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Maximal Distance of Splatters and Droplets Projections Produced by Dental Air and Water-Cooled Instruments Around a Dental Chair in an Open-Plan Area

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Abstract

A dental chair and its environment can be contaminated with droplet/splatter and aerosol particles, which contain various pathogens, including SARS-Cov-2, that can be transmitted by contact or inhalation. We aimed to evaluate the maximal distance of droplet/splatter projections for four different air and water-cooled dental instruments using a patient simulator, to define the boundaries of the open-plan area contaminated immediately after treatment.

We used a dental chair unit placed in a room in the open-plan area. Fluorescent powder was added to water, to know the maximal distance reached by the droplet/splatter on the surfaces of the dental room covered with white sheets.

Dental care was performed in an artificial mouth using either an air turbine handpiece, a high-speed electric contra-angle, an ultrasonic scaler, or an air/powder polisher with a constant volume of colored water. Maximal distances of droplet/splatter projections were measured after identifying the fluorescent patterns on the surfaces. Calculated heights and angles were then used after normalization to know the maximal distance that could be reached by these projections.

In these conditions, the theoretical maximal distance of droplet/splatter projection was 295 cm for the air-powder polisher, followed by 238 cm for the high-speed electric contra-angle, 93 cm for the air turbine and 77 cm for the ultrasonic scaler.

Theoretical projections for the ultrasonic scaler did not go beyond the dental room.

In our open-plan area, droplet/splatter projections can extend beyond the dental room entrance, but not over 1.80 m-high partitions, and could contaminate areas located nearby. Simple preventive measures would be to limit the perimeter of these projections, for example by installing a door, in addition to measures to limit the scope of aerosols.

Keywords: Dental Instruments, Droplets, Splatters, Dentistry, Covid-19

Introduction

The dental division of the Lyon University Hospital (Hospices Civils de Lyon) provides oral treatments that are conducted mostly by dental students and residents under academic teachers' supervision. It is in a 6-floor building that possesses 84 dental care rooms the majority of which are distributed in four open-plan areas. Open rooms are separated only by man-height (1.80 m) lateral partitions and are opened (without any door) onto the corridor running the length of the open-plan area. At the beginning of the COVID-19 pandemic in March 2020, the organization of the dental division was greatly modified to limit the spread of the severe acute respiratory syndrome coronavirus 2 (SARSCoV-2) and infection transmission in populations. All scheduled care was cancelled, and only dental emergencies were dealt with in compliance with highest hygiene standards. The latter included extensive use of rubber dam and high-volume aspiration, since dental care performed with spray-using instruments such as air turbine handpieces, high-speed electric contra-angles, ultrasonic scalers, and air/powder polishers, results in the formation of droplet/splatter and aerosols that could be potential vehicles for transmission of viruses present in the oral cavity [1,2]. Understanding the spread distance of droplet/splatter and aerosols thus appears to be of major importance in open-plan areas to manage adequately the risk of transmission of SARS-Cov-2 in dental students' training structures [3].

Droplet/splatter and aerosols could contaminate the dental team or the patients once deposited on the exposed work surfaces [3]. In medicine, particles less than 5 micrometers in size are considered as aerosols,[3] beyond 5 micrometers, the terms "droplets" and "splatter" are used but without clear definition in terms of size between these[4,5] Aerosols can remain suspended in the air for hours and can deposit far away from the dental chair by being transported by airflow, the distance being greatly influenced by environmental factors such as air humidity and ventilation,[5] small aerosol particles can remain in suspension for long periods (up to 39 days for those less than 0.1 micrometers) [6] and can be transported over long distances (7 to 8 meters) [1,7,8] Conversely, droplets/splatters fall rapidly with a ballistic trajectory [1,5,9] Specifically for SARS-Cov-2 transmission, both aerosols and droplet/splatter are of concern as particles 5 micrometers or below in size can reach directly bronchioles and alveoli and larger ones are able to penetrate into the trachea and large intrathoracic airways[1,4,9]. The dispersion of aerosols in the context of SARS-Cov-2 pandemic has been extensively studied, [2,9] but there is little published data reporting the projection distances of droplet/splatter in open-plan areas during dental care. Llandro et al. studied this in relation to orthodontic debonding using a speed-increasing handpiece that was compared to an air turbine handpiece used for anterior crown preparation as a control [10] Holliday et al. did so for tooth reduction using an air turbine handpiece and different air flow suctions [11] However, these two studies do not reflect the full range of regularly used air-water-cooled dental instruments. Although the use of these instruments was avoided as much as possible during the lockdown period to prevent spray generation, the return to usual practice with the full range of instruments required not only knowledge of aerosol dispersion techniques but also that of the maximal distance of droplet/splatter projections to reduce the risk of SARS-Cov-2 transmission. We therefore developed an experimental protocol to assess this distance for the instruments the most commonly used in dental practice, in order to define the boundaries of the contaminated open-plan areas immediately after treatment.

Materials and Methods

Before the full recovery of hospital activity in September 2020, we used a dental room in the open-plan area situated at the second level of the dental division building of the Lyon University Hospital (Hospices Civils de Lyon, Lyon, France), before the start. The room had a surface of 2.65 m by 2.97 m (7.9 m2) and was surrounded by 1.80 m-high partitions. The opening to the corridor was 1.63 m-wide and was located on the left side behind patient's head (Figure 1), without any door. The dental chair unit (ADEC hybrid model 400/200, ADEC, Newberg, OR, USA) was located 0.8 m from the room entrance and was placed in the most horizontal position. It had an autonomous water tank that supplied all air-water-cooled instruments. Since fluorescein staining is a simple and proven method for visualizing projections such as droplet/splatter, [11,12] fluorescent powder (VISIO TECH, 15mg/L, VISIOSOL®, St Jean de Luz, France), a non-toxic and stain-free dye, was added to the water tank. The maximal distance reached by droplet/splatter was determined by identifying the fluorescent pattern on the surfaces of the dental room covered with white sheets (Figure 2). The pressures of air and water sprays were optimized with a 4-way manometer to limit heating of dental tissues, while avoiding unnecessary spray emissions (Figure 3). Dental care was performed for each instrument on the right maxillary central incisor of the artificial mouth (educational arch AG-3 DA with face mask P-6GM, Frasaco GmbH, Tettnang, Germany) of a patient simulator (P-6/5 TSE, Frasaco GmbH). The operator, who was the same for all experiments, stood on the right rear side of the patient's head to interfere as little as possible with the spray emissions. For each experiment, the position of the right maxillary central incisor was measured to know the distance between it and the sheet and between it and the ground. The working time varied from 7 to 15 minutes according to the air and water spray instrument tested, since we chose to use a constant volume (200 mL) of colored water to compare fluorescein stains from the emission area to the most distant projection area. The following instruments were tested, only once, on the dental chair unit: air turbine handpiece (TA98L, W&H Dentalwerk, Bürmoos GmbH, Bürmoos, Austria), high-speed electric contra-angle (Smax M95, NSK Nakanishi Inc, Tochigi, Japan), ultrasonic scaler (Newtron LED, F12609, V3 Satelec, Acteon group, Merignac, France) and air/powder polisher (Eco Pulimax polisher, Rumar Cedeira, Madrid, Spain). A low volume suction saliva ejector was used with each of them. Furthermore, we fixed a 43 cm-high wooden superstructure at the top of the partitions to increase partition height in order to evaluate whether droplet/splatter were projected over it and to cover the entrance with a sheet. Fluorescent stains on the sheets were visualized using an ultraviolet flashlight (Figure 4). The distance between the right maxillary central incisor and the furthest fluorescence stains was measured on the sheets with a tape measure. The angle of the projection corresponding to the stain the furthest from the right maxillary central incisor was calculated (Figure 5). To obtain comparable measurements between experiments and correct the discrepancies related to small position changes of the head simulator that could possibly occur during sheet changes, all measured distances were normalized by taking as a reference the shortest distance between the sheet placed at the entrance to the dental room and the right maxillary central incisor. Height projections were also normalized by taking as a reference the height of the tooth relative to the ground, to consider the changes made during the cleaning and repositioning operations of the head simulator between the experiments. The angle of projection was then used to calculate the normalized projection height. This distance was obtained by subtracting the height of the right maxillary central incisor, measured from the ground using a tape measure, to the height of the fluorescent stain. We simplified the trajectory calculation by assuming that droplet/splatter trajectories were straight. From these data, the maximal distance of the projections emitted by dental instruments if a sheet did not close the entrance of the room was extrapolated. In a second experiment conducted without the patient simulator, the maximal distance reached by droplet/splatter at 0 degrees was measured for each instrument, to consider, the characteristics of air resistance and dispersion of droplets, including the smallest. This measurement was made by placing each air-water-cooled dental instrument at the same height as the right central incisor and directing its spray horizontally (0°). In this condition, the distance of the maximal projection was measured. Then, using the projection angle calculated above and a ballistic trajectory calculation (theoretical maximum distance = height of the projection/cos (calculated angle)), the theoretical maximal distance of droplet/splatter projections outside the dental room was calculated by subtracting the maximal calculated distance from that measured between the instrument and the sheet placed at the entrance of the dental room. The maximal distance reached by the projections that deposit on the ground was also measured (Figure 6).

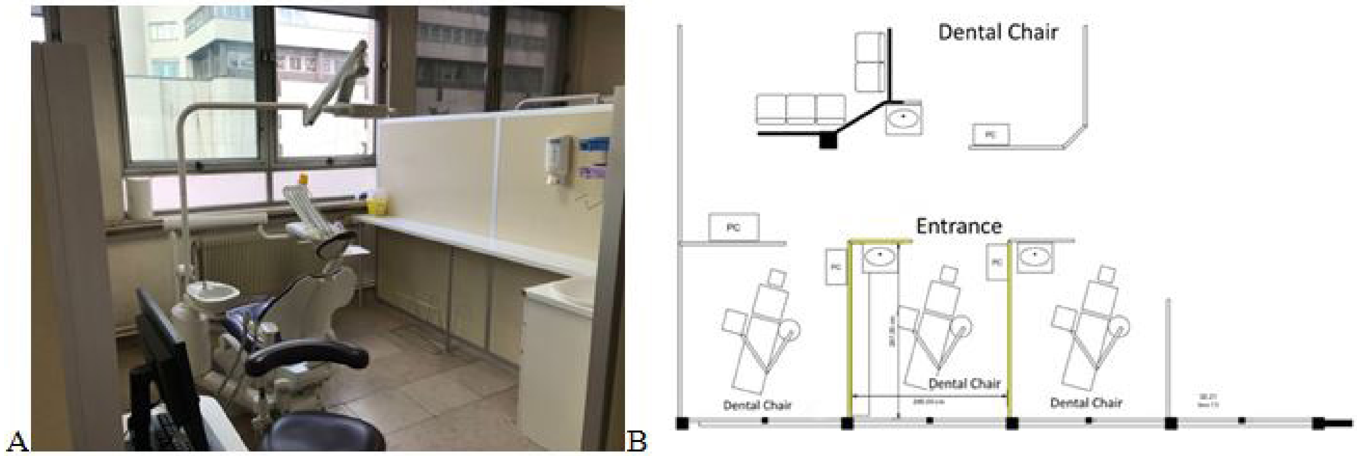

Figure 1: Dental room showing dental chair and partitions. A: view from the opening. B: map of the dental room

Figure 2: Patient simulator on the dental chair with sheets covering the floor and the partitions

Figure 3: Specific 4-way manometer. Top: air pressure going in the rotor (2.5 bar), Bottom: air pressure going out of the rotor (0.75 bar), Right: air pressure of the cooling spray (set to 1 bar), Left: water pressure of the cooling spray (set to 1 bar)

Figure 4: A: Ultraviolet flashlight. B: Fluorescent-stained aerosols on the sheet

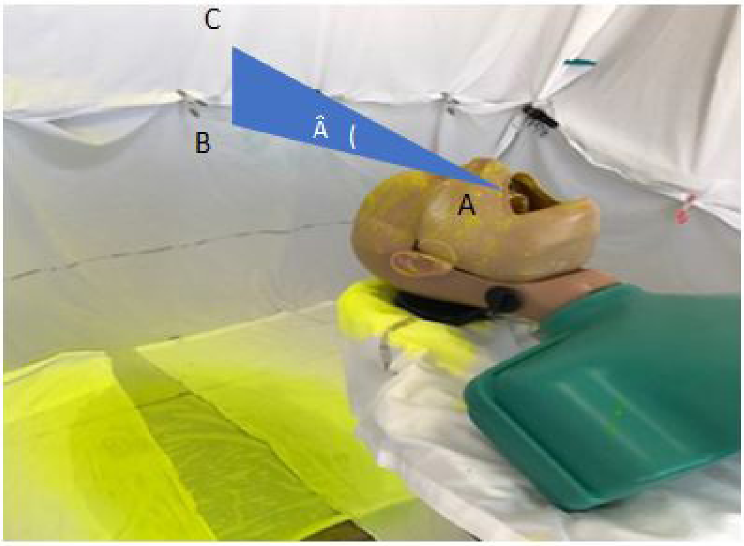

Figure 5: A represents the position of the right maxillary central incisor, B the sheet closing the entrance to the room and C the maximum height of the colored spots. The calculated angle Â was obtained by the following formula: tan Â = CB/AC, where AB is the distance between the central incisor and the sheet placed behind the patient simulator and BC is the height between the highest projection relative to the central incisor

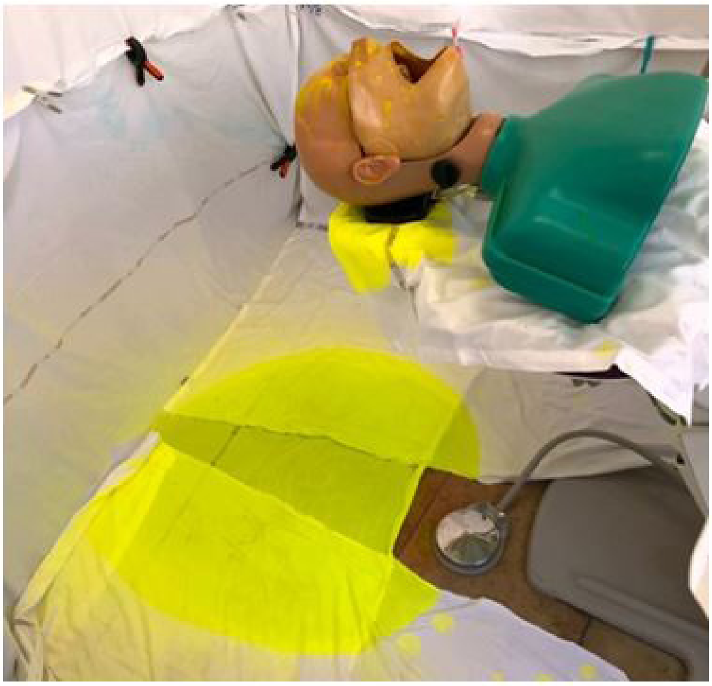

Figure 6: Patient simulator and ground surfaces sprayed after 15 minutes of ultrasonic scaler use

Results

For the air turbine, the maximal normalized projection height was 0.139m and the maximal normalized ground projection was 0.79m behind the patient (100% of the distance from the tooth to the vertical sheet). For the air-powder polisher, the maximal normalized projection height was 0.502m and the maximal normalized ground projection was 0.79m behind the patient (100% of the distance from the tooth to the vertical sheet). For the high-speed electric contra-angle, the maximal normalized projection height was 0.82m behind the patient and the maximal normalized ground projection was 0.66m behind the patient (84% of the distance from the tooth to the vertical sheet). For the ultrasonic scaler, the maximal normalized projection height was 0.632 m, and the maximal ground projection was 0.743m behind the patient (94% of the distance from the tooth to the vertical sheet, Table 1).

Air and water sprays instruments	Height of right central incisor position, cm **Normalized height (bold), cm**	Maximal projection height, cm **Normalized height (bold), cm**	Maximal distance between the right central incisor and the vertical sheet, cm **Normalized distance (bold), cm**	Maximal ground projection,in cm **Normalized distance (bold), cm (proportion of distance from the tooth to the vertical sheet)**	Calculated projection angle, in degrees
Air turbine	102.0 **97.0**	118.0 **13.9**	91.0 **79.0**	91.0 **79.0 (100%)**	10.0
High speed electric contra-angles	99.0 **97.0**	182.0 **82.0**	80.0 **79.0**	67.0 **66.4 (84%)**	46.1
Ultrasonic scaler	102 .0 **97.0**	34.0 **-63.2**	85.0 **79.0**	80.0 **74.3 (94%)**	-38.7
Air-powder polisher	97.0 **97.0**	149.5 **50.2**	84.0 **79.0**	84.0 **79.0 (100%)**	32.0

Caption: The maximal projection height is the vertical distance between the right central incisor and the highest fluorescence stains on the sheet. The maximal distance is the horizontal distance between the right maxillary central incisor and the furthest fluorescence stains. The maximal ground projection is the is the same as before, but on the sheet placed on the ground.

The angle of the projection is calculated using the vertical and the horizontal measurements. The normalization was made by taking as a reference the shortest distance.

Table 1: Most distant visible fluorescent stains on the sheets under different experimental conditions and calculated projection angles

Air and water sprays instruments	**Experimental maximal distance of droplet/splatter projections at zero degrees, cm**	**Theoretical maximal distance of droplet/splatter projections, cm**
Air turbine handpiece	92	93
High speed electric contra-angle	165	238
Ultrasonic scaler	60	77
Air-powder polisher	250	295

Caption: the maximal distance reached by droplet/splatter at 0 degrees is the measured distance when the nozzles, through which the spray comes out, are parallel to the ground. The theoretical maximum distance is the result of the projection angle calculated in table 1 and the measurements made at 0°.

Table 2: Maximum distance of droplet/splatter projections according to the instrument

At 0 degrees, the greatest of the maximal projection distances was found for the air-powder polisher (2.50 m), followed by the high-speed electric contra-angle (1.65 m), the air turbine (0.92 m) and the ultrasonic scaler (0.60 m, Table 2). According to these values and to the calculated projection angle (Table 1), the theoretical maximal distance of droplet/splatter projection was 2.95m for the air-powder polisher, followed by 2.38m for the high-speed electric contra-angle, 0.93m for the air turbine and 0.77m for the ultrasonic scaler (Table 2).

The theoretical distance of droplet/splatter projections beyond the dental room (i.e., through the entrance) was 2.11m for the air powder polisher, 1.58m for the high-speed electric contra-angle and 0.93m for the air turbine. Theoretical projections of the ultrasonic scaler did not go beyond the dental room (Table 3).

Air and water sprays instruments	Distance between the entrance of the dental room and the right central incisor, cm	Theoretical distance of droplet/splatter projections beyond the dental room, cm
Air turbine handpiece	91	2
High speed electric contra-angle	80	158
Ultrasonic scaler	85	0
Air-powder polisher	84	211

Caption: The theoretical distance of droplet/splatter projections outside the dental room (right column) is calculated by subtracting the maximal calculated distance from that measured between the instrument and the sheet placed at the entrance of the dental room (left column).

Table 3: Theoretical distances of droplet/splatter projections occurring outside the dental room

Discussion

The present study has shown that the droplet/splatter projections of the four dental instruments tested did not exceed the height of the partitions of the dental room, i.e., 1.80m. However, those of the air-powder polisher, high-speed contra-angle, and air turbine extended beyond the dental room through the entrance, potentially contaminating areas located nearby.

The measurements were carried out immediately after the use of the instruments since the present study focused on droplet/splatter which fall to the ground quickly. Droplet/splatter have a trajectory close to a ballistic trajectory. Conversely, particles smaller than 5 micrometers fall to the ground very slowly and have a trajectory difficult to calculate [12] They may deposit beyond the areas affected by droplet/splatter in case of horizontal ventilation flow [9] If the usual precautions concerning the ventilation of the dental room are respected, this aerosol should be quickly dispersed [3,13] and therefore the maximal projection distances of droplet/splatter should define the boundaries of the contaminated area. In addition, the characteristics of the spray are different according to the instrument, as indicated by the difference in the maximal projections on the ground of the high-speed contra-angle and the air-polisher. This could be due to the internal structure of the instruments since the diameter of the pipes, the number of air and water outlet nozzles, their orientations, and their diameter, are likely to influence the initial velocity of the emitted spray [14]. This has been considered by the measured projections at 0 degrees.

In the context of SARS-CoV-2, it is recommended to use a rubber dam, [3,13,15] but for full crown preparation this is not always possible, especially in case of sub-gingival margins [16] Furthermore, a low-volume saliva ejector was chosen instead of the recommended high-flow suction because this corresponds to the usual practice of dental students, particularly in the context of tooth preparation. It is of note that Holliday et al. found that even low-volume suction confers a substantial benefit on the reduction of projections, especially of distant projections emitted by air turbine handpieces[11] However, for ultrasonic scaling, saliva ejector was not found to reduce significantly aerosol and droplet/splatter projections[17] Interestingly, despite these conditions, the theoretical maximal projections were smaller than that found in other studies, Shahdad et al. reported 1.33 m for the air turbine[18], and Llandro et al. reported 1 m for the air-turbine during anterior crown preparation[10] As regards the height of the projections, they are also lower for the air-turbine than those of the Holliday et al. study[11]. This could be due to the optimization of air and water pressures that has probably a direct impact on the distance of droplet/splatter projections since they modify their initial velocity [14]

The present study has some limitations. Only one experiment was carried out for each instrument, which makes the measurements only descriptive, but this is likely to be of limited importance as the variability of distances reported previously [11,18] is low, and the initial pressures of water and air were precisely controlled. Another point is the ballistic trajectory assumption used for the theoretical calculation of the trajectory of droplet/splatter projections. In addition, although the characteristics of the spray trajectories for each instrument were taken into consideration by measuring the angle at 0 degrees, the maximal theoretical distance of the projections was obtained by associating theoretical calculation and measured data.

Conclusions

In our open-plan areas droplet/splatter projections can extend beyond the dental room entrance and could thus contaminate areas located nearby. The present study found that the 1.80m-high partitions of the dental rooms used for training in our dental hospital are sufficient to prevent droplet/splatter projections between two adjacent rooms but can extend beyond the dental room entrance and could contaminate areas located nearby. Simple preventive measure would be to limit the perimeter of these projections by placing physical obstacles to close the room without forgetting the recommended measures to disperse aerosols after using dental air and water-cooled instruments.

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Declarations

Not applicable

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Conflict of Interest

None

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