COVID-19 risk management in dental practice. Part 4: The 10 pillars of SARS-CoV-2 control in clinical dental practice

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Keywords: coronavirus, COVID-19, SARS-CoV-2, infection control, prevention, dentistry, airborne transmission, PPE, surface disinfection, ventilation, immune boosting, antibodies, vaccine.

Introduction

The practice of dentistry exposes dental health care professionals and patients to infectious disease pathogens.[1] In addition, the SARS-CoV-2 pandemic has become a major infection control and prevention challenge for dentistry primarily due to transmission of infectious respiratory droplets and aerosols;[2-9] and direct contact with the oral cavity and saliva, a recognized reservoir and portal of exit and entry for SARS-CoV-2.[8-11]

Patients seen by dentists may be asymptomatic carriers of SARS-CoV-2. Oral health is integral to general health care and therefore a potential risk for COVID-19 severity.[13]

COVID-19 infection control and prevention policies world-wide for healthcare workers have focussed on the use of PPE. The importance of source control at oral level to reduce the spread of contaminated droplets and aerosols has not received the same recognition as that of PPE. Infection control and prevention globally seems to be a point of considerable confusion within the dental profession.[14]

Internationally the recommendations for re-opening dental services have no referenced, underpinning evidence, and some areas are unlikely to ever have strong (or any) research evidence.[15] Most recommend avoiding or minimizing the use of aerosol generating procedures (AGPs) to reduce the risk of transmitting virus contaminated aerosols.[15]

As the COVID-19 pandemic continues to explode, hospitals and dental practices are scrambling to implement and intensify infection control measures to protect themselves and patients from exposure to the coronavirus. This has to be done in an ethical manner.

Purpose and Methodology

The purpose of this Covid review is: (i) to outline contemporary evidence on enhanced precautions for infection control and prevention (ICP), with focus on SARS-CoV-2 source control to reduce generation of contaminated droplets and aerosols, (ii) to explore the relevance of enhanced precautions for dental professionals, and (iii) to outline the limitations of the current evidence relating to ICP within the dental practice.

Emerging literature on COVID-19 is rapidly evolving and scattered over various sources, is characterized by incomplete or uncontested evidence-based data and by a plurality of voices within the health care, academic, environmental research community and media. This makes it difficult to clearly and rapidly synthesize and articulate scientific evidence.

A comprehensive literature search of multiple bibliographic databases was conducted, including Medline PubMed, Embase, the Cochrane Collaboration and Google Scholar. COVID-19 repositories with lists of grey literature sources (e.g., LitCOVID, COVID-END and WHO-COVID-19) and pre-print servers or repositories for biological and medical sciences (e.g., medRxiv, bioRxiv) were also included.

Search keywords used in this review include: coronavirus, COVID-19, SARS-CoV-2, infection control, source control, dentistry, airborne transmission, fomites, standard

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precautions, enhanced precautions, dental workplace, screening, hand sanitation, procedural rinse, mouth wash, rubber dam, high volume suction, PPE, surface disinfection, ventilation and Boolean search terms AND/OR. Electronic databases were searched to August 31, 2020.

Standard precautions, policies and legal requirements for ICP

Standard ICP measures are designed to prevent or reduce the potential transmission of pathogen or disease from patient to dental health care workers (DHCWs), from DHCWs to patient, and from patient to patient in dental practices. These standard precautions apply to all patient care.

Infectious respiratory airborne disease has now entered the arena and dentists have to modify existing bloodborne ICP measures to reduce the risk of SARS-CoV-2. The Centers for Disease Control (CDC)[16] and United States Occupational and Safety Health Administration (OSHA)[17] both stipulate that dental practices require enhanced precautions to protect the DHCWs and patients from AGPs.

While there are differences in the standard of care for dental infection control globally, most countries follow the same basic policies and procedures, namely that of the CDC,[18,19] European Centre for Disease Prevention and Control,[20] and Organisation for Safety Asepsis and Prevention.[21]

Standard precautions[22-26] and Government policies guidance regarding ICP of COVID-19 and SARS-CoV-2 in the dental workplace[21,27,28] do not fall within the scope of this review.

Enhanced precautions for reducing contaminated aerosols and risk of SARS-CoV-2 transmission

Understanding the characteristics of the infection chain pathway is critical in the adoption of appropriate ICP strategies in the dental practice. Breathing, talking, sneezing, coughing and AGPs are all implicated in the transmission of virus-laden droplets and aerosols from the oral cavity. The infection chain can be blocked at various levels, most importantly at its source by applying appropriate ICP measures. This reduces the viral load in saliva/oral cavity and the risk of exposure and spreading of infection. (for review of this refer to Part 2)

Enhanced ICP measures to limit airborne contagion and transmission of SARS-CoV-2 in the dental practice setting are based on the following 10 pillars derived from the infection control chain pathway.

Pillar 1. Screening and isolation for high-risk patients and DHCWs

All patients entering a dental practice or phoning to schedule an appointment should be screened and triaged for signs and symptoms of COVID-19 prior to dental treatment.[29] DHCWs should also be subjected to daily screening protocols. Anyone with symptoms of COVID-19 or suspect cases should be properly managed and advised to self-quarantine. Most recommend patient triage by telephone, whilst others recommend temperature screening at reception to screen for COVID-19 cases.[15] This should be observed in addition to procedures required by the Occupation Health and Safety Act and workplace safety regulations of the Department of Labour and Employment [27] to limit exposure to potential infectious patients.

However, transmission of SARS-CoV-2 can occur in asymptomatic and pre-symptomatic persons, therefore screening offers no assurance of identifying infected individuals. In addition, testing prior to dental care at this stage in time is not an option due to costs, time constraints and false negative results. Because triage is currently unable to identify infected individuals, the only safe and realistic approach is to consider all patients infectious. [7]

Pillar 2. Facial masking

Evidence related to other respiratory viruses indicate that facial masking can protect the wearer from becoming infected by blocking viral particles.[30] Public health authorities define a significant risk of exposure to COVID-19 as face-to-face contact within 6 feet with an infected patient, sustained for at least 10-30 minutes.[31] Therefore it is prudent to accept the principle of universal masking for DHCWs and patients within the dental practice. More compelling is the possibility that wearing a mask may reduce the likelihood of transmission from asymptomatic and minimally symptomatic DHCW's to other providers or patients.[31] Current scientific evidence suggests that masking or face covering as a protective measure alone significantly reduces the number of asymptomatic cases and severity of COVID-19 infections.[32,33] This possibility is consistent with the theory that the severity of diseases is proportionate to the viral inoculum received.

Universal masking of all healthcare workers has significantly reduced the rate of health-care acquisition of SARS-CoV-2, thereby flattening the health-care associated COVID-19 infection epidemiologic curve. This mitigated the spread from asymptomatically infected or minimally-symptomatic individuals, thus reducing the strain on healthcare systems.[35]

Pillar 3. Hand sanitation

Human to human transmission contributes a major part to this infection pandemic.[36] Coronavirus transmission is spread via droplets, aerosols, and contaminated hands/surfaces.[37]

Transmission can be prevented/reduced by frequent disinfection of hands with water/soap or alcohol-based hand-sanitizer. Ethanol (60-70%) and isopropyl alcohol (70-72%) is the optimum strength that is recommended. Frequent use of alcohol based hand sanitizers may wash out the oils from the skin surface resulting in dehydrated skin. Therefore hand washing with soap remains the most effective strategy for reducing this mode of transmission.[38] Soap molecules emulsifies the lipid content of the material adhering to the hand, and convects it away.[39] Soap molecules dismantles the lipid envelop of SARS-CoV-2, thereby deactivating it.[40] Alternatively hypochlorous acid (HOCL) used for hand sanitizers are effective at 100-200 ppm strengths.[41]

DHCWs should be aware of what they touch, including computer keyboard and mouse, unit instrument tray handles, dental lights, drawers and handles and x-ray tubes. Hand sanitize whenever interacting with these items and apply appropriate disinfection of these surfaces after each patient visit.

Pillar 4. Pre-procedural mouth rinse

Recent research recommend the use of pre-procedural mouth rinses to reduce transmission of SARS-CoV-2 in dental practices.1[5,42-45]

It should be emphasized that natural saliva is a viscoelastic liquid and thus, is a mitigating factor in the process of aerosolization.[46]

Emerging studies increasingly demonstrate the importance of the throat and mouth as sites or reservoirs of virus replication, shedding and transmission in early COVID-19 disease.[42,47] DHCWs are in close contact with the upper respiratory-digestive tract and therefore at high risk of exposure to SARS-CoV-2 from the patient.[48,49] Recent research suggests that the viral load in the oropharynx with SARS-CoV-2 infection is as high in asymptomatic versus symptomatic patients.[50]

Oral rinsing with hydrogen peroxide (H2O2), povidone-iodine (PVD-I), chlorhexidine and cetylpyridium chloride are known for their ability to disrupt the viral lipid membrane through oxidation. This has the potential to inactivate the virus and reduce transmission of SARS-CoV-2.[42,51] The purpose of using a pre-procedural mouth rinse/gargle is to reduce the viral load expectorated or produced during AGPs.[45,52] Routine use of a mouth rinse/gargle pre-operatively is recommended to render contamination from the oropharyngeal complex less infective as well as from the oral cavity to other internal systems (i.e. lungs).[53,54]

• Povidone-Iodine

PVD-I is a water-soluble iodine complex widely used as a pre-surgical skin antiseptic and as a mouthwash.[55] PVD-I has an excellent safety profile and broad spectrum antiviral, antibacterial and antifungal effect.[56] PVD-I mouthwash or spray is typically used in a 1% concentration for prophylaxis of oropharyngeal infections and prevention of ventilator-associated pneumonia.[45,51,57] PVD-I has higher virucidal activity than other antiseptic agents, including H2O2,[58] CHX and benzalkonium chloride.[59]

Its effectiveness has been well demonstrated by in vitro studies against multiple viruses, including SARS-CoV, MERS-CoV, influenza virus and SARS-CoV-2.[58-61] The use of 0.2% PVD-I as gargle /mouth rinse is suggested for reducing the virus load in the oral cavity thus minimizing the risk of SARS-CoV-2 transmission.[51]

According to available literature the most effective method for reducing viral load and reducing the risk of SARS-CoV-2 transmission during AGPs is through pre-procedural rinsing and gargle with PVD-I. (0,2% to 1%)[55,58,61-63] Based on the current evidence, preprocedural rinsing with dilutes of PVD-I may be preferred over hydrogen peroxide during CoVID-19 pandemic.[58]

It is safe and does not produce tooth or tongue discoloration or taste disturbances.[64,65] PVD-I is not recommended during pregnancy or for patients with active thyroid diseases, those undergoing radioactive therapy or individuals that are allergic to iodine.

• Hydrogen peroxide

Hydrogen peroxide is an odourless, clear and colourless liquid with no adverse effect on soft tissue. Hydrogen peroxide causes disruption of lipid membranes. Since SARS-CoV-2 is vulnerable to oxidation, preprocedural mouth rinses containing oxidative agents such as 1% H2O2 have been suggested to reduce the salivary viral load.[2,43,66]

Recent studies reported that 0.5% H2O2 inactivated coronavirus and other enveloped viruses.[67,68] However, H2O2 has a low substantivity as it is rapidly inactivated in the oral environment.[69]

• Chlorhexidine (CHX)

CHX is a broad-spectrum antiseptic that acts against bacteria, viruses and fungi by increasing the permeability of the cell membrane, causing its lysis.[70] Chlorhexidine formulations have been shown to retain oral antimicrobial activity for up to 12 hours.[72] A recent meta-analysis showed that chlorhexidine (rinse or gel) can reduce the risk of ventilator associated pneumonia in patients undergoing mechanical ventilation.[73]

Recent evidence suggest that chlorhexidine, although considered as the gold standard for reducing bacterial load, has decreased effectiveness due to lack of oxidative action, while use of 1% hydrogen peroxide and 0.23-1% Povidone-Iodine (PVD-I) are more effective alternatives.[2,8,74]

• Cetylpyridium chloride

Cetylpyridium chloride (CPC), a quaternary ammonium compound that is safe to use in humans,[75, 76] was recently shown to have virucidal activity against influenza virus through direct disruption of the viral envelope.[76,77]

These findings suggest that 0.05% CPC could be effective against other enveloped viruses such as SARS-CoV-2.[45,78] CPC is used in medicated oral rinses at concentrations between 0.025-0.075%.[77]

Pillar 5: Personal protective equipment (PPE)

• Importance and relevance of PPE in clinical dental practice

PPE including gloves, masks, respirators, protective outerwear, protective surgical glasses, goggles and face shields are required to provide a physical barrier or shield that could prevent or minimize risk of exposure to infectious pathogens such as SARS-CoV-2. [2,3,8,36,79]

PPE is of critical importance for all DHCWs due to working in close proximity with potentially infected patients.[80-85]

Recommendations about the appropriate use of PPE have been controversial and at times conflicting.[79] In the absence of direct evidence from studies in a dental setting, we have to apply the general evidence regarding PPE in health care settings.[84] A physical barrier at the checkpoint (mouth, nose and eyes) may reduce the spread of droplet or aerosol mediated viral infection.[36,66]

The suggested minimal composition of PPE to be used in healthcare settings to prevent contact, droplet and airborne transmission of SARS-CoV-2 are: (i) respiratory protection (surgical masks, N95/FFP2 or N98/FFP3 respirators), (ii) eye protection (goggles or face shields), (iii) body protection (long sleeve water resistant gown), and (iv) hand protection (gloves).[20]

• Respiratory protection devices - Surgical mask or filter face-piece (FFP) respirator?

A mask is a core component of PPE to protect DHCWs.[31] It has been shown that in dental practice, central areas of the face such as the inner part of the eyes and around the nose and mouth were the most contaminated areas.[85] It is therefore recommended to use protective means such as a mask, goggles and protective shield when performing AGPs.

The effectiveness of face masks however has generated significant controversy during the COVID-19 pandemic.[86-88] Knowledge about specific characteristics of surgical masks and respirators is of utmost importance to select the appropriate type according to the clinical setting and procedure.[79]

Respiratory protection devices (masks) have been classified into 2 groups depending on the filtering efficiency capacity.

(i) Medical or surgical mask (SMs)

SMs are indicated for low risk routine clinical procedures where no AGPs are performed or where a rubber dam is used.

SMs are loose fitting source barriers, primarily designed for one way protection of vulnerable patients. Contrary to belief, SMs are not designed to protect the wearer and most SMs do not have a safety rating assigned to them.

An obvious flaw with surgical masks compared to respirators is their lack of tight face fit, which leaves gaps around the edges through which viruses and other infectious pathogens can be inhaled or exhaled.[89] SMs are for single use only and must be discarded after every procedure.

With the scarcity of N95 respirators and considering cost implications, dentists may opt to resort to wearing a face shield over surgical mask for additional protection.

SMs contaminated with aerosols/biofluid/moisture not only loses protective characteristics but also provides a suitable environment for microbes to breed.[36]

Cloth masks are also not indicated for clinical use.

(ii) Filter face-piece respirators (FFRs)

FFRs are tightfitting to create a facial seal and designed to provide 'inward' protection by filtering virus-laden aerosolized particles and 'outward' protection by trapping virus-laden droplets expelled by an infected person.[30] Respirators are primarily designed to protect the wearer up to the safety rating of the respirator. The effectiveness of a respirator is determined by two significant factors, the filtration efficiency and fit.[90]

FFRs are tight fitting, available as disposable half face or full face design, and designed to filter airborne droplet nuclei (< 5 micron in diameter). The US National Institute for Occupational Safety and Health (NIOSH) classifies FFRs into nine categories N95,(95%) N99 (99%), N100 (100%), P95 (95%), P99 (99%), P100 (100%), R95 (95%), R99 (99%), and R100 (100%).[91]

The letters N designates 'not resistant to oil', R 'resistant to oil' and P 'oil proof', whereas the numeric characters describe the minimum filtration efficiency. The European Standard (EN149:2001) classifies FFRs into three classes , FFP1 (80%) , FFP2 (94%), FFP3 (99%).[92]

FFRs are the most appropriate barrier against aerosol because they provide a tight seal to the facial skin. Their principle function is to protect the wearer from the environment, and therefore indicated when performing high risk AGPs.

The current gold standard respiratory protection device for protecting the wearer and the patient in dentistry is a N95 respirator.[79] The most recent indications of the WHO about the use of PPE during COVID-19 pandemic, recommend the use of N95 or equivalent FFP2 for AGPs performed on patients with COVID-19.[93]

The CDC have also updated their guidance for dental settings, emphasizing the use of N95 masks and eyewear during high risk procedures.[94]

• Risks and limitations of FFRs

N95 or FFP2 respirators are not intended to be one-size-fits -all. Filtering performance strongly depends on fitting. DHCWs should test different devices to find the best fitting model and size for their face (i.e.the presence of a beard can alter the sealing).[79]

Powered and air supply respirators are reusable devices that can be disinfected and have interchangeable high efficiency particulate filters (HEPA). Concerns about the clinical use of re-usable respirators are difficult communication, and the exposure of personnel in charge of disinfection to an additional biological risk.[79] Moreover, respirators are more expensive than medical masks. Wearing a face shield over a N95 , or use of a local exhaust ventilation system are likely to reduce respirator surface contamination.[95,96]

Common mistakes that occur in dental practice is removing the mask with contaminated gloves or by touching possible contaminated surfaces of the mask.[89] The correct procedure for removing a N95 mask is to remove contaminated gloves first, hand sanitize, put on a new pair of gloves, and remove the mask by the strings. A mask will not protect providers against SARS-CoV-2 infection if it is not accompanied by meticulous hand hygiene, eye protection, gloves and gown.[31]

Evidence suggests that surgical masks and N95 respirators offer similar protection against viral respiratory infection, including coronavirus in health care workers during non-AGPs. N95 respirators should only be considered for high-risk AGPs when in short supply.[97]

• Can masks with exhalation valves or valved respirators be used in dental practice?

The outward protection afforded by masks has emerged as a particularly important issue in the COVID-19 pandemic because SARS-CoV-2 transmission may occur in asymptomatic or early pre-symptomatic infections.[98-100]

FFRs are available with and without an exhalation valve. Valved masks only filters air breathed in to protect the wearer from inhaling aerosols containing the virus and reduce excessive dampness and warmth in the mask from exhaled breath.

Valved respirators are designed to make it easier to exhale air and to prevent fogging of goggles and shields. This make them more comfortable to wear and creates less moisture build-up inside the respirator.[79]

Respirators with exhalation valves protect the wearer from SARS-CoV-2, but may not prevent the virus spreading from wearers (dentists and chairside assistant) to patients. Exhaled air passes unfiltered into the environment defeating one important purpose – protecting the patient.[101-103] Respirators with exhalation valves are therefore not recommended for use in dentistry.[89]

• Practical guidelines on extended use versus reuse of N95 masks

Shortages of N95 masks may occur during disease outbreaks. Wearing a N95 respirator for hours at a time (extended use) or re-using a respirator several times are practices used to ease shortages and reduce costs.

Studies support prioritizing extended uses over reuse because of the following:[104] (i) The reported pathogen transfer risk from N95s is high by contact transmission donning and doffing; (ii) The reported pathogen transfer risk from N95s is low by aerosol spread by breathing through a used mask; (iii) Use of surgical masks or a similar disposable cover over N95s during extended use, are unlikely to cause any significant adverse effects on breathing or gas exchange to the user; (iv) Mechanical failures (e.g., broken straps and poor sealing) with only a few re-uses were common across N95s; (v) Commonly used effective disinfection methods (i.e., autoclaves, bleach, H2O2 vapor or ultraviolet light irradiation) can achieve adequate disinfection with some filter performance loss.

• Can I decontaminate and reuse N95 respirators?

In general N95 respirators are designed for single use. Different methods have been suggested to decontaminate masks from infectious SARS-CoV-2, including Heat (70°C), 70% Ethanol, UV Irradiation (260-285nm) and vaporized H2O2. (VHP)

A recent study was done to assess the effectiveness of these methods on the reduction of contamination with infectious SARs-CoV-2 and their effect on respirator function.[105] This study found that VHP exhibits the best combination of rapid inactivation of SARS-CoV-2 and preservation of N95 respirator integrity. UV radiation kills the virus more slowly but preserves respirator function. Dry heat kills the virus with similar speed to that of UV and is likely to maintain acceptable fit for 2 rounds of decontamination. Ethanol decontamination is not recommended due to loss of N95 integrity. This study suggests that N95 respirators can be re-used in times of shortages for up to 3x when decontaminated with UV and VHP, and up to 2x with dry heat.[105]

• Face and eye protection - Goggles/Face shield

Mucous membranes of the eyes are also a possible portal of entry.[106] Therefore eye protection with face shields, goggles, plastic glasses or visors have become a mandatory part of PPE during the COVID-19 pandemic. Another advantage of a face shield is its protection of masks from splashes.[107]

Eyes and face masks should be protected with goggles or a full-face shield in all AGPs.[89] After AGPs, PPE must be disposed of or disinfected.

Hard plastic glasses were the most effective means of protection against conjunctival contamination during orthopaedic AGPs (83%). Modern prescription glasses provided only 17% protection, and are not recommended as sole eye protection during AGPs.[108] Loupes on their own provided only 50% protection, and facemasks and eye shields 70% protection.

A modification of a visor mask to allow use of loupes and a head light has been described whilst maintaining adequate aerosol/air droplet protection.[109]

Common mistakes by DHCWs: (i) Using common prescription glasses as protection, (ii) Using only dental loupes or microscopes, (iii) removing protections after each procedure by touching the external shield surface.

Protective safety glasses and face shields should undergo thorough disinfection with 70% isopropyl after each procedure.

- Hand protection - Gloves

Gloves are for single use purposes only, and should be discarded after each procedure and patient use.

Sterile gloves should be used for all invasive procedures that require surgical asepsis.

The use of nitrile gloves is preferred over latex gloves because of their resistance to some chemicals, including disinfectants such as chlorine and alcohol.[36]

An unacceptable practice is using the same pair of gloves for different procedures and/or for different patients and not washing or sanitizing hands before and after using gloves.[89]

- Body, head and shoe protection

Transmission via surfaces like clothing can be prevented by careful behaviour (no touch) or by wearing protective clothing.

When conducting high risk AGP's or sterile surgical procedures, donning a comprehensive set of PPE (including head cover and surgical gown), will reduce the risk of transmission.[20]

Head caps and covers and gowns can be disposable or reusable. PPE for body protection must meet the following criteria: sterility if reusable, long sleeves to cover arms and must be water resistant.

Plastic aprons are not recommended as they do not provide full body and arm cover.[110]

The WHO recommends long-sleeved non-sterile gowns and gloves for both AGPs and non-AGPs to provide protection from contamination of clothes.[110] Current guidance on PPE in the context of COVID-19 does not specifically mention shoe covers.[111]

Covering more of the body leads to better protection. It does increase cost and decreases user comfort.[112]

- Key concerns and limitations of PPE

The available evidence was judged to be low to very low.[84] Common reasons for lack of compliance amongst DHCWs were: (i) policies and practices were inconsistent, (ii) PPE was not available in many facilities and its use was limited to high risk situations, (iii) face masks and gloves were the most commonly used PPE, (iv) reuse of PPE was common, (v) lack of training in proper use and knowledge on when and what PPE to use, and (vi) the high cost implications of complying with appropriate PPE use.[113,114]

Pillar 6: Use of rubber dam

Patients, dentists and assistants as well as surfaces and objects in the operative area are at a risk of exposure to airborne contamination up to 3X greater than the norm.[115] Rubber dam provides a barrier protection from the primary source and can virtually eliminate all pathogens emerging from AGPs.[15,116]

Studies have shown that during conservative dental procedures (15-30 minutes) without use of rubber dam, the airborne bacterial load increased from 8.8 to 25.1 colony forming units (CFUs). Various other studies have also shown that use of rubber dam isolation during AGPs resulted in a 98.8% bacterial reduction.[118-22] This reduction increased with use of antiseptic mouth rinse used before rubber dam application.

The use of dental rubber dam to reduce exposure to contaminated aerosols during treatment is very important.[123] Several published guidelines recommend the use of rubber dam wherever possible.[66]

Another device that delivers quick, easy, reliable isolation with uninterrupted retraction and continuous evacuation of fluids and oral debris with a reduction of aerosol is the Isolite (Zyris™)[124].

Extra high-volume suction for aerosol and spatter should be used during rubber dam procedures in conjunction with regular suction.[125]

Pillar 7: High volume suction and suppression of aerosolization

- High volume evacuation (suction) (HVS)

The use of HVS of the aerosol generating field in the oral cavity is an essential and important method for reducing aerosol-related transmission of pathogens.[15,117] Aerosols and splatter produced when air rotary handpieces, ultrasonic, sonic and air polishing devices are used in dental procedures, contain contaminated saliva, blood bacteria and periodontal pathogens.[18,122] Once airborne, aerosol particles can linger in the surgery for an hour or more while droplets land on surfaces immediately surrounding the treatment area. This poses a risk for the spread of infectious diseases such as COVID-19.[126] Studies have shown that HVS can reduce aerosols by 80% to 98% regardless of the source.[127,128]

There is no single solution that will provide complete protection in the clinical environment. Thus a combination of protective measures, including PPE, pre-procedural rinses, rubber dam, and HVS is suggested to reduce risk of exposure to infectious disease such as COVID-19. Combining pre-procedural rinse and rubber dam with HVS are more efficient compared to the individual methods.[122,129]

- Suppression of aerosolization

The generation of pathogen contaminated aerosols in dentistry, an unavoidable part of most dental treatments, creates a high-risk situation with the potential for airborne transmission of SARS-CoV-2. The avoidance of all AGPs is one approach advocated during the pandemic, or to reduce procedural times as a means of reducing the total aerosol generated. This is not sustainable and counter-productive in the long-term for routine dentistry.

A new novel approach has been developed to suppress aerosolization in dental procedures by adding high molecular weight polymers to the water supply to alter the physical or visco-elastic response of water to AGPs. The generation of aerosol particles and the distance any aerosol may spread beyond the point of generation can be markedly suppressed or completely eliminated in comparison to water for AGPs.[117]

Complete suppressions of aerosolization from an air turbine rotary handpiece and an ultrasonic scaler was demonstrated using diluted aqueous solutions of FDA-approved polymer [2wt.% polyacrylic acid (PAA)] (20 gm PAA + 1L H2O) or hydrogel [0.8 wt.% xanthan gum] (8gm xanthan gum + 1L H2O).[117] The integrated pressurized fill bottle of a dental chair allows control of the fluid being delivered to rotary or ultrasonic instrumentation. These FDA -approved additives alter the physicochemical properties of the irrigation solution, suppressing droplet formation without altering flow behaviour, thereby reducing the risk of aerosol transmission of infectious diseases.[117]

Pillar 8: Cleaning and disinfection

• Background

Contaminated surfaces can become a reservoir of infectious material with the potential to spread to health care personnel and patients.[130] Prevention of transmission of infectious contagion from contaminated surfaces (fomites) is best accomplished by reduction of any source of contamination. It is therefore critical to incorporate surface disinfection preventions to reduce the risk of infectious disease transmission.

The two main routes of transmission of SARS-CoV-2 is by airborne or direct contact.[131] Respiratory droplets are generated when an infected person talks, coughs or sneezes, while contaminated aerosols are generated during AGPs on infected patients. Droplets and contaminated aerosols may also land on inanimate objects (equipment) or environmental surfaces (fomites) where the SARS-CoV-2 virus can remain viable for up to 9 days.[67] The immediate chairside environment of an infected or potentially infected patient can serve as a source of contact transmission.[5,132-135]

The ability of SARS-CoV-2 to persist on inanimate environmental surfaces (fomites),[67] warrants thorough cleaning and disinfection to assure effective infection control and prevention.[67,136,137] Environmental surfaces in the dental practice setting can be classified into two groups: (i) Highly-touched clinical contact surfaces including all clinical devices, (ii) house-keeping surfaces including working surfaces, door handles, floor, blinds, sinks, furniture and fixed items inside and outside patient rooms and bathrooms.[130]

Routine cleaning (i.e. using water and soap) as well as disinfection procedures to inactivate the virus, are appropriate for SARS-CoV-2 in the dental workplace setting. SARS-CoV-2 viruses are enveloped by a phospholipid layer that is susceptible to soaps and detergents.[138] It is also susceptible to other lipid solvents and can be efficiently inactivated within 1 minute contact time by surface disinfection procedures such as sodium hypochlorite (bleach) (0.1% or 0.5%), hydrogen peroxide (0.5%), alcohol (62-71% ethanol or isopropyl alcohol), benzalkonium chloride (BAC) and peroxyacetic acid.[67] (Table 1)

• General principles of cleaning

- The cleaning procedures must progress systematically from least soiled to the most soiled area, and conducted from top to bottom with the floor cleaned last.
- Detergent-impregnated wipes may be used but should not be used as a replacement for the physical cleaning process.[130,139-141]

• General principles of disinfection

- Lack of hand hygiene and inadequate disinfection of environmental surface /devices between patients are the most important failures of infection control.[25,142]
- Bleach works on hard and non-porous surfaces, but requires pre-cleaning with a detergent.
- Most disinfectants used in health care are one-step products that clean and disinfect using the same product.[143]
- Cleaning of surfaces with common disinfectants such as ethanol and sodium hypochlorite inactivates the coronavirus within 1 minute of exposure.[67]
- Strength levels of common disinfectants are dependent upon concentration and contact time. Bleach (sodium hypochlorite) at 500ppm (0.05%) and 1000ppm (0.1%) solutions are both able to reduce the SARS virus.[144,145]
- Surface disinfectants should be sprayed directly onto surface and left on as directed before being wiped systematically and carefully.
- A short contact time (to kill microbes), of approximately 1-2 minutes, is desirable to ensure the disinfectant has killed the microorganisms before the disinfectant dries on the surface.[140]
- Pump spray bottles are an appropriate method of applying liquid germicides, with the exception of hypochlorite solutions. An advantage of a pump spray is better penetration of the liquid germicide into crevices in the equipment where wipes may not effectively contact.[130,146]

• Criteria for selecting a safe and effective disinfectant

The use of disinfectant wipes is becoming more widespread in the health care environment because these products are

Table 1: Comparison of low-level disinfectant products recommended for inactivating SARS-CoV-2

Disinfectant	Sodium hypochlorite (bleach) (NaOCL)	Hypochlorous acid (HOCL	Alcohol Ethanol Isopropyl alcohol	Quaternary Ammonium compounds (QACs)	Hydrogen peroxide H2O2
Recommended concentration	0,05% to 0.1% (500-1000ppm)	80-200ppm	70-90%	0.1%	>0.5% 1.5% - 3%
Contact time	10-30 min	10 min	2-5 minutes	3-10min	1.5% - 10 min 3% - 20min
Compatibility with surface	Corrosion of metal surfaces Discoloration of plastics & fabrics	Compatible with metal and plastic and fabrics	Surface compatible May cause hardening, cracking of rubber and plastics	Surface compatible	Compatible with most surfaces Benign for environment, silver plating Not compatible with brass, Copper zinc Non-corrosive
Toxicity & Safety	Irritation of skin, eyes and mucous membranes	Safe & Non-toxic to skin & eyes	Toxic and irritant to skin & eyes	EPA registered Non-irritating	Eye irritant Low EPA toxicity Environmental friendly
Ease of use	Spray and wipe Mist & Fogging	Aerosol spray Fogging	Wipes Sprays	Wipes Sprays	Wipes Sprays
Stability	Decays rapidly when exposed to UV-light. Stable for 30 days in opaque containers. Prepare fresh solutions every day	Increasing stability with decreasing pH Less stable when exposed to sunlight, UV radiation, contact with air and increased temperature	Stable with good detergent properties	Stable with good detergent properties	Very stable stored in dark container
Other advantages/ disadvantages	Odour and leaves residue Corrosiveness to metals	Odourless No residue	Not sporicidal Inflammable Affected by organic matter	Not Sporicidal Narrow spectrum	No odour More expensive

Reference: [130,136]

convenient to use, limits indiscriminate application of any chemical agent, decreases human contact and the amount of chemicals introduced into the environment.[130]

A disinfectant agent upon contact with the virus changes the virus protective coat, which loses is structure and aggregates, forming clumps with other viruses.[147,148]

Dental practitioners need to have an inexpensive, non-toxic, and practical disinfectant that is effective in disinfecting and sanitizing against viruses, specifically SARS-CoV-2. An ideal surface disinfectant must have low contact time with significant antiviral activity.

Several disinfectants have been recommended against SARS-CoV-2 and 5 major classes of surface disinfectants are identified for the dental practice setting: (Table1) [130,136,149-153]

• Precautions and hazards with disinfectants

Improper or excessive use of surface disinfectants poses potential health risks to users. Therefore, consistent and evidence-based recommendations are crucial to protect dental health care workers not only from SARS-CoV-2 but also accidental exposures to dangerous chemicals.

- Bleach disinfectants solutions should be prepared fresh each day.

- Avoid using sodium hypochlorite (bleach) on metals or acrylic resins because it has a strong corroding effect.[154]
- Hydrogen peroxide is explosive with heat.[154]
- Always wear gloves when cleaning and disinfecting.
- Because occupational diseases, such as asthma, among cleaning personnel have been associated with use of several disinfectants (e.g., chlorine, formaldehyde, glutaraldehyde), precautions should be used to minimize exposure to toxic chemicals(e.g., gloves, PPE, and proper ventilation).[155-157]

• Aerosolization, spraying and fogging

Available studies show that SARS-CoV-2 can be detected in the air inside a room occupied by a confirmed COVID-19 patient for 3 hours after aerosolization.[158]

Fogging machines that rely on the dispersion of a fine mist of disinfectants in the air have proven their performance in the health care sector and food industry.[159,160] Commercial fogging machines are also designed and based on the same flow physics of aerosolization, and their droplet size is below 10μ in order to facilitate extended airborne duration.[161]

It is suggested that using hypochlorous acid (HOCL) fogging daily in the dental practice setting is an inexpensive, non-toxic, easy to use procedure with high predictability and effectiveness against SARS-CoV-2.[151]

HOCL is a powerful disinfectant produced by a sterilized water generator and has a pH of 5-6.5 and a low effective chlorine concentration of 10-30ppm. Fogging with HOCL can achieve reduction of microbes and is safe for humans and the environment. Five minute fogging with H2O2 was sufficient to achieve inactivation of enveloped as well as non-enveloped viruses.[162-165]

The fogging process can alter the physical and chemical properties of the disinfectant, resulting in the reduction of available free chlorine concentration.[166,167] Pre-adjustment of the concentration (200ppm) and pH (pH3-5) of the fogging solution to appropriate levels can produce reductions of all tested viruses on both vertical and horizontal surfaces, suggesting that it is an effective approach to reduce viruses on surfaces.[168,169]

• Surface disinfection - Best practice guidelines

- Frequent hand washing or sanitizing and avoiding touching the face should be the primary prevention approach to reduce any potential transmission associated with animate surface contamination.[170]
- Cleaning with a neutral detergent and some form of mechanical action (brushing or scrubbing) helps to remove pathogens and is an essential first step in any disinfection process.[171]
- Spraying and fogging of bleach, formaldehyde, or quaternary ammonium compounds, is not recommended due to adverse health effects.[172,173]

Pillar 9: Ventilation, air conditioners, air cleaning, and airborne disinfection

• Aerosols, airborne transmission and the significance of ventilation

SARS-CoV-2 is transmitted via airborne transmission (aerosols).[174,175] To date, the European Centre for Disease Prevention and Control[176] as well as the Robert-Koch Institut[177] have recognized aerosol transport. After initial denial, the WHO added aerosol transmission to their transmission mode brief.[178,179] Given the persistence of SARS-CoV-2 viral loads in both the lower and upper respiratory tracts,[180] as well as the persistence of the virus in the air 3 hours after aerosolization in laboratory settings, airborne transmission is possible.[158,181] An airborne virus is not naked but is contained inside expelled respiratory fluid droplets. Droplet desiccation is a fast process.[182] Large droplets (>50μm) fall down on surfaces, but small droplets (<50μm) or droplet nuclei (<10μm) stay airborne and can travel long distances.[182] Droplet nuclei distribution depends on the position of people, air change rate, the type of air distribution system and other air currents in the space.[183] Analysis of superspreading events have shown that closed environments with minimal ventilation strongly contributed to a characteristically high number of secondary infections.[184]

Airborne transmission has made ventilation measures the most important engineering control in ICP. Mechanical ventilation can significantly increase the expulsion of air, and natural ventilation can be improved by active ventilation, creating a draft through the room.[186]

• Ventilation, airflow and air cleaning/disinfection

One of the most overlooked aspects in air cleaning/sterilization is controlled airflow aimed at killing harmful bacteria and viruses. Traditional air ventilation (air conditioning) systems are closed ventilation systems that pushes air back into the breathing zone, thus increasing the risk of cross-contamination with viruses trapped in the ventilation system. New air flow and air sterilization technologies have been developed to control air flow and air sterilization in indoor settings including, dental practices, operating theatres, waiting rooms and offices. Current technology is based on the use of HEPA (High efficiency particulate air) filters to scavenge small particles like viruses, combined with UV radiation and nano photocatalytic oxidation that kills respiratory viruses, including coronavirus on a single air exchange. HEPA filters are designed to trap or scavenge virus particles down to 0.3 microns.[174,182]

Forced airflow (with air filtering (HEPA) and UV light), uses a powerful fan that draws contaminated air away from the breathing zone (dentist–patient interface), removes or inactivates contaminated airborne particles, sterilizes the air and then sends it back into the breathing zone.[128,186-189] It is possible that UV-C is safe for skin genotoxicity,[190] however its effect to the naked eye that may cause impaired vision is not confirmed.[191]

Drawing contaminated air away from the dentist and the patient reduces the viral load in aerosols and surfaces by 80%.[3,192] Increasing ventilation indoors (open windows) and preventing recirculation of air through closed air ventilation systems can go some way to ensure that infectious aerosols are diluted or flushed out of the air.

• Practical ventilation and airflow measures to reduce the risk of airborne transmission of SARS-CoV-2

- Dispersion of aerosols that have not been removed by HVS is primarily achieved by dilution of air changes. Effective heating, ventilation and air conditioning systems (HVAC) ventilation is a major factor in dissipating aerosols.
- HVAC systems may have a complimentary role in decreasing transmission in indoor spaces by increasing the rate of air exchange, decreasing the recirculation of air, and increasing the use of outdoor air.[174,182]
- HEPA filters must be used not only in clinical settings but also in outlet exhaustion tubes.[193]
- Open windows more to increase the amount of fresh air per square meter of floor area.
- Direct airflow should be diverted away from the individuals (e.g., the dentist, assistant and patient microenvironment).[174,182]
- AGPs should not be performed in a room that has no natural or mechanical ventilation.
- If air cleaners are used in larges spaces , they need to be placed close to people. Air cleaners are an easy to apply short term mitigation measure, but in the longer run, ventilation system improvements to achieve adequate outdoor ventilation rates are needed.[174,182]

Pillar 10: Immune boosting, designer antibodies and vaccines

• Immune boosting

It is important to boost your personal immunity and self-resistance by taking the following actions: (i) Get adequate sleep – sleep deprivation has an impact on the immune response.[194] (ii) Moderate exercise seems to exert a protective effect, whereas bouts of strenuous exercise can result in immune dysfunction.[195] (iii) Studies suggest proper supplementation with vitamin D may enhance one's resistance to SARS-CoV-2.[196] Vitamin D supplementation has an overall protective effect against acute respiratory infections.[197,198] However, prospective clinical studies are required to address the association between vitamin D and COVID-19 severity.

Conclusion

The COVID-19 pandemic is a stark reminder of the ongoing challenge of emerging and re-emerging infectious pathogens and the need for constant updating of standard ICP measures.

It is inevitable that every dentist will see asymptomatic patients or will be exposed to asymptomatic staff. The risk of transmission of SARS-CoV-2 by seemingly healthy individuals may account for 30-62% of potential infection exposure events. The disturbing reality is that we have no idea who among us is spreading the disease.

Even with the availability of vaccines, it remains important to apply a combination of protective measures, including screening for high risk patients, facial masking, hand sanitation, pre-procedural rinses, PPE, rubber dam and suppression of aerosolization. In addition, cleaning and disinfection, ventilation and air cleaning and paying adequate attention to healthy lifestyle and immune support are also important measures to prevent spread of infection. No infection control measure can be practiced in isolation, nor is any one more important than the other.

DHCWs are obliged to follow the ethical principles of providing the best possible care that is in the patients' best interest, while maintaining a balance in managing risks to optimally protect the patient and dental staff.

It seems acceptable to adopt the principle of 'consider all patients as potentially infectious for air droplet /airborne disease and treat every case with equal and uniform precaution measures' as a realistic, effective and safe approach towards infection prevention and control.

There are more research questions than answers to assist dentists in their infection control and prevention decision-making processes.

Educational Institutions should help in providing appropriate continuing professional education programs to develop DHCWs' basic knowledge on appropriate respiratory virus infection and airborne control and prevention measures.

References

References are available on request from:
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