction with a side-wing tip, or high-power suction with EasyPrep®, since these devices are small and can be placed near the source of aerosol easily in the oral cavity. Moreover, they do not obscure the vision or obstruct the dentist's work, thereby reducing the amount of aerosols greatly.

For the effective removal of aerosols generated by dental procedures, a saliva ejector is recommended for only suctioning of water and saliva. For aerosols, the use a high-power suction combined with a tip that can be placed as close as possible to the aerosol source is recommended. Aslam et al. suggested that the high-power suction should be connected to a large tip at least 8 mm in diameter.[13] Although Shahdad *et al,* 2020 and Noordien *et al,* 2021 showed that an extraoral suction could reduce contamination by aerosols, droplets, and splatter.[14,15] Our present study recommended that an extraoral suction could be used as an additional option to enhance the elimination of aerosol diffusion from the procedure. Shahdad *et al,* 2020 also recommended that four-handed dentistry and the appropriate use of rubber dam should remain the primary mitigating factors.[14] Lloro *et al* 2021 showed that the percentage contamination reductions were highest on the operator face-shield. They recommended standard protective gear such as goggles, face shield, and surgical gloves for maximum safety.[16] Piela et al studied aerosol generated particles using ultrasonic scaling and high-speed handpiece in 2022. They evaluated the efficacy of different high-volume and low-volume suction devices in preventing particle escape during procedures. They found that the use of any suction device tested resulted in a significant reduction in particle counts compared with no suction. Our present study also showed that all tested devices could effectively reduce aerosols.[17]

The previous study revealed no significant difference in splatter and aerosol reduction between Isolite illuminated isolation system (Isolite Systems) and a saliva ejector.[18] Since those devices were attached to the high-volume suction, they may work similarly to the high-volume evacuator (HVE). The HVE has effectively reduced 90 % of aerosols and spatter from the operation site.[7,19.20] In contrast, this study showed a significant difference in aerosol reduction of saliva ejectors compared to other suction devices. All types of suction tips used in this study were attached to the HVE except saliva ejector—this causes low efficiency in aerosol reduction. This study's findings showed that suction systems attached to HVE can remove a large volume of aerosols within a short period, similar to other studies.[7,19,20] Moreover, the extraoral suction at 1-minute showed significant aerosol reduction compared to other suction tips attached to HVE. The extraoral suction can suck up a large volume of air and aerosols since it has a wide-mouth suction hood and power level of the device. However, after 5 and 10 minutes, the effectiveness of decreasing the aerosols of the extraoral suction was not different from other suction tips attached to HVE.

In the actual clinical situation, the placement of the aerosol-generating instruments in each position is different, resulting in the pattern, direction, and distribution of aerosols from the instruments. The results of this study can be applied to the appropriate positioning of the aerosol reduction tools by choosing to place them in the most critical dispersed position to minimize the spread and contamination as much as possible. Although no definitive study has reported the effect of 2019 coronavirus infection and susceptibility to dental aerosol contamination, this study showed that the aerosol control from each instrument had the potential to control dispersion. However, the quantity and the distribution of pathogens in aerosols are related to many factors, such as the types of procedures performed, tools, positions, and the efficient air circulation system. Therefore, further studies of those factors are still needed, including the accumulation of viruses in closed areas of the dental treatment room and a study of the mean probabilities of how many more people will spread through dental work, known as the Reproductive number, R0 or R naught.[21]

This study was done in a closed system and without airflow to determine the true potential of the instrument. However, in actual practice, the ventilation system may spread germs and droplets farther and longer in the air. It can be seen from several reports that infected people were linked to locations in the enclosed space, not adequately ventilated, in crowded condition, staying in the place for a long time, and without personal protection. Therefore, various methods must be combined to reduce the risk of infection. Improving ventilation systems in the building and dental treatment rooms may decrease the concentration of germs in the air and reduce the spread of contaminated droplets in the air by means of bringing sufficient fresh air from the outside to fill the working area and have exhaust air to be disposed of, resulting in better air quality.[22-24] Even though we know the effectiveness of suction devices in aerosol reduction, the range of the suction tip to the operating sites and the proper direction to obtain the best practice to control the aerosol dispersion of each working area in the mouth still need to be determined in the future.

Conclusion

The most effective method to reduce the amount of aerosol dispersion caused by dental treatment is still doubtful whether it is worth using. From the results of this study, it was found that the use of an inexpensive high-power suction tip in combination with the saliva ejector can reduce the relative humidity well. Notably, based on the results of this study, the saliva ejector alone is ineffective in reducing dental aerosols. Although the extraoral suction has the potential to reduce the aerosols, it has a limitation and is challenging to be used effectively. Therefore, in terms of investment cost-effectiveness, using extraoral aerosol suction devices could only be an alternative to enhance the efficiency and could not be used as the primary replacement for other devices.

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