Chiang Mai
Dental Journal

Original Article

Editor:
Wannakamon Panyarak,
Chiang Mai University, Thailand.

Received: November 9, 2022
Revised: December 10, 2022
Accepted: December 19, 2022

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Droplet Spread Pattern Produced by Magnetostrictive Scaling with and without a High-volume Evacuator

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Abstract

Objectives: To study the droplet spread pattern from magnetostrictive scaling and the effect of a high-volume evacuator (HVE) on spread reduction.

Methods: Magnetostrictive scaling was simulated on a dental unit using dye-stained water. Gridded filter paper was installed at five vertical heights. Each height consisted of a center point with six radial directions, each divided into four horizontal distances. Eight minutes of scaling was performed in triplicate for two groups, scaling with HVE (H) and scaling without HVE (NH). The stained paper grid cells were counted, and the number and percentage of stained cells were calculated. Statistical comparison of H and NH was performed using SPSS.

Results: The 2 and 4 o'clock directions showed the highest number of stained areas in both groups. Pieces of paper located 30 cm from center horizontally in all directions from floor level up to 30 cm above the scaler tip were completely stained in both groups. The furthest distance that droplets spread was 120 cm from center at 2 and 4 o'clock in the NH group. The highest vertical spread was 45 cm above the tip in both groups and it was significantly decreased in the H group. The total stained area was reduced by 3.15% when using HVE.

Conclusions: Droplet spread from magnetostrictive scaling can reach 120 cm from the dental unit in the 2 and 4 o'clock directions. An HVE with adequate airflow rates is necessary for reducing contamination risk.

Keywords: high-volume evacuator, scaling droplets, spread pattern, ultrasonic scaler

Introduction

The coronavirus disease (COVID-19) pandemic has affected socioeconomic and health issues worldwide. The infection of the respiratory tract caused by the SARS-CoV-2 virus generally causes a wide range of symptoms, from mild fever or coughing to life-threatening complications. As of the writing of this article, 6.5 million people worldwide and over 30,000 people in Thailand have died from COVID-19 infection since its outbreak in 2020.[(1)] It is well known that the transmission of COVID-19 primarily occurs between people at a conversational distance through droplet transmission, which occurs when an uninfected person inhales droplets generated by an infected person coughing, speaking, or breathing. In 2021, the World Health Organization announced that COVID-19 can additionally spread in poorly ventilated environments via airborne transmission, remaining suspended in the air for a longer period and traveling farther than conversational distances.[(2)] This increased the concerns of viral transmission during dental procedures.

Periodontal scaling using ultrasonic scalers is a fundamental and routine dental procedure that aims to remove bacterial plaque and calculus from the gingival sulcus. Regular professional scaling is critical for maintaining periodontal health and preventing the development of periodontal disease, the common oral disease that leads to tooth loss. Ultrasonic scaling is an aerosol-generating procedure due to its high vibrational energy combined with the necessary use of water coolant. Although there are no reports of transmission of COVID-19 to dental staff from infected patients,[(3)] the anxiety of both patients and dental staff has been heightened due to the unavoidable direct contact in a closed environment that occurs between dental staff and patients' oral cavities during these dental procedures.

Numerous studies have investigated the bacteria-contaminated areas generated by ultrasonic scaling and methods to reduce contamination, such as pre-procedural rinsing with disinfectant and using a high-volume evacuator (HVE).[(4-8)] However, the majority of studies have not extensively evaluated the spread pattern of droplets, leading to an incomplete understanding of the pattern of maximal spread.[(4,5,8-10)] Moreover, differences in research methodology (simulated or clinical tests)[(7,10)] and unclearly defined experimental setups, including incomplete information regarding the type of scalers, position of scaler tip, and environmental considerations such as the presence of an air conditioner, have caused further controversy in the results of previous studies.[(5-7)] Therefore, the present study aimed to evaluate the droplet spread pattern during ultrasonic scaling and the effect of using an HVE on droplet reduction.

Material and Methods

This laboratory research was conducted at the Periodontology Clinic, Faculty of Dentistry, Chiang Mai University, Thailand. The dental unit was adjusted to a fully supine position with the headrest positioned 75 cm from the ground. The tip of the magnetostrictive scaler (Scalex 800 Ultrasonic Scaler, Dentamerica Inc., San Jose, CA, USA), which is routinely used in the undergraduate clinic of the faculty, was fixed in a position perpendicular to the floor. To simulate the portion of the scaling produces the highest droplet volume and prevent factors affecting the droplet spread pattern, scaling was performed in one fixed position that mimicked the scaling of the palatal surface of the upper incisors. The HVE was installed on the left side of the unit, 2 cm from the scaler tip. Pieces of paper measuring 9x9 cm with 324-cell grids were used to trap the colored droplets during scaling. The water coolant was mixed with carmoisine dye at a ratio of 1 g of dye to 3 L of water.

Droplet spread was assessed at five vertical heights: the level of the floor, the level of the scaler tip, 30 cm above the tip, 45 cm above the tip and 60 cm above the tip. At each vertical height, the direction of spread was examined in the 12, 2, 4, 6, 8 and 10 o'clock directions, excepted for 6 o'clock at the level of the floor which was the area under the dental unit, and horizontal distance in each direction was assessed at 0, 30, 60, 90 and 120 cm from the center point. The experimental setup is shown in Figure 1.

The experiment, which was repeated three times of each height level, consisted of 8 min of scaling with HVE and 8 min of scaling without HVE. The air conditioner vents were closed to prevent interference with droplet spread. The grid cells with colored stains were then counted, and the sums and percentages of stained cells were calculated as shown in Figure 2.

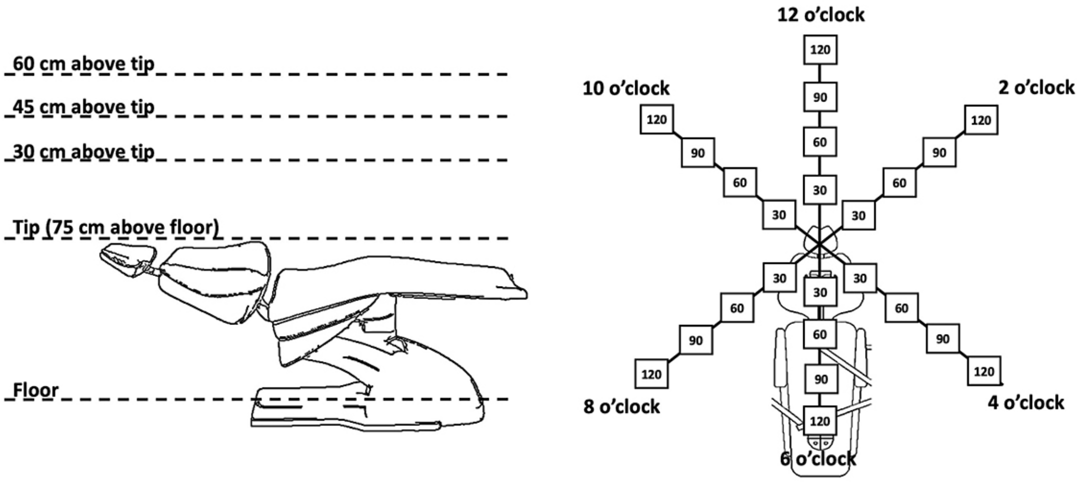

Figure 1: Position of installed grid paper at different vertical levels (left) and horizontal distances. The unit of horizontal distance was centimeters.

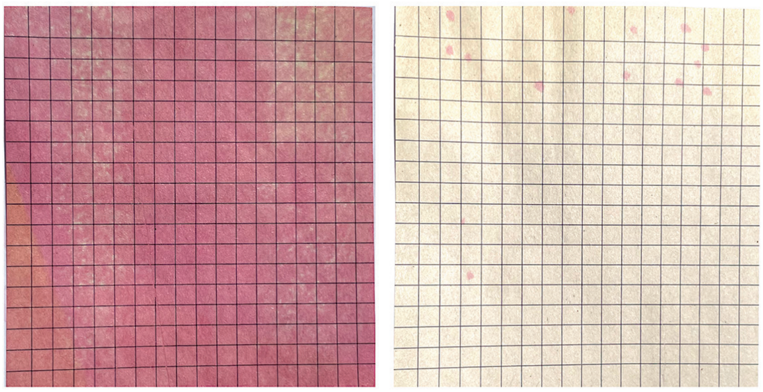

Figure 2: The examples of gridded filter paper after scaling. The number of stained cells was counted as 324 (100%) and 18 (5.56%) for the left and right, respectively.

Statistical analysis

Data were analyzed using SPSS (Windows version; SPSS, Chicago, IL, USA). The Shapiro–Wilk test was used to demonstrate the non-normal distribution of the data. The number of stained grid cells obtained from triplicate scaling was calculated into the mean. The total number of stained grid cells that occurred during scaling with and without HVE at each vertical height, direction, and horizontal distance was compared via the Mann–Whitney U test. A *p*-value of < 0.05 was considered statistically significant.

Results

In the direction of droplet spread, the most stained area during scaling without HVE was in the 2 o'clock direction, followed by the 4 o'clock direction. With the addition of the HVE, the stained areas decreased at 2 and 4 o'clock but slightly increased at 8 and 10 o'clock. The farthest distance of droplet spread was 120 cm from center, which occurred in the 2 and 4 o'clock directions at floor level only when scaling without the HVE. However, the difference of number of stained grid cells from scaling with and without HVE was not significant (Table 1).

Considering the vertical level, the pattern of droplet distribution was relatively similar with and without the HVE. All pieces of paper located at a horizontal distance of 30 cm from center in all directions from the floor level up to 30 cm above the tip were fully covered in droplet stains, while staining was substantially decreased and absent on paper located 45 and 60 cm above the tip,

Table 1: Mean number of stained grid cells from scaling alone and with HVE in each direction and horizontal distance

		Direction (o'clock)											
		12		2		4		6		8		10	
		NH	H	NH	H	NH	H	NH	H	NH	H	NH	H
Horizontal distance (cm)	30	965.8	973.3	1055.7	971.7	766.7	663.0	654.0	648.7	972.3	943.7	827.0	985.8
	60	342.3	324.3	686.0	608.4	539.0	321.6	0	6.3	18.0	303.7	18.3	55.7
	90	5.7	5.8	227.7	21.7	15.3	28.7	0	0	1.0	25.3	6.7	6.0
	120	0	0	2.0	0	2.0	0	0	0	0	0	0	0
	Sum	1313.8	1303.4	1971.3	1601.8	1323.0	1013.3	654.0	655.0	991.3	1272.7	852.0	1047.6
p-value*		> 0.05		> 0.05		> 0.05		> 0.05		> 0.05		> 0.05	

H = scaling with HVE; NH = scaling without HVE; *Number of stained grid cells from H and NH at each direction was compared via the Mann–Whitney U test.

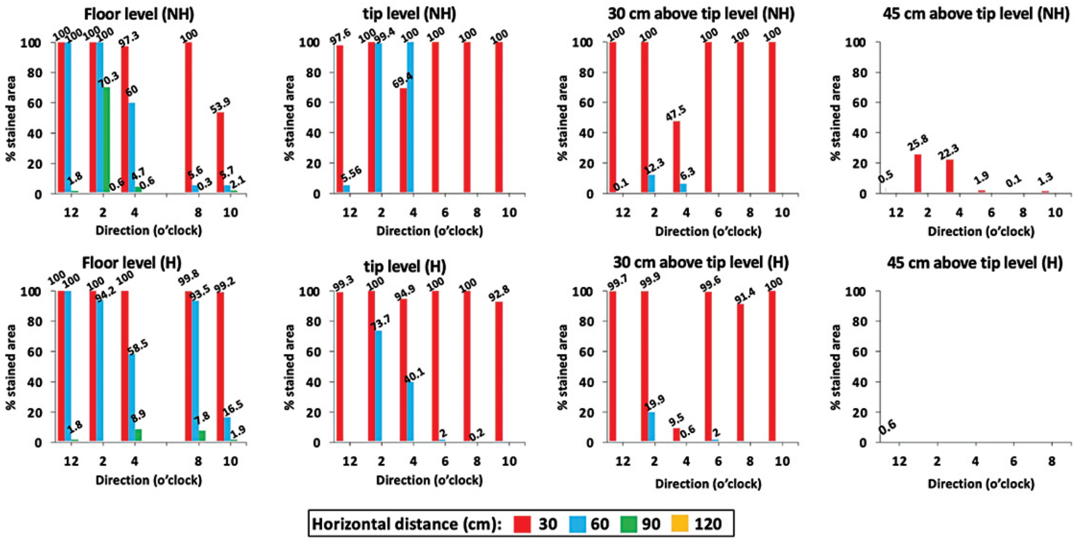

Figure 3: Percentage of stained area from scaling alone and with HVE at four vertical levels. H = scaling with HVE; NH = scaling without HVE.

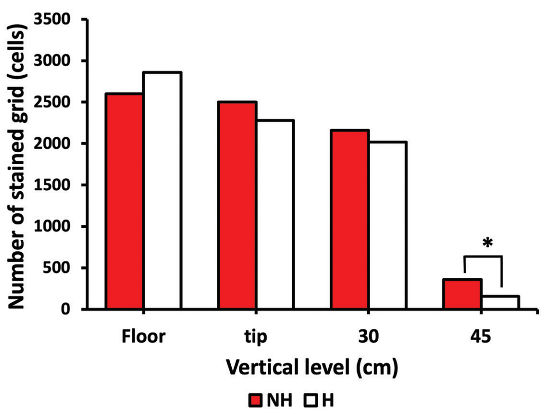

Figure 4: Number of stained grid cells from scaling alone and with HVE in each vertical level. * = comparison between NH and H tested via the Mann–Whitney U test. H = scaling with HVE; NH = scaling without HVE.

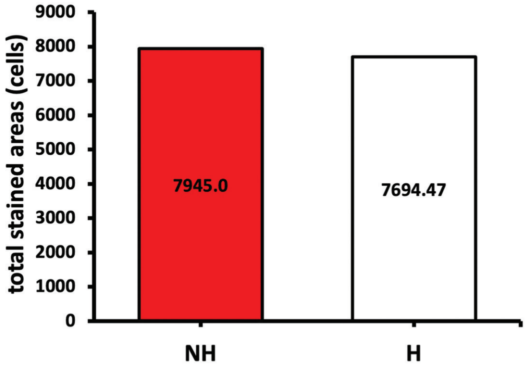

Figure 5: Comparison of total stained area between scaling alone and with HVE. H = scaling with HVE; NH = scaling without HVE.

respectively (Figure 2). At 45 cm above the tip, stained regions were significantly decreased when the HVE was used, while the significant difference at the other vertical level was not observed (Figure 3). The total stained surface during scaling with the HVE was 3.15% insignificantly less than the total stained surface during scaling without the HVE (7105.4 cells vs 6893.8 cells, respectively) (Figure 4).

Discussion

The present study showed that the droplet spread direction with the most color staining occurred at 2 and 4 o'clock, both with and without using an HVE, which corresponds to the working position of the dental assistant. This is in agreement with a previous study that found that the 4 o'clock direction was the most contaminated area immediately and up to 30 min after 15 min of ultrasonic scaling.(6) Moreover, previous studies have demonstrated that the areas corresponding to the nose and chest of the dental assistant had a high risk of contamination, comparable to the areas of the dentist's and patient's chest.(11) This is in line with our results showing complete staining of all paper located 30 cm horizontally from center in every direction from the floor level up to 30 cm above the tip. These findings highlight the importance of maintaining strict contamination prevention measures for all staff positioned around the dental unit, not only the operator and patients. However, one previous study presented a controversial result in its finding that the assistant was in the position with the lowest contamination compared to the dentist and patient.(5) This might be due to the study's experimental methodology, as the study was performed in a real clinical environment in which the position of the scaler tip moved during scaling, while our study was a simulation test in which the scaler tip was fixed throughout the experiment. Our attempt to reduce confounding factors affecting droplet spread by fixing the scaler tip might lead us to understand more clearly in possible spread pattern generated by magnetostrictive scaling.

In addition, we found that the farthest distance of droplet staining was 120 cm from center horizontally and 45 cm above the tip vertically, which is consistent with the findings of several previous experiments.(6,10) However, other studies demonstrated that bacterial contamination could be found up to 300 cm from the oral cavity on the floor or even on the ceiling.(12,13) These conflicting reports might be a result of differences in study designs, particularly in the method employed to detect droplets. In the present study, we used grid paper to absorb colored water, while the counting of bacteria-forming units on agar plates was performed in previous studies. Although their technique might elicit a higher sensitivity for aerosol detection, the challenge of controlling contamination from other sources could lead to false-positive outcomes. Therefore, it is impossible to conclude the actual distance of viral contamination from the current evidence, but overestimating viral spread might be considered for the purpose of prevention. Regardless, no contamination occurred at 120 cm from center in the 2 and 4 o'clock directions when scaling was combined with HVE in this study, which indicates that HVE might limit the radius of droplet spread during scaling.

The present study further demonstrated that the application of an HVE during scaling reduced the stained area by merely 7.2% compared to scaling alone. This is consistent with one study that found no significant difference in colony-forming units between scaling with and without an HVE.[14] However, a group of earlier studies suggested that placing a large-bore HVE within 2 cm of the scaler tip reduced splatter by more than 93%,[15-17] which was in agreement with additional studies that showed contamination reduction rates of 83% to 94% when using an HVE, evaluated by the staining of filter paper strips, the number of colony-forming units, and the area of image subtraction.[8,11,18] Desarda and colleagues speculated that high efficacy when using an HVE might be achieved by modifying the device, such as by attaching the HVE tip to the scaler handle so that they act as a single unit.[14] The low efficacy of the HVE in our study was likely contributed to by an inadequate suction flow rate (120 L/min) of the dental unit, as one study illustrated that 160 L/min was the minimum flow rate required for the prevention of particle emission.[19] Moreover, a recent study conducted by Li and colleagues demonstrated that a flow rate of 300 L/min induced significantly more effective particle removal than flow rates of 150 L/min or lower, as assessed by a laser light-scattering technique.[20] This was in line with the findings of Puljich's study, in which a flow rate of 325 L/min obtained a reduction rate of over 80%.[8] It was suggested that regular maintenance and evaluation of suction flow rate are crucial. Nevertheless, our findings showed that despite a potentially inadequate flow rate, using an HVE could limit the radius of droplet spread at a vertical level of 45 cm above the scaler tip and a horizontal distance of 120 cm from center in the 2 and 4 o'clock directions. No previous studies have shown complete prevention of contamination from using an HVE alone. Recently, several studies demonstrated a significantly higher efficacy in reducing aerosols when using HVE combined with extraoral suction devices.[21-23] These studies employed combination protocols to optimize the prevention of COVID-19 and other airborne disease transmission. Further studies in confined settings and with consistent methodology are still needed to clarify the pattern of droplet spread.

The present study had some limitations. First, it was a simulation study, which was free of the confounding impact of an air conditioner and used a fixed-position scaler tip; the observed spread pattern thus might not be applicable to clinical scenarios. However, the outcome obtained with the scaling in the position that produces the most droplet spread should be a reminder of the possibility of viral transmission even in low-risk situations. Second, the result obtained using a magnetostrictive scaler may not be transferable to other types of scalers, such as piezoelectric scalers, due to their different mechanisms. Finally, droplet detection via filter paper may only detect large molecules, such as splatter or droplets, but not aerosols, which might have led to underestimated results. Further investigation using bacterial culture plates as the detection method may be required.

Conclusions

The droplets generated from magnetostrictive scalers had a maximal spread at the left side of the operator, with maximum distances of 120 cm horizontally and 45 cm vertically from the scaler tip. Although using an HVE might limit droplet spread in both dimensions, an inadequate airflow rate led to lower efficacy in spread reduction.

Acknowledgments

We thank all staff of the Periodontal Clinic, Faculty of Dentistry, Chiang Mai University for supporting us and all research committees for their useful suggestions. This research did not receive any specific grant or funding from funding agencies in the public, commercial, or not-for-profit sectors.

Conflicts of interest

The authors declare no conflicts of interest.

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