Aerosol-generating procedures and associated control/ mitigation measures: Position paper from the Canadian Dental Hygienists Association and the American Dental Hygienists' Association

PRACTICAL IMPLICATIONS OF THIS RESEARCH

This position paper will help inform dental hygienists and other oral health care professionals of the current evidence on effective devices, methods, and protocols to mitigate the risk of infection transmission when performing aerosol-generating procedures.

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ABSTRACT

Background: Since the outbreak of COVID-19, how to reduce the risk of spreading viruses and other microorganisms while performing aerosol-generating procedures (AGPs) has become a challenging question within the dental and dental hygiene communities. The purpose of this position paper is to summarize the evidence of the effectiveness of various mitigation methods used to reduce the risk of infection transmission during AGPs in dentistry. **Methods:** The authors searched 6 databases—MEDLINE, EMBASE, Scopus, Web of Science, Cochrane Library, and Google Scholar—for relevant scientific evidence published between January 2012 and December 2022 to answer 6 research questions about the risk of transmission, methods, devices, and personal protective equipment (PPE) used to reduce contact with microbial pathogens and limit the spread of aerosols. **Results:** A total of 78 studies fulfilled the eligibility criteria. The literature on the risk of infection transmission including SARS-CoV-2 between dental hygienists and their patients is limited. Although several mouthrinses are effective in reducing bacterial contaminations in aerosols, their effectiveness against SARS-CoV-2 is also limited. The combined use of eyewear, masks, and face shields is effective in preventing contamination of the facial and nasal region while performing AGPs. High-volume evacuation with or without an intraoral suction, low-volume evacuation, saliva ejector, and rubber dam (when appropriate) have shown effectiveness in reducing aerosol transmission beyond the generation site. Finally, the appropriate combination of ventilation and filtration in dental operatories is effective in limiting the spread of aerosols. **Discussion and Conclusion:** Aerosols produced during clinical procedures can pose a risk of infection transmission between dental hygienists and their patients. The implementation of practices supported by available evidence will ensure greater patient and provider safety in oral health settings. More studies in oral health clinical environments would shape future practices and protocols, ultimately to ensure the delivery of safe clinical care.

RÉSUMÉ

Contexte : Depuis l'éclosion de la COVID-19, la façon de réduire le risque de propagation de virus et d'autres microorganismes tout en effectuant des interventions générant des aérosols (IGA) est devenue un enjeu complexe au sein des communautés de la médecine dentaire et de l'hygiène dentaire. L'objectif de cet exposé de position est de résumer les données probantes de l'efficacité des diverses méthodes d'atténuation utilisées pour réduire le risque de transmission des infections pendant les IGA en médecine dentaire. **Méthodes :** Les auteurs ont effectué des recherches dans MEDLINE, EMBASE, Scopus, Web of Science, Cochrane Library et Google Scholar pour trouver des preuves scientifiques pertinentes publiées entre janvier 2012 et décembre 2022 afin de répondre à 6 questions de recherche sur le risque de transmission, les méthodes, les dispositifs et l'équipement de protection individuelle (EPI) utilisés pour réduire le contact avec les agents pathogènes microbiens et limiter la propagation des aérosols. **Résultats :** Au total, 78 études ont satisfait aux critères d'admissibilité. La documentation est limitée en ce qui concerne le risque de transmission des infections, y compris le SRAS-CoV-2, entre les hygiénistes dentaires et leurs patients. Bien que plusieurs rince-bouches soient efficaces pour réduire la contamination bactérienne dans les aérosols, leur efficacité contre le SRAS-CoV-2 est limitée. L'utilisation combinée de lunettes, de masques et d'écrans faciaux est efficace pour prévenir la contamination de la région faciale et nasale lors de l'exécution d'IGA. L'évacuation à volume élevé avec ou sans aspiration intraorale, l'évacuation à faible volume, l'aspirateur de salive et la digue dentaire en caoutchouc (le cas échéant) ont démontré une efficacité à réduire la transmission des aérosols au-delà du site de production. Enfin, la combinaison appropriée de ventilation et de filtration dans les salles de traitement dentaire permet de limiter efficacement la propagation des aérosols. **Discussion et conclusion :** Les aérosols produits lors des interventions cliniques peuvent présenter un risque de transmission des infections entre les hygiénistes dentaires et leurs patients. La mise en œuvre de pratiques appuyées par les données probantes disponibles assurera une plus grande sécurité des patients et des prestataires dans les milieux de santé buccodentaire. Un plus grand nombre d'études dans les environnements cliniques de santé buccodentaire permettrait de façonner les pratiques et les protocoles futurs dans le but d'assurer la prestation sécuritaire des soins cliniques.

Keywords: aerosol generating procedures; COVID-19; infectious disease transmission; mouthrinses; personal protective equipment; respiratory aerosols and droplets; SARS-CoV-2

CDHA Research Agenda categories: risk assessment and management; capacity building of the profession

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POSITION STATEMENT

No outbreaks of SARS-CoV-2 have been reported in dental or dental hygiene practices or within their patient populations during the pandemic. Nonetheless, despite the low risk of transmission of SARS-CoV-2 in oral health care settings, the possibility still exists, until proven otherwise. In light of the available evidence, the following recommendations are made to lower the risk of cross-contamination between dental hygienists and their patients while performing aerosol-generating procedures (AGPs). Preprocedural mouthrinses are recommended to reduce the level of bacterial and viral contamination in aerosols generated, albeit with very limited trial evidence after the use of AGPs for the latter. It is also recommended to use high-volume evacuation with or without an intraoral suction, low-volume evacuation, saliva ejector, and rubber dams (when appropriate) to reduce the aerosols generated. The combined use of protective eyewear and face shields, as well as the use of ventilation and filtration systems in conjunction with aerosol-scavenging systems, are recommended to prevent the contamination of the facial and nasal regions when performing AGPs. Finally, in enclosed spaces with sufficient air ventilation, a fallow time of 10 minutes or less can be enough for aerosols to completely settle.

BACKGROUND

Aerosols can be defined as the suspension of solid or liquid particles in the air, which can be generated by either natural or anthropogenic phenomena, and may be present in different forms, such as fumes, mist or dust.[1–3] Within health care settings, aerosol-generating procedures (AGPs) are described as any clinical procedures that lead to the production of respiratory aerosols or liquid particles of different sizes. These respiratory aerosols or liquid particles, depending on their size, may remain airborne for long periods of time.[4,5] In the wake of the Severe Acute Respiratory Syndrome (SARS) pandemic in 2003, health organizations used the term "AGPs" to describe procedures associated with a higher rate of infection among health care workers performing them.[6,7] As such, for medical practices, aerosol-generating medical procedures (AGMPs) was the initial common terminology.[1] Similarly, when applied to procedures specific to oral health care practices, the term became aerosol-generating dental procedures (AGDPs).[1,4] However, AGPs is the term commonly used today in the health care literature, including oral health care.

Owing to the nature of clinical dental or dental hygiene practice, the generation of spray in the form of aerosols, droplets, droplet nuclei, spatter or splatter is common while performing various procedures.[8,9] When contaminated with saliva, these airborne particles may transmit pathogens from one individual to another through either direct contact with uncovered skin or mucosa, or indirect contact after settling on inanimate objects.[10,11] Therefore, the proximity of the oral health care provider and patient during routine dental and dental hygiene procedures is a concern for infection transmission.[12,13] Usage of dental equipment such as handpieces (low or high speed), sonic and ultrasonic scalers, air polishers, electrosurgery units, and air/water syringes during routine procedures has been associated with significant aerosol generation, and in turn with the potential of infection transmission.[5,14]

There are no generally accepted terms and definitions of various forms of airborne matter and no clear delineations between terms frequently used in the field. One of the distinguishing criteria is the size of the matter particle; the smaller the size, the lighter it is, and the greater potential it has to stay airborne for a longer duration. Using the definitions developed by Micik and colleagues[16] through their pioneering work in aerobiology in the 1960s, the Centers for Disease Control and Prevention (CDC) and the World Health Organization (WHO)[15] have differentiated the various forms of airborne matter as follows:

- *Splatter:* Mixtures of airborne particles (air, water and/or solid) greater than 50 microns (µm) in diameter, which is visible to the naked eye. These particles are often projectile in nature, and usually remain airborne for brief periods only.[8,15]
- *Spatter:* Mists that contains droplets that are up to 50 µm in diameter and are usually quick to settle.[4]
- *Aerosols*: Particles smaller than 50 µm in diameter.[16] These are often small enough to remain suspended in the air for longer periods before they enter the respiratory tract or settle on environmental surfaces.[8,16]
- *Droplets:* Inspirable particles larger than 5 µm in diameter.[8,15]
- *Droplet nuclei:* Residue of dried aerosols ≤5 µm in diameter that results from evaporation of droplets.[15,17] Droplet nuclei of 0.5 µm to 1 µm in diameter are known to possess a higher risk of infection transmission in dental settings.[11,16]

Research in the past suggests that some diseases are known to spread via aerosols containing a variety of respiratory pathogens,[8,9,18] including measles, influenza, and mycobacterium tuberculosis.[18–20] With the advent of the COVID-19 pandemic, the virus' potential spread through aerosols was a big question. For dentistry, an aerosol-generating profession, the importance of infection control and aerosol reduction in oral health care settings became a crucial concern.[11,14] It is important to note that evidence demonstrating the risk of transmission of COVID-19 in oral health care settings remains limited and is still being

explored.[14,18] A recent study by Rafiee et al.[21] found that the majority of clinicians' aerosol exposure came from sources other than the patients' saliva and nasal fluids, suggesting a low risk of cross-contamination between clinicians and their patients in dental settings. It is also worth noting that, while sneezing, coughing, and even talking can generate respiratory droplets of various sizes and can cause the spread of viral infections,[22] this paper only focuses on the evidence of disease transmission via aerosol-generating clinical procedures in oral health care settings.

The need for a better understanding of coronavirus transmission via AGPs in oral health care settings has been continuously recognized over the last 3 years, as dental hygiene care has experienced major disturbances in North America due to provincial and state restrictions on AGPs in oral health care settings. These restrictions prompted the exploration of the effectiveness of various methods of aerosol mitigation to control and minimize the risk of disease transmission when performing AGPs. As a result, there has been an influx of evidence on this topic with varying degrees of quality and with different contextual settings, study design, and methodological limitations. This profusion of new knowledge has outpaced clinicians' ability to keep up with the current evidence on how to conduct AGPs in the safest manner possible. Finally, with most regulatory bodies lifting COVID-19 mandated restrictions, many dental hygienists are still uncertain about the best practices that support safe care delivery.

This position paper aims to provide dental hygienists with timely, high-quality evidence based on scientific literature about infection control and disease transmission related to AGPs. The target audience includes but is not limited to dental hygienists practising in clinical, public health, and educational settings. In addition, the information presented in this position paper will be essential for policymakers, regulators, health care provider organizations, clinicians, and the public to understand the considerations for AGPs in dental hygiene practice in accordance with infection prevention and control practices.

METHODS

Through a collaborative partnership with the Canadian Dental Hygienists Association (CDHA), the American Dental Hygienists' Association (ADHA), an ad-hoc AGPs Steering Committee, and the consulting team, the objectives of the research project were developed to synthesize information on AGPs that will inform dental hygiene practices. The research topics that dental hygienists would potentially be interested in knowing more about 1) the risk of infection transmission associated with conducting AGPs; 2) types and effectiveness of preprocedural mouthrinses in reducing the microbial load of aerosols generated through AGPs; 3) the effectiveness of dental evacuation systems; 4) personal protective equipment (PPE) considerations for AGPs; 5) operatory setups to control the spread of aerosols; and 6) an appropriate fallow period following AGPs.

Therefore, the scope of this position paper encompasses the risk of transmission, methods used to minimize the microbial count in aerosols, devices and PPE used to reduce contact with microbial pathogens, and operatory structures used to limit the spread of aerosols. Specifically, the position paper aims to answer the following research questions relevant to dental and dental hygiene practices with the aid of a PICO framework (Population, Intervention, Comparison, Outcome):

1. What is the risk of transmission of microbial pathogens between clinical dental hygienists performing AGPs and their patients?
2. Does the use of preprocedural mouthrinses reduce the count of microbial pathogens and/or the risk of infection transmission between dental hygienists performing AGPs and their patients?
3. Does the use of aerosol-scavenging systems (e.g., intra and extraoral evacuation systems, high-and low-volume suction systems) limit the spread of aerosols and reduce the risk of infection transmission between dental hygienists performing AGPs and their patients?
4. What are the types and effectiveness of the PPE used to reduce contact with aerosols and the risk of infection transmission between dental hygienists performing AGPs and their patients?
5. What should the operatory setup criteria be to limit the spread of aerosols in dental and dental hygiene settings?
6. What is the appropriate fallow time that allows aerosols to completely settle and reduces the risk of infection transmission between dental hygienists and their patients after performing AGPs?

Inclusion criteria

Six databases—MEDLINE, EMBASE, Scopus, Web of Science, Cochrane Library, and Google Scholar—were searched for relevant scientific evidence published between January 2012 and December 2022 using the search strategy outline in the appendix. Due to the fast-evolving nature of science and technology, it was decided to limit the search to this 10-year period to ensure the suitability of evidence to current practices. The literature search for the 6 PICO questions was conducted between October 15 and November 15, 2022. On December 20, the search was re-run for all the questions to ensure the inclusion of any new literature. The search was limited to studies published in English. Commentaries and expert opinions were only included if no other studies of higher quality were identified according to the hierarchy of evidence. Finally, the reference lists of identified studies were also reviewed as a snowball mechanism to capture any study not identified through the original search terms.

Exclusion criteria

Grey literature including governmental and organizational guidelines and recommendations were excluded as they may be based on jurisdictional, political, and regulatory approaches rather than scientific ones. Conference abstracts and media articles were also excluded.

Identification, screening, and inclusion of studies

Search results were imported into Covidence software and duplicates were removed prior to review.[23] Three reviewers (AG, DP, HK) independently reviewed titles and abstracts using a screening form developed by the consulting team and approved by the AGPs Steering Committee. If the abstract was not available, the source was included for full-text review. The full texts of the remaining publications were retrieved and screened by the 3 reviewers using a standardized screening checklist. Any uncertainties related to study selection were resolved through discussion with the research supervisor (SS).

For every question, the research output was reviewed by the assigned reviewer along with the research supervisor. All reviewers and the research supervisor completed a calibration exercise using 5% of articles from the initial search, and again after the final search using Cohen's kappa coefficient. The average interrater reliability score was 0.73, indicating a substantial level of agreement among reviewers.

Data extraction, quality appraisal, and synthesis plan

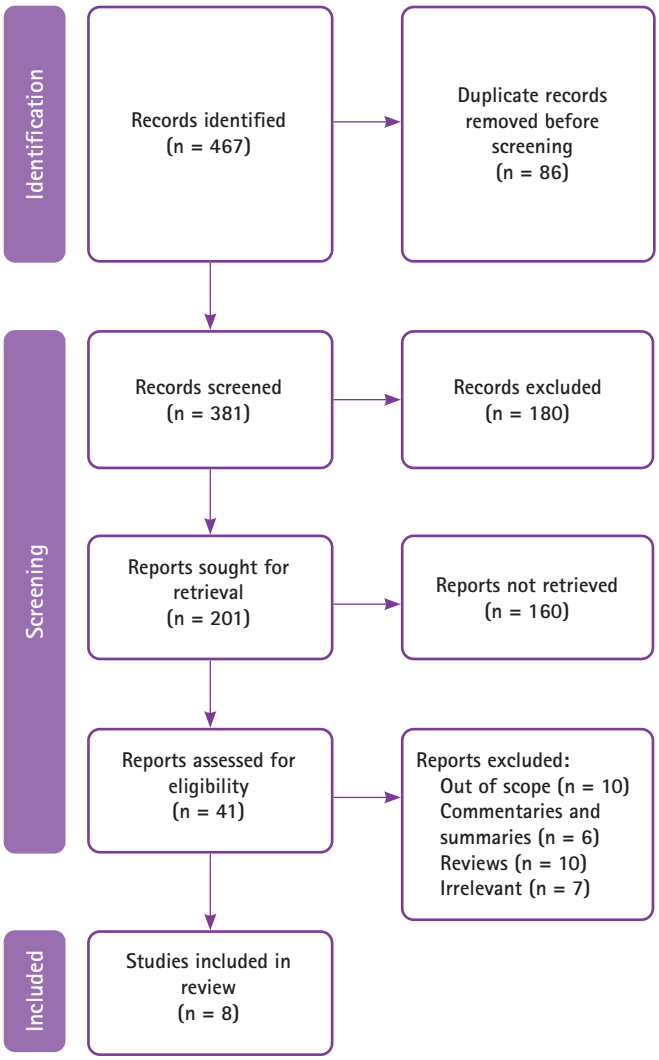
A data extraction form was used to populate pertinent information from each data source (i.e., article). Information was categorized to answer questions relevant to any oral health care setting. Since this position paper aims to explore the breadth of the evidence related to the proposed questions, a quality appraisal of the full-text articles was not conducted. Finally, the consulting team utilized the Covidence software, which is recommended by the Cochrane network, to organize sources and synthesize data.[23]

RESULTS

Q1: What is the risk of transmission of microbial pathogens between clinical dental hygienists performing AGPs and their patients?

The search retrieved 467 studies related to this question. After the reviewers removed duplicates and irrelevant studies, 8 were included in the final analysis. Three were systematic reviews[24–26] and the remaining 5[27–31] were experimental in nature. Figure 1 outlines the PRISMA flowchart and Supplementary Table S1 summarizes the characteristics of the articles identified to answer this question. The main modes of transmission of SARS-CoV-2 in oral health care settings are aerosols, respiratory droplets, and close interpersonal contact (<1 m).[24,29,30] In fact, airborne transmission is the dominant route of transmission for SARS-CoV-2.[29] Common AGPs include prophylaxis with ultrasonic scaler and polishing; periodontal treatment with ultrasonic scaler; any tooth preparation with high- or low-speed handpieces; direct and indirect restoration and polishing; cementation of crown or bridge; mechanical endodontic treatment; and surgical implant placement.[24,30] An experimental study by Baldion et al.[30] developed a risk prediction model by assessing the settlement of particulate matter generated during dental procedures performed on mannequins. The factors associated with greater risk of particle settlement were as follows: a distance of less than 78 cm from the mannequin head, inadequate ventilation, and use of high-speed handpieces.[30] In terms of particle size, it was found that most settled particles produced during AGPs ranged from 1 µm to 5 µm. However, it is important to keep in mind that authors limited their analysis to particles that settled within 30 minutes. Therefore, smaller particles that require more time to settle, and are likely to settle farther, were not considered in this analysis.

Figure 1. PRISMA flowchart for Q1



Next, a systematic review[24] conducted in 2020 examined documented cases of transmission within different oral health care settings worldwide. It demonstrated that there was not adequate evidence regarding the actual cases of infection transmission among both patients and oral health care providers while delivering care. Similarly, another systematic review[25] from 2021 corroborated the lack of evidence relating to transmission rates of SARS-CoV-2 in oral health care settings. Additionally, a cross-sectional survey conducted among 51 hospitals in Japan in 2022[29] suggested that COVID-19 clusters were unlikely in both dental and oral surgical care settings especially when appropriate protective protocols were implemented. In addition, a yearlong retrospective cohort study[31] showed that the risk of contracting SARS-CoV-2 among oral health care providers was considerably low. It was also implied that this lower number can be attributed to the intensive precautions and preventive measures taken before and during patient care.

A study from 2021[28] indicated that, even in the absence of evidence of direct SARS-CoV-2 transmission through AGPs in oral health care environments, the possibility still exists. Therefore, oral health care providers should not consider any in-office procedure risk-free. More recently, a systematic review conducted by Al-Moraissi et al.[26] found that dental, maxillofacial, and orthopedic surgical procedures produce significant number of aerosols. However, the evidence suggesting their infectivity to transmit diseases such as SARS-CoV-2 remains very weak. Finally, other research shows that the relative risk of infection transmission during an in-office visit can be dependent on epidemiological context; geographical region; patient characteristics; and the kind of procedure being performed.[24,30]

Therefore, based on the infection risk prediction model for COVID-19 developed by Baldion et al.,[30] the authors of this position paper classified the procedures undertaken in a dental office according to the settlement of the aerosolized particles generated during AGPs as the following:

- *Low risk*: Procedures limited to the common areas (outside the operatory) with proper social distancing (e.g., administrative tasks)
- *Moderate risk*: Procedures related to cleaning, disinfection, and sterilisation; procedures conducted in a clinical environment (inside the operatory) without AGPs; i.e., no use of ultrasonic or rotation instruments, or 3-way air or water spray
- *High risk*: Clinical procedures conducted using aerosol generating equipment

To summarize, oral health care providers should be aware of the risk of infection transmission and take adequate preventive measures while rendering care to patients. The literature search revealed that there is limited evidence of the risk of infection transmission, including SARS-CoV-2, among oral health care providers and their patients. While most studies retrieved were related to modes or routes of aerosol transmission, assessment, and distribution of aerosols or splatter, only a few assessed the possible risk. Further research is, therefore, required to estimate the rates of infection transmission among oral health care providers including dental hygiene practitioners and their patients related to AGPs.

Q2: Does the use of preprocedural mouthrinses reduce the count of microbial pathogens and/or the risk of infection transmission between dental hygienists performing AGPs and their patients?

The search strategy yielded 789 articles for this question; after the reviewers removed duplicates and irrelevant studies, 15 met the eligibility criteria. Figure 2 outlines the PRISMA flowchart and Supplementary Table S2 summarizes the characteristics of the articles identified to answer this question. Three of the studies were systematic reviews[32–34] and 12 were experimental trials.[35–46] The studies tested an array of antimicrobial mouthrinses including, but not limited to, cetylpyridinium chloride (CPC), chlorhexidine (CHX), essential oils (EO), hydrogen peroxide (HP), and povidone iodine (PI). The AGPs tested were ultrasonic scaling, polishing, high-speed handpiece use for restorative preparations, and debonding of orthodontic braces. The duration of the procedures ranged from 3 minutes to 90 minutes.

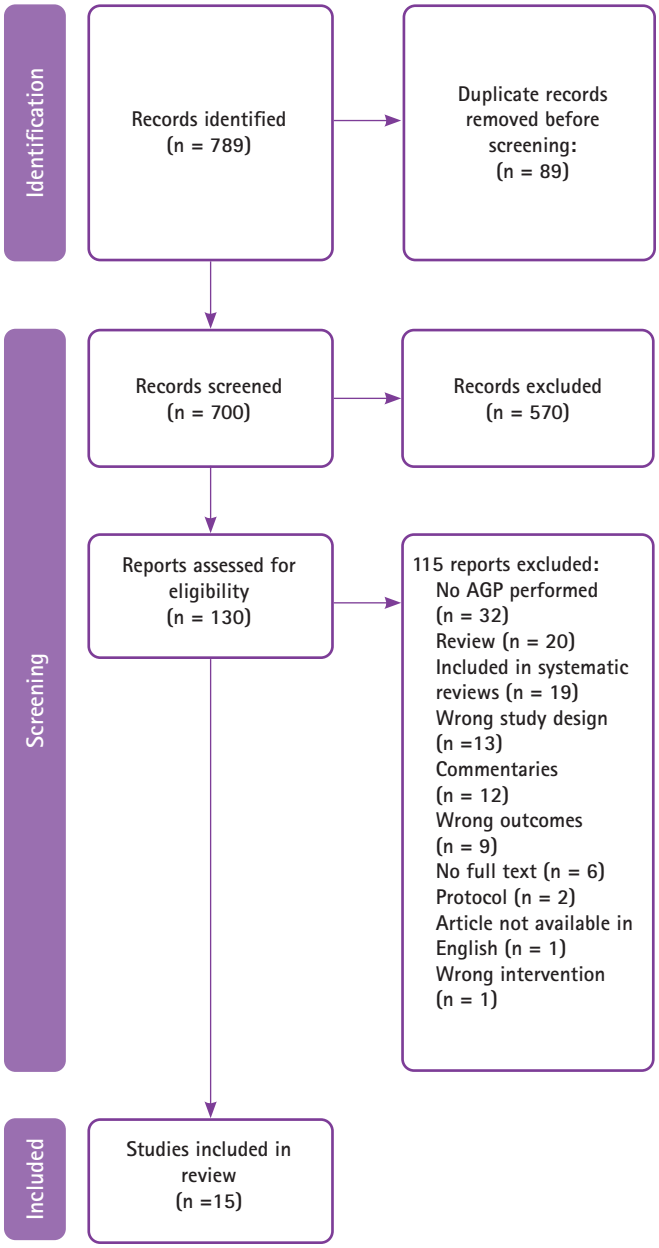
The included studies were homogenous both in their methodologies and results. The majority of studies (86.7%, n = 13) assessed the effectiveness of various types of preprocedural mouthrinses on the bacterial loads found in the generated aerosols by measuring colony-forming units (CFUs) at various locations (e.g., the chest of the patient and the clinicians, the face shield of the clinician) in the setting in which AGPs were performed.[33–35,37–46] The authors compared the CFUs formed before and after performing the AGP to determine the effectiveness of the tested mouthrinse. Almost all primary studies that tested the effectiveness of CHX (77.8%, n = 7/9) found that rinsing with 10 mL to 15 mL of 0.12% or 0.2% CHX for 30 seconds to 1 minute before treatment significantly reduced the amount of CFUs compared to water or other rinses.[35,37–41,46] Interestingly, 2 studies found that the use of 0.1% octenidine and neem, a novel antiseptic mouthrinse, was more effective than 0.2% chlorhexidine in reducing the bacterial load in the aerosol produced during ultrasonic scaling.[44,45] Neem (*Azadirachta indica*) is a tree that grows in tropical regions such as India and has been researched in the oral health care field for its therapeutic effects including its anticariogenic, anti-inflammatory, and antimicrobial properties.[47]

The 2 systematic reviews conducted by Marui et al.[33] and Mohd-Said et al.[34] corroborated those findings and suggest that the use of preprocedural mouthrinses prior to performing AGPs can effectively reduce the level of bacterial contamination of aerosols. However, Marui and colleagues[33] reported that the included studies had high or unclear risk

of selection bias, blinding, and detection bias. Hence they stated that the results must be interpreted with caution.

Despite the fact that many of the 15 studies were published after 2019 (66.7%, n = 10),[32,34,36,38–40,42–45] only 2 studies assessed the impact of preprocedural mouthrinses on viral loads, especially coronavirus, following AGPs. First, Burgos-Ramos et al.[36] compared the viral loads captured by portable air cleaners (PAC) with high-efficiency particulate air (HEPA) filters over 3 months in the waiting room (where patients wore face masks but did not undergo mouth rinsing), and in 3 treatment rooms (where patients wore no masks but carried out 1-minute mouth rinsing with 1% HP) at a dental clinic in Spain.[36] The authors found viral load in filters from the waiting room but not from the treatment rooms, where patients rinsed with 1% HP as soon as they removed the facemask to undergo AGPs.

Figure 2. PRISMA flowchart for Q2



Similarly, Nagraj et al.[32] conducted a systematic review with the primary objective to assess the evidence of the incidence of infection among oral health care providers. A secondary outcome of the review was to identify any reduction in the contamination level of the dental operatory environment.[32] The authors did not come across any study that addressed their primary objective. In terms of reductions in the contamination level, they found only a few studies that assessed reduction in bacterial contamination level in aerosols. None evaluated viral or fungal contamination.

In contrast, several studies including systematic reviews and randomized controlled trials explored the virucidal effect of mouthrinses on the viral load, specifically SARS-COV-2, in saliva. However, these were mere repeated measures studies that did not utilize AGPs. The explored mouthrinses had mixed results on the viral loads post use. For example, a systematic review conducted by Mohebbi et al.[48] found that 1% PI, Listerine™(EO), and CHX reduced the viral load in the saliva samples after rinsing compared to baseline, albeit with various effect rates and substantivities. This finding corroborated the results from an earlier review conducted by Silva et al.[49] that also demonstrated significant reductions in the salivary viral load after rinsing with PI and CPC. Alternatively, a systematic review conducted by Ortega et al.[50] did not find evidence to support the use of HP to reduce the viral load of SARS-CoV-2 or any other viruses in saliva.

However, the limitations of this body of evidence are twofold. First, these studies did not assess the viral load produced by AGPs, and therefore might not be informative for clinicians looking for evidence to support their practices. Second, they did not assess clinical end point outcome (i.e., cross infection between clinicians and patients) and subsequently might not translate to clinical recommendations. In other words, despite their proven effectiveness in reducing the viral load in saliva, mouthrinses have not been shown to reduce the risk of cross-contamination. Therefore, to better inform the dental hygiene community about the effectiveness of tested preprocedural mouthrinses, more experimental studies need to be conducted to assess the change in viral load in the aerosols generated during a procedure and, more importantly, if it changes the possibility of infection transmission.

To summarize, there is substantial evidence to suggest that the use of preprocedural mouthrinses reduces the level of bacterial contamination in aerosols generated by procedures commonly performed by dental hygienists. While there is some evidence to suggest the virucidal effect of preprocedural mouthrinses, the findings are limited to studies that did not involve AGPs.

Q3: Does the use of aerosol-scavenging systems (e.g., intra and extraoral evacuation systems, high- and low-suction systems) limit the spread of aerosols and reduce the risk of infection transmission between dental hygienists performing AGPs and their patients?

The search strategy yielded 934 articles. After the reviewers removed duplicates and irrelevant studies, 34 met the eligibility criteria and were included in the analysis. Figure 3 outlines the PRISMA flowchart and Supplementary Table S3 summarizes the characteristics of the articles identified to answer this question.

Studies found were conducted in varied clinical settings, the most common of which was a single-chair dental operatory. More than half of the studies reviewed (n = 19) were done on mannequins, 2 were in vitro studies without mannequins, 9 were observational studies using live participants, and 4 studies were systematic reviews, including 1 Cochrane review from 2020. In addition, 18 studies examined aerosol-reducing methods using intraoral devices (i.e., low- and high-volume evacuators), 3 compared high-volume evacuators intraorally and extraorally, and 13 studies examined other extraoral devices (i.e., 10 assessed extraoral suction systems, 2 dental chambers, and 1 a dental barrier).

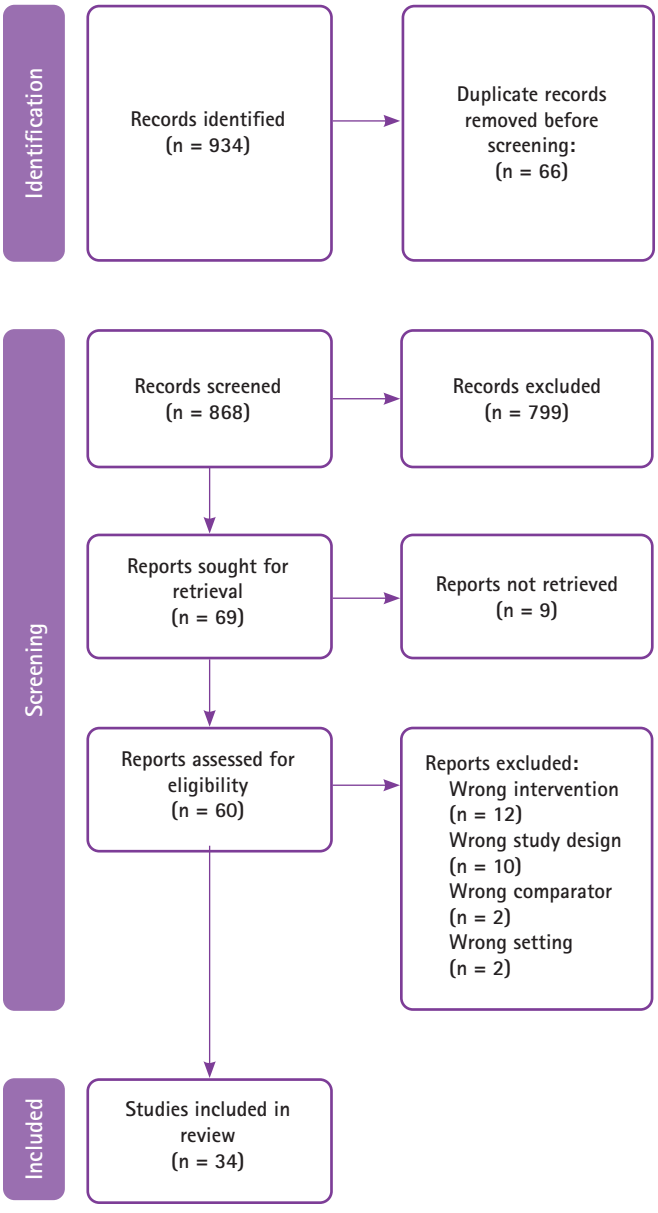
It is relevant to note the high number of studies using mannequins in the studies reviewed. Although the use of mannequins instead of human participants could limit the extrapolation of results, the use of human participants could raise ethical concerns in experimental studies because of the risk of infection to the health care provider, or vice-versa, when performing dental AGPs.

The dental AGPs tested were commonly ultrasonic scaling or procedures using high-speed handpieces as these are considered to generate the largest amount of aerosols.[51–66] The duration of the AGPs mostly ranged from 5 to 10 minutes and, most commonly, studies used bacterial contamination or particle counts to test aerosol mitigation effectiveness.

The studies on intraoral aerosol-reducing methods almost entirely focused on assessing high-volume evacuators (HVE), which showed greater effectiveness when ultrasonic scalers were used.[51,63] One study, conducted in dental offices in Italy, evaluated only low-volume evacuators (LVE),[67] and found LVE to be effective in reducing the number of particles during AGPs. Other studies suggest that using intraoral HVE compared to LVE is more beneficial in reducing aerosol particles.[56,58] In addition, if the HVE is dynamic (i.e., follows the path of the dental AGP), it is more effective in mitigating aerosol generation than static intraoral devices (i.e., that don't follow the path of the AGP, whether HVE or LVE).[63]. The HVE and LVE, however, can be used in combination to yield positive results.[9,21,65] As Rafiee et al.[21] highlight, the addition of HVE to the saliva ejector produces a low number of particles during ultrasonic scaling and is, therefore, not seen as a high-risk exposure. Moreover, the effectiveness of HVE can be improved by using isolation adapters (i.e., with soft tissue retractors)[58,66,68] or a rubber dam (when appropriate),[61,65] compared to HVE alone.

Similarly, the use of rubber dam alone to limit the spread of aerosols was also identified in the literature. In the Cochrane review conducted by Kumbargere Nagraj et al.,[77] the authors found 3 studies that assessed the impact of the use of rubber compared to no use at different locations. They found that the use of rubber reduced aerosol contamination 1 and 2 metres away from the mouth. However, the use of a rubber dam resulted in significantly higher presence of aerosols on the practitioner's forehead, left ear, submental triangle, and occiput, emphasizing the importance of PPE.

Figure 3. PRISMA flowchart for Q3



In terms of the HVE characteristics, Graetz et al.[55] suggest that the use of a suction cannula of 16 mm in diameter at a high-flow rate of ≥250 l/min produces the lowest splatter contamination values.[55] In addition, Matys and Grzech-Lesniak[58] suggest that the use of a wider customized HVE-tip is more effective than the standard tip.

In addition, 3 studies have compared the effectiveness of using HVE intra- and-extraorally to reduce aerosols.[64,68,69] Ehtezazi et al.[69] report that intraoral HVE is superior to extraoral HVE, while D'Antonio et al.[64] suggest that intraoral HVE, HVE intraoral adapter or extraoral suction devices are equally effective in preventing respirable aerosol. Furthermore, Choudhary et al.[68] report that the use of an extraoral conical HVE was more effective in reducing aerosol concentration than the standard-tip HVE due to its relatively larger surface area.

Among studies assessing other extraoral aerosol-reducing methods, 10 examined extraoral suction systems,[9,51,53,55,60,62,70–73] 2 assessed innovative chamber devices,[52,74] and 1 examined an individual dental barrier.[75] Although authors reported positive results for the chamber devices and individual dental barriers, these were isolated studies. Some studies suggest that extraoral suction systems paired with HVE or LVE showed the greatest reduction in particle concentration, aerosol and droplet level when compared to no extraoral suction systems during dental AGPs.[9,60,73,76] In addition, D'Antonio et al.[64] indicated that pairing extraoral suction systems with local ventilation is effective in reducing aerosols in a multichair open clinic setting.

The systematic reviews examined were mostly published during the pandemic (2020 and 2021). The Cochrane review published in 2020 considered studies that assessed bacterial contamination and aerosol particle concentration, but not necessarily the risk of infectious disease transmission.[77] In addition, the authors reported that the studies reviewed were of low certainty, due to the high heterogeneity in findings, risk of bias, small sample size, wide confidence intervals, and no minimal clinical importance of the difference in CFUs. Furthermore, the studies they reviewed did not evaluate costs, acceptability or ease of implementation.[77] Their main findings, nevertheless, highlighted the use of HVE and HVE with rubber dam when applicable.[77]. This main finding accords with that found by Samaranayake et al.[78], Robertson et al.[79], and Deana et al.[80] in their systematic reviews. These researchers also agree on the effectiveness of HVE in reducing aerosol.[78–80] Moreover, Samaranayake et al.[78] add that this effect depends on the suction strength, proximity to the operating site, and number of HVE used (as they found a study where 2 HVE had a greater aerosol reducing effectiveness than only 1).

To summarize, the evidence reviewed sheds light on the benefits of the use of HVE either with or without an isolation adapter, LVE saliva ejector, and rubber dam (when appropriate) for reduced aerosol contamination. In that sense, HVE can be seen as required for oral health practitioners during dental AGPs, especially when performing procedures that generate the largest concentration of aerosols, such as ultrasonic scaling and high-speed drilling of anterior teeth.

Q4: What are the types and effectiveness of the PPE used to reduce contact with aerosols and the risk of infection transmission between dental hygienists performing AGPs and their patients?

The search strategy yielded 370 articles. After reviewers removed duplicates and irrelevant studies, 7 studies were included in the final analysis.[81–87] Figure 4 outlines the PRISMA flowchart and Supplementary Table S4 summarizes the characteristics of the articles identified to answer this question. Four of the identified studies were conducted in simulated settings with mannequins and structured cubicles that resemble a real oral health clinic.[82,84–86] Three studies tested the effectiveness of conventional protective eyewear, masks, and respirators while the rest tested innovative protective devices such as air-fed masks,[82] individual biosafety capsule devices (IBCD),[85] rigid protective devices,[86] and the Cupola.[87] The outcomes assessed were bacterial contamination on eye lenses,[81] facial contamination,[82] bacterial filtration efficacy (BFE),[83] containment of aerosols,[85–87] and the viral load on the forehead and inside the mouth of an operator mannequin.[84]

Afzha et al.[81] found that the use of protective eyewear reduced the bacterial contamination on contact lenses compared to not using eyewear. After 10 minutes of high-speed handpiece activity, Bridgman et al.[82] found that 1) the use of N95 masks did not prevent nasal and oral contamination with aerosols; 2) the use of the novel air-fed mask in combination with glasses and N95 resulted in the elimination of all facial contamination; and 3) the use of air-fed mask and a sealed hood resulted in no contamination of the face, head or neck. Donning and doffing instructions for the air-fed mask system are described elsewhere.[82] However, it is worth noting that 1) the authors did not mention that participants were properly fit-tested for the evaluated N95 respirators; and 2) only one type of N95 respirator (FFP2) was tested. Therefore, the findings from this study must be interpreted with caution. All 3 studies that assessed the aerosol-containing devices found reduction in aerosol dispersion when used compared to no use. Finally, the only study that assessed viral loads found that using a face shield resulted in below-detection levels on the operator mannequin's forehead.[84] Similarly, all surgical masks and respirators resulted in undetectable viral loads inside the operator mannequin's mouth, with or without the use of a face shield.[84] Therefore, the authors suggested that the combined use of face shields and masks, regardless of the type, can prove effective in reducing the viral load on the practitioner's forehead and inside their mouth to an insignificant level.

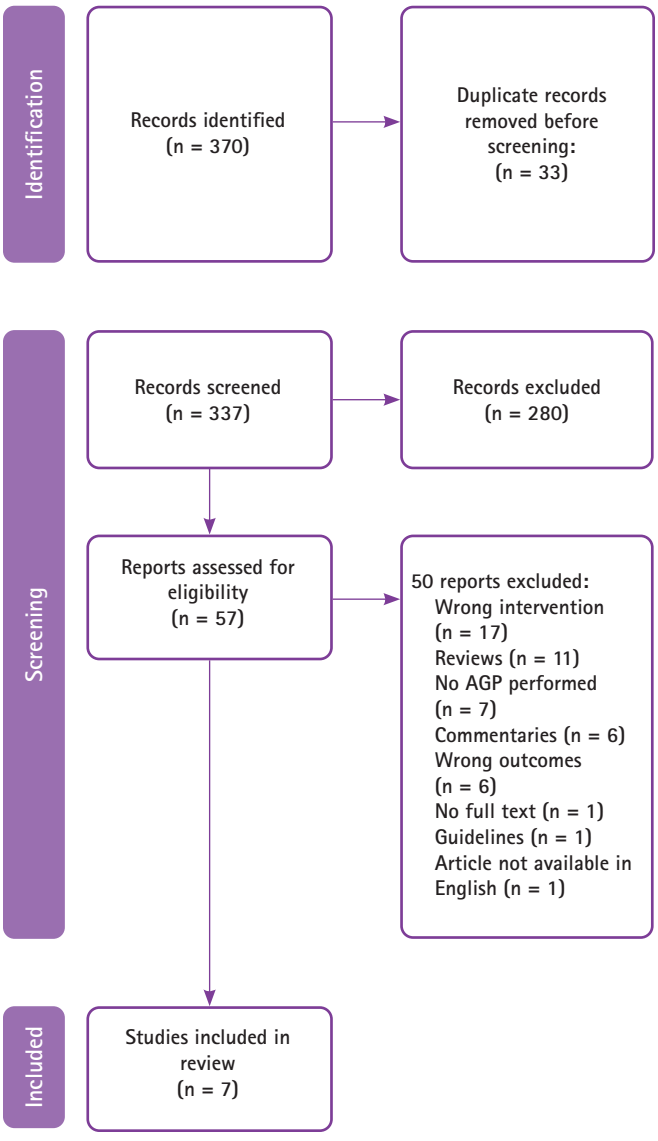
Additionally, 3 systematic reviews were conducted to test the effectiveness of N95 respirators versus surgical masks

in reducing viral illness (e.g., influenza and COVID-19) without performing AGPs.[88–90] The study by Long et al.[88] did not find the use of N95 respirators superior to surgical masks in terms of reducing the risk of laboratory-confirmed influenza. The American Society for Testing and Materials (ASTM) level (Level 1, 2 or 3) of surgical masks was not specified in these studies. More recently, the Cochrane review conducted by Jefferson et al.[89] found no evidence to suggest that medical or surgical masks offer any greater protection against viral respiratory illnesses compared to no masks, although only 2 of the 10 included studies were conducted in health care settings.[89] The authors also did not find any additional protection when using N95/P2 respirators compared to medical or surgical masks on laboratory-confirmed influenza infection.[89] On the contrary, in the systematic review conducted by Collins et al.,[90] the authors found that the use of N95 respirators was associated with fewer viral infectious episodes among health care workers compared with surgical masks. However, the high-risk biases and the limited number of studies included (n = 8) suggests the need for higher quality evidence on this matter. The mixed evidence suggested by these systematic reviews highlights the uncertainty about the effectiveness of N95 respirators versus surgical masks when it comes to preventing viral infections.

Overall, there are several limitations that hinder the applicability of the findings to the dental hygiene context. First, all studies utilized surrogate outcomes (i.e., the presence of aerosols on the body or masks) rather than clinical outcomes such as transmission of infection. Second, only 2 studies assessed the effectiveness of these methods for more than 10 minutes, which more closely resembles the real-life scenario in which a dental hygienist might be conducting AGPs for extended periods of time. Finally, the use of simulated settings, while useful, does not provide a similar experience to studies on real patients.

To summarize, despite the paucity of studies addressing this research question, the overall evidence suggests that the combined use of protective eyewear, masks (N95, FFP2 or air-fed), and face shields is effective in preventing contamination of the facial and nasal region. Other innovative devices, such as the IBCD and the Cupola have also shown promising results in limiting aerosol contamination. However, more studies with real patients and while performing AGPs for prolonged times are necessary to establish their effectiveness.

Figure 4. PRISMA flowchart for Q4



Q5: What should the operatory setup criteria be to limit the spread of aerosols in dental and dental hygiene settings?

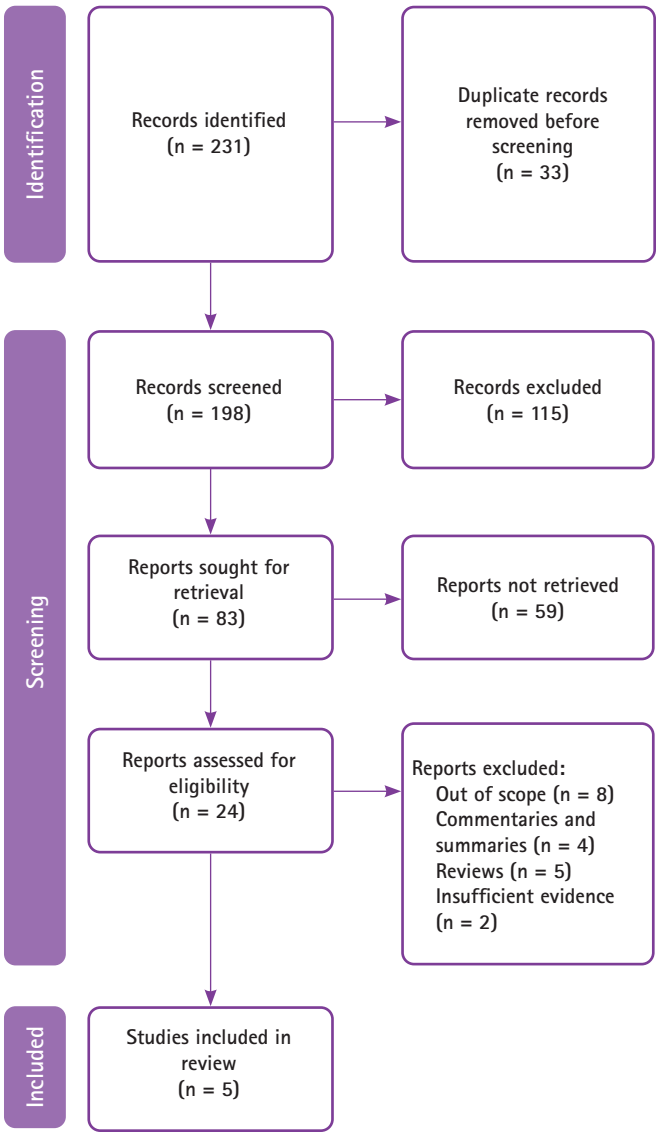
The purpose of this research question was to assess the role of architectural or engineering controls within a dental clinic or operatory in limiting the spread of aerosols. Air cleaning systems or ventilation systems are considered helpful in reducing airborne transmission in indoor environments. The search strategy yielded 231 articles. After reviewers removed duplicates and irrelevant studies, 5 were included in the analysis. Four studies were experimental[51,91–93] in nature and 1 was a Cochrane review.[77] Figure 5 outlines the PRISMA flowchart and Supplementary Table S5 summarizes the characteristics of the articles identified to answer this question.

Ventilation controls can assist in the removal of air contaminants and are usually dependent on the infrastructural configuration.[51,92] Filtration increases the effective air-exchange rate, and the effect of filtration devices usually depends on the distance from the source and airflow in the room.[92] Ren et al.[92] assessed the effectiveness of aerosol removal by mechanical ventilation and a portable air cleaner (PAC) with a high-efficiency particulate air (HEPA) filter in a simulated study at a dental facility. Aerosol accumulation was higher in rooms with poor mechanical ventilation than in rooms with

high ventilation, hence an inverse correlation between speed of aerosol removal and mechanical ventilation. The study concluded that using a PAC in combination with a HEPA filter was highly effective in reducing aerosol accumulation and thereby accelerating aerosol removal. In this case, the authors stated that only rooms with air changes greater than 15 could completely remove the aerosols by mechanical ventilation alone within the 30-minute observation period in this study. Given that this might not be achieved in many oral health care settings, ventilation alone might not achieve aerosol removal in less than 30 minutes. Therefore, the effectiveness of PACs was noteworthy and recommended in rooms with poor mechanical ventilation.

Furthermore, one study[51] looked at the impact of incorporating additional local ventilation systems into the operatory setup. Allison et al.[51] looked at local exhaust ventilation (LEV) systems that can capture aerosols at the source and limit their dispersion. They studied the effect of LEV on the distribution of aerosols produced during dental procedures after adding it to existing suction devices, while using an air-turbine handpiece and ultrasonic scaler. The observations included a 90% (within 0.5 m) reduction in aerosol production from the air-turbine handpiece, and a 99% reduction from the ultrasonic scaler. Based on their experiment, they inferred that LEV systems reduce aerosol and droplet contamination by at least 90% in the breathing zone of the clinician.

Figure 5. PRISMA flowchart for Q5



In addition to studying aerosol spread and aerosol settling time after dental procedures in an open plan clinic, Holliday et al.[91] also looked at the impact of cross-ventilation (windows were fully opened). It was found that dental suction and natural ventilation are beneficial in reducing aerosol contamination. As for the clinic layout, the authors found that the risk of aerosol migration from AGPs in an open plan clinic is likely to be minimal when the adjacent dental bays are ≥5 m apart.[91] For other aerosol mitigation strategies, Zhu et al.[93] suggested the installation of physical barriers between adjacent dental bays in a multichair setting (dental school environment in this case). The total partition height between stations was 2.5 metres, and transparent plastic sheets (<1 cm in thickness) were used to supplement the original partitions (1.3 metres and made of fabric covered material). They concluded that such barriers reduced dispersion of aerosols to adjacent dental bays. However, this study did not comment on the spread of aerosol contamination.

The Cochrane review by Kumbargere Nagraj et al.[77] included studies that previously measured the volume of contaminated aerosols in oral health care environments. One compared operative settings with an air cleaning system (ACS) versus those with no air cleaning system; the other compared settings with laminar air on with HEPA versus those with laminar air off to study decontamination of aerosols in air. The results for both studies estimated fewer CFUs after the procedures, showing a reduction in the aerosol load. Kumbargere Nagraj et al.[77] noted the lack of laboratory studies as one limitation. Another was the inclusion of dated studies in their review.

The search did not yield any studies on other methods such as ionisation, use of UV light and fogging, and few studies assessed operatory design. Future research is required in this area, especially interventional studies that assess architectural or infrastructural as well as engineering controls in clinical practice environments. Some studies[93–97] have described the mechanism of similar controls (such as installing high-efficiency air filters, increasing ventilation levels, providing negative ventilation pressure, and incorporating isolation rooms) in dental or dental hygiene practices. However, due to insufficient evidence of absolute reduction of aerosol contamination in dental operatories, they are not reported here.

To summarize, based on the studies reviewed, it can be inferred that by using a combination of ventilation and filtration approaches, in conjunction with aerosol-scavenging systems, dental or dental hygiene practices can limit the spread of aerosols generated by AGPs. Future studies, which would assess the impact of newer technologies and innovations in limiting the spread of aerosols, would be interesting as they may change the traditional setup of dental operatories.

Q6: What is the appropriate fallow time that allows aerosols to completely settle and reduces the risk of infection transmission between dental hygienists and their patients after performing AGPs?

The search strategy yielded 115 articles for this question. After reviewers removed duplicates and irrelevant studies, 9 studies (3 reviews and 6 experimental studies) were included in the analysis. Figure 6 outlines the PRISMA flowchart and Supplementary Table S6 summarizes the characteristics of the articles identified to answer this question.

The required time for particles to settle down (i.e., fallow times) is relevant for dental AGPs, as suspended microorganisms (e.g., bacteria, fungi, viruses) may be found in the contaminated bio-aerosol.[98] Dental AGPs include the use of 3-way air/water spray, cleaning with an ultrasonic scaler and polishing, periodontal treatment with an ultrasonic scaler, and dental preparation with high- and low-speed handpieces.[99] Studies on fallow time are relevant in the context of the COVID-19 pandemic. Most of the studies identified examined AGPs from ultrasonic scaling, some from high-speed and low-speed drilling, and a few from crown or root canal preparations, all of which were mainly conducted in enclosed spaces.[62,68,69,99–101]

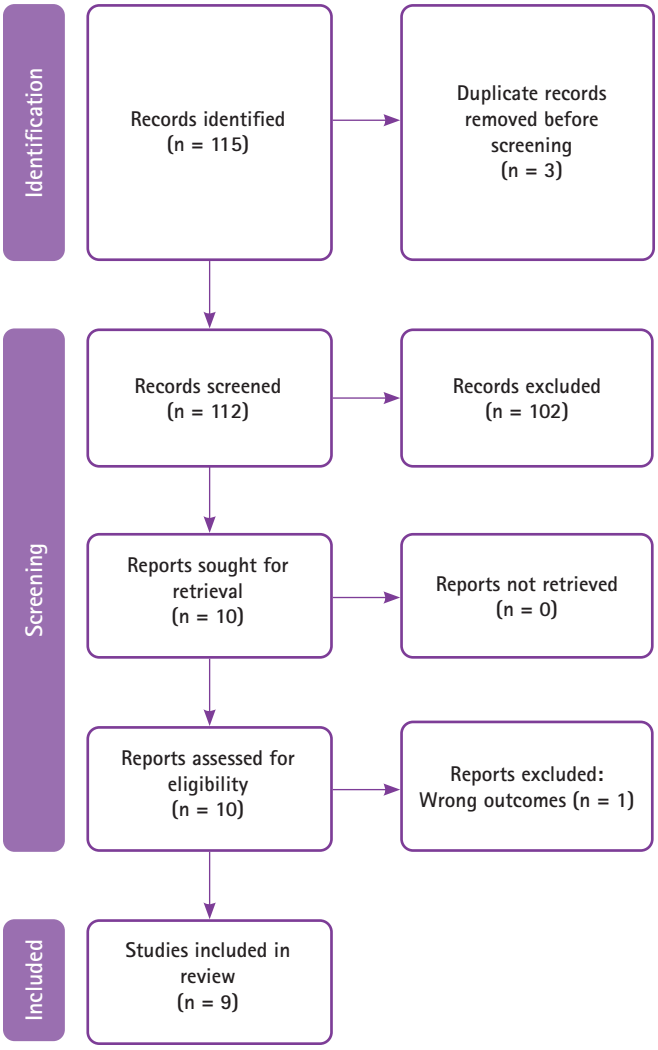
Mathematical formulas for fallow times have been proposed in the literature and are commonly used in guidelines, although consensus has not yet been reached on the appropriate threshold for contaminant removal efficiency (90% vs 99%).[102] One mathematical formula has been provided by the National Institute for Occupational Safety and Health (NIOSH) to model the rate of decline in the concentration of an airborne contaminant.[102] However, most of the studies reviewed did not provide calculations on how fallow times were determined.[68,79,99,101,103,104] Few studies described using baseline aerosol concentrations to calculate the time it took to return to those levels.[62,69,100]

From the studies reviewed, it is complex to establish a set fallow time threshold without considering other critical factors. For example, fallow time is highly dependent on the air change per hour (ACH) in the oral health care setting[62,103]; that is, the higher the change per hour, the lower the fallow time. When the ACH is unknown, guidance has varied from 15 to 180 minutes. Other authors have suggested that a minimum of 10 minutes is sufficient when good ventilation (>10 ACH) exists.[79,103] Nevertheless, Shahdad et al.[62] suggest that the longest fallow times occur when windows are closed and there is no mechanical ventilation. A more recent study conducted by Longo and colleagues[105] suggested even shorter fallow time intervals. The authors stated that, to restore the baseline aerosol level values after the cessation of AGPs, less than 3 minutes of fallow time would be enough when there is no additional ACH, and no fallow time is required with 20 additional ACH.[105]

The fallow time also depends on the dental equipment (e.g., air-turbine, high-speed contra-angle handpiece), length of the procedure, the size of the aerosols generated, and other aerosol mitigation strategies, such as the use of rubber dams, high-volume evacuators (HVE), and extraoral suction devices.[68,69,99–101,103] According to a review done by the College of General Dentistry in the United Kingdom[103], fallow time is also critically impacted by the absence of HVE and poor ventilation (e.g., 1 to 2 ACH). Under those circumstances, the fallow period can increase by up to 60 minutes.[103]

In addition, one study assessed different clinical setting configurations (single room layout, semiprivate operatory

Figure 6. PRISMA flowchart for Q6



with partial wall, and large multioperator space), the use of HVE, and fallow times.[68] The authors concluded that aerosols were transient when HVE was employed regardless of the setting configuration, and as such the fallow times could be considered to be of 5 minutes under such conditions. Ultimately, it is important to be mindful that fallow time recommendations originated in the tuberculosis literature, and therefore might not be relevant when making recommendations in the context of respiratory viruses such as SARS-CoV-2.[106]

To summarize, ACH levels and HVE use are relevant characteristics to consider when estimating fallow times after performing AGPs. As such, well-ventilated areas, with 10 to 15 ACHs,[107] and/or the use of HVE can reduce fallow times (10 minutes or less) after dental AGPs, such as ultrasonic scaling.

DISCUSSION

With viral infections such as COVID-19 and other communicable diseases that have the potential to spread through aerosols, AGPs will pose a viable risk of infection transmission for dental hygienists working in clinical settings. The purpose of this position paper is to provide dental hygienists and other oral health care providers with guidance when performing AGPs based on the latest scientific evidence. This includes identifying the risk of infection transmission associated with conducting AGPs; effectiveness of different types of preprocedural mouthrinses in reducing the microbial load of aerosols generated through AGPs; examination of dental evacuation systems to reduce the transmission of aerosols far from their origin; appropriate PPE to provide optimal barriers to aerosols that may be contaminated; appropriate operatory setups for proper ventilation; and finally, setting optimal fallow periods for aerosol to settle or leave the room. All of these aspects are reviewed to ultimately control the risk of infection transmission via aerosols following AGPs.

While there is a varying degree of robustness in the literature addressing the proposed questions, the following recommendations can be made based on the current evidence to help dental hygienists make informed decisions about their practices and to ensure their patients' and their own safety:

1. There is not enough direct evidence of risk of transmission of SARS-CoV-2 between dental hygienists and patients despite AGPs being considered high-risk procedures.
2. This review suggests that CHX is effective in reducing bacterial contaminations in aerosols. However, there are limitations in understanding which preprocedural mouthrinses are effective against SARS-CoV-2.
3. The customized HVE tip with a suction cannula of 16 mm diameter at a high-flow rate offers the lowest splatter contamination.
4. The combined use of protective eyewear, masks, and face shields is effective in preventing contamination of the facial and nasal region. However, there is no evidence to suggest their effectiveness against infection transmission.
5. The appropriate combination of ventilation and filtration in dental operatories supports the containment of aerosols.
6. In terms of fallow time, several factors must be considered when deciding on the appropriate resting time. When combining the use of HVE with a high ACH, minimal fallow time (10 minutes or less) seems to be enough for aerosols to settle.

The recommendations made by this position paper are based on the most recent scientific evidence rather than simply taking a precautionary approach adopted by many guidelines published over the last 3 years. Moreover, since it provides evidence on AGP-related issues, it also serves as a guide for all other members of the oral health care team. Several limitations have to be considered when analysing the results from this review. First, only studies published in English were included. Therefore, evidence published in other languages might have been missed. Second, no quality appraisal was conducted on the included studies. As such, no comments on the quality of the evidence presented can be made, and dental hygienists are advised to contextualize the recommendations made to inform their practices. Finally, this review was conducted using scientific literature and experimental studies, and did not include guidelines and grey literature, as they may be restricted in their approach, reflecting only specific jurisdictional, organizational or regulatory contexts.

AGPs are an integral part of oral health care settings, and it is a constant reality that aerosols appear to pose a risk of disease transmission between clinicians and their patients. Therefore, utilizing the best available evidence, analysing, and understanding the risk of infection transmission is important to support oral health care providers in making safe practice decisions. Recommendations made by this position paper are meant to complement, and not replace, existing standard infection control protocols, vaccination requirements, and precautions such as prescreening for illness to mitigate the risk of disease transmission in oral health care settings.

CONCLUSION

Aerosols produced during AGPs can pose a risk of infection transmission between dental hygienists and their patients. In the last 3 years, there has been an influx of evidence and guidelines about various aspects of AGPs. Therefore, it is important to integrate that knowledge to keep oral health care providers, including dental hygienists, updated on the current evidence regarding effective devices, methods, and protocols to mitigate the risk of infection transmission when performing AGPs.

Key considerations

- Few studies report direct evidence of risk of transmission of SARS-CoV-2 among dental hygienists and their patients. However, even in the absence of evidence of direct SARS-CoV-2 transmission through AGPs in dental or dental hygiene environments, the possibility still exists, until proven otherwise.
- There is substantial evidence to suggest that the use of preprocedural mouthrinses reduces the level of bacterial contamination in aerosols generated by procedures commonly performed by dental hygienists. To a lesser extent, studies suggest that some mouthrinses have a virucidal effect but with very limited trial evidence after the use of AGPs.
- Evidence suggests that the use of HVE either with or without an intraoral suction reduces aerosol contamination. Combining HVE with saliva ejectors, isolation adapters (i.e., with soft tissue retractors) or a rubber dam (when appropriate) may yield even greater reductions in aerosols.
- The overall limited evidence suggests that the combined use of protective eyewear, masks (N95, FFP2 or air-fed), and face shields is effective in preventing contamination of the facial and nasal regions when performing AGPs.
- The appropriate combination of engineering (ventilation and filtration) systems in conjunction with aerosol-scavenging systems can limit the spread of aerosols when performing AGPs.
- With sufficient air ventilation, a fallow time of as low as 10 minutes or less can be enough for aerosols to completely settle in enclosed spaces. However, factors such as the length of the AGPs, the type of equipment used, and the presence of aerosol-mitigating strategies and HVE can alter the time required.

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CONFLICTS OF INTEREST

The authors have no conflicts of interest to declare.

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