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Research Article

Spatter-Reduction Efficacy of Different Suction Methods in Ultrasonic Scaling Procedure

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Abstract

Background: The spatter or aerosol reduction of suction devices during ultrasonic scaling need to be further evaluated to better mitigate the risk of COVID-19 infection for both dental health care providers and patients.

Methods: Ultrasonic scaling procedures were performed without suction, with high volume evacuation (HVE) and with Isovac®. Fluorescein dye in the scaler water line tracked contamination produced by scaling. Filter paper discs placed at differing locations in the operatory were used to collect spatter and aerosol were analyzed.

Results: Fluorescence showed large amounts of spatter contamination produced by scaling procedures. Contamination was reduced by 68% with HVE ($p < 0.05$) and by 52% with Isovac® ($p < 0.05$), with no significant difference between these two suction methods. However, this technique failed to capture aerosol 0 - 60 minutes after ultrasonic scaling.

Conclusion: The study showed that HVE or Isovac® significantly reduce the spatter contamination produced by ultrasonic scaling. Newly-developed suction devices can be evaluated the extent of spatter contamination using this method.

Keywords: *Safety Management; Dental Scaling; Spatter; Aerosol; Contamination*

Introduction

The major transmission route of the SARS-CoV-2 is widely considered to be via respiratory droplets, produced when an infected person coughs, sneezes, sings, talks, or breathes. Dental health care providers are considered high risk occupations in this pandemic due to their close contact with the patients' oral cavities and aerosol-generating procedures they conduct on daily basis [1,2]. Screening of dental patients for symptoms reduces the infection risk of dental care team, the potential for asymptomatic patients to carry and spread the virus still remains [3].

SAR-CoV-2 virus was found in the salivary glands and dental biofilm of COVID-19 patients [4,5]. Saliva harbors a high number of viruses in nearly all infected patients [6]. Despite the general lack of evidence that these air droplets produced in dental procedures are a source of SARS-CoV-2 transmission, many state dental boards have eliminated or reduced the use of aerosol-generating procedures during this pandemic. Aerosol-generating procedures including those using ultrasonic scaler, high-speed handpiece, air/water syringe, air polishing, and air abrasion, produce both spatter and aerosol. Spatter, droplet mixture of air, water, saliva and /or tissue debris from the oral cavity, larger than 10 μm in diameter, were found to be forcibly ejected from the ultrasonic tip or high speed rotary hand piece and travel along a bullet-like trajectory until they contact a surface [7]. Before these spatter droplets contact a surface, they may evaporate and remain as droplet nuclei or aerosol, in the air for a longer period. Therefore, aerosol droplets, different from spatter, contains particles less than 10 μm in diameter which have the potential to penetrate surgical masks and enter the respiratory system. In the previous studies, both of these dental droplets were captured and quantified using bacterial growth medium plates [8,9], filter paper strips [10,11] and air samplers [12,13]. Because of different sampling methods and experimental settings, quantitative data and spatial distribution were reported differently.

The Covid-19 pandemic has also increased dental personal protection equipment (PPE) requirement. It is now standard to include N95 respirators, face shields, and gowns during aerosol-generating procedures. Mitigating the direct and the indirect contamination in the working environment has become more crucial to minimize the threat to both patients and dental care providers. The ADA states in its Return to Work Interim Guidance Toolkit [14] that dentists should use high-velocity evacuation (HVE) whenever possible. Many new intra-oral or extra-oral suction devices have been developed and introduced since the pandemic commenced [15]. However, information about potential issues or best practices when using these devices is limited. The efficacy of these evacuation products could change significantly in different clinical settings, depending upon experience of operator and assistant and maintenance conditions. More quantitative evidence is needed to illustrate the effectiveness of these evacuation methods during dental aerosol-generating procedures.

This study simulated a clinical setting where a full mouth ultrasonic scaling procedure was performed on a mannequin by an experienced dental hygienist who was assisted by a dental student. The same scaling procedures were repeated, without suction, with high-velocity evacuation (HVE) or with an intraoral device, Isovac® system (Zyris, Goleta, CA). We chose Isovac® to compare with HVE because it is one of the most commonly used intraoral suction and isolation devices when assistantship is not available. Spatter and aerosol contamination were evaluated during and after the procedures. Our ultimate goal is to set up a fast and accurate technique to evaluate the efficacy of any new suction device to be employed in the dental clinic in order to mitigate the spatter or aerosol transmission risk of airborne infectious diseases.

Materials and Methods

In an enclosed dental operatory in the Periodontics clinic, a dental mannequin mimicking the patient's head was set up in place of the head rest and a box was used to mimic the patient's body. A Cavitron® Bobcat Pro Unit (Dentsply Sirona, Charlott, NC) with a Cavitron® Slimline® 10s ultrasonic insert (Dentsply Sirona, Charlott, NC) was connected to the water source containing 1 gram of Fluorescein dye powder in each liter of distilled water. The same equipment and solution was used in all the experiments in the study. PPE including gloves, gowns, N95 masks, face shields, head bonnets, and shoe coverings were worn by operator and assistant. Filter paper discs in 9cm diameter were attached to operator's chest, abdomen, left shoulder, mask, head, right and left shoes as well as assistant's chest, mask, head, right left shoe (See figure 1). Discs were also placed on the patient's chest and the location at 12 o'clock direction to the head, approximately one foot from oral cavity. To detect aerosol remaining in the air after procedure, filter paper discs were placed at a variety of locations with different directions and distances in the operating room at 0 - 30 minutes and 30 - 60 minutes after the procedures, using the same method in Veena's study [11].

Three experiments following the same protocol of ultrasonic scaling were conducted on three different days. Each experiment included three scaling procedures which were scaling with no suction, scaling with HVE suction and scaling with Isovac®. Each scaling procedure

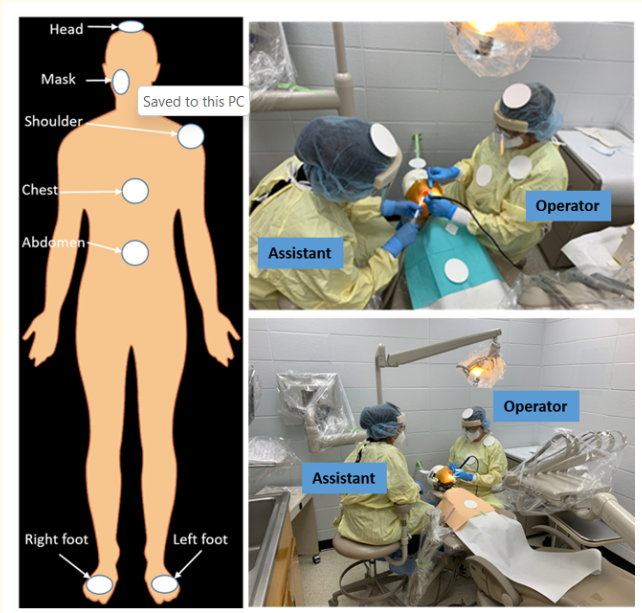

Figure 1: *Images showing experimental setting and filter paper disc placement. The operator is left-handed and the assistant is sitting on the right side of the mannequin.*

lasted 15 minutes. Medium power of Cavitron® Bobcat Pro unit and appropriate water flow were chosen when either HVE or Isovac® was applied at the highest suction. At start of each procedure, PPEs were changed to clean ones, the operation area was completely wiped down with disinfection wipes and the filter paper discs at all locations were replaced. A blacklight was used to scan the room to make sure there were no previous fluorescent debris.

In an additional dual-staining experiment, GloGerm powder was applied to the teeth on the mannequin. The same ultrasonic scaling with fluorescence dye in water source was performed to demonstrate the distribution of tooth surface origins of the spatter contamination. The GloGerm appears orange which can be easily distinguished from green fluorescence under blacklight. No suction was applied in this experiment.

Air-dried paper discs were scanned using the Chemidoc™ imaging system. ImageJ lab software was used to analyze the discs. The total pixels of the fluorescence on all the disc images from each procedure were summed. The results from triplicate experiments were compiled in an Excel sheet and evaluated. After the dataset was checked and verified by Normality Test (Shapiro-Wilk) (P = 0.953) and Equal Variance Test (Brown-Forsythe) (P = 0.351), Pairwise testing with Tukey's HSD was used to compare the different results from each procedure. To analyze the size difference between the droplets in different locations, Kruskal-Wallis one-way ANOVA on ranks was applied.

Results

The scaling procedure using no suction produced highest fluorescein contamination throughout the operation field. A large amount of fluorescence was noticed on mannequin's orbital areas, head and auricular areas, especially on operator's side. Discs placed on the operator's abdomen accumulated the most contamination followed by operator's chest, shoe and patient's chest. Even with the protection of the face shield, the operator's mask and, much less frequently, the assistant's mask were contaminated (Table 1). However, the discs placed at 0 - 30 and 30 - 60 minutes after the procedure showed no fluorescence. In the dual-staining experiment, the orange GloGerm particles from the tooth surface were spread to most of the monitored areas, along with yellow fluorescence staining (Figure 2).

	1st Experiment			2nd Experiment			3rd Experiment		
Suction methods	**No suction**	**HVAC**	**Isovac**	**No suction**	**HVAC**	**Isovac**	**No suction**	**HVAC**	**Isovac**
Operator's Chest	105818	367143	263975	641236	202976	299530	325830	46466	28327
Operator's Abdomen	*646229	104257	388286	646229	158708	213189	*646229	101863	274981
Operator's Shoulder	52908	3166	1437	9300	4914	4361	13107	1131	81133
Operator's Head	5276	15	128	937	239	16	2812	0	5006
Operator's Mask	17	0	0	8189	717	282	0	0	0
Operators Shoe -R	17868	4223	4624	68317	19234	13577	6863	1834	0
Operators Shoe -L	20822	606	0	2252	1299	8	36674	225	4
Assistant's Chest	0	490	0	0	17275	0	3747	10729	0
Assistant's Head	0	0	0	2	39	0	16	0	0
Assistant's Mask	1	0	0	0	0	0	0	0	0
Assistant's Shoe -R	0	0	0	0	0	0	0	315	0
Assistant's Shoe -L	3	0	0	80	0	0	0	0	1
Mannequin's chest	95325	33491	40068	60815	131296	69173	21095	10234	11391
**Mannequin's head direction	57	1706	0	420	634	41	198	1046	0
Total	848942	479900	658450	1376542	405401	530963	1056571	173843	400843
Operator's chest and abdomen/Total (%)	89%	98%	99%	94%	89%	97%	92%	85%	76%

Table 1: *Total pixels of fluorescence dye on the images of filter paper discs placed in different locations.*
**Due to extremely high fluorescence signal, ImageJ couldn't analyze correctly, so the raw number of pixels was replaced by the highest number we have obtained in the whole study.*
*** Patient's head direction (12 o'clock) at 1 foot away from oral cavity.*

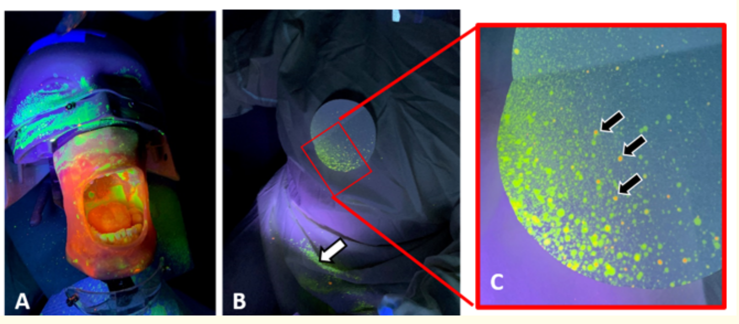

Figure 2: *Images showing contamination after a Cavitron® scaling procedure with both fluorescein added to the water reservoir and GloGerm powder applied to mannequin's teeth. There is no suction used in the procedure. A. fluorescence contamination on mannequin's face. B. Fluorescence contamination on operator's chest and the area below the operation field (white arrow). C. Green fluorescence particles (white arrow) and orange Glo-Germ particles (black arrows) on the filter paper disc placed on operator's chest.*

Using either HVE or Isovac produced a significant reduction in the spatter contamination compared to no suction. Filter paper discs collected 353048 pixels (SD = 130316) fluorescence during scaling with HVE, 530085 pixels (SD = 105169) during scaling with Isovac®, compared to 1094018 pixels (SD = 217013) during scaling with no suction (Figure 3). Filter paper disc contamination was reduced by 68% with HVE and by 52% with Isovac® compare to no suction ($p < 0.05$). Although we saw less contamination in the procedures with HVE than with Isovac®, this comparison was not statistically significant between two suction methods. On the mannequin's face, the fluorescence contamination had been largely eliminated by using HVE and Isovac®. However, with both suctions, the operator's abdomen and chest remained heavily contaminated areas, where 76 - 99% of total contamination were located (Table 1). Discs placed on operator's head, mask and shoes showed varying fluorescence (Table 1). The assistant's chest and shoes had more contamination during the scaling with HVE because of the proximity and more involvement in the procedure compared to scaling with no suction and scaling with Isovac®.

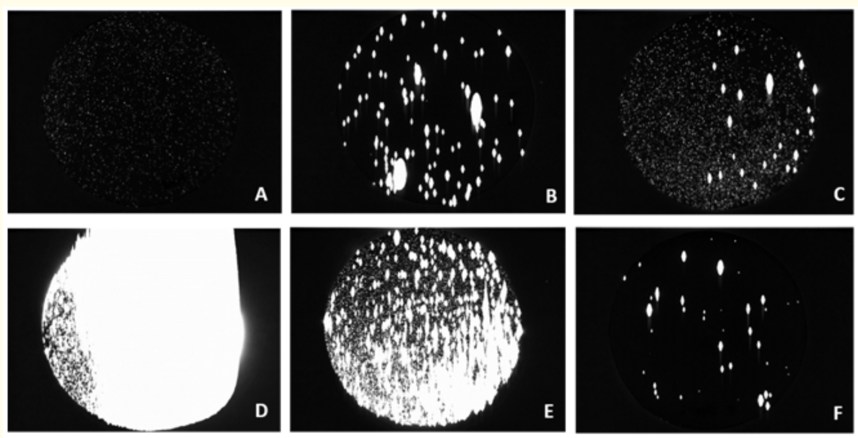

Figure 3: *Sample images of scanned paper discs placed on different areas during a scaling with no suction. A. Operator's Head; B. Patient's Chest; C. Operator's shoulder; D. Operator's abdomen; E. Operator's chest; F. Operator's left shoe.*

The size of the single droplets collected on the operator's head and mask appeared small and even ($p< 0.001$), while droplets shown on the operator's feet and the operator's chest, abdomen and the mannequin's chest were larger and irregular ($p < 0.001$). Droplets caught by the discs on the operator's shoulder appear as mix-sized. Figure 4 shows sample images of filter paper discs placed at different locations.

An extremely intense fluorescence signal on the disc placed on the operator's abdomen when no suction was applied, was above the instruments working limit, showing as saturated with artifact signal beyond the disc (Figure 5). The total size area could not be calculated by ImageJ. We replaced it with the highest number we obtained in the whole study which was 646229 pixels (labeled with * in table 1).

Discussion

Ultrasonic scaling produces more contamination than we can see

Ultrasonic scaling has been widely used in dental practice since the 1950s. Water from the dental unit keeps the metal tip from overheating, which prevents patient discomfort or tooth damage. Biofilm, calculus, saliva and blood from the patient's oral cavity mix with the water mist generated around the scaling tip and spread to the surroundings. Zemouri de Soet., *et al*. [16] reviewed bio-aerosols in dental environment in 2017. Nineteen bacterial species including pathogenic bacteria such as *Staphylococcus aureus, Legionella spp*, *Pseudomo-*

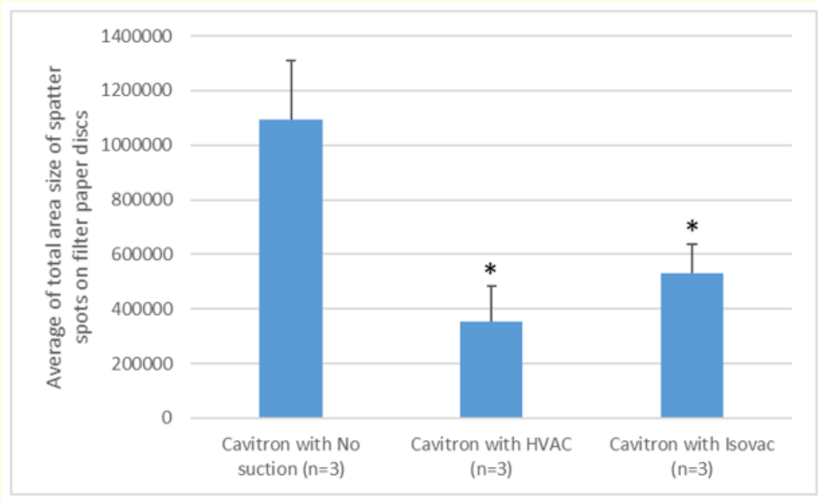

Figure 4: *Comparison of total area sizes of the fluorescence spatter spots collected on filter paper discs in Cavitron® scaling with different suction methods. (n = 3, *p < 0.05, One-Way ANOVA, Pairwise testing with Tukey's HSD when Cavitron® with HVAC and Cavitron® with Isovac® compared to the Cavitron® with no suction. However, there is no significant difference between using two different suctions in the same scaling procedures).*

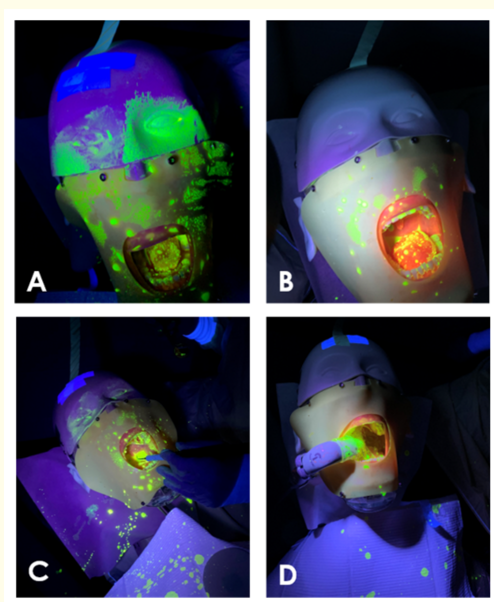

Figure 5: *Fluorescence contamination on mannequin face in different procedures. A and C. Cavitron® with no suction; B. Cavitron® with HVAC; D. Cavitron® with Isovac®.*

nas aureus and 23 fugal species had been measured in the aerosols produced by dental procedures. No viral species had been reported [16]. The reason of scarce study on viruses in dental aerosol could be the complexity of air sampling and virus detection. Due to virus's smaller sizes (0.06 - 0.14 micro) and clear evidence of respiratory transmission, it is very reasonable for dental care providers to maintain the vigilance to all the aerosol-generating procedures in the COVID-19 and other viral pandemics [7,17-19].

Heavy contamination on the mannequin's face, especially when no suction was applied (Figure 2) should raise a concern for patient protection during the scaling procedure. We often discuss PPE for the providers but this shows it is also important for the patient. Protective eyewear and hair cover are necessary to shield the patient from potentially transplanting microorganisms originated from oral cavity to eyes or other areas that could lead to secondary infections. Additionally, if they touch contaminated areas such as their ear or hair after the procedure it could lead to them transplanting their microorganisms onto other frequently contacted surface, thus potentially spreading them to subsequent individuals.

We applied GloGerm on mannequin's teeth to simulate the supragingival plaque in the oral cavity. Orange GloGerm particles deposited on the filter paper discs at different locations, mixed with the yellow fluorescence dye from the dental unit waterline (Figure 2). Even though GloGerm particles cannot substitute for the spreading microorganisms through the spatter due to its insoluble property, the trajectory of particles may be similar to the trajectory of microorganisms. When an ultrasonic scaler is used without any coolant water, potentially infectious material from patient's oral cavity will form a spray that can be ejected up to 18 inches from the scaler tip [20].

ADA Guidelines for COVID-19 state that dental health care providers should change from scrubs to personal clothing before returning home after working to help prevent infection [14]. CDC guidelines for environmental infection control in health-care facilities specified that scrubs should be washed on-site at the dental office, or may be laundered by the practice owner by a service of their choosing [21]. This study showed most of spatter (76 - 99%) fell on the chest and abdomen of the operator. While these parts on operator's body are usually covered by a protective gown, being aware of the high level of contamination in these areas could improve PPE doffing performance. Heavier fluorescence contamination was noticed on the gown that covers operator's lower body in the thigh areas (Indicated by white arrowhead in figure 2), but unfortunately, contamination was not measured for this area in the present study. Both the operator's and the assistant's shoes were contaminated. In the US, the common protective gown typically stops at knee level and shoe covers or knee high boot covers are rarely used. This could potentially leave the knees, calves, and shoes of the provider uncovered and become the most contaminated parts of the dental professional when they walk out of the clinic. Davidson measured and analyzed bacteria on the thigh areas of the dental students' clinic scrubs after a working day. The study indicated there is a potential risk of dental professionals' contaminated clothing to spread the microorganism from the patients to the community [22]. Despite that fomite transmission of SARS-Cov-2 virus becomes questionable with more studies conducted [23-26] and the positive evidence seems sporadic, dental care providers' clinic clothing could still be a likely source of transmission. This could indicate that longer gowns or knee high boot covers may provide more effective protection.

We analyzed the size difference of the droplets in difference locations, and observed that the larger droplets produced by the procedures are much more likely to soil the areas below the operation field than above, presumably due to the gravity force. However, we are not able to differentiate spatter and aerosol produced during scaling based on the size difference of these droplets collected on filter disc paper. Our assumption is that any droplet collected after the procedure should be aerosol that remains in the air, but we unfortunately failed to detect this in the present study.

HVE and Isovac® show different efficiency in spatter reduction

HVE is the most commonly used suction method in four-hand dentistry. HVE should be held by the assistant approximately 6 - 15 mm away from the active ultrasonic tip during the whole procedure. The power and airflow volume of the HVE need to be checked periodically. Low static measurement of vacuum pressure or clogged lines could both lead to low airflow reducing the efficiency of HVE to capture aerosol and spatter. A huge discrepancy in previous studies about the efficiency of HVE, from none to 90% [20,27-29], could be largely explained by different experimental settings and contamination measurement techniques. In our study, the dental student who assisted was not able to follow the scaler tip closely with the HVE in the areas like the buccal side of the posterior teeth causing more spatter ejected from the operation field to be missed. With training and practice, the assistant's suction technique became more consistent increasing contamination control. Our result shows HVE mitigated spatter contamination by 68% during a 15-minute full mouth scaling procedure, which better simulates the scenario in a regular periodontal prophylaxis than 10-minute duration [30] or localized restorative procedures [28,31] reported in other studies.

Isovac®, with no assistant involved, reduced spatter from the scaling procedure by 52%. However, the statistics doesn't support the hypothesis that Isovac® is less efficient than HVE at spatter control. Most of dental hygienists work by themselves, so Isovac® provides particular convenience to eliminate the droplets. Since its suction power sits between the maxillary and mandibular molars, Isovac® can efficiently remove the accumulated water in the posterior area of oral cavity instead of the spatter and aerosol generated from scaling, especially on the buccal side of the teeth.

While a number of new intra-oral or extra-oral suction products have flooded into the market during the pandemic, there has been limited study on their efficacy in mitigating the spatter or aerosol generated during procedures. Our technique could potentially become a screening tool to compare the new suction devices with the commonly-used devices such as HVE and Isovac®.

Novel investigational methodology is needed to measure aerosol and indicate more viability of SAR-CoV-2 transmission

Many investigational methods to study dental aerosol have been reported [7-9,12,19,32,33]. Microbial capture method may have more clinical relevance but the survival rates of the microorganism on the culture discs could possibly distort the truth of patterns and paths of spatter spread. Computational operating models endow great consistency in operator's behavior and accurate droplet capture and measurement, but it may not reflect the real-life clinical scenarios. We consider fluorescein as a low-cost, easy-to-use and highly efficient indicator of the droplets due to its good solubility, stability and detectability. We are the first using computerized scanning and imaging system to analyze the fluorescent droplets captured on the filter paper discs, therefore the accuracy and consistency was improved when compared to manual counting described in the other studies [28,31]. We think this experimental method can be quickly applied in any clinical setting thus each individual clinic or school program can test any desired suction method in their customized clinical environment. If our scanning and imaging method could be replaced by a simple digital program on desktops or an App on smart phones, the technique would be even more easily applicable.

Weakness of our technique included inability to capture aerosol 0 - 60 minutes after ultrasonic scaling. A similar technique used in Veena's study[11] detected few fluorescence spots during 0 - 30 minutes after scaling, but none during 30 - 60 minutes. Our inability to see aerosol could be that aerosol droplets are so small that they couldn't be detected by our scanning and imaging system. Identifying a new methodology to measure post-procedure aerosol will be important to evaluate possible cross contamination risk between patients and create specific guideline for air purification or disinfection in the dental working environment. Besides, the sonication of scaler and the irrigant used with it could affect the contents of the spatter and aerosol, so experiments with a live viral tracer or bacterial analog could better mimic the spreading of SARS-CoV-2 and help identify the magnitude of the proposed threat.

Conclusion

Ultrasonic scaling procedure produces spatter contamination more than our eyes can see. Use of personal protective equipment during aerosol-generating procedures needs to be reinforced in daily clinical practice especially during this pandemic. Ultrasonic scaling with high volume evacuator or Isovac® significantly reduce the spatter spread to the dental operatory including the operator's body and areas around patient's head. Newly-developed suction methods can be evaluated by comparing to these two commonly-used ones. New experimental techniques are needed to elucidate the physics of both the spatter and aerosol and to translate more to the transmission of air-borne diseases such as COVID-19 in the real-life dental scenario.

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