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Spray mist and aerosol control in dental room air – summary of current evidence

Introduction: An evidence-based, balanced discussion of the facts regarding the reduction of infection risk during the SARS-CoV-2 pandemic by aerosol-controlling measures in dental practice has not yet been fully conducted. Therefore, the current state of knowledge on spray mist and aerosol control in dental offices will be reported in order to present conclusions on risk reduction of aerogen-transmitted infectious diseases in the dental practices.

Methods: Results of studies directly related to spray mist and aerosol control in a dental office, as well as recommendations from publications including national position statements and guidelines for dentistry, are discussed in a narrative format.

Results: Decision-making at the onset of the SARS-CoV-2 pandemic was hampered by the limited evidence base, but could be improved as the pandemic duration progressed by publishing more studies about spray mist and indoor aerosol control. Study results on the routine use of dental suction systems (intraoral) can be used to specify limits to their effectiveness in aerosol reduction. Similarly, findings on ubiquitously available natural room ventilation shows very high air exchange per hour (ACH) of up to 40 with continuous cross-ventilation under optimal room geometry with opposing windows, whereas only a limited additional effect can be expected for decentralized mobile air cleaning (DMAC) devices in reducing smaller aerosol particles in the treatment room.

Discussion: For optimized infection protection in dentistry, in addition to natural room ventilation and compliance with all known hygiene guidelines, the use of intraoral suction (high-volume evacuator (HVE) with a suction volume > 250 l/min) using a sufficiently large suction cannula (opening ≥ 10 mm), positioned close to the aerosol-generating treatment field, is mandatory. From a clinical point of view, supplementary DMAC devices provide a negligible additional reduction effect during aerosol-generating activities. Room air exchange by natural room ventilation in combination with HVE systems shows a high efficiency and continues to be the standard procedure in dental practices. Future studies must clarify whether DMAC devices with

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ACH ≥ 6 can be a supplement in exceptional situations with a high risk of infection, for example, when no intraoral suction is used or protective/hygiene measures can only be observed to a limited extent.

Conclusion: Established hygiene concepts and protective measures, including room ventilation with fresh air, have proven to be sufficiently effective in dental practice even during the SARS-CoV-2 pandemic.

Keywords: aerosol; guidelines; aerogene-transmitted infectious diseases; SARS-CoV-2

Introduction

Scientific statements and guidelines provide the basis for decision-making for dental activity on the basis of current knowledge. However, this presupposes that 1. corresponding knowledge is available in the form of studies of high evidence with direct relevance and 2. corresponding publications with recommendations are also known to practicing dentists. In the course of the SARS-CoV-2 pandemic, it was observed that both aspects changed continuously. It must be critically noted that, especially in the initial phase of the pandemic, recommendations were published on the basis of assumptions due to a lack of evaluation bases. The SARS-CoV-2 pandemic affected almost all private and professional spheres of life. This often led to emotionally driven discourses on partially appropriate catalogs of measures but not to a desirable balanced discussion on facts about the risk of infection in dentistry. It is obvious that a retrospective view is always easier. Moreover, for the SARS-CoV-2 pandemic, decision-making was complicated, particularly in its early stages, because a very limited evidence base existed. Even at the present time, fundamentally important questions about the origin of the virus as well as its infectivity, e.g., after illness or vaccination, have not been conclusively resolved. Therefore, in this article, the authors would like to present conclusions for the future use of spray mist and aerosol control to minimize the risk of aerogenously transmitted infectious diseases in dental practices based on the latest evidence.

The following remarks must be preceded by the fact that there can only be an effective pandemic containment and a protection against infections if all known preventive measures are implemented. Examples are compliance with room ventilation, distance and hygiene rules and the wearing of medical or FFP-2 masks. For dental practices, however, it must be taken into account that patients cannot wear mouth/nose coverings during treatments and the close treatment contact with a distance of only around 30 cm between patients and the treatment team. There is no question that rubber dam application is very effective in reducing droplets and aerosols which are potentially contaminated by microorganisms [1, 3, 8, 25, 30, 35]. However, this protective measure is not always possible with the wide range of activities in the dental practice. Spray mist and aerosol-generating measures occur in close proximity to the dental staff. In addition, the patients release aerosols and droplets through speaking, breathing, and coughing. The spray mist is a mixture of droplets and droplet nuclei of different sizes, consisting of cooling water, (powder) particles, splashes of saliva, blood and microorganisms, and is generated during the use of high-speed instruments including sonic/ultrasonic scalers and powder water jets. If this spray mist is not properly extracted, a potentially infectious aerosol cloud is created. Since the beginning of the SARS-Cov-2 pandemic, 497 cases with infections with the SARS-Cov-2 virus in the dental sector have been reported to the Employer's Liability Insurance Association for Health Services and Welfare Care (Berufsgenossenschaft für Gesundheitsdienst und Wohlfahrtspflege, BGW) in Germany until June 2021, of which the BGW lists 143 as occupational cases (query as of 01.06.2021). Even if underreporting must be assumed with regard to the published case numbers, this results in a prevalence of ≤ 0.1 % for SARS-CoV-2 infections among dental personnel [10], which can be seen as an indication of the high level of protection provided by established behavioral and hygienic measures in dentistry in Germany. Therefore, it has been proven to be useful to integrate the additional protective measures in the sense of a bundle of measures into recommendations already in force [28]. This can be seen in analogy to the precautionary approach of radiation protection [19], which means that the probability of exposure to SARS-CoV-2, the number of persons exposed, and the individual pathogen dose affecting a person are kept as low as reasonably achievable in dental practice. This set of measures has been shown to include room ventilation [19].

Room ventilation and pathogen transmission

Unlike outdoors, the transmission route plays a central role in an aerogenously transmissible infectious disease indoors. But especially in the case of SARS-CoV-2 there is still controversy about the proportion of direct contact or other routes including droplets [13] and airborne transmission [39], that are responsible for virus spread [23] (Figure 1).

Physically, droplets with 4–8 µm size will fall to the ground within 20–90 minutes according to indoor air conditions, while aerosol particles with sizes smaller than 4 µm can remain in the air for up to 30 hours [9]. However, as droplets lose water and become smaller with lower humidity (at a droplet size < 10 µm, the water fraction evaporates within splits of a second), and droplet nuclei are formed. Indoors they can remain suspended for hours and are transported with the airflow [19, 37]. This might inactivate bacteria and viruses, thus reducing the infectivity of the indoor air. It is undisputed that droplets contain significantly more pathogens than smaller droplet nuclei due to their size, and thus their infectious dose is higher. Especially in closed rooms, despite the smaller amount of pathogens in the aerosol, there is a higher risk of disease transmission because the particles do not dry out,

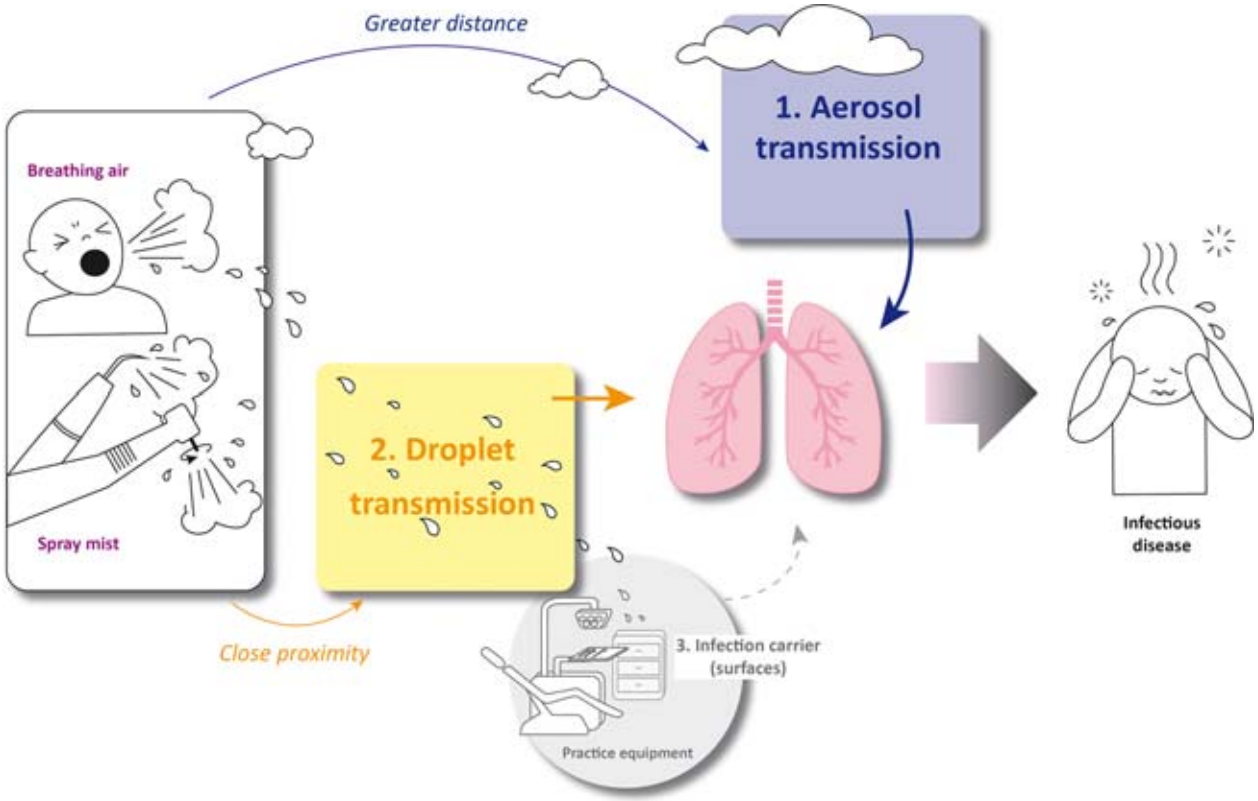

Figure 1 Schematic representation of possible transmission routes using the example of the SARS-CoV-2 virus in dental practices (Note: Transmission via surfaces cannot be ruled out, although the authors consider this route to be rather less significant based on corresponding studies from medical facilities [4]).

especially in high humidity, and are kept in suspension for a long time. Therefore, the circulation and exchange of particles in the room air (air exchange) plays a central role in infection control. It can be implemented naturally (e.g., ventilation with fresh air through open windows) or supported by technical systems (e.g., room ventilation system, decentralized mobile air purification units) (Figure 2). The air exchange rate (ACH) describes the amount of air supplied per room volume per hour.

Natural ventilation

In case of free ventilation, a distinction can be made between shock ventilation, cross ventilation and gap ventilation (Figure 2). Shock and cross ventilation can quickly lead to a dilution of aerosol-containing indoor air if a high temperature difference between in- and outdoor air is provided [18, 19]. However, the result of natural ventilation depends on quite a few factors that cannot be influenced, such as the outside temperature, wind direction and strength, as well as window size and position in the room. Also, after closing the window, the aerosol concentration in the treatment room will increase again. Gap ventilation by means of permanently tilted windows is insufficient (ACH: 0.3–1.5) and can be considered as a supplementary measure to shock or cross ventilation at most, with windows fully open for a short time (ACH: 0.3–4) [18, 19]. Even though cross-ventilation by opening 2 opposite windows in the building may be partly limited or even impossible during treatment due to the room architecture and privacy in dental offices, this is the most effective method (ACH: up to 40). To protect the patient's privacy but still minimizing aerosols efficiently it is therefore suggested to open opposite windows after dental treatments and while preparing for the following patient [19]. A smaller temperature difference especially during warmer summer months can lead to insufficient air exchange and a longer ventilation time (10 min) must be aimed for. During the colder winter months, sufficient air exchange is provided by high temperature differences already at a ventilation time of 3 min, which is also helpful in reducing energy loss during natural ventilation. In autumn, winter and spring, regular shock ventilation for 3–10 minutes following dental treatment is a practicable method of air exchange and thus also reduces aerosol concentrations in the treatment or waiting room [12]. However, longer ventilation durations of 10–15 minutes should be aimed for in the summer [22], as the air exchange rate may be lower than in other seasons due to the approximately equal temperatures outside and inside. Kienbaum et al. [19] therefore recommend that a ventilation plan is drawn up based on the type of ventilation (number of windows, doors if necessary), ventilation duration/interval (season) and additional ventilation occasions (specific treatment/exposure situations).

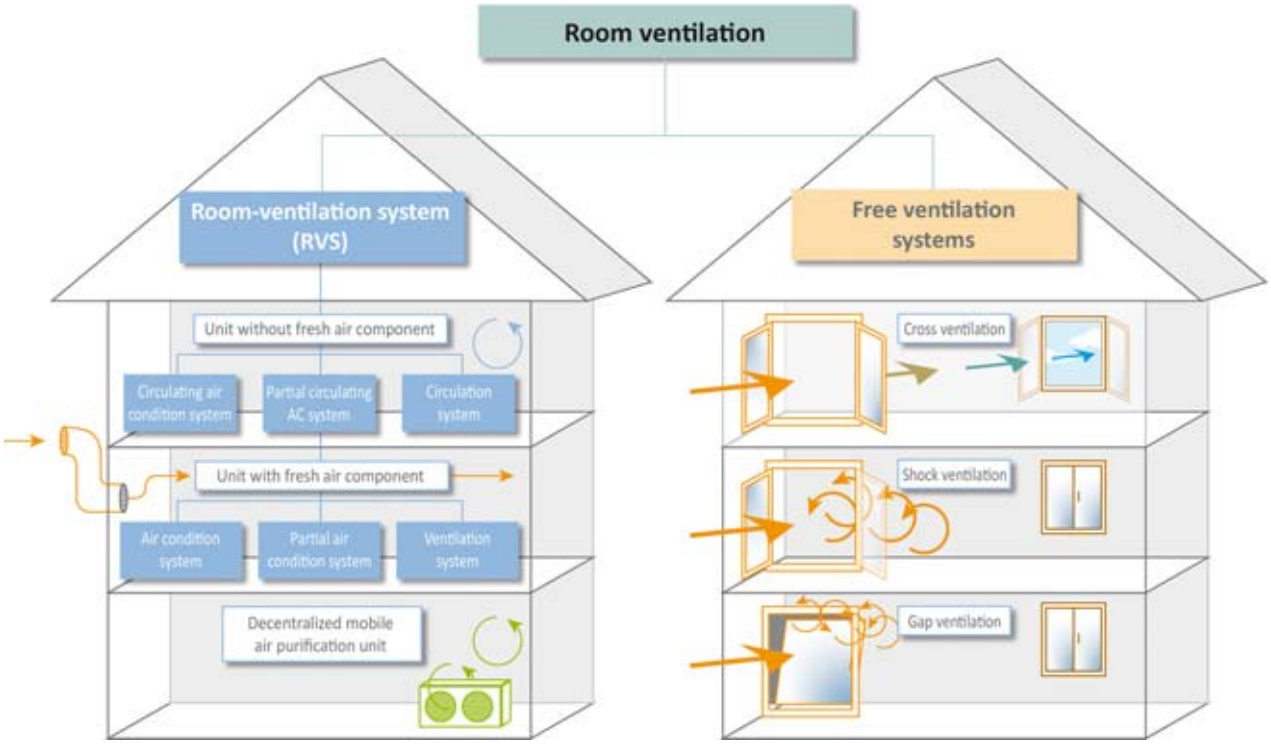

Fig. 1 + 2: C. Graetz

Figure 2 Simplified presentation on ventilation technology and its subsections according to DIN 1946 (part 1 of the standard), among others, as well as the possible room air ventilation.

Ventilation through technical equipment

The use of room ventilation systems (RVS) with defined ACH can be an alternative for larger practices/clinics with special structural requirements and/or for specific situations in summer and winter months, but also as a supplementary solution to natural ventilation. RVS systems in healthcare facilities (i.e. including dental practices) are regulated by DIN 1946/4. Their task is to heat or cool rooms, remove chemical pollutants or odors, minimize the colony count of microorganisms in the air (operating rooms), but above all to supply fresh air to rooms that are not naturally or sufficiently ventilated. Examination and treatment rooms are assigned to room class II. These rooms must be supplied with at least 40 m^3 of fresh air per hour and person present (if there is no window ventilation). This ensures an air exchange rate of about 6 times per hour. Taking into account this minimum proportion of fresh air and in order to minimize the heating costs for the fresh air supplied by the air handling system, the use of recirculated air is permissible. Fresh air and recirculated air are processed together (heated, cooled, filtered and, if necessary, humidified). The air is passed through 2 filter stages of classes F7 and F9. According to EN 779, the average efficiency of F9 filters is 95 % for particles of 0.4 µm diameter (i.e. including droplet nuclei).

According to DIN 1946/4, recirculating air cooling units (without fresh air component) are also possible in rooms in which a supply of fresh air is possible through sufficient window ventilation, if the air is returned to the same room from which it was taken (air-conditioning split units). At present, these must also be equipped with filters of classes F7 as well as F9. In general, devices in recirculation mode without filters (e.g. stand fans, mobile air conditioners, fan heaters) should be avoided in dental treatment rooms, as they do not lead to a reduction in aerosol concentrations, but can rather contribute to a distribution of aerosols in the room through the air flow. If operation is nevertheless necessary, care should be taken to ensure regular, intensive natural room ventilation [19].

Decentralized mobile air cleaning units

When neither sufficient natural ventilation nor technical room air systems with fresh air operation and filtration are operated, the additional use of decentralized mobile air cleaning devices (DMAC) is currently being discussed in the context of the pandemic [27, 29, 36]. There is a wide range of device types that are designed to separate the intake room air by various processes (UV, ionization, filtration, etc.) or to inactivate airborne substances, and then discharge them back into the same room. The air flow rate of the units and the achievable ACH, i.e. how quickly the relevant particles can be filtered out of the room air, play a decisive role here. Effective devices with high ACH requiere a high air volume flow. At this point, it has to be said that the high air volume flow leads to high sound pressure levels and thus consecutively to noise pollution [2]. Chavis et al. [2] measured up to 86 dB (comparative measurement tooth preparation without DMAC: 82 dB) when a DMAC was used at maximum suction power and

tooth preparation was performed simultaneously. On the other hand, Comisi et al. [5] measured sound pressure levels between 87 dB and 89 dB when operating a high-power intraoral suction system. When using a prototype 3D-printed lip retractor with internal suction and funnel, even up to 99 dB could be measured. In this experimental study, the sole operation of a DMAC was even associated with the lowest noise levels (less than 80 dB) [5]. These elevated sound pressure levels may not only affect intercommunication and patient comfort, but also make patient monitoring more difficult for staff.

For DMAC, as for the operation of an air handling unit, a possibly more cost-intensive unit operation and regular maintenance must be taken into account compared to natural room ventilation. Finally, the filtration performance of the units is also influenced by the room geometry and the arrangement in the room. In the case of particulate aerosols, there is no distribution equilibrium in the room [11], which is why an optimal placement of the devices should, for example, be near the treatment unit [2] – with all the disadvantages that this entails, such as annoyance due to noise, airflow, and a constricted room.

For a planned use of DMAC, only devices in which the room air is filtered by a separation process with classified H13 filters (or higher) should be considered. For all other devices with coarser filters, an insufficient effectiveness of the filtration of fine particles must be assumed [11]. Although the effectiveness of all devices can possibly still be increased by the aforementioned processes such as ozone or ions, scientific studies on effectiveness are lacking.

As our own experimental studies by the Kiel working group around Graetz et al. with a DMAC in the dental curriculum [15], and also observational studies in dental practices showed, the definition of the measurement method and experimental conditions is very complex [31, 41] and not directly comparable [16]; moreover, the results may often not be generalized [2]. Also, experimental studies with simulation of activities in dentistry may not be used to assess indoor air quality [40]. For example, the Kiel experiments were conducted using a phantom in a closed treatment room (16.94 m^2). The tested DMAC was aligned at a distance of 35 cm from a phantom head, on which various aerosol-generating treatments such as high-speed preparation or tooth cleaning using a powder water jet device were simulated. With the exception of the controls (no aerosol-generating treatment), a 16 mm suction cannula was always tested in combination with a saliva ejector using a dental high-volume evacuator (HVE) (suction volume (air) at the tip of the suction cannula: ≥ 300 l/min), in each case with versus without DMAC. With simultaneous monitoring of room air parameters such as CO_2 saturation, temperature, and air ventilation, the particle number concentration (PNC) of aerosols was recorded by an optical method using scattered light from a cleanroom counter (LasAir III, PMS Inc., USA). A mean ACH of 3 h^{-1} was determined for the DMAC, and only for particles with small diameters (0.1–0.3 µm) was there a significant reduction ($p < 0.001$) when the DMAC was used in addition to conventional intraoral suction [15]. In contrast to other experimental studies, which also demonstrated a further significant reduction for droplets and splashes by means of additional DMAC [2], the authors of the Kiel working group did not observe any additional reduction in room air concentration for particles with a larger diameter compared to the sole intraoral application of the HVE (0.5–5.0 µm; $p = 0.089$).

Intraoral dental suction systems

The intraoral use of a spray mist evacuation system is an established measure in the context of most dental treatments and thus already makes a decisive contribution to adequate hygiene and infection control [14, 32]. To ensure this function, HVEs with a suction volume (air) of ≥ 250 l/min have been described [34] and are regulated by ISO 10637:2018 (German version EN ISO 10637:2018). This describes not only the design of the central suction machine, but also notes on piping. Both the suction power and the diameter of all pipes, including the applied suction cannula, must be considered in the design and for the operation of an optimal dental suction system. For optimal risk reduction of aerogenically transmissible infectious diseases during spray mist generating interventions, suction cannulas with secondary air inlets (preventing stuck suction and thus blocking of the cannula) with diameters > 10 mm are recommended [28]. Suction with a narrow saliva ejector (diameter < 8 mm) and suction volume < 200 l/min is unsuitable for the reduction of aerosols [20], even though liquids can be eliminated sufficiently from the oral cavity. Rupf et al. [33] were able to show that fine particle aerosols released in the oral cavity of a phantom are only reduced by high-volume suction. Therefore, in addition to the technical requirements, the role of the optimal suction technique should be discussed within the practice team to ensure optimal infection control in the daily routine. Unfortunately, as already mentioned, suctioning with HVE systems leads to noise emissions that should not be underestimated, and these can make internal communication between practitioner and assistant as well as between patients more difficult. As already discussed for the previous technical systems, this also requires regular inspection (practice team) and maintenance (manufacturer-specific), for example, to counteract deposits with subsequent displacement/constriction of the inner tube diameters.

Summary discussion of the internal and external evidence

Even before the onset of the SARS-CoV-2 pandemic, it was known that dental activities are associated with the release of aerosols and particles that may have adverse health effects [26, 38]. According to current studies, effective reduction of aerosols with potential risk for aerogenically transmitted infectious disease is most easily achieved via natural ventilation. Technical filtration of room air by means of air handling systems is possible, but the use of DMAC de-

vices has only been described as a complementary measure for rooms in which primary infection control measures cannot be implemented adequately [11]. Operationally, every dental practice in Germany has a HVE unit that primarily succeeds in aspirating liquids from the patient's oral cavity and, at the same time, can effectively reduce the potentially contaminated spray rebound [14, 32] – corresponding to primary infection control. Compared with the routine operation of such configured HVE systems, DMAC devices can represent a complementary measure for the control of potentially infectious aerosols only in small to medium-sized practice rooms [6, 15, 18], always associated with not inconsiderable acquisition and operating costs of the devices (e.g., regular cleaning or replacement of the HEPA (high-efficiency particulate air) filters so that they do not themselves become a source of microorganisms and air pollutants [11, 18]), noise, or a limitation of space. Although HVE systems also require regular maintenance, their use is familiar in dental practice, and with an adequately sized and correctly positioned intraoral suction cannula and a suction volume flow (air) of approximately 300 l/min, aerosols from the patient's mouth can be significantly reduced during use [15]. In a study of SARS-CoV-2 and other microorganisms in dental aerosols with 28 participants, salivary bacteria were detected in the condensed aerosol in only 8 individuals [24]. Meethil et al. [24] found no viruses in the generated aerosol despite detectable SARS-CoV-2 viruses in the saliva of some asymptomatic patients. These results should be interpreted cautiously, and it must also be kept in mind that aerosol removal only ever occurs when suction cannulae are used at all due to measures involving spray mist generation. In addition, the results indicate that exposure to pathogens from saliva cannot be completely prevented in all cases despite the use of an HVE. In certain dental activities, for example intraoral examinations, aerosols will also occur, but diameter-optimized suction cannulas in particular are generally not used in this case.

Conclusion

For optimized infection protection in dentistry, high-volume intraoral suction during aerosol-generating treatments is mandatory in addition to compliance with all known hygiene guidelines [24, 28, 34]. For this purpose, HVE (according to ISO 10637:2018 type 1 with a suction volume > 250 l/min) in combination with a suction cannula that has a sufficiently large opening (≥ 10 mm) and is positioned close to the treatment field have proven effective [7, 14, 34]. It can significantly reduce aerosol and droplet dispersion in the treatment environment directly [7, 14, 17, 21, 32]. Although additionally used DMAC devices could cause a further significant reduction especially of smaller aerosol particles in the treatment room [15, 29, 36], but especially of the spray mist/droplet generating activities the effect is negligible from a clinical point of view, because the mandatory HVE devices already cause a significant reduction intraorally [15]. Thus, during dental treatment, both staff and patients appear to be largely protected from exposure to potential pathogens when the bundle of measures already postulated several times [28] is applied [24]. Even though natural ventilation is highly dependent in its efficiency on external and uninfluenceable variables (temperature difference indoor and outdoor air, wind conditions, room architecture), it is the simplest measure and almost always available measure with a high ACH and should be replaced only in exceptional cases. DMAC devices, even those with high ACH (≥ 6) and HEPA filters according to DIN EN 1822, can only be a supplementary protective measure for example during a high incidence phase and simultaneous limited implementation of the bundle of measures for infection control. However, it should be emphasized once again that, due to the proven high effectiveness of the HVE systems used in Germany and natural room ventilation, the additional benefit of DMAC devices for improved infection control must be the subject of future scientific investigations.

Conflict of interest

The authors declare that there is no conflict of interest as defined by the guidelines of the International Committee of Medical Journal Editors. The authors C. Graetz, M. Cyris, P. Düffert indicate that they have conducted scientific studies in cooperation with manufacturers for HVE (Dürr Dental SE, 74321 Bietigheim-Bissingen, Germany) and DMAC devices (ULT, Löbau, Germany) on the efficacy of aerosol and spray mist reduction in dentistry over the past 5 years.

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References

1. Ather A, Patel B, Ruparel NB, Diogenes A, Hargreaves KM: Coronavirus Disease 19 (COVID-19): Implications for clinical dental care. J Endod 2020

2. Chavis SE, Hines SE, Dyalram D, Wilken NC, Dalby RN: Can extraoral suction units minimize droplet spatter during a simulated dental procedure? J Am Dent Assoc 2021; 152: 157–165

3. Cochran MA, Miller CH, Sheldrake MA: The efficacy of the rubber dam as a barrier to the spread of microorganisms during dental treatment. J Am Dent Assoc 1989; 119: 141–4

4. Colaneri M, Seminari E, Novati S et al.: Severe acute respiratory syndrome coronavirus 2 RNA contamination of inanimate surfaces and virus viability in a health care emergency unit. Clin Microbiol Infect 2020; 26: 1094 e1–1094 e5

5. Comisi JC, Ravenel TD, Kelly A, Teich ST, Renne W: Aerosol and spatter mitigation in dentistry: Analysis of the effectiveness of 13 setups. J Esthet Restor Dent 2021; 33: 466–479

6. Curtius J, Granzin M, Schrod J: Testing mobile air purifiers in a school classroom: Reducing the airborne transmission risk for SARS-CoV-2. Aerosol Science and Technology 2021: 1–14

7. Davies MH, Rosen M, Eccles JD, Marshal RJ: Criteria of air flow and negative pressure for high volume dental suction. Br Dent J 1971; 130: 483–7

8. Day CJ, Sandy JR, Ireland AJ: Aerosols and splatter in dentistry – a neglected menace? Dent Update 2006; 33: 601–2, 604–6

9. Duguid, J.P.: The size and the duration of air-carriage of respiratory droplets and droplet-nuclei. J Hyg (Lond) 1946; 44: 471–9

10. Estrich CG, Mikkelsen M, Morrissey R et al.: Estimating COVID-19 prevalence and infection control practices among US dentists. J Am Dent Assoc 2020; 151: 815–824

11. Exner M, Walger P, Gebel J, Schmithausen R, Kramer A, Engelhart S: Zum Einsatz von dezentralen mobilen Luftreinigungsgeräten im Rahmen der Prävention von COVID-19. In: Stellungnahme der Deutschen Gesellschaft für Krankenhaushygiene (DGKH) vom 25.09.2020, DGKH, Editor. 2020: https://www.krankenhaushygiene.de/ccUpload/upload/files/2020_09_03_DGKH_Stellungnahme_Zum_Einsatz_von_dezentralen_Luftreinigern_zur_Praevention.pdf (Abgerufen 09.07.2021)

12. Fitzner K, Finke U: Lüftungsregeln für freie Lüftung. Bundesanstalt für Arbeitsschutz und Arbeitsmedizin 2012: 1–89 https://www.baua.de/DE/Angebote/Publikationen/Berichte/F2072.pdf?__blob=publicationFile&v=1 (Abgerufen 09.07.2021)

13. Ge ZY, Yang LM, Xia JJ, Fu XH, Zhang YZ: Possible aerosol transmission of COVID-19 and special precautions in dentistry. J Zhejiang Univ Sci B 2020; 21: 361–368

14. Graetz C, Bielfeldt J, Tillner A, Plaumann A, Dorfer CE: Spatter contamination in dental practices – how can it be prevented? Rev Med Chir Soc Med Nat Iaşi 2014; 118: 1122–34

15. Graetz C, Düffert P, Heidenreich R, Seidel M, Dörfer CE: The efficacy of an extraoral scavenging device on reducing aerosol particles </= 5 microm during dental aerosol-generating procedures: an exploratory pilot study in a university setting. BDJ Open 2021; 7: 19

16. Innes N, Johnson IG, Al-Yaseen W et al.: A systematic review of droplet and aerosol generation in dentistry. J Dent 2021; 105: 103556

17. Ishihama K, Koizumi H, Wada T et al.: Evidence of aerosolised floating blood mist during oral surgery. J Hosp Infect 2009; 71: 359–64

18. Kähler C, Fuchs T, Hain R: Können mobile Raumluftreiniger eine indirekte SARS-CoV-2 Infektionsgefahr durch Aerosole wirksam reduzieren? 2020

19. Kienbaum T: Hygienemanagement in Gesundheitseinrichtungen – Teil 4: Effektives Lüften während der Pandemie. HYGIENEMANAGEMENT 2020; 10: 47–55

20. Koch M, Graetz C: Spray mist reduction by means of a high-volume evacuation system-Results of an experimental study. PLoS One. 2021;16(9):e0257137.

21. Kohn WG, Harte JA, Malvitz DM et al.: Guidelines for infection control in dental health care settings – 2003. J Am Dent Assoc 2004; 135: 33–47

22. Kun-Szabo F, Gheorghita D, Ajtai T et al.: Aerosol generation and control in the dental operatory: An in vitro spectrometric study of typical clinical setups. PLoS One 2021; 16: e0246543

23. Lewis D: Is the coronavirus airborne? Experts can't agree. Nature 2020; 580: 175

24. Meethil AP, Saraswat S, Chaudhary PP, Dabdoub SM, Kumar PS: Sources of SARS-CoV-2 and other microorganisms in dental aerosols. J Dent Res 2021: 220345211015948

25. Meng L, Hua F, Bian Z: Coronavirus Disease 2019 (COVID-19): emerging and future challenges for dental and oral medicine. Journal of Dental Research; 0: 0022034520914246

26. Mittmann-Frank M, Berger H, Rupf S et al.: Exposition gegenüber Nanopartikeln und neuen Materialien in der Zahnheilkunde. Zentralbl Arbeitsmed Arbeitssch Erg. 2011; 61: 40–53

27. Morawska L, Tang JW, Bahnfleth W et al.: How can airborne transmission of COVID-19 indoors be minimised? Environ Int 2020; 142: 105832

28. Müller LK, Heider J, Frankenberger R et al.: German guidelines: dealing with aerosol-borne pathogens in dental practices. Dtsch Zahnärztl Z INT 2020; 2: 164–9

29. Nulty A, Lefkaditis C, Zachrisson P, Van Tonder Q, Yar R: A clinical study measuring dental aerosols with and without a high-volume extraction device. Br Dent J 2020

30. Peng X, Xu X, Li Y, Cheng L, Zhou X, Ren B: Transmission routes of 2019-nCoV and controls in dental practice. Int J Oral Sci 2020; 12: 9

31. Polednik B: Exposure of staff to aerosols and bioaerosols in a dental office. Building and Environment 2021; 187: 1–13

32. Reitemeier B, Jatzwauk L, Jesinghaus S, Reitemeier C, Neumann K: Effektive Reduktion des Spraynebel-Rückpralls – Möglichkeiten und Grenzen. ZMK 2010; 26: 662–673

33. Rupf S, Berger H, Buchter A, Harth V, Ong MF, Hannig M: Exposure of patient and dental staff to fine and ultrafine particles from scanning spray. Clin Oral Investig 2015; 19: 823–30

34. Samaranayake LP, Fakhruddin KS, Buranawat B, Panduwawala C: The efficacy of bio-aerosol reducing procedures used in dentistry: a systematic review. Acta Odontol Scand 2021; 79: 69–80

35. Samaranayake LP, Reid J, Evans D: The efficacy of rubber dam isolation in reducing atmospheric bacterial contamination. ASDC J Dent Child 1989; 56: 442–4

36. Shahdad S, Patel T, Hindocha A et al.: The efficacy of an extraoral scavenging device on reduction of splatter contamination during dental aerosol generating procedures: an exploratory study. Br Dent J 2020

37. Stadnytskyi V, Bax CE, Bax A, Anfinrud P: The airborne lifetime of small speech droplets and their potential importance in SARS-CoV-2 transmission. Proc Natl Acad Sci U S A 2020; 117: 11875–11877

38. Szymanska J: Dental bioaerosol as an occupational hazard in a dentist's workplace. Ann Agric Environ Med 2007; 14: 203–7

39. van Doremalen N, Bushmaker T, Morris DH et al.: Aerosol and surface stability of SARS-CoV-2 as compared with SARS-CoV-1. N Engl J Med 2020; 382: 1564–1567

40. Veena HR, Mahantesha S, Joseph PA, Patil SR, Patil SH: Dissemination of aerosol and splatter during ultrasonic scaling: a pilot study. J Infect Public Health 2015; 8: 260–5

41. Watanabe A, Tamaki N, Yokota K, Matsuyama M, Kokeguchi S: Use of ATP bioluminescence to survey the spread of aerosol and splatter during dental treatments. J Hosp Infect 2018; 99: 303–305.

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