# Evaluation of the efficiency of source control for the capture of aerosols generated by dental care

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**Abstract.** Among medical practices, dentistry is particularly exposed to any aerosol transmissible diseases due to the close proximity of dentists and health staff to the patient's mouth. Dental procedures involve operations that generate saliva, dental plaque and blood aerosols, which are vectors for infectious agents. These vectors may directly reach the health staff, be suspended in the room or deposit on surfaces, which could lead to contamination of both the personnel and following patients. Collective protection measures exist to reduce the risk of exposure, like the capture at the source using suction systems and air change rate in the treatment room using general ventilation. This study aimed to assess the effectiveness of the source aerosol mitigation measures for one of the most common dental operations, drilling. Aerosols were generated, by means of a manikin head mounted on a dental unit, using a speed-increasing contra-angle handpiece in two-handed dentistry setup. A saliva ejector (SE) and a high-volume evacuator (HVE) were used as aerosol mitigation measures. Aerosol concentrations were measured using a light-scattering aerosol spectrometer system. Results are analysed in terms of aerosol mitigation using SE or HVE for all dental operations. These results will help improve biological safety in dental offices.

## 1 Introduction

The recent coronavirus pandemic has once again highlighted the medical profession's sensitivity to disease transmission. Considering its transmission routes, WHO indicated that "COVID-19 spreads between people through […] contact with infected people via mouth and nose secretions. That includes saliva, respiratory secretions, or secretion droplets." Among medical practices, dentistry is particularly at risk because of the close proximity between the practitioner, the health staff and the patient's mouth, making them exposed to this disease and, more generally, every disease being transmitted the same way.

The main concern comes from aerosol-generating procedures (AGPs), which are defined as "medical or dental procedures that result in the production of respirable airborne particles" [1]. According to the comparative review of Innes et al. (2021), the highest levels of contamination during AGPs were met using ultrasonic scalers, highspeed air-rotors, air polishers or air-water syringes [2]. The visible mist formed by these procedures consists of droplets that tend to settle on nearby surfaces and aerosols that can remain in suspension for long periods. The hazard of these particles is relative to their size: the smaller the particle, the longer it will remain suspended and the deeper it can penetrate the respiratory system [3]. Additionally, both droplets and aerosols may contain respiratory pathogens that could spread to the health staff or the following patients [2, 4].

Multiple management methods exist to limit the risk of contamination from aerosol particles. The most commonly recommended after the COVID-19 outbreak included personal protective equipment, preprocedural mitigation, environmental mitigation and the implementation of a fallow period [5]. Apart from these methods, source controls remain the most efficient means for aerosol mitigation by directly limiting their dispersion outside of the mouth. For this, saliva ejectors (SE) and high-volume evacuators (HVE) may be found in most dental units. While no recent studies measured the impact of modern SE alone, they heavily contribute to the reduction of saliva in the mouth. Field observations prior to this study also shown that SE were often used as the only source control, which was never considered by previous studies. On the other hand, the efficiency of HVE or SE+HVE were proven to reduce the concentration of particles up to 98% for most dental cares [6]. However, considerable disparities of efficiencies may be found within the literature, and the wide variety of methods and configurations used as well as the absence of comparative study of aerosol generation data makes it difficult to draw conclusion relative to AGPs.

This study aimed to determine the effectiveness of different source capture solution (SE or HVE) for drilling using speed-increasing contra-angle handpiece, expected to be one of the most AGP.

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## 2 Material and methods

### 2.1 Experimental setup

Simulated dental procedures were carried out in a cubicle equivalent to a single-patient dental clinic room of 5 m wide by 4 m deep and a ceiling height of 3 m (volume: 60 $m^3$). The room was equipped with a dental simulation unit (KaVo DSE Expert), consisting of a manikin head and a dental unit. The patient simulator head used basic KaVo model teeth. Standard tools commonly used by general practitioners were present on the dental unit.

This study focused on drilling and employed a red speed-increasing contra-angle handpiece KaVo EXPERTmatic E25L, at its maximum speed of 200,000 rpm (drive speed: 40,000 rpm; transmission speed 1:5) and with a water spray cooling of 21.6 ml/min. The contra-angle handpiece was mounted by a Meisinger round diamond bur. Source control was employed with a SE (suction performance: 40 l/min) or a HVE (suction performance: 230 l/min), both were used in the same standardised manner.

### 2.2 Experimental procedure

The risk posed by drilling was assessed by mock procedures on the dental simulation unit, performed by a postgraduate dentist in a two-handed dentistry setup, with the aerosol size and concentration measured.

The practitioner was placed at 12 o'clock relative to the patient head, which was adjust at a fixed position. The mouth was divided into sextants (Fig. 1) and a random tooth was chosen for each segment, assuming a low variability within the teeth of a segment. The resultant chosen teeth were the 12, 16, 26, 31, 36 and 46 according to the dental numbering system. Three faces were tested for drilling: facial (F; facing outwards from the mouth), occlusal (O; biting edge) and lingual (L; facing the tongue or palate).

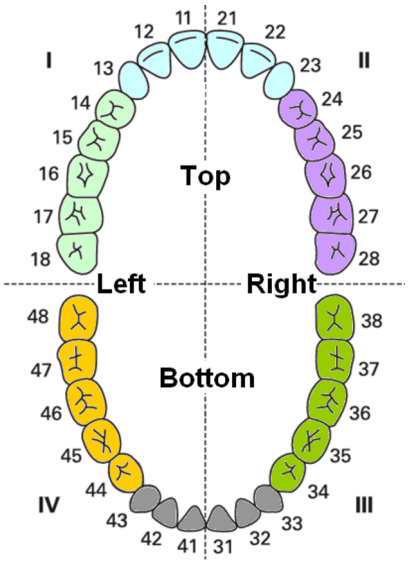


**Fig. 1.** Chart of the tooth numbering. The colours represent the sextants division of the mouth.

The drilling procedure was standardized according to the treatment process for caries on sites 1, 3 and stage 4 as classified by Mount and Hume (1997), representing the worst-case scenario and the most drilling-intensive operation for caries care [7]. Drilling was done perpendicularly to the surface tested. Procedures were carried out in triplicate without source control, with SE or with HVE. Both SE or HVE were used as source control device by placing them next to the treated area.

Particle size analysis and concentration determination were obtained using the PALAS Promo® 2000 light-scattering aerosol spectrometer. The sensor of the aerosol spectrometer was used with a measuring range of 2 to 100 µm in diameter. It was positioned vertically, 10 cm above the mouth, as shown by Fig. 2. Measurements were taken with a time-step of 1 s, looking at the concentration in number $C_n$ (#/$cm^3$) and in mass $C_m$ (mg/$cm^3$).

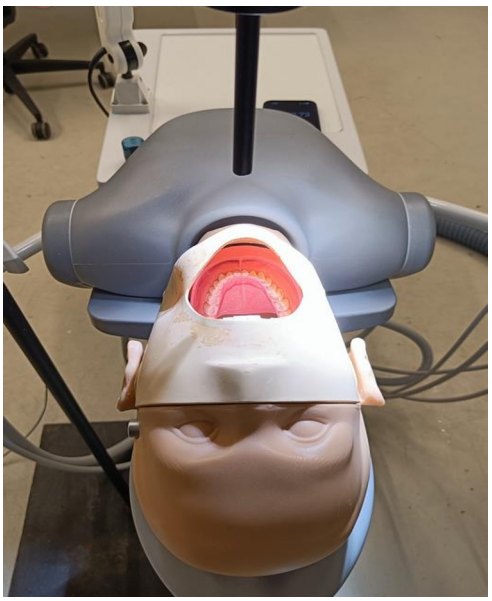

**Fig. 2.** Manikin head with the sensor of the aerosol spectrometer positioned above the mouth.

To assess the aerosol risk, each drilling operation was performed for 30 s. A fallow period was respected to ensure a return to nominal concentrations within the room. For this, general ventilation was provided by an air-handling unit, which distributed air throughout the room via fabric ducts (as shown on Fig. 3), supplied at an air change rate of 1 $h^{-1}$.

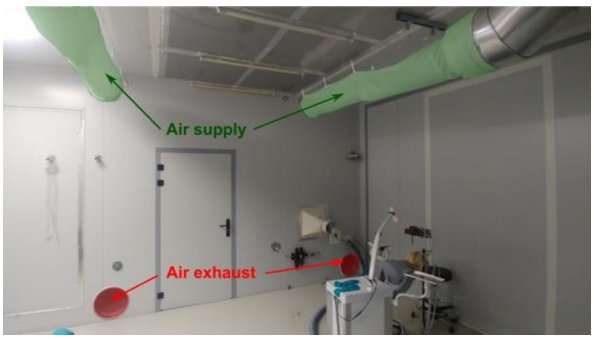


**Fig. 3.** Positioning of the air supply through fabric ducts and the air exhausts.

### 2.3 Data processing

Aerosol data were extracted for both number and mass concentration. The mean value was calculated as the average concentration over the three repetitions of the 30 s experiments. Standard deviation (SD) was also calculated as the variation between the repetitions.

The reduction rates $R$ (Eq. 1) of number and mass aerosol concentrations were calculated as the difference between the mean aerosol concentration without $\overline{C_W}$ and with the use of source control $\overline{C_{SC}}$, normalized by the value without source control.

$$R\ (\%) = \frac{\overline{C_W} - \overline{C_{SC}}}{\overline{C_W}} \quad (1)$$

## 3 Results and discussion

Table 1 and Table 2 list the aerosols number and mass concentration 10 cm from the mouth during the drilling, respectively. The three faces of the teeth drilled are facial (F), occlusal (O) and lingual (L). Both the mean value for the three repeated tests for each situation and the standard deviation (SD) are displayed for the three mitigation situations, namely no mitigation, SE and HVE.

Table 3 shows the reduction of aerosols concentration resulting from the use of either suction instruments, compared to a situation where no mitigation solution is used.

Suction efficiency varies greatly when SE is used, as it ranges from 34 % to 100 % (mean: 94.6 %) using number concentration and from 3 % to 100 % (mean: 84.4 %) using mass concentration. Using the HVE as a suction instrument, the suction efficiency is very close to 100 %, considering either the number concentration or the mass concentration as the criterion to define efficiency.

**Table 1.** Aerosols number concentration 10 cm from the mouth during the drilling.

| Tooth | Face | $C_n$ (#/cm$^3$) | | | | | |
|---|---|---|---|---|---|---|---|
| | | No mitigation | | SE | | HVE | |
| | | Mean | SD | Mean | SD | Mean | SD |
| 12 | F | 82.7 | 4.3 | 6.0 | 5.6 | 0.1 | 0.1 |
| | O | 213.4 | 122.2 | 7.7 | 3.4 | 0.1 | 0.0 |
| | L | 164.9 | 19.6 | 14.4 | 12.9 | 0.1 | 0.1 |
| 16 | F | 461.1 | 251.6 | 8.9 | 13.4 | 0.1 | 0.1 |
| | O | 116.0 | 89.8 | 20.3 | 14.9 | 0.0 | 0.0 |
| | L | 246.7 | 296.3 | 0.5 | 0.4 | 0.1 | 0.0 |
| 26 | F | 125.7 | 167.1 | 16.9 | 11.3 | 0.2 | 0.1 |
| | O | 122.4 | 56.7 | 28.1 | 24.8 | 0.1 | 0.0 |
| | L | 363.4 | 246.7 | 23.7 | 29.8 | 0.1 | 0.1 |
| 31 | F | 111.5 | 82.9 | 0.7 | 0.4 | 0.1 | 0.1 |
| | O | 161.9 | 140.3 | 0.3 | 0.2 | 0.0 | 0.0 |
| | L | 419.0 | 435.6 | 21.6 | 20.5 | 0.1 | 0.1 |
| 36 | F | 148.3 | 95.1 | 0.4 | 0.1 | 0.1 | 0.0 |
| | O | 206.7 | 79.0 | 25.5 | 8.0 | 0.1 | 0.1 |
| | L | 316.4 | 217.4 | 2.5 | 3.9 | 0.1 | 0.0 |
| 46 | F | 420.0 | 290.8 | 3.4 | 2.1 | 0.1 | 0.1 |
| | O | 68.9 | 24.9 | 45.5 | 59.2 | 0.1 | 0.0 |
| | L | 462.0 | 263.9 | 0.3 | 0.1 | 0.1 | 0.1 |

Only one test leads to a reduction of aerosols number concentration lower than 77 %. Further tests will be carried out for this specific face (46-O) to ensure this is no peculiar result from very specific test conditions.

The reduction of number concentration being higher than the reduction of mass concentration using the SE and the reduction of both concentrations being significantly lower than the suction efficiency of the HVE both highlight the lack of suction power from the SE to limit the concentration of aerosols near the respiratory tract of the practitioner.

**Table 2.** Aerosols mass concentration 10 cm from the mouth during the drilling.

| Tooth | Face | $C_m$ (mg/cm$^3$) | | | | | |
|---|---|---|---|---|---|---|---|
| | | No mitigation | | SE | | HVE | |
| | | Mean | SD | Mean | SD | Mean | SD |
| 12 | F | 27.7 | 12.0 | 20.5 | 23.0 | 0.0 | 0.0 |
| | O | 65.6 | 44.7 | 2.5 | 1.8 | 0.0 | 0.0 |
| | L | 117.9 | 49.4 | 21.1 | 12.0 | 0.0 | 0.0 |
| 16 | F | 164.2 | 91.9 | 3.5 | 5.6 | 0.0 | 0.0 |
| | O | 39.7 | 25.8 | 38.5 | 24.7 | 0.0 | 0.0 |
| | L | 34.0 | 33.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 26 | F | 49.8 | 56.0 | 13.1 | 8.4 | 0.1 | 0.1 |
| | O | 65.4 | 72.7 | 11.9 | 7.3 | 0.0 | 0.0 |
| | L | 252.8 | 121.2 | 16.1 | 24.9 | 0.0 | 0.0 |
| 31 | F | 31.7 | 25.4 | 0.3 | 0.4 | 0.0 | 0.0 |
| | O | 114.9 | 73.4 | 0.2 | 0.2 | 0.0 | 0.0 |
| | L | 179.0 | 179.3 | 11.8 | 12.0 | 0.0 | 0.0 |
| 36 | F | 78.8 | 40.0 | 0.4 | 0.3 | 0.0 | 0.0 |
| | O | 145.9 | 108.2 | 23.6 | 17.2 | 0.0 | 0.0 |
| | L | 112.7 | 94.1 | 6.8 | 10.8 | 0.0 | 0.0 |
| 46 | F | 49.2 | 27.4 | 1.0 | 0.6 | 0.0 | 0.0 |
| | O | 74.6 | 55.0 | 43.5 | 43.0 | 0.0 | 0.0 |
| | L | 101.2 | 72.3 | 0.1 | 0.1 | 0.0 | 0.0 |

**Table 3.** Reduction rate of aerosols concentration 10 cm from the mouth during the drilling by using suction instruments.

| Tooth | Face | $C_n$ (#/cm$^3$) | | $C_m$ (mg/cm$^3$) | |
|---|---|---|---|---|---|
| | | SE | HVE | SE | HVE |
| 12 | F | -92,7% | -99,8% | -25,7% | -100,0% |
| | O | -96,4% | -100,0% | -96,1% | -100,0% |
| | L | -91,3% | -99,9% | -82,1% | -100,0% |
| 16 | F | -98,1% | -100,0% | -97,9% | -100,0% |
| | O | -82,5% | -100,0% | -2,9% | -100,0% |
| | L | -99,8% | -100,0% | -99,9% | -100,0% |
| 26 | F | -86,6% | -99,9% | -73,6% | -99,9% |
| | O | -77,1% | -100,0% | -81,9% | -100,0% |
| | L | -93,5% | -100,0% | -93,7% | -100,0% |
| 31 | F | -99,4% | -99,9% | -99,2% | -100,0% |
| | O | -99,8% | -100,0% | -99,8% | -100,0% |
| | L | -94,8% | -100,0% | -93,4% | -100,0% |
| 36 | F | -99,7% | -100,0% | -99,6% | -100,0% |
| | O | -87,6% | -99,9% | -83,8% | -100,0% |
| | L | -99,2% | -100,0% | -94,0% | -100,0% |
| 46 | F | -99,2% | -100,0% | -97,9% | -100,0% |
| | O | -34,0% | -99,9% | -41,7% | -100,0% |
| | L | -99,9% | -100,0% | -99,9% | -100,0% |

The following tables (Table 4 and 5) present the diameters d10, d50 and d90 for both number and mass particle size distributions when either the SE or no mitigation was used.

During the tests using the HVE and a few tests with the SE, $C_n$ was lower than 1 #/cm$^3$. In these cases, there was not enough data to establish a relevant distribution. This means that the suction devices were efficient for the whole range of particle sizes during these tests.

**Table 4.** Number particle size distributions during the drilling. BLQ indicates the diameters below the limit of quantification of 2 µm.

| Tooth | Face | No mitigation | | | SE | | |
|---|---|---|---|---|---|---|---|
| | | $d10_n$ (µm) | $d50_n$ (µm) | $d90_n$ (µm) | $d10_n$ (µm) | $d50_n$ (µm) | $d90_n$ (µm) |
| 12 | F | 2.16 | 4.90 | 10.2 | 6.49 | 9.43 | 14.8 |
| | O | BLQ | 3.36 | 6.97 | 2.11 | 3.27 | 8.37 |
| | L | 2.19 | 4.92 | 12.1 | 3.19 | 7.12 | 14.8 |
| 16 | F | BLQ | 3.79 | 8.74 | 3.04 | 3.99 | 8.79 |
| | O | BLQ | 3.66 | 8.65 | 2.11 | 4.58 | 12.2 |
| | L | BLQ | 2.68 | 6.73 | N/A | N/A | N/A |
| 26 | F | BLQ | 3.92 | 10.6 | 2.12 | 4.18 | 12.0 |
| | O | BLQ | 3.55 | 8.99 | BLQ | 3.40 | 10.0 |
| | L | 2.02 | 4.73 | 11.4 | 2.21 | 4.19 | 8.41 |
| 31 | F | BLQ | 3.75 | 8.72 | N/A | N/A | N/A |
| | O | BLQ | 4.07 | 10.0 | N/A | N/A | N/A |
| | L | 2.31 | 4.93 | 12.6 | 3.05 | 3.05 | 10.7 |
| 36 | F | 2.01 | 4.19 | 10.9 | N/A | N/A | N/A |
| | O | BLQ | 3.52 | 8.99 | BLQ | BLQ | 9.46 |
| | L | BLQ | 3.64 | 9.09 | 2.10 | 2.10 | 10.9 |
| 46 | F | BLQ | 3.23 | 6.96 | 2.54 | 2.54 | 9.18 |
| | O | BLQ | 3.98 | 10.1 | BLQ | BLQ | 9.32 |
| | L | BLQ | 3.59 | 7.89 | N/A | N/A | N/A |

**Table 5.** Mass particle size distributions during the drilling. BLQ indicates the diameters below the limit of quantification of 2 µm.

| Tooth | Face | No mitigation | | | SE | | |
|---|---|---|---|---|---|---|---|
| | | $d10_m$ (µm) | $d50_m$ (µm) | $d90_m$ (µm) | $d10_m$ (µm) | $d50_m$ (µm) | $d90_m$ (µm) |
| 12 | F | 9.57 | 23.2 | 28.9 | 40.1 | 46.0 | 48.8 |
| | O | 19.8 | 39.8 | 45.2 | 18.8 | 21.6 | 22.5 |
| | L | 11.7 | 38.6 | 48.4 | 32.6 | 40.4 | 44.2 |
| 16 | F | 13.3 | 38.5 | 49.0 | 11.5 | 18.1 | 19.4 |
| | O | 22.4 | 38.0 | 41.2 | 44.4 | 65.4 | 69.1 |
| | L | 11.0 | 20.8 | 29.1 | N/A | N/A | N/A |
| 26 | F | 23.1 | 34.0 | 39.3 | 35.6 | 43.3 | 47.3 |
| | O | 24.6 | 36.8 | 42.3 | 27.0 | 34.6 | 35.5 |
| | L | 26.0 | 46.7 | 58.2 | 24.5 | 27.7 | 29.7 |
| 31 | F | 21.9 | 31.3 | 36.2 | N/A | N/A | N/A |
| | O | 46.6 | 59.9 | 66.5 | N/A | N/A | N/A |
| | L | 23.1 | 34.8 | 45.3 | 8.21 | 17.3 | 27.2 |
| 36 | F | 18.9 | 40.0 | 49.0 | N/A | N/A | N/A |
| | O | 25.1 | 54.4 | 60.0 | 27.7 | 46.5 | 49.0 |
| | L | 8.77 | 29.7 | 40.3 | 52.8 | 54.5 | 56.1 |
| 46 | F | 6.14 | 17.1 | 26.1 | 10.5 | 16.6 | 17.4 |
| | O | 30.5 | 45.8 | 50.3 | 34.7 | 45.0 | 47.8 |
| | L | 7.96 | 22.9 | 36.7 | N/A | N/A | N/A |

The next figure shows the results from Table 4 and Table 5 as averaged over every faces of every teeth.

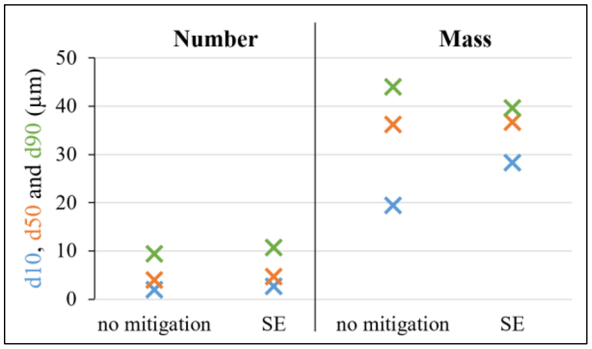


**Fig. 4.** d10, d50 and d90 for both number (left) and mass (right) particle size distributions when either the SE or no mitigation was used.

The slight increase of d10 for both number and mass particle size distributions could be attributed to a better efficiency of the SE for smaller particles, even though it can be considered efficient over the whole range as detailed before.

## 4 Conclusion

In this work, the effectiveness of source control was assessed for drilling, an aerosol-generating procedure commonly performed by general practitioners in dentistry. Source controls were proven to be highly effective in aerosol capture. This study also showed that SE alone already enabled a significant reduction in concentration.

More dental procedures will be investigated with the same means and purposes, namely ultrasonic scaling, air polishing and the use of air-water syringe. Where standard deviation is too high, tests will be further repeated. The reduction of aerosols concentration within the room due to general ventilation will be evaluated in a second phase of the study. More tests will be carried using the SE to differentiate situations where the practitioner actively manipulates it and situations where it stays still within the mouth during the procedures.

Results are expected to give leads to propose recommendations regarding both local and general ventilation for dental practices.

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