Aerosol generation and control in the dental operatory

Ph.D. Thesis

Dorottya Gheorghita, D.M.D.

Supervisor:

Márk Antal, D.M.D., Ph.D., Habil.

Faculty of Dentistry

University of Szeged

Szeged

2023

Publications related to the subject of the thesis

I. *Kun-Szabó F,* ***Gheorghita D,*** *Ajtai T, Hodovány S, Bozóki Z, Braunitzer G, Antal MÁ.* Aerosol generation and control in the dental operatory: An in vitro spectrometric study of typical clinical setups. *PLoS One. 2021 Feb 4;16(2):e0246543. doi: 10.1371/journal.pone.0246543. PMID: 33539439; PMCID: PMC7861533.*

IF: 3.752 **Q1**

II. ***Gheorghita D****, Kun Szabó F, Ajtai T, Hodovány S, Bozóki Z, Braunitzer G, Antal MÁ.* Aerosol Reduction of 2 Dental Extraoral Scavenger Devices In Vitro. *Int Dent J. 2022 Oct;72(5):691-697. doi:10.1016/ j.identj. 2022.05.007. Epub 2022 Jun 2. PMID: 35810011; PMCID: PMC9159968.*

IF:3.3 **Q1**

Introduction

Aerosol itself is a commonly known medium responsible for transmitting various diseases. During the COVID-19 epidemic the importance of prevention has risen steeply. So that, deeper interest towards the aerosol and its examination in different fields of medicine has appeared. In terms of aerosol production, dentistry is a high-risk profession: the most dangerous interventions usually happen when turbine and ultrasound scalers are in use. Studies before the pandemic haven't really focused on methods of reducing aerosol load. However proper protection (FFPs, shields) can reduce the risk of airborne infection of the dental team, the dynamics of aerosol generation and the importance of its concentration during or after the treatment can be the first line of prevention regarding spatter related infections in the dental operatory. The most important goal is to protect the patients from viral transmission. After stronger extraoral suctions systems appeared on the market, with no solid background of their efficacy, further studies are necessary to improve this field.

Aims of the study

Our research is composed of two different layers to understand the spreading properties of the aerosol formed during dental treatments and to measure the efficacy of the extraoral scavenger devices.

1) The first in vitro study was to model typical treatment setups to find out about aerosol production and aerosol control in a clinically relevant manner. The setups were defined by the instrument (high-speed turbine with air spray or ultrasonic scaler with air spray) and the applied aerosol control system (the conventional high-volume evacuator or a lately introduced aerosol exhaustor). The turbine and the ultrasonic scaler are used differently: aerosol from the scaler never gets directly in the air while, the turbine is moved around in all directions during a treatment, so that aerosol spreads both directly and indirectly. Changing in aerosol load due to airing in the same model is another perspective to be examined during our research.

Hypothesis: that both the instrument/spray direction and the aerosol control system would be significant determinants of aerosol concentration.

Hypothesis: a regular method of airing manageable in any dental operatory would be sufficient to reduce aerosol concentration in a clinically reasonable timeframe between two treatments.

2) Based on the first investigation, the aim of the second study was to examine the aerosol reduction efficiency of 2 different extraoral scavenger devices (EOSs) in an experimental setting, modelling dental treatment with a high-speed turbine – when aerosol gets in the air directly.

Hypothesis: both EOSs would significantly reduce the aerosol load.

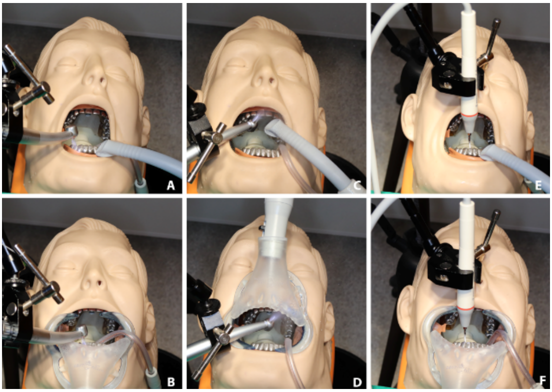
Material and Methods

1) The setups to measure the aerosol production were defined by the instrument (high-speed turbine with air spray or ultrasonic scaler with air spray) and the applied aerosol control system (the conventional high-volume evacuator or a lately introduced aerosol exhaustor). The effect of post-treatment airing on aerosol concentrations

was also studied for each setup. An experimental setup was prepared in a regular dental operatory (4.15 m x 2.6 m) with one door and one window.
To simulate a patient, a mannequin head was used in the supine position. The turbine or ultrasonic scaler was attached to a holder. The high-volume evacuator or aerosol exhaustor were attached to the same dental unit. Measurements were carried out with a Scanning Mobility Particle Sizer (SMPS-3938) spectrometer (TSI, Minnesota, USA). The endpiece of the spectrometer was positioned above the head of the mannequin at 20 cm.

Before the test measurements, the operatory had been intensively aired and air purified for 12 hours. This was followed by baseline aerosol determination and then the measurements for the different setups. Aerosol reduction was repeated after each test measurement by airing.

The following setups were tested: a) turbine, direct spray, high-volume evacuator (DS-HVE); b) turbine, indirect spray, high-volume evacuator (IS-HVE); c) turbine, direct spray, aerosol exhaustor (DS-AE); d) turbine, indirect spray, aerosol exhaustor (IS-AE); e) ultrasonic scaler, high-volume evacuator (US-HVE); f) ultrasonic scaler, aerosol exhaustor (US-AE).



The measurements for each setup were carried out in triplicate, lasted 1 measurement cycle (326 s), and were separated by airing for 3 measurement cycles, during which concentration decay was measured. Airing was done by opening both the door and the window of the operatory, while operating a standard fan directed toward the window. Values from all three measurements were used for the analyses.

2) Experiments to compare 2 extraoral scavenger devices were done in the same operatory with the exact same conditions as mentioned above. Measurements were

carried out with an Engine Exhaust Particle Sizer (EEPS-3090) spectrometer (TSI, Minnesota, USA).

In study setup 1 (NO EOS), no EOS was used in combination with the aforementioned turbine positions. In study setup 2 (EOS A), we used Dental Aerosol System, and in study setup 3 (EOS B), we used Eighteeth VacStation. For all 3 setups, 3 measurement cycles were carried out. Each cycle lasted 5 minutes and included 10 consecutive scans (sampling frequency: 30 s). Aerosol reduction by airing was repeated after each measurement by airing.

Statistical analysis

For statistical analysis, we used SPSS (IBM, USA) software versions 23.0 and 26.0. Due to space limitations, a comprehensive description of the statistical tests is omitted here; however, interested readers can find these descriptions in full length in the thesis and the publications serving as the basis for the thesis.

Results

1) In terms of aerosol control, the most well-controlled setups were US-AE and US-HVE, followed by IS-HVE, IS-AE, DS-AE and DS-HVE, the latter being the least efficient. From this, we inferred that the applied instrument/spray direction (DS/IS/US) was of primary importance in terms of aerosol control. Aerosol control alone did not contribute significantly to the variance of either parameter.

2) Comparisons within the groups defined by instrument and spray direction regarding aerosol control revealed that the aerosol control system had a significant effect only in the case of indirect spray with high-speed turbine, and in that case, HVE was the more efficient method.

3) Regarding the dynamics of aerosol concentration during the airing period a massive drop in TNC occurred between 5 and 10 minutes for all setups- except for DS-HVE. After 15 minutes all results (not the DS-HVE) were close to the base-line concentration.

4) Regarding TNC 60.4-392.4 critical size range, the efficiency of EOS A and EOS B was comparable, and both were superior to NO EOS in aerosol reduction.

Discussion

The aim was to determine in a clinically relevant way what aerosol particle concentrations two typical dental instruments featuring air spray generate and how efficiently these concentrations are controlled by two widespread control devices, as such quantitative measurements were lacking. To interpret the results correctly, one must understand that in real-life dentistry, the spray is never exclusively directed inward or outward, rather, the instrument alternates between these positions, and even that with breaks. We hypothesized that both the instrument/ its use and aerosol control would be significant determinants of aerosol concentration.

The type of dental instrument and its way of use was indeed a key factor in aerosol generation. Scaler generated the least aerosol, followed by turbine with indirect spray, and turbine with direct spray. However, earlier studies found the scaler the most problematic instrument in aerosol production.

The applied aerosol control system was not a significant factor in any of the setups, except for indirect high-speed turbine, where HVE was the most efficient method.

Regarding the effect of airing between treatments, we hypothesized that a conventional method of airing would be sufficient to reduce aerosol concentration to safe levels in a clinically reasonable timeframe. This was true for all setups, except for DS-HVE (which is never used exclusively during any treatment). Based on the results, a safety airing period of at least 15 minutes is recommendable between two treatments. By the application of more advanced airing methods (such as a built-in ventilation unit) shorter periods may be achievable.

A rising amount of different high-volume suction systems (EOSs) has appeared on the market, due to the pandemic.

Their efficacy has never been compared, only their superior suction capacity over the general HVE method was proven. While some studies suggested that their use is not necessary for proper aerosol control, there is an agreement in the literature that they are efficient and increase the safety of the dental operatory. Our results show that EOS devices can differ in their aerosol-reduction efficacy and the particle size range in which they are most efficient. As the aerosol control multipliers show, total number concentrations in the 60.4-392.4 nm range were approximately two times the baseline with both EOS A and EOS B, while without any EOS device, approximately six times higher values were measured. These results corroborate the findings of Nulty et al. who concluded that extra-oral suction can be a useful means of mitigating the risk of SARS-CoV-2 infection in a clinical context. Meanwhile there is inconsistency in literature regarding the position and the distance of the EOSs during dental treatments. These parameters should be tested in further studies.

Conclusion and New findings

Aerosol, as a steeply rising topic since the pandemic, requires deeper understanding. Dental operatory is a high-risk area in transmitting airborne infection. Based on our research we can state that the type of dental instrument and its way of use is a key factor in aerosol generation. Ultrasound scaler generates the least aerosol, followed by turbine with indirect spray, and turbine with direct spray, meanwhile the type of aerosol control system is not a significant factor. HVE has the best controlling capacity in most of the situations. The efficiency of airing between two treatments for at least 10 minutes can reduce aerosol concentration to a safe level in most typical treatment scenarios (with doors and windows open and using a commercially available standard fan). However, if during the intervention a high amount of aerosol could get in the air directly, our suggestion is to expand this up to 15-minutes. Advanced airing methods (e.g. a built-in ventilation unit) may shorten this period.

The EOSs allow a significantly greater reduction of particle counts and aerosol load compared to the setup when no EOS is in use. Our results support the assumption that EOS devices for aerosol reduction increase safety in the dental operatory, lowering the risk of further spreading certain contagious diseases.

Acknowledgment

First, I would like to thank Dr. Márk Antal, my supervisor, for his support and the professional background he provided over these years. Guiding experiments on aerosol production during the pandemic requires extra attention and power. His patience and guidelines are inevitable cornerstones of my thesis.

It is with immense gratitude that I acknowledge the help of Dr. Gábor Braunitzer with statistical analysis and lingual corrections.

I am grateful to my co-researchers to help our work with their own ideas and equipment of different scientific fields. Without the support of the Department of Optics and Quantum Electronics, Faculty of Science and Informatics this thesis would not exist.

I would like to extend my sincere thanks to Dr. Eszter Nagy for her language editing and translational efforts, so as her professional advice.

I would also like to thank my family and close friends their support and encouragement during the years.