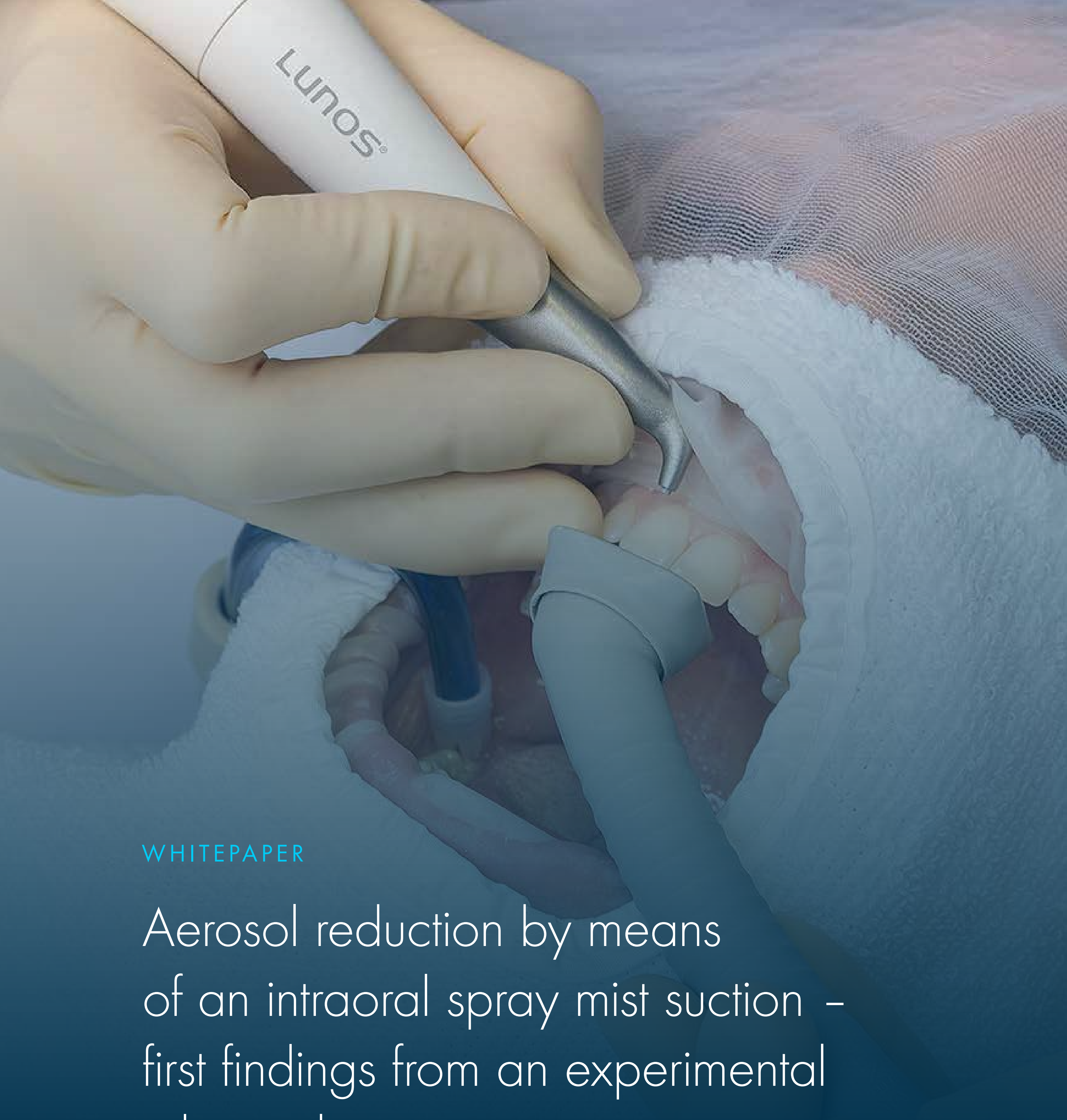

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Aerosol reduction by means of an intraoral spray mist suction – first findings from an experimental pilot study

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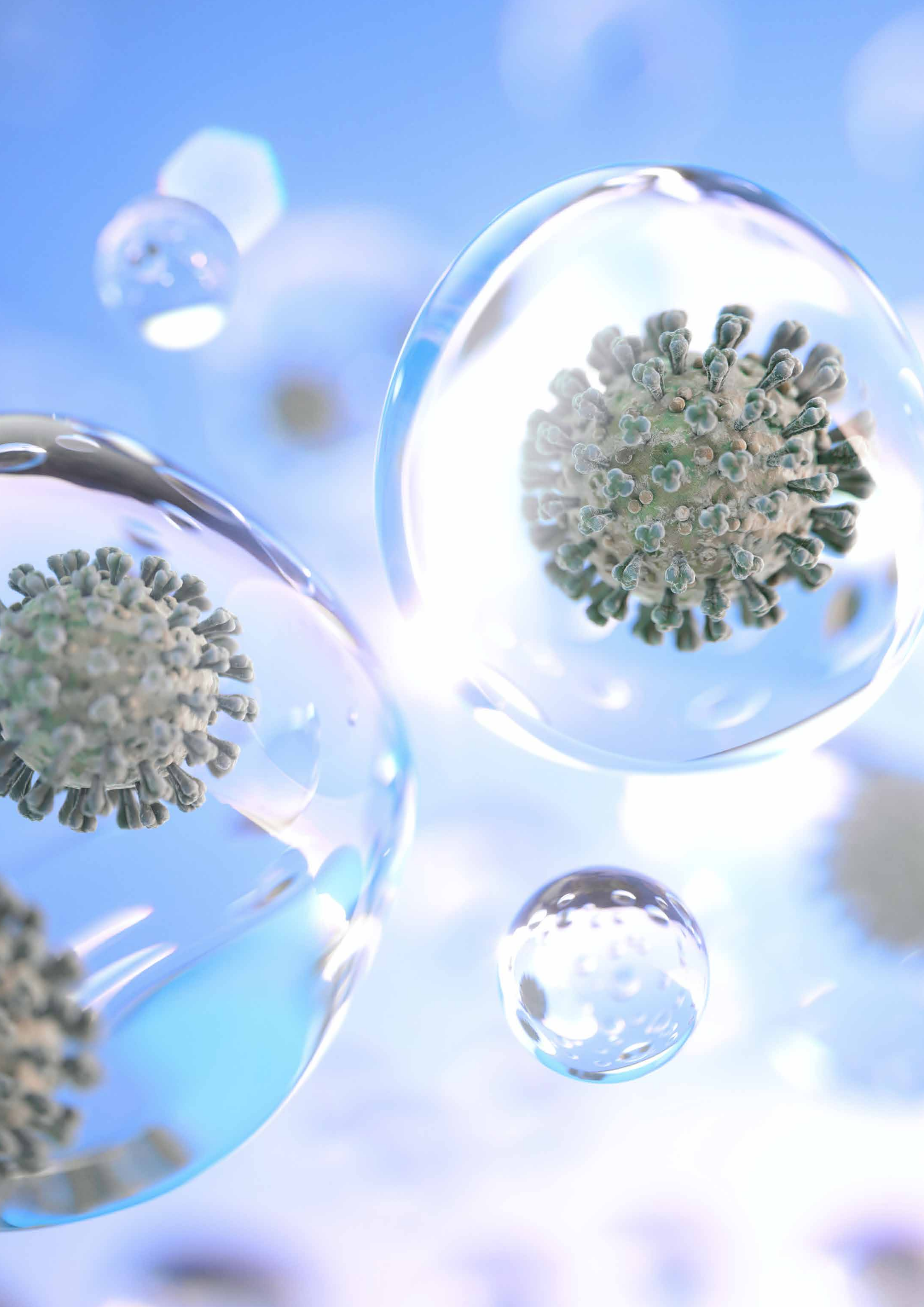


Aerosol reduction by means of an intraoral spray mist suction – first findings from an experimental pilot study

1 Introduction

To the best of our current knowledge, SARS-CoV2 is transmitted primarily through aerosols and droplets. Aerosols are defined as suspensions of solid or liquid particles in a gas, such particles having a diameter of less than 5 µm. Particles larger than 5 µm are described as droplets. In practice, however, the transition is a gradual one since the process of evaporation can turn droplets into aerosols. In the examination that follows, the term „particle" is therefore used for both size groups.

Dental personnel are more exposed to infection through aerosols and droplets. Aerosols and droplets are produced when dental instruments are used during treatment. Various rotating instruments (turbines, straight and contra-angle hand pieces) and ultrasonic instruments (scalers) are cooled by water. A cooling jet hits the surface of the tooth at high speed and rebounds as spray mist. Spray mist is also produced by powder jet instruments. A powder-water mixture is blasted onto the surface of the tooth using compressed air, and then rebounds.

Dental aerosol, produced on the surface of the tooth as the cooling jet rebounds when a turbine is used.

As well as water and solid particles, the spray mist also contains potentially infectious agents in the patients blood and saliva. The infection potential of these dental aerosols has been described and supported in technical literature many times. From the evidence available, transmission of SARS-CoV2 through dental aerosols and droplets cannot be ruled out.

As early as 1971, Davis et al. (Br. Dent. J, 130, 483), showed that a better aerosol reduction can be achieved using intraoral suction at a high flow rate (300 l/min) and a low vacuum than at a low flow rate. In Europe, this suction philosophy (high flow rate at low vacuum) has become the accepted gold standard. In many other countries, procedures are still performed using low flow rates (e.g. saliva ejector) and a high vacuum.

From a risk minimisation perspective, it must be possible to precisely measure the performance of dental intraoral suction solutions. This pilot study therefore examined the efficiency of intraoral suction relating to a reduction in the number of particles leaving the mouth.

The following methodical steps were taken:

1. Characterisation of particle emission without intraoral suction and optimisation of the examination setup
2. Influence of the suction system on particle reduction
3. Influence of the suction system on suction power (flow rate)
4. Influence of the flow rate on particle reduction
5. Influence of the suction position on particle reduction

Again from a risk minimisation perspective, a sub-optimal intraoral suction technique at a distance of 5 cm from the preparation point was selected for examinations 2 and 4.

2 Methodology

In this study, an imaging process (so-called shadow imaging) was used for the quantitative determination of particle emissions in an in-vitro model (mannequin). The particle emissions were compared during preparation with a turbine (Super-Torque LUX 3 650 B (KaVo), 400,000 rpm, 58 ml/min water) by using various intraoral suction solutions. The suction power, the hose diameter, the suction system and the suction position were altered. A powerful spray mist suction system (model Variosuc, Dürr Dental, max. flow rate 370 l/min) and a Venturi system (Belmont) were employed as the suction system. The suction power (flow rate) was controlled by means of a slide on the suction handpiece. Moreover, various suction cannula (saliva ejector (Henry Schein), universal cannula Protect (Dürr Dental), universal cannula Petito (Dürr Dental), aerosol cannula (Dürr Dental)) and suction handpiece (large suction handpiece (Dürr Dental), small suction handpiece (Dürr Dental), stainless steel handpiece (A-dec)) were used. The flow rate (l/min) was measured at the cannula using a float volume flowmeter (ROTA G 4.4000 SW=N4 10x).

The particle emission was measured by the shadow imaging technique (ParticleMaster, Lavision) with pulsed background lighting (image frequency 12.95 Hz, pulse duration of the light source: 0.4 µs, shooting method: Double frame mode with an exposure time of 42 µs; interval between 2 images: 10 µs). Each measurement involved analysing 127 single images (measurement time 10 s) using the DaVis software solution (Lavision, Version 10.1.1.60438) in a frame of 6.6 x 5.3 x 1.1 mm. Particles larger than 50 µm were not included in the analysis because, as large drops, they fall rapidly and are of little significance for the transmission of infection through droplets and aerosols.

> ” In this study, an imaging process (so-called shadow imaging) was used for the quantitative determination of particle emissions in an in-vitro model (mannequin) “

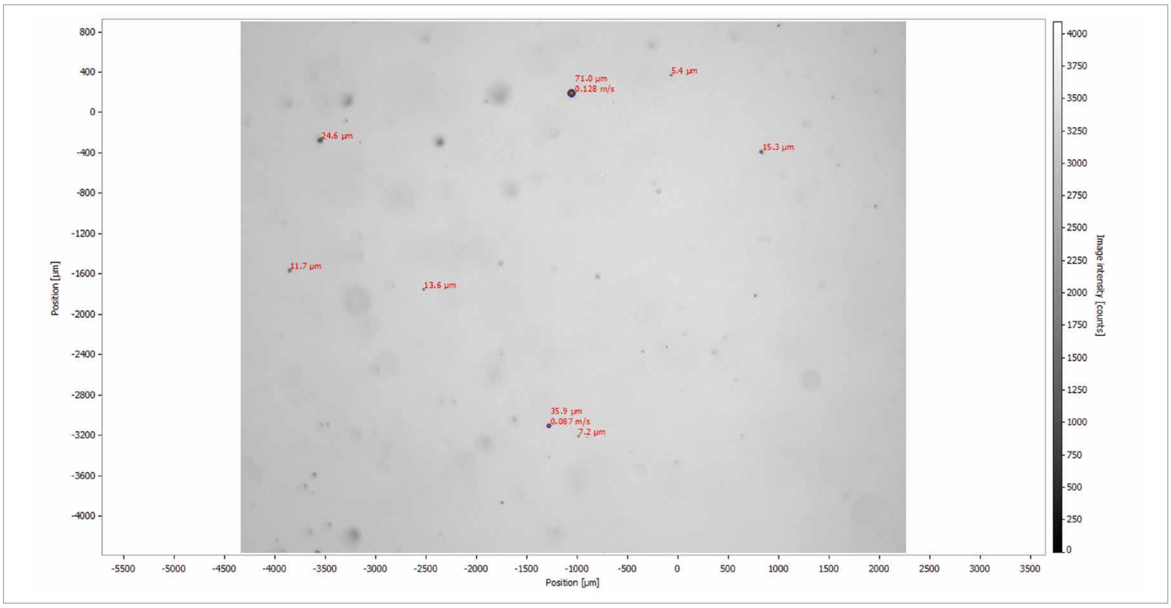
The following measurement parameters were recorded:

- Particle count [p/s]: Number of particles measuring between 5 µm and 50 µm that pass through the frame
- Velocity [m/s]: Velocity of the particles that pass through the frame
- MVF [µg/s*cm^3]: Mass volume flow of the particles per second (calculation where density =1)
- Reduction rate [%]: Particle emission with suction in relation to particle emission without suction (flow rate = 0 l/min) relative to the MVF

Measurement setup with unit for background lighting on the left and lens on the right, close to the head.
The optical frame is located 5 cm above tooth 11.

The measurement setup was chosen so as to generate a reproducible spray mist in a vertical direction towards the operator and to prevent this being deflected by the cheek (see Fig. 1). This was the case when preparing tooth 14 on the buccal side in the upper jaw. The instrument was located immediately above the surface of the tooth, thereby preventing the removal of any tooth substance. The head was stretched on. The lens was positioned to allow the spray mist to flow through the frame unhindered (5 cm above tooth 11).

Each measurement involved analysing 127 single images (measurement time 10 s) using the imaging software and determining the number of particles and the velocity of each individual particle. Each measurement was repeated at least 3 times and the average calculated.

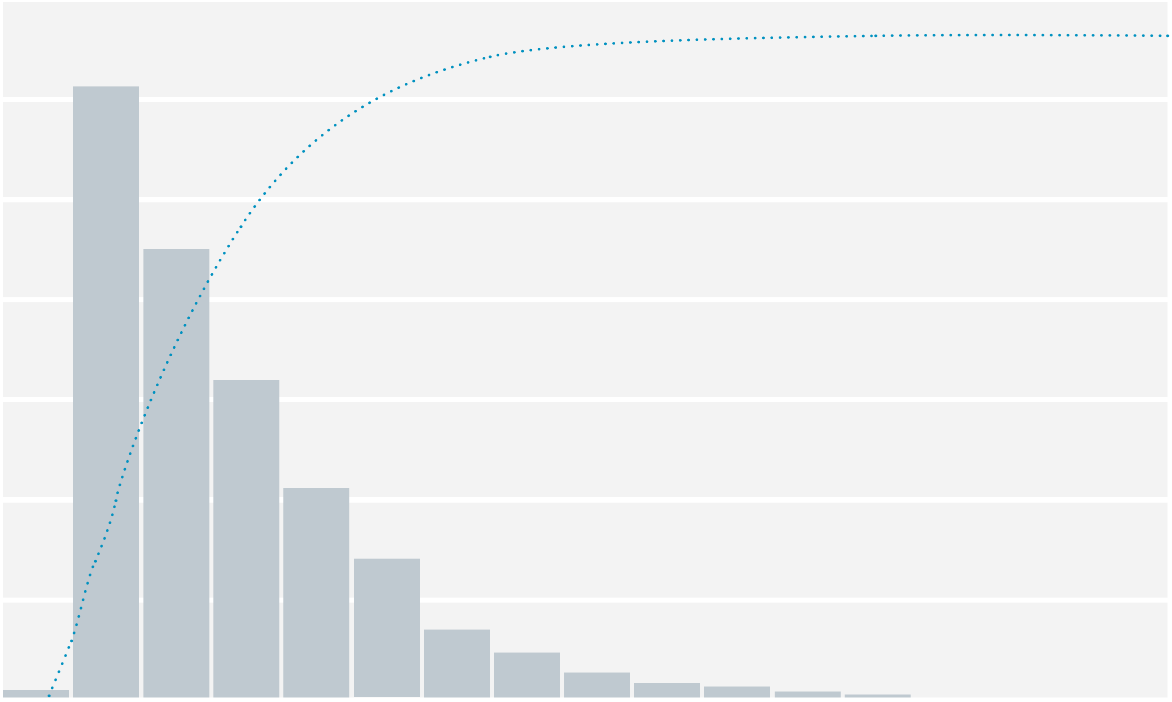


Analysis of a single image using imaging software. 7 particles measuring between 5.4 µm and 74 µm were detected.

3 Results

3.1 Characterisation of particle emission

In the spray mist of a turbine, a large number of particles measuring between 5 μm (resolution limit) and 75 μm can be detected at a distance of 5 cm using the shadow imaging technique (see Fig.). 99% of the particles measured less than 50 μm. The maximum velocity of the particles was 0.7 m/s. Because, as drops, large particles fall rapidly and are of little significance for the transmission of infection through droplets and aerosols, particles larger than 50 μm were not included in the analysis during subsequent measurements.



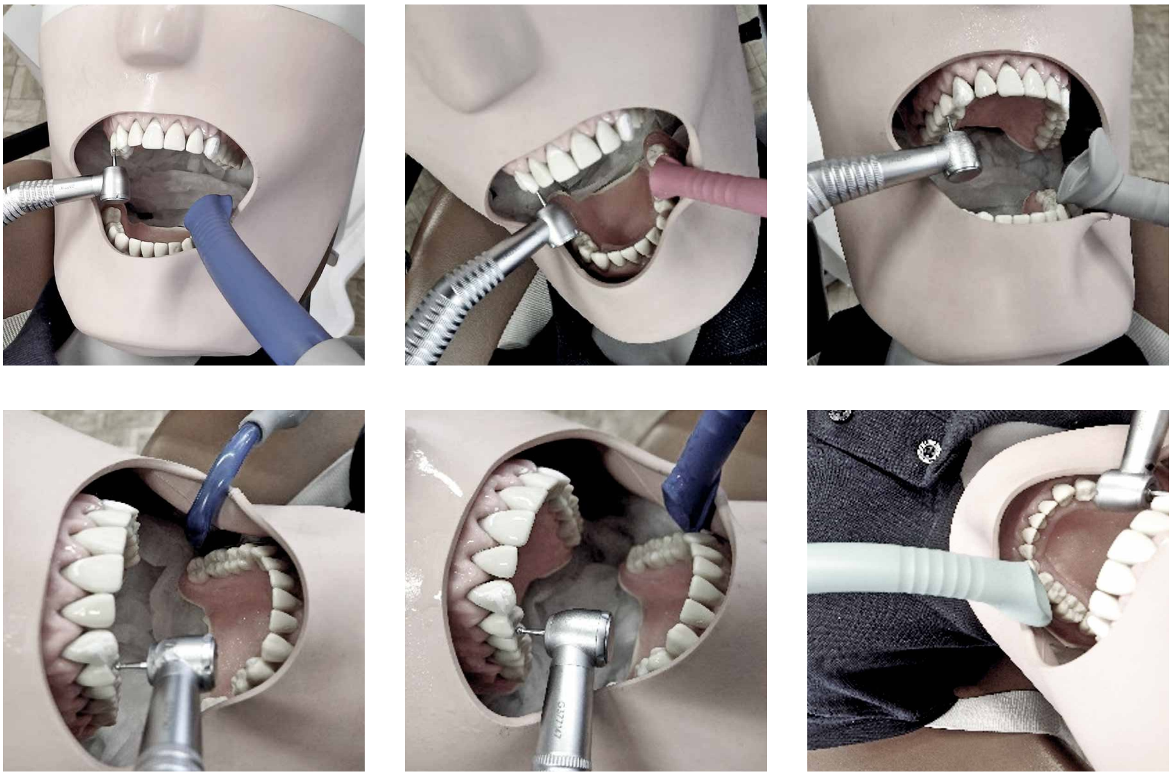
Size distribution of the particles in a spray mist cloud caused by a turbine.

3.2 Influence of the suction system on particle reduction

The suction cannula was positioned sub-optimally on the buccal side of tooth 34. The distance to the preparation site on tooth 14 was 5 cm. The influence of various suction system components on aerosol reduction was examined when the spray mist suction system was operating at maximum capacity.

Various cannula with different shapes and diameters, various suction hoses and handpieces, as well as a Venturi suction system, were examined in the following combinations:

- CU 16: Large suction hose, large suction handpiece, universal cannula Protect 16 mm
- CP 16: Large suction hose, large suction handpiece, universal cannula Petito 16 mm
- CA 16: Large suction hose, large suction handpiece, aerosol cannula 16 mm
- SE: Saliva ejector hose, small suction handpiece, saliva ejector
- CU 11: Saliva ejector hose, stainless steel handpiece, universal cannula Protect 11 mm
- CU 11-16: Saliva ejector hose, stainless steel handpiece, 11-16 mm adapter, universal cannula Protect 16 mm
- VU 16: Venturi suction system, large suction hose, large suction handpiece, universal cannula Protect 16 mm



Use of various components, from left to right: CU 16, CP 16, CA 16, SE, CU 11, CU 11-16

	CU 16	CP 16	CA 16	SE	CU 11	CU 11-16	VU 16
Particles [p/s]	0	4	0	301	644	710	720
MVF [µg/scm^3]	0	0,03	0	1,7	3,1	3,6	3,5
Spray mist reduction rate [%]	100	99	100	31	-25	-44	-40

MVF: Mass volume flow of the particles per second

The suction hose, suction handpiece and suction cannula had an enormous influence on the reduction rate of the emitted particles. The combination of „large suction hose and powerful suction system (Variosuc, Dürr Dental)" resulted in an aerosol reduction rate of almost 100%. Where cannula with a large diameter were used (universal cannula, aerosol cannula, Dürr Dental), no particles measuring between 5 µm and 50 µm were detectable in the frame during the measurement time of 10 s. The result was not the same for a Venturi suction system. In this case, numerous large particles were detectable by the „large suction hose and large suction cannula" combination.

The saliva ejector customarily used in dentistry was unable to suction off the aerosols completely. Over 300 particles per second were still detectable.

All examination approaches using the small saliva ejector hose resulted in an increased particle count within the measurement range. The insufficient suction power produced a visually observable accumulation effect of the particle cloud in the frame. This resulted in an increase in the particle count in the frame due to the measuring technical and, arithmetically, in a negative particle reduction.

3.3 Influence of the suction system on suction power (flow rate)

The influence of various suction system components on the flow rate was examined. The suction power of the Variosuc spray mist suction system used amounted to a maximum of 370 l/min.

	Flow rate [l/min]
without suction handpiece and cannula	370
CU 16: Large suction hose, large suction handpiece, universal cannula Protect 16 mm	330
CP 16: Large suction hose, large suction handpiece, universal cannula Petito 16 mm	270
CA 16: Large suction hose, large suction handpiece, aerosol cannula 16 mm	330
SE: Saliva ejector hose, small suction handpiece, saliva ejector	70
CU 11: Saliva ejector hose, stainless steel handpiece, universal cannula Protect 11 mm	120
CU 11-16: Saliva ejector hose, stainless steel handpiece, 11-16 mm adapter, universal cannula Protect 16 mm	120
VU 16: Venturi suction system, large suction hose, large suction handpiece, universal cannula Protect 16 mm	160

The use of various hose diameter, suction handpieces and suction cannula reduced the flow rate at the suction cannula. The smaller the cross-sections, the lower the flow rates achieved at the cannula. The poorest suction power, at 70 l/min, was achieved by the saliva ejector.

When the same components were selected (suction handpiece, suction cannula), the Venturi suction system achieved only 48% of the suction power compared to the spray mist system from Dürr Dental.

3.4 Influence of the flow rate on particle reduction

The suction cannula was positioned sub-optimally on the buccal side of tooth 34. The distance to the preparation site on tooth 14 was 5 cm. The flow rate was set to between 100 l/min and 330 l/min by means of a slide on the large suction handpiece. Three different 16 mm suction cannula were examined: Universal cannula Protect, universal cannula Petito and aerosol cannula (all Dürr Dental).

Examination setup with sub-optimal suction position using the universal cannula Protect suction cannula.
The flow rate was set by means of the slide on the suction handpiece

CU 16 Universal cannula Protect

	Flow rate [l/min]						
CU 16 Universal cannula Protect	0	100	150	200	250	300	330
Particles [p/s]	483	633	726	94	63	0	0
MVF [µg/scm³]	2,5	3,0	3,5	0,5	0,3	0	0
Spray mist reduction rate [%]	0	-20	-39	79	87	100	100

MVF: Mass volume flow of the particles per second

CP 16 Universal cannula Petito

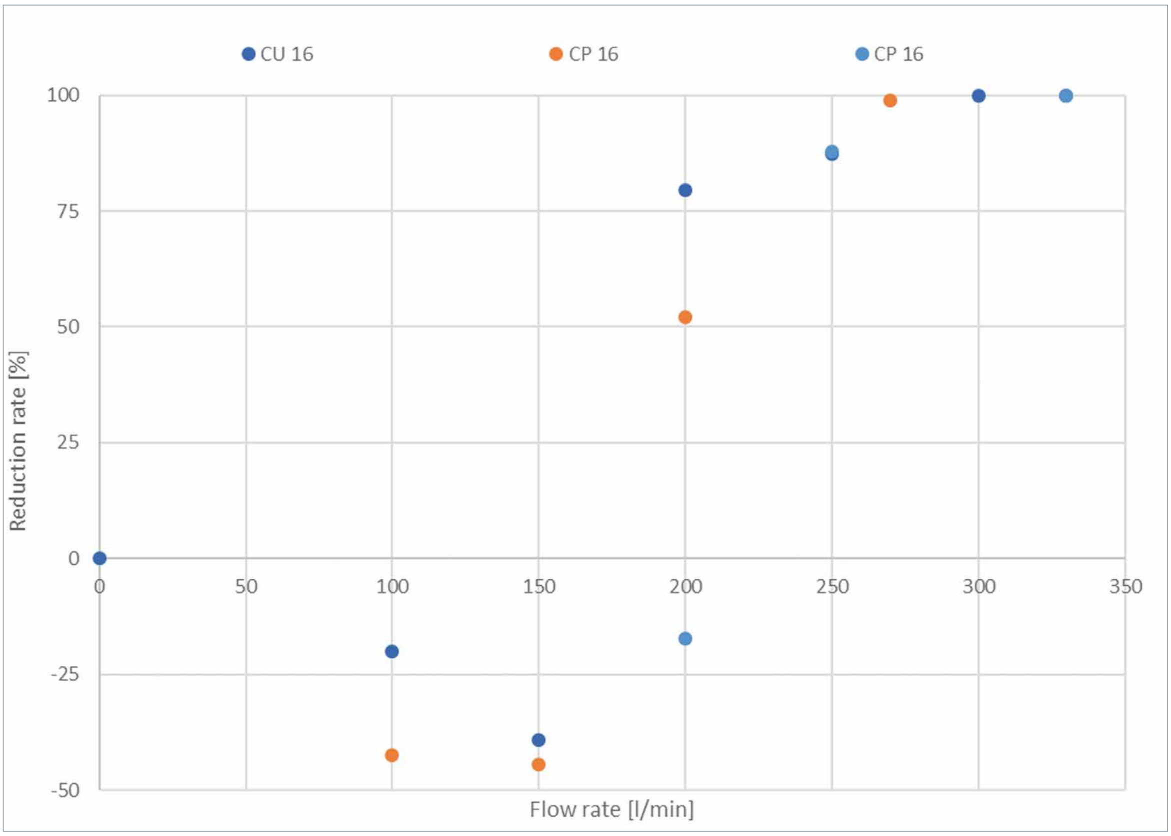
	Flow rate [l/min]				
CP 16 Universal cannula Petito	0	100	150	200	270
Particles [p/s]	483	671	725	223	4
MVF [µg/scm³]	2,5	3,6	3,6	1,2	0,03
Spray mist reduction rate [%]	0	-43	-44	52	99

MVF: Mass volume flow of the particles per second

CA 16 Aerosol cannula

	Flow rate [l/min]			
CA 16 Aerosol cannula	0	200	250	330
Particles [p/s]	483	639	63	0
MVF [µg/scm³]	2,5	2,9	0,3	0
Spray mist reduction rate [%]	0	-17	88	100

MVF: Mass volume flow of the particles per second



Dependence of particle reduction on the intraoral suction flow rate with various 16 mm suction cannula. CU 16: Large suction hose, large suction handpiece, universal cannula Protect 16 mm, CP 16: Large suction hose, large suction handpiece, universal cannula Petito, 16 mm, CA 16: Large suction hose, large suction handpiece, aerosol cannula 16 mm

Without intraoral suction (flow rate 0 l/min), an average of 480 particles per second were detectable in the frame. At a flow rate of up to 200 l/min, the particle count per second rises initially. This results in the negative reduction rate of the emitted particles. The process of intraoral suction causes the particles to slow down. This produced a visually observable accumulation effect of the particle cloud in the frame. By contrast, from a flow rate of 270 l/min, no particles measuring between 5 µm and 50 µm were detectable in the frame during the 10 s measurement time with any of the three suction cannula examined. Under the measurement conditions selected, this is equal to a reduction rate of 100%.

3.5 Influence of the suction position on particle reduction

The flow velocity of the counterflow generated by the intraoral suction process decreases rapidly as the distance to the suction cannula increases. The examination was therefore repeated with an optimal suction technique (1 cm distance to the preparation point on 14) and the results compared to those achieved by a sub-optimal suction technique.

Examination setup with optimal suction position using the universal cannula Protect suction cannula.
The flow rate was set by means of the slide on the suction handpiece.

Sub-optimal suction

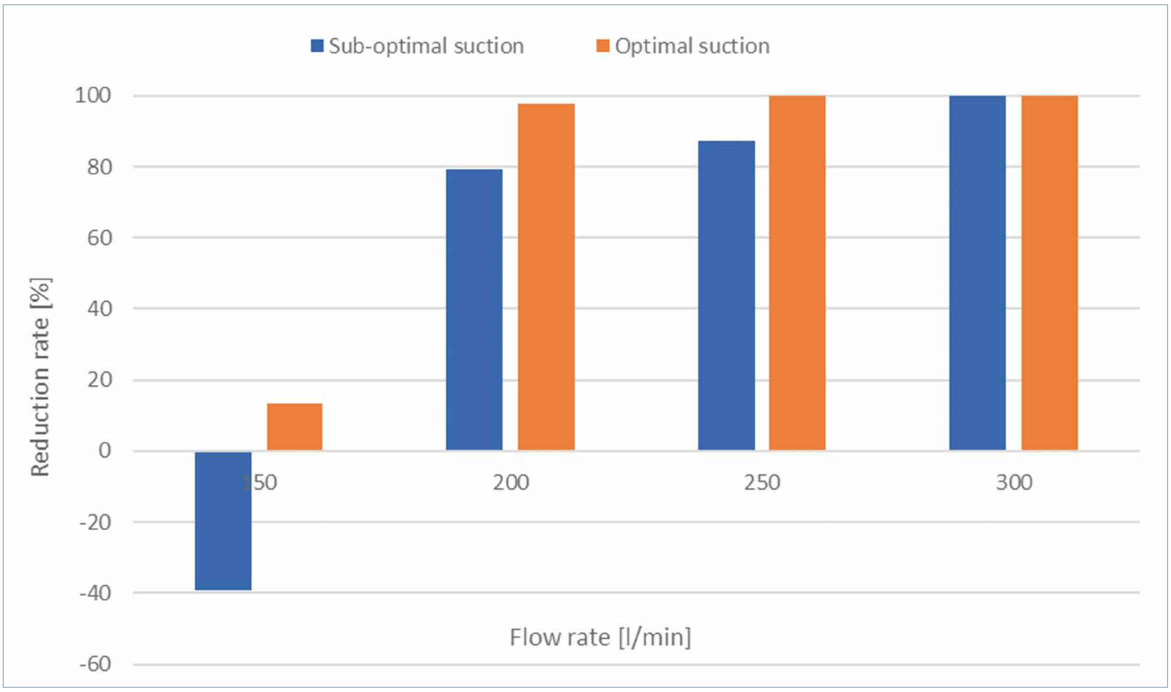
	Flow rate [l/min]						
Sub-optimal suction	0	100	150	200	250	300	330
Particles [p/s]	483	633	726	94	63	0	0
MVF [µg/scm³]	2,5	3,0	3,5	0,5	0,3	0	0
Spray mist reduction rate [%]	0	-20	-39	79	87	100	100

MVF: Mass volume flow of the particles per second

Optimal suction

	Flow rate [l/min]				
Optimal suction	0	150	200	250	300
Particles [p/s]	483	460	11	0	0
MVF [µg/scm³]	2,5	2,2	0,06	0	0
Spray mist reduction rate [%]	0	13	98	100	100

MVF: Mass volume flow of the particles per second

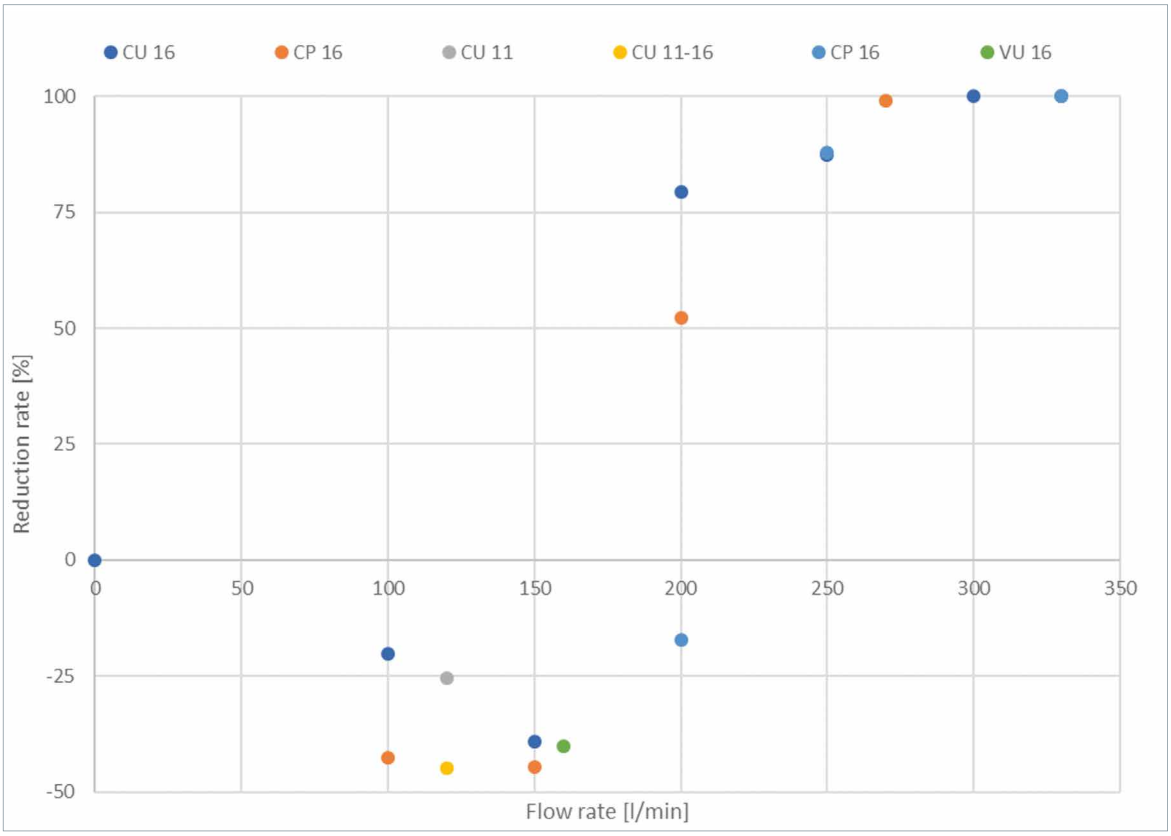


Comparison of the particle reduction rate with sub-optimal and optimal suction techniques depending on flow rate

With sub-optimal suction, particles were detectable in the frame up to a flow rate of 250 l/min. At optimal suction power, the value shifts towards lower flow rates. The efficiency of an intraoral suction process was able to be optimised through an better suction technique (short distance). From a flow rate of ≤200 l/min, a particle reduction was no longer possible in the examinations.

4 Discussion

An intraoral suction process generates a counterflow, which in turn slows down the emitted particles. Ideally, the intraoral suction is so strong that the particles do not leave the mouth region and are suctioned off through the suction cannula. The physical variable is the flow velocity v [cm/s]. According to $v = f / d$ (where d = diameter in cm^2 and f = flow rate in cm^3/s) this increases as the flow rate increases. The flow rate at the suction cannula is therefore the crucial physical variable for the reduction of dental aerosols.



Dependence of particle reduction on the intraoral suction flow rate with various intraoral suction solutions. CU 16: Large suction hose, large suction handpiece, universal cannula Protect 16 mm, CP 16: Large suction hose, large suction handpiece, universal cannula Petito, 16 mm, CA 16: Large suction hose, large suction handpiece, aerosol cannula 16 mm, CU 11: Saliva ejector hose, stainless steel handpiece, universal cannula Protect 11 mm, CU 11-16: Saliva ejector hose, stainless steel handpiece, 11-16 mm adapter, universal cannula Protect 16 mm, VU 16: Venturi suction system, large suction hose, large suction handpiece, universal cannula Protect 16 mm.

The graphic summarises all the measurement results achieved in this pilot study and highlights the correlation between flow rate and particle reduction.

A flow rate of less than 200 l/min is not enough to prevent particle emission. Even an optimised suction technique does not result in improved particle reduction in this case. It would appear that the velocity of the counterflow is to insufficient for suctioning off the particles. At flow rates of between 200 l/min and 250 l/min, a good suction technique can optimise the effect of the suction process. At a flow rate of 270 l/min only a few particles are detectable in the measuring field. From a flow rate of 300 l/min, the particle emission can be reduced below the detection limit during preparation with a turbine.

In Europe, a spray mist suction of at least 300 l/min at the suction handpiece has been routinely used for decades. According to the presented study, when using a cannula with a large diameter, this suction volume can reduce the aerosols under the detection limit even if the suction holding technique is not optimal. An additional extraoral suction system seems not to be indicated according to the results of this study.

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