

Minireview

Stopping the COVID-19 pandemic in dental offices: A review of SARS-CoV-2 transmission and cross-infection prevention

Maya Hartig¹ , Carley Stephens², Aaron Foster², Douglas Fontes³, Michael Kinzel² and Franklin García-Godoy^{4,5}

¹Burnett School of Biomedical Sciences, University of Central Florida, Orlando, FL 32766, USA; ²University of Central Florida, Mechanical and Aerospace Engineering, Orlando, FL 32766, USA; ³Florida Space Institute, University of Central Florida, Orlando, FL 32766, USA;

⁴Department of Bioscience Research, College of Dentistry, University of Tennessee Health Science Center, Memphis TN 38163, USA;

⁵The Forsyth Institute, Cambridge, MA 02142, USA

Corresponding author: Michael Kinzel. Email: michael.kinzel@ucf.edu

Impact statement

This is different from previous work in that it addresses the importance of vaccinations for dentists and presents all-encompassing guidance in good detail. There are so many pieces of information regarding infection mitigation strategies but finding each and every one individually takes time which many in the dentistry profession may lack. Having a single article where everything related to SARS-CoV-2 can be found is useful and can further help prevent spread of misinformation.

Abstract

Due to the essential role of dentists in stopping the COVID-19 pandemic, the purpose of this review is to help dentists to detect any weaknesses in their disinfection and cross-contamination prevention protocols, and to triage dental treatments to meet the needs of patients during the pandemic. We used PRISMA to identify peer-reviewed publications which supplemented guidance from the center for disease control about infection control and guidelines for dentists. Dentists must triage dental treatments to meet the needs of patients during the pandemic. The ongoing pandemic has changed the practice of dentistry forever, the changes make it more cumbersome, time-consuming, and costly due to the possible pathways of transmission and mitigation steps needed to prevent the spread of

COVID-19. Dental chairside rapid tests for SARS-CoV-2 are urgently needed. Until then, dentists need to screen patients for COVID-19 even though 75% of people with COVID-19 have no symptoms. Despite the widespread anxiety and fear of the devastating health effects of COVID-19, only 61% of dentists have implemented a change to their treatment protocols. As an urgent matter of public health, all dentists must identify the additional steps they can take to prevent the spread of COVID-19. The most effective steps to stop the pandemic in dental offices are to; vaccinate all dentists, staff, and patients; triage dental treatments for patients, separate vulnerable patients, separate COVID-19 patients, prevent cross-contamination, disinfect areas touched by patients, maintain social distancing, and change personal protective equipment between patients.

Keywords: Dentists, triage dental treatments, COVID-19 testing, SARS-CoV-2, COVID-19 vaccination

Experimental Biology and Medicine 2021; **246**: 2381–2390. DOI: 10.1177/15353702211034164

Introduction

Impact of the COVID-19 pandemic on dentists

Dentists can have a high risk of contracting COVID-19 from their patients because of its transmission by respiratory droplets and the use of dental handpieces that can generate aerosols.¹ Nevertheless, due to the wearing of personal protective equipment (PPE, gloves, masks, eye shields, and gowns) and using disinfection procedures, this risk can be significantly mitigated. A survey of dentists found that

only 0.3% (20/2195) had a probable COVID-19 diagnosis, 82.2% were asymptomatic, 16.6% were tested, and 3.7%, 2.7%, and 0% tested positive via respiratory, blood, or a salivary sample.² The most commonly reported health problems among dentists were anxiety and depression.²

Most professions had little or no need for infection protections in the pre-pandemic era and have now had to urgently adopt new safety protocols. In contrast, dentists are uniquely qualified, even among healthcare professionals due to their career-long training to become specialists

at diagnosing infections.³ Moreover, dentists routinely perform aseptic treatments to prevent cross-infection⁴ and expertly use disinfecting regimens to eliminate infections such as dental caries.^{4,5} Over hundreds of years, dentists have adapted their skills to eliminate all types of infections, by recognizing that infections are common threats to public dental health.⁶ Nevertheless, after the COVID-19 pandemic began, most dentists still had to introduce enhanced working practices to stop the spread of the coronavirus,^{2,7} and to keep themselves, their staff, and dental patients safe and healthy.

Towards this goal, the U.S. Centers for disease control has issued guidance for dental offices during the COVID-19 pandemic, these are to: (i) Recognize dental settings have unique characteristics that warrant specific infection control considerations; (ii) Prioritize the most critical dental services and provide care in a way that minimizes harm to patients from delaying care and harm to personnel and patients from potential exposure to SARS-CoV-2 infection. (iii) Proactively communicate to both personnel and patients the need for them to stay at home if sick. (iv) Know the steps to take if a patient with COVID-19 symptoms enters a dental facility.⁸ All dentists abide by infection prevention protocols,⁹ but the COVID-19 pandemic created unprecedented additional disinfection and cross-infection challenges,¹⁰ driven by fear and anxiety. Up to 78% of dentists have reported some anxiety and fear induced by the devastating effects of COVID-19.¹⁰

Impact of the COVID-19 pandemic on dental patients

The COVID-19 pandemic has been reported to cause tooth loss and increased dental problems. A quarter of COVID-19 patients report an inflamed swelling of their tongue with bumps and rashes appearing.¹¹ A review of several studies of the effects of COVID-19 on dental patients has reported that they are predisposed to suffer oral lesions, fissures and ulcers, likely caused by a lack of oral hygiene, opportunistic infections, stress, immunosuppression, vasculitis, and hyper-inflammatory responses secondary to COVID-19.¹²

Patients with periodontal disease are 9 times more likely to die from COVID-19, 4.5 times more likely to require a ventilator, and 3.5 times more likely to be admitted to a Hospital Intensive Treatment Unit.¹³ Periodontal disease by itself is unlikely to be dangerous to health.¹⁴ The reason why patients with periodontal disease are more likely to suffer severe medical and dental problems, is that they also suffer from underlying health conditions like heart disease¹³ and asthma.^{15,16}

Oral mucosa is a potential entry route for the SARS-CoV-2 virus that causes COVID-19 disease.¹⁷ The presence of ACE2, which is the cellular entry receptor of SARS-CoV-2, in oral mucosa tissues, tongue, and gum epithelium supports that oral cavity is an entry point of the virus.¹⁸ There may be an increase in ACE2 receptors in people with poor oral health.¹⁹ Thus, maintaining good oral hygiene and dental health status are important in combating the COVID-19 pandemic.

COVID-19 patients are reporting long-term disabilities.²⁰ After tooth loss and periodontal disease, more

patients may require dental implants and dentures. Worryingly the stress of the COVID-19 pandemic can increase demand for restorative dental treatments, while potentially decreasing their healing success rate, due to COVID-19 hyper-inflammation and cytokine release syndrome, which causes tissue damage.²¹

The best advice for dental patients is to maintain a good dental health regimen by brushing their teeth at least twice a day,²² keeping regular dental check-ups, obtaining urgent treatment for any pain and periodontal, gingival, and endodontic problems. It is never advisable to delay dental treatment, because it allows more time for infections to spread, increases the severity of damage, and can destroy more healthy bone and soft tissues. The prognosis for uncomplicated dental infections is good. Dental infections that spread to deeper neck structures carry a worse prognosis and significant mortality rate. Deep neck infections have a mortality rate ranging from 1% to 25%, and mediastinitis can carry a mortality rate of 40%.²⁰

More dentists need to take additional steps to stop COVID-19 from spreading

Clearly, dentists could benefit from learning about some additional steps they can take to stop the COVID-19 pandemic spreading from dental offices. This requires that they be able to detect weaknesses in their disinfection and cross-infection prevention protocols. This can be accomplished by analyzing the possible pathways of transmission and disinfection steps needed to prevent the spread of COVID-19. Despite the widespread anxiety and fear of the devastating health effects of COVID-19, as few as 61% of dentists have implemented a change to their treatment protocols.¹⁰ As an urgent matter of public health, more dentists must identify the additional steps they can take to prevent the spread of COVID-19. The most effective steps include triaging treatments for patients, separating vulnerable patients, preventing cross-contamination, disinfection of the areas touched by patients, social distancing, changing personal protective equipment between patients.

Stopping the COVID-19 pandemic spreading from dental offices

There have been more than 112 million humans who are known to be infected with COVID-19, the ongoing pandemic has caused almost 2.5 million deaths, and it has a 3% mortality rate.²³ Due to the COVID-19 pandemic, curfews, quarantines, stay-at-home orders, shelter-in-place orders, shutdowns, and lockdowns have been implemented. Many dental offices which did not offer emergency treatments were shutdown. Now due to some relaxation of the pandemic shutdown orders, dentists must provide safe treatments to patients, while also stopping the COVID-19 pandemic spreading from dental offices.

COVID-19 origin

These viruses are called coronaviruses because their surfaces have crown-like spikes and "corona" is the Latin word for crown.²⁴ Human coronaviruses (HCoVs) prior to the

recent pandemics were incorrectly assumed to be inconsequential pathogens, limited to causing "common cold" symptoms in otherwise healthy people.²⁵ In 2003, the first of three highly pathogenic HCoVs were reported in Asia; severe acute respiratory syndrome coronavirus (SARS-CoV). In 2012, Middle East respiratory syndrome coronavirus (MERS-CoV) was transmitted to humans Saudi Arabia from camels, and now COVID-19 has emerged from zoonotic (animal) reservoirs to cause global epidemics with alarming morbidity and mortality.²⁶ The probable Horseshoe bat (*Rhinolophus affinis*) coronavirus origin of the COVID-19 pandemic named "RaTG13" was traced back to a cluster of pneumonia cases connected to Huanan Seafood Wholesale Market in Wuhan City, Hubei Province, China.²⁷ However, misinformation, conspiracy theories, and political agendas are preventing us from determining how the virus first infected people.²⁸

The meaning of COVID-19

The World Health Organization announced an official name for the disease that is causing the 2019 novel coronavirus outbreak. In COVID-19, "CO" stands for "corona," "VI" for "virus," and "D" for disease.²⁹ Formerly, this disease was referred to as "2019 novel coronavirus" or "2019-nCoV." COVID-19 is caused by severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2).³⁰ SARS-CoV-2 is highly transmissible, with an alarmingly high attack rate of 83% from asymptomatic carriers to their family members living in close proximity.³¹ SARS-CoV-2 has a reproductive number of 2.2 days and a mean incubation time of 5.2 days, prior to presenting symptoms.³¹ The clinical manifestations of COVID-19 tend to be more severe and more morbid, in older age and compromised patients with pre-existing health conditions.³² Strains or mutated variants of the SARS-CoV-2 are evolving to become even more dangerous, by causing more severe illnesses and with a 40–74% increase in transmissibility³³ increasing the challenges in stopping the COVID-19 pandemic.

Use of PRISMA evidence-based minimum set of items for reporting in systematic reviews and meta-analyses

On 4 March 2021, we conducted a PubMed search using the term "dental COVID-19 CDC guidelines," which yielded a total of nine publications, but found all these publications were surveys about dentists' opinions, and articles concerning educational practices, with little or no relevant advice for dentists to stop the COVID-19 cross-infection in their offices. Thereafter, due to the lack of relevant publications, we pursued a more customized PRISMA approach by identifying the most useful and relevant articles, for each topic of the guidelines, e.g., infection control and vaccines, as described in the following paragraphs. Multiple databases were searched to identify articles of relevance which consisted of key development toward information pertaining to COVID-19 and dentistry pathogen transmission. Following the search for articles, quality of included studies was examined, the key evidence highlighted, and results interpreted.

Health risks and symptoms from COVID-19

COVID-19 is a pandemic like no other, the variable severity of COVID-19 continues to confound researchers, who are unable to fully explain why one person infected with SARS-CoV-2 becomes severely ill, while another person has no symptoms at all²⁸; 43.7% of people infected with COVID-19 may have no symptoms, 61.4% can have low symptoms such as a loss of smell, and 18.6% can have fever and flu-like symptoms.³⁴ The numbers of undiagnosed people with COVID-19, but who had a seroprevalence of SARS-CoV-2 antibodies, ranged from 6 to 24 times the actual number of reported cases.³⁵ Several factors are associated with higher COVID-19 mortality rates. People older than 65 years are at much greater risk than are young people. Men are more likely to die of COVID-19 than women, and members of ethnic minority groups tend to have more severe cases.³⁶ People with underlying chronic health conditions, such as lung disorders, coronary heart disease, diabetes, and cancer increase a person's likelihood of dying from COVID-19.³⁶ COVID-19 symptoms appear on average four days (with a range of 2–14 days) after exposure to SARS-CoV-2.³⁷ They are: fever or chills, cough, shortness of breath or difficulty breathing, fatigue, muscle or body aches, headache, new loss of taste or smell,³⁸ sore throat, congestion or runny nose, nausea or vomiting, and diarrhea.³⁹ Emergency medical care is needed for someone showing any of these signs; trouble breathing, persistent pain or pressure in the chest, new confusion, inability to wake or stay awake, and bluish lips or face.⁴⁰

SARS-CoV-2 infection detection

Many people with COVID-19 are asymptomatic (43.7%)³⁴ and even people with COVID-19 may not express any symptoms until 2–14 days after exposure to SARS-CoV-2.³⁷ A viral polymerase chain reaction (PCR) test checks specimen swabs from a person's nose or saliva from their mouth to determine if they have COVID-19 by genetic testing.⁴¹ Alarmingly SARS-CoV-2 PCR tests may give an unacceptably high false negative rate of 2.7%. This is because 18 patients out of 660 patients hospitalized with COVID-19 had two negative PCR test results, when they later proved to positive for SARS-CoV-2 using a blood antibody serology test.⁴² As shown in Figure 1, the PCR test results may not become accurate until a week after infection, during which time people can be transmitting SARS-CoV-2 to others, while having COVID-19 for up to four weeks. Despite the potential inaccuracy of COVID-19 tests, people should get PCR tests if they have symptoms of COVID-19, had close contact with someone who is confirmed to have COVID-19, or people who traveled or attended large social gatherings, or people doing jobs that may expose them to COVID-19. People who got viral tested should quarantine in isolation until the test is negative. Researchers are working to speed up the COVID-19 tests, and it would be desirable to have a rapid chair-side test for COVID-19 that the dentist can give to each patient prior to commencing treatment.

SARS-CoV-2 transmission

The principal mode by which people become infected with SARS-CoV-2 is through inhaling an aerosol of respiratory droplets expelled by someone with COVID-19 coughing, sneezing, talking, and breathing³¹ without a face mask. In addition, the use of ultrasonic scalers, burs in rotary dental handpieces, surgical instruments, endodontic files, orthodontic retainers, air-water syringes, lasers, and cavitron devices can mechanically release aerosol droplets.⁸ The other possible transmission vectors are through contact with infected body fluids such as saliva, blood and fecal matter, or by fomite infection of the surfaces of objects.^{43,44} The physics of transmission is governed by fluid dynamics and thermodynamics which can be influenced by wind, temperature, and humidity.⁴⁵ The modes of SARS-CoV-2 transmission in dental offices are summarized in Figure 2.

Spreading SARS-CoV-2 by respiratory droplets

SARS-CoV-2 is highly contagious because it can be transmitted by respiratory droplets from infected saliva and

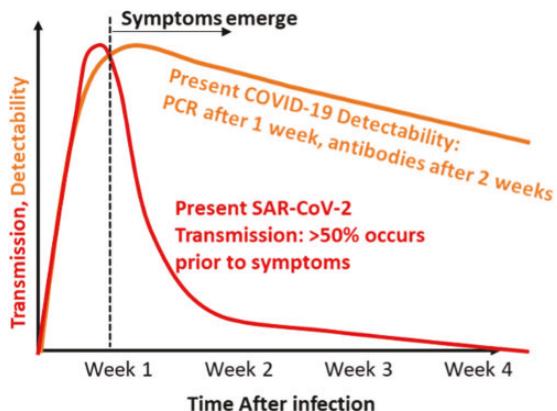


Figure 1. Detection and transmission response for COVID-19. The graph shows the SARS-CoV-2 likelihood of transmission from week 1 to 4 in red, and the PCR test detectability for SARS-CoV-2 from week 1 to 4 in orange (adapted from Scientific Brief: SARS-CoV-2 and Potential Airborne Transmission). (A color version of this figure is available in the online journal.)

mucus biofilms coating the respiratory tracts, lungs, throat, and mouth. Droplets are expelled due to respiratory airflow. Large respiratory droplets can fall quickly to the ground, whereas smaller droplets in aerosols can remain suspended in the air for minutes or several hours,^{46,47} until they become completely evaporated. Over time, evaporation leads to droplets shrinking in size, this dehydrates the viral particle (Figure 3). Size is the key distinguisher between droplets and aerosol particles, with some size overlap. Microscopic droplets can have a diameter of 2 to 100 μm , whereas aerosol particles have a diameter of less than 10 μm .^{43,44} Avoiding contact with SARS-CoV-2 in aerosols is challenging as they can readily pass around barriers, face shields, through many air-conditioning filtration systems, and masks with large pore sizes. SARS-CoV-2 can be infectious in aerosols up to 16 h at room temperature and is detectable up to 16 h after aerosolization.⁴⁸

Respiratory aerosol from a sneeze or cough can expel droplets at speeds up to 100 mph and create aerosol clouds that reach 27 feet away,⁴⁹ which suggests the 6 feet distance recommended for social distancing is not enough distance to protect people from being infected with SARS-CoV-2.⁵⁰ Therefore, the social distance of 6 feet can only offer reasonable protection against SARS-CoV-2 if everybody wears face masks in daily life activities. Some people produce more aerosol than others,⁵¹ these "COVID-19 super spreaders" can infect 60% of the coworkers around them, even when a social distance of 24 feet was maintained.⁵²

Spreading SARS-CoV-2 by touching fomite surfaces

SARS-CoV-2 is highly contagious because its potential transmission by respiratory droplets does not end when the droplets fall downwards, they coat fomite surfaces of objects, and can remain infectious for up to 72 h.⁴⁸ A new transmission phase of SARS-CoV-2 begins through a fomite path, where the virus has coated surfaces.^{53,54} The SARS-CoV-2 droplets on object surfaces are infectious until they are completely dry.⁵⁵ SARS-CoV-2 is killed when the respiratory droplets are completely evaporated, the

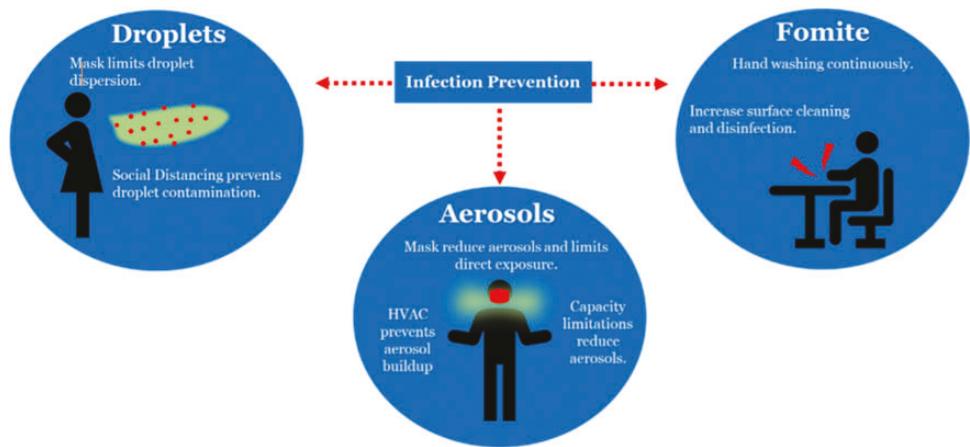


Figure 2. Modes of transmission and cross-infection prevention. SARS-CoV-2 is transmitted by infected fluids in the air, such as droplets and aerosols, or by fomite infection of the surfaces of objects. Rigorous cross-infection prevention protocols must be used to stop the transmission of COVID-19 from dental offices. (A color version of this figure is available in the online journal.)

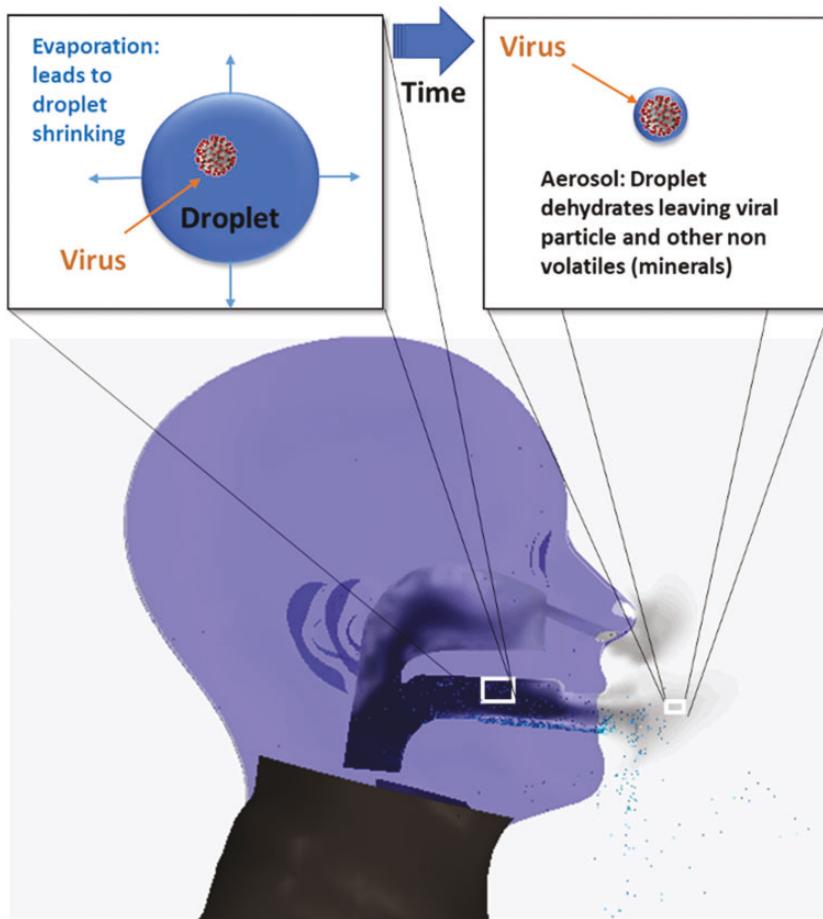


Figure 3. Spreading SARS-CoV-2 by respiratory droplets and their evaporation. (A color version of this figure is available in the online journal.)

evaporation shrinks the droplets, and is influenced by the climate⁵⁶ (Figure 4). Surfaces that are hydrophobic; most resistant to droplet evaporation, such as a smart phone screen tend to prolong virus transmissibility by 60%, when compared with fabric clothes. This explains the advice to disinfect hard surfaces, such as door handles, tables, and touch screens more frequently than fabric furniture to stop the spread of COVID-19. SARS-CoV-2 can survive (remain infectious) for up to three days on the fabric of clothes, and up to six days on plastic and metal surfaces.⁵⁶ Controversially, in a reversal of guidance to routinely disinfect and clean common touch surfaces such as door handles,⁵⁶ some of the most recent guidance suggests that the risk of SARS-CoV-2 transmission through surfaces is grossly exaggerated, because it is not a commonly spread from contact with infected surfaces.⁵⁴ Hospital swabs for coronavirus showed no culture growth.⁵⁷ Erring on the side of caution, disinfecting surfaces, and wearing PPE including gloves is always recommended for treating dental patients.

Stopping the COVID-19 pandemic in dental offices

The ongoing COVID-19 pandemic has created an extraordinary range of consequences that have changed the practice of dentistry forever, some are favorable, whereas other

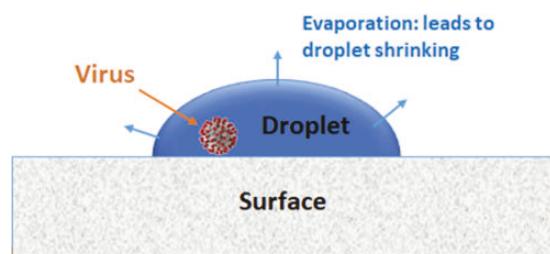


Figure 4. SARS-CoV-2 on fomite surfaces. SARS-CoV-2 is highly contagious because it can be transmitted by touching infected fomite surfaces that have not been disinfected or are not completely dry. (A color version of this figure is available in the online journal.)

changes⁸ likely make it more cumbersome, time-consuming, and costly. The precise long-term changes remain to be seen, there are risks in predicting the future, but dentists recognize their professional duty to take all appropriate measures to stop the COVID-19 pandemic. During the ongoing COVID-19 pandemic, most dentists and their staff provided valuable health services to meet the dental needs of their patients. While minimizing the health risks to themselves and their patients,⁸ a condition favoring dentists and dental offices is that they already have all the personal protective equipment (PPE) that includes masks, gloves, disposable overalls, and face shields, that are needed to minimize the risk of infection

with SARS-CoV-2. Dentists also routinely practice aseptic, disinfection, and sterilization procedures with dental instruments to prevent the cross-contamination of a disease from one patient to another. Nevertheless, dentists must make strategic revisions to their working practices⁸ to stop the spread of COVID-19.

Unreliability of COVID-19 detection and need for chair-side SARS-CoV-2 testing

Dentists and their staff can take a patient's temperature and ask COVID-19 screening questions, but due to the high proportion of people who have no symptoms, these methods are not reliable for determining if a patient has COVID-19. At this time, few patients have been vaccinated against COVID-19, and even with vaccinated patients, it remains unclear how long the vaccine is effective. It is likely that everyone will have to get a COVID-19 vaccine at least once per year.⁵⁸ Dentists may request that patients take a SARS-CoV-2 test and be negative prior to treatment. However, a patient can become infected with SARS-CoV-2 after taking the test, or be given a false negative test result,⁴² and attend a dental appointment. An emergency patient who suddenly experiences dental pain requiring urgent treatment should not be expected to wait days or even hours for the results of a SARS-CoV-2 test. Therefore, until a reliable dental chairside rapid test for COVID-19 is developed, a dentist should assume that their patient is a potential carrier of SARS-CoV-2⁴². This requires that the dentist and patient use all the PPE at all times⁸ when it is practical.

Guidance to not treat COVID-19 patients suffering dental pain is likely impractical and unethical

Some guidelines instruct dentists not to treat patients with COVID-19 and advises people with COVID-19 to stay home and isolate.⁸ This advice may be impractical when someone suffers severe dental pain, which requires emergency treatment. It is not advisable for dentists to make home visits to patients with COVID-19 who are suffering a dental emergency, unless the dentist has all the PPE and has portable dental equipment to provide treatment. Dentists have a duty to alleviate pain and suffering so the advice to refuse to care for patients who are suspected to have COVID-19 can be discriminatory and unethical. Reassuringly, dentists by wearing PPE and using aseptic, disinfection, and cross-infection prevention working practices can protect themselves against COVID-19 and provide treatment to patients.⁸ If a patient has a confirmed positive case of COVID-19 and visits a dental office, it is essential that they not come into contact with any other patients, to prevent cross-contamination. Furthermore, when treating patients positive for COVID-19, concern for airborne spreading of aerosols is high, and dental staff should curtail use of rotary and ultrasonic instruments as much as possible. It is further recommended that a standardized method for modification of aerosol-generation equipment when dealing with high-risk transmission patients be created for the guidance of dentists and dental staff.⁵⁹

Dentists can prioritize patients who need emergency appointments, and delay others who have COVID-19 until they have recovered

Patients can have COVID-19 and be unaware they have coronavirus, because they have no symptoms.³⁴ Screening all dental patients for SARS-CoV-2 prior to providing treatment or even before allowing them to enter the dental office is essential. Non-emergency patients who display COVID-19 symptoms can have their dental treatment delayed and be referred for SARS-CoV-2 testing. If the SARS-CoV-2 test is negative, the patient can be provided with non-emergency dental treatment.

Dental patients who have COVID-19 symptoms, tested positive for SARS-CoV-2, or have been exposed to people with COVID-19, or have attended large social gatherings or traveled to countries with COVID-19 can be prioritized for emergency appointments if they require dental treatment to alleviate severe pain and suffering. Otherwise in the absence of pain, patients with COVID-19 can be asked to wait until they are no longer contagious, which is 10 days after the onset of symptoms,⁶⁰ or 20 days in cases of severe symptoms, or two negative PCR tests administered within 24 h.⁸

Several triage systems have been proposed for dental treatments around the world,⁶¹ due to some conflicting dental triage advice, and even variations in local health regulations. We advocate the simplest method of dividing COVID-19 patients into those requiring emergency and non-emergency treatments. The emergency treatments are those which are needed to alleviate acute or chronic pain associated with trauma avulsion or luxation, fractures, abscess, cellulitis, infections, swelling, lesions discharging fluid, and perfuse bleeding. Whenever a dentist and dental staff are providing dental treatments to COVID-19 patients, they should wear PPE, practice social distancing, disinfection, cross-contamination prevention, and aseptic techniques, as shown in Table 1.

Not all surgical face masks provide the same protection against transmitting SARS-CoV-2

Wearing surgical face masks at all times is effective for preventing the transmission of SARS-CoV-2, because it can reduce the outward respiratory particle emission rates by up to 90% when compared to not wearing a mask.⁶² Droplet emission ranged from 0.1% from a fitted N95 mask to 110% from the use of a neck gaiter. Similarly wearing a bandana as a mouth covering was not very effective at preventing particle emissions. The types of masks from the most to the least effective at preventing particle emissions are; a fitted N95 respirator, surgical mask, poly/cotton blend mask, PolyProb fabric mask, swath mask, cotton type 5-13 mask, valved N95 respirator, cotton type 4-8 mask, MaxaT-6 material mask, cotton type 1-10 mask, cotton type 3-9 mask, and a knitted mask, and bandana, as shown in Table 2.

Table 1. Triage of dental treatments for people with COVID-19.

| Type | Advice/dental treatment types |
|--|---|
| Non-emergency treatments | Delay treatment until the patient has two a negative SARS-CoV-2 tests, or at least 10 days after symptoms, or reports pain and suffering. |
| All dental treatments which are non-emergency. | |
| Emergency treatments | Provide treatment using PPE, social distancing, disinfection, cross-contamination prevention, and aseptic techniques. |

Modified from Sivaraman et al.⁶⁴**Table 2.** The effectiveness of face coverings to prevent particle emission.

| Most effective mask types | Least effective mask types | Not effective |
|---|---|--|
| N95 respirator, surgical mask, poly/cotton blend mask, or a polypropylene fabric mask | Fabric mask, swath mask, cotton type 5-13 mask, valved N95 respirator, cotton type 4-8 mask, MaxaT-6 material mask, cotton type 1-10 mask, cotton type 3-9 mask, and a knitted mask | Lack of a mask or use of neck gaiter or use of a bandana to cover mouth. |

Modified from Sivaraman et al.⁶⁴

Limiting dental office capacity and patient waiting times

Anecdotal reports that the capacity of dental offices is being limited to 25% or 50% of the maximum number of persons in many COVID-19 lockdown areas. Some dentists are offering video or tele-dentistry check-ups to reduce patients' visits. Some dentists are instructing patients to wait outside the dental office in their car, until they are screened by questions over the telephone, before receiving approval to enter the dental office for treatment. Mostly, dentists are scheduling patients more sparsely to minimize delays and waiting times.⁸ Clearly, there should never be a mixing of COVID-19 positive patients in the dental office for emergency treatment, with regular patients. Some dental offices have chairs placed 6 feet apart for social distancing. Often dental offices will have windows open or have the air conditioning turned up with high-efficiency particle air (HEPA) filters installed, or a minimum efficiency rating value (MERV) 13–16 size filter can effectively filter particulate associated with the size of coronavirus particles. These are aimed to increase the office ventilation and dispersal of air to remove any potential SARS-CoV-2 droplets and minimize the spread of COVID-19.

Enhanced cross-infection prevention procedures to stop the COVID-19 pandemic in dental offices

Enhanced cross-infection prevention procedures were implemented in 99.7% of dentists' primary practices, most commonly disinfection, COVID-19 screening, social distancing, and wearing face masks.² Ideally, every surface that a dental patient touches; door handles, waiting room chair, and dental chair should be disinfected with an antibacterial cleaning product, prior to the next dental patient entering the dental operatory. In addition to the regular use of sterilized instruments and materials, aseptic techniques, disinfection of equipment, and the dentist and dental staff

changing their PPE and gloves between touching each patient to prevent any possible cross-contamination. Some dentists can use UV lights to disinfect areas; however, this is not recommended when people are present, due to the risks of inadvertently leaving the near invisible UV light on and causation of serious eye damage.⁶³ A summary of the SARS-CoV-2 transmission, disinfection, personal protective equipment and cross-infection prevention strategies to stop the COVID-19 pandemic in dental offices is shown in Table 3. During the COVID-19 pandemic, in a study of over 2000 patients who attended dental practices in New York, zero dentists, dental staff, or contracted COVID-19.¹ This suggests that if dental offices introduce strict protocols to prevent the spread of COVID-19, they are successful. Among the mitigation protocols was the use of antibacterial mouth rinses and the use of rubber dams to isolate the dental operating area, which reduced the spread of aerosols.⁶⁴

COVID-19 vaccinations

The single most important step that dentist's staff and patients can take to stop the COVID-19 pandemic in dental offices is to take a COVID-19 vaccine. Taking the vaccine will help ensure that COVID-19 cannot be transmitted or contacted by others. There are approximately 58 vaccines in development against SARS-CoV-2.⁶⁵ Some vaccines have more than 90% efficacy against COVID-19 in clinical trials.⁶⁶ A two-dose regimen of the Pfizer BioNTech BNT162b2 vaccine conferred 95% protection against COVID-19 in persons 16 years of age or older.⁶⁷ A two-dose regimen of the Oxford AstraZeneca COVID-19 had an efficacy of 70.4%,⁶⁶ whereas a two-dose regimen of the Moderna vaccine in a clinical trial conferred a 94.5% effectiveness against infection with COVID-19.⁶⁸ The most commonly reported vaccine side effects were fatigue, headache, and fever, which were quickly resolved.⁶⁷ We expect that

Table 3. Summary of the enhanced cross-infection prevention procedures aimed to stop the COVID-19 pandemic in dental offices.

| Goal | Enhanced cross-infection prevention procedures |
|--|--|
| Minimize contact risk with COVID-19 patients | All staff and patients should get COVID-19 vaccinations. Triage patients who need emergency dental appointments, and delay non-emergency patients who have COVID-19 until they have recovered. Offer video and tele-dentistry dental appointments Ask patients to wait outside in their vehicle until called into office for an appointment Screen patients for COVID-19 prior to entering the dental office. Maintain social distancing, limit the numbers of patients waiting, arrange waiting room seats 6 feet apart, prohibit patients bringing guests Never allow an emergency patient with COVID-19 to have contact with any other patients. Ask patients scheduled for elective dental treatment to have two negative SARS-CoV-2 PCR tests within 24 h of dental appointment. Give SARS-CoV-2 tests. Screen everyone for COVID-19 symptoms prior to entering the dental office. Anyone who has COVID-19 symptoms or tests positive must quarantine. Quarantine will end until after two negative SARS-CoV-2 PCR tests, or remain quarantined for 10–20 days after the onset of symptoms. Post signs instructing everyone to wear PPE. At a minimum, patients must always wear a face mask. Do not accept bandana's, neck gaiters, or knitted masks as effective PPE. Dentists and staff must wear effective PPE (personal protective equipment) including N95 respirators or face masks, gowns, gloves, eye protection, face shields, and overalls, that are changed between each patient. Disinfect equipment, dental chair and everything touched by a patient, before treating another patient. Give dental patients a mouthwash prior to dental treatment to disinfect any potential SARS-CoV-2 in the mouth. Supply sanitizers for hands and disinfectants for surface cleaning. Install physical barriers (clear screens) between patients and reception staff. Remove toys and magazines from the waiting area. Increase dental office ventilation, increase air conditioning, and use HEPA or MERV filters to remove potential SARS-CoV-2 particles. Use rubber dams and minimize aerosols during dental treatments. Use electronic forms and contactless payment methods. |
| Screen for COVID-19 and test for SARS-CoV-2. | |
| COVID-19 cross-infection prevention | |

COVID-19 vaccines will become a licensing requirement for dentists and their staff in the future.

Conclusions

The ongoing COVID-19 pandemic has changed the practice of dentistry forever. Fortunately, dentists already have most of the training, equipment, and PPE they need to stop the pandemic in dental offices. What is urgently needed is enhanced cross-infection prevention procedures aimed to stop the cross-infection of COVID-19 from or to dentists and patients. To stop the COVID-19 pandemic in dental offices, the single most important step that all dentists, staff, and patients can take, is to get the COVID-19 vaccine. Until everyone has the COVID-19 vaccine, there must be a focus on preventing a possible cross-infection of SARS-CoV-2 by triaging dental treatments for patients, separating vulnerable patients from COVID-19 patients, and preventing cross-contamination by disinfecting areas touched by patients, maintaining social distancing, and changing personal protective equipment between patients.

AUTHORS' CONTRIBUTIONS

All authors participated in the design, interpretation of the studies and analysis of the data and review of the manuscript; CS, MH, and FGG contributed to the drafting of the manuscript, DF and AF supplied critical overall manuscript revision, and MK supervised and supported review development in fluid dynamics and overall editing.

DECLARATION OF CONFLICTING INTERESTS

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

FUNDING

The author(s) disclosed receipt of the following financial support for the research, authorship, and/or publication of this article: This work was supported by the National Science Foundation [grant number 2031227].

ORCID iD

Maya Hartig  <https://orcid.org/0000-0002-4137-6018>

REFERENCES

1. Froum S, Froum S. Incidence of COVID-19 virus transmission in three dental offices: a 6-month retrospective study. *Int J Periodontics Restorative Dent* 2020;40:853–9
2. Estrich CG, Mikkelsen M, Morrissey R, Geisinger ML, Ioannidou E, Vujicic M, Araujo MWB. Estimating COVID-19 prevalence and infection control practices among US dentists. *J Am Dent Assoc* 2020;151:815–24
3. Clarkson E, Mashkoor F, Abdulateef S. Oral viral infections: diagnosis and management. *Dent Clin North Am* 2017;61:351–63
4. Taiwo JO, Aderinokun GA. Assessing cross infection prevention measures at the Dental Clinic, University College Hospital, Ibadan. *Afr J Med Sci* 2002;31:213–7
5. Barber LR, Wilkins EM. Evidence-based prevention, management, and monitoring of dental caries. *J Dent Hyg* 2002;76:270–5

6. Connors WJ, Rabie HH, Figueiredo RL, Holton DL, Parkins MD. Acute dental infections managed in an outpatient parenteral antibiotic program setting: prospective analysis and public health implications. *BMC Infect Dis* 2017;17:202
7. Passarelli PC, Rella E, Manicone PF, Garcia-Godoy F, D'Addona A. The impact of the COVID-19 infection in dentistry. *Exp Biol Med* 2020;245:940-44
8. Centers for Disease Control and Prevention. Guidance for dental settings. Interim infection prevention and control guidance for dental settings during the COVID-19 response. Atlanta, GA: Centers for Disease Control and Prevention, 2021
9. Amato A, Caggiano M, Amato M, Moccia G, Capunzo M, De Caro F. Infection control in dental practice during the COVID-19 pandemic. *Int J Environ Res Public Health* 2020;17:4769
10. Ahmed MA, Jouhar R, Ahmed N, Adnan S, Aftab M, Zafar MS, Khurshid Z. Fear and practice modifications among dentists to combat novel coronavirus disease (COVID-19) outbreak. *Int J Environ Res Public Health* 2020;17:2821
11. Nuno-Gonzalez A, Martin-Carrillo P, Magaletsky K, Martin Rios MD, Herranz Mañas C, Artigas Almazan J, García Casasola G, Perez Castro E, Gallego Arenas A, Mayor Ibarguren A, Feito Rodríguez M, Lozano Masdemont B, Beato M, Ruiz Bravo E, Oliver P, Montero Vega MD, Herranz Pinto P. Prevalence of mucocutaneous manifestations in 666 patients with COVID-19 in a field hospital in Spain: oral and palmo-plantar findings. *Br J Dermatol* 2021;184:184-5
12. Iranmanesh B, Khalili M, Amiri R, Zartab H, Aflatoonian M. Oral manifestations of COVID-19 disease: a review article. *Dermatol Ther* 2021;34:e14578
13. Marouf N, Cai W, Said KN, Daas H, Diab H, Chinta VR, Hssain AA, Nicolau B, Sanz M, Tamimi F. Association between periodontitis and severity of COVID-19 infection: a case-control study. *J Clin Periodontol* 2021;48:483-91
14. Genco RJ, Borgnakke WS. Risk factors for periodontal disease. *Periodontol 2000* 2013;62:59-94
15. Yaghobee S, Paknejad M, Khorsand A. Association between asthma and periodontal disease. *Front Dent* 2008;5:47-51
16. Thomas MS, Parolia A, Kundabala M, Vikram M. Asthma and oral health: a review. *Australian Dental Journal* 2010;55:128-33
17. Peng X, Xu X, Li Y, Cheng L, Zhou X, Ren B. Transmission routes of 2019-nCoV and controls in dental practice. *Int J Oral Sci* 2020; 12:9
18. Xu H, Zhong L, Deng J, Peng J, Dan H, Zeng X, Li T, Chen Q. High expression of ACE2 receptor of 2019-nCoV on the epithelial cells of oral mucosa. *Int J Oral Sci* 2020; 12:8
19. Azarpazhooh A, Leake JL. Systematic review of the association between respiratory diseases and oral health. *J Periodontol* 2006;77:1465-82
20. Wang F, Kream RM, Stefano GB. Long-term respiratory and neurological sequelae of COVID-19. *Med Sci Monit* 2020; 26:e928996
21. Henderson LA, Canna SW, Schulert GS, Volpi S, Lee PY, Kernan KF, Caricchio R, Mahmud S, Hazen MM, Halyabari O, Hoyt KJ, Han J, Grom AA, Gattorno M, Ravelli A, De Benedetti F, Behrens EM, Cron RQ, Nigrovic PA. On the alert for cytokine storm: immunopathology in COVID-19. *Arthritis Rheumatol* 2020;72:1059-63
22. U.S. Department of Health and Human Services. *Oral health in America: a report of the surgeon general*. Rockville, MD, <https://www.nidcr.nih.gov/research/data-statistics/surgeon-general> (2000, accessed 10 July 2021)
23. Website counting COVID-19 statistics, https://www.worldometers.info/coronavirus/?utm_campaign=homeAdUOA? (accessed 22 February 2021)
24. Washington-Brown L, Cirilo R. Coronavirus disease-2019-nCoV (COVID-19). *J Natl Black Nurses' Assoc JNBNA* 2020;31:19-25
25. Paules CI, Marston HD, Fauci AS. Coronavirus Infections-More than just the common cold. *JAMA* 2020;323:707-8
26. Omrani AS, Al-Tawfiq JA, Memish ZA. Middle east respiratory syndrome coronavirus (MERS-CoV): animal to human interaction. *Pathog Glob Health* 2015;109:354-62
27. Hu B, Guo H, Zhou P, Shi Z-L. Characteristics of SARS-CoV-2 and COVID-19. *Nat Rev Microbiol* 2021;19:141-54
28. Goodman JR. A pandemic like no other. *New Sci* 2021;249:38-41
29. Center for Disease Control and Prevention. About COVID-19, <https://www.cdc.gov/coronavirus/2019-ncov/cdcresponse/about-COVID-19.html> (accessed 5 March 2021)
30. Li H, Liu S-M, Yu X-H, Tang S-L, Tang C-K. Coronavirus disease 2019 (COVID-19): current status and future perspectives. *Int J Antimicrob Agents* 2020;55:105951
31. Chan JFW, Yuan S, Kok KH, To KKW, Chu H, Yang J, Xing F, Liu J, Yip CCY, Poon RWS, Tsui HW, Lo SKF, Chan KH, Poon VKM, Chan WM, Ip JD, Cai JP, Cheng VCC, Chen H, Hui CKM, Yuen KY. A familial cluster of pneumonia associated with the 2019 novel coronavirus indicating person-to-person transmission: a study of a family cluster. *Lancet* 2020;395:514-23
32. Iaccarino G, Grassi G, Borghi C, Ferri C, Salvetti M, Volpe Massimo M. Age and multimorbidity predict death among COVID-19 patients: results of the SARS-RAS study of the Italian Society of Hypertension. *Hypertension* 2020;76:366-72
33. Davies NG, Jarvis CI, Edmunds WJ, Jewell NP, Diaz-Ordaz K, Keogh RH. Increased hazard of death in community-tested cases of SARS-CoV-2 variant of concern 202012/01. *medRxiv* 2021;593:270-74
34. Feehan AK, Fort D, Velasco C, Burton JH, Garcia-Diaz J, Price-Haywood EG, Sapp E, Pevey D, Seoane L. The importance of anosmia, ageusia and age in community presentation of symptomatic and asymptomatic SARS-CoV-2 infection in Louisiana, USA; a cross-sectional prevalence study. *Clin Microbiol Infect* 2021;27: 633.e9-633.e16
35. Havers FP, Reed C, Lim T, Montgomery JM, Klena JD, Hall AJ, Fry AM, Cannon DL, Chiang CF, Gibbons A, Krapiunaya I, Morales-Betoule M, Roguski K, Rasheed MAU, Freeman B, Lester S, Mills L, Carroll DS, Owen SM, Johnson JA, Semenova V, Blackmore C, Blog D, Chai SJ, Dunn A, Hand J, Jain S, Lindquist S, Lynfield R, Pritchard S, Sokol T, Sosa L, Turabelidze G, Watkins SM, Wiesman J, Williams RW, Yendell S, Schiffer J, Thornburg NJ. Seroprevalence of antibodies to SARS-CoV-2 in 10 sites in the United States, march 23-May 12, 2020. *JAMA Intern Med* 2020;180:1576-86
36. Yanez ND, Weiss NS, Romand JA, Treggiari MM. COVID-19 mortality risk for older men and women. *BMC Public Health* 2020;20:1742
37. Tindale LC, Stockdale JE, Coombe M, Garlock ES, Lau WYV, Saraswat M, Zhang L, Chen D, Wallinga J, Colijn C. Evidence for transmission of COVID-19 prior to symptom onset. *Elife* 2020;9: e57149
38. Passarelli PC, Lopez MA, Bonaviri GNM, Garcia-Godoy F, D'Addona A. Taste and smell as chemosensory dysfunctions in COVID-19 infection. *Am J Dent* 2020;33:135-7
39. Wiersinga WJ, Rhodes A, Cheng AC, Peacock SJ, Prescott HC. Pathophysiology, transmission, diagnosis, and treatment of coronavirus disease 2019 (COVID-19): a review. *JAMA* 2020;324:782-93
40. Centers for Disease Control and Prevention. Symptoms of Coronavirus (COVID-19), https://www.cdc.gov/coronavirus/2019-ncov/symp_toms-testing/symptoms.html (2020, accessed 5 March 2021)
41. Yüce M, Filiztekin E, Özkaya KG. COVID-19 diagnosis – a review of current methods. *Biosens Bioelectron* 2021;172: 112752
42. Li Y, Yao L, Li J, Chen L, Song Y, Cai Z, Yang C. Stability issues of RT-PCR testing of SARS-CoV-2 for hospitalized patients clinically diagnosed with COVID-19. *J Med Virol* 2020;92:903-8
43. Wei J, Li Y. Airborne spread of infectious agents in the indoor environment. *Am J Infect Control* 2016;44(9 Suppl):S102-8
44. Mittal R, Ni R, Seo J-H. The flow physics of COVID-19. *J Fluid Mech* 2020;894:F2
45. Dbouk T, Drikakis D. Fluid dynamics and epidemiology: seasonality and transmission dynamics. *Phys Fluids* 2021;33. DOI: 10.1063/5.0037640
46. Xie X, Li Y, Chwang ATY, Ho PL, Seto WH. How far droplets can move in indoor environments – revisiting the wells evaporation-falling curve. *Indoor Air* 2007;17:211-25
47. Morawska L, Cao J. Airborne transmission of SARS-CoV-2: the world should face the reality. *Environ Int* 2020;139:105730
48. van Doremale N, Bushmaker T, Morris DH, Holbrook MG, Gamble A, Williamson BN, Tamin A, Harcourt JL, Thornburg NJ, Gerber SI, Lloyd-Smith JO, de Wit E, Munster VJ. Aerosol and surface stability of SARS-CoV-2 as compared with SARS-CoV-1. *N Engl J Med* 2020;382:1564-67

49. Bourouiba L. Turbulent gas clouds and respiratory pathogen emissions: potential implications for reducing transmission of COVID-19. *JAMA* 2020;323:1837-38

50. Setti L, Passarini F, De Gennaro G, Barbieri P, Perrone MG, Borelli M, Palmisani J, Di Gilio A, Piscitelli P, Miani A. Airborne transmission route of COVID-19: why 2 meters/6 feet of inter-personal distance could not be enough. *Int J Environ Res Public Health* 2020;17:2932

51. Fontes D, Reyes J, Ahmed K, Kinzel M. A study of fluid dynamics and human physiology factors driving dropletsdispersion from a human sneeze. *Phys Fluids* 2020;32:111904

52. Fears AC, Garry RF, Roy CJ, Reed DS, Klimstra WB, Duprex P, Hartman A, Weaver SC, Plante KC, Mirchandani D, Plante JA, Aguilar PV, Fernández D, Nalca A, Totura A, Dyer D, Kearney B, Lackemeyer M, Bohannon JK, Johnson R. Comparative dynamic aerosol efficiencies of three emergent coronaviruses and the unusual persistence of SARS-CoV-2 in aerosol suspensions. *medRxiv* 2020. DOI: 10.1101/2020.04.13.20063784

53. Port JR, Yinda CK, Owusu IO, Holbrook M, Fischer R, Bushmaker T, Avanzato VA, Schulz JE, van Doremale N, Clancy CS, Munster VJ. SARS-CoV-2 disease severity and transmission efficiency is increased for airborne but not fomite exposure in Syrian hamsters. *bioRxiv* 2020. DOI: 10.1101/2020.12.28.424565

54. Goldman E. Exaggerated risk of transmission of COVID-19 by fomites. *The Lancet Infect Dis* 2020;20:892-3

55. Bhardwaj R, Agrawal A. How coronavirus survives for days on surfaces. *Phys Fluids* 2020;32. DOI: 10.1063/5.0033306

56. Warnes SL, Little ZR, Keevil CW. Human coronavirus 229E remains infectious on common touch surface materials. *MBio* 2015;6. DOI: 10.1128/mBio.01697-15

57. Dowell SF, Simmerman JM, Erdman DD, Wu JSJ, Chaovavanich A, Javadi M, Yang JY, Anderson LJ, Tong S, Mei SH. Severe acute respiratory syndrome coronavirus on hospital surfaces. *Clin Infect Dis* 2004;39:652-7

58. Chang WH. A review of vaccine effects on women in light of the COVID-19 pandemic. *Taiwan J Obstetr Gynecol* 2020;59:812-20

59. Ionescu AC, Cagetti MG, Ferracane JL, Garcia-Godoy F, Brambilla E. Topographic aspects of airborne contamination caused by the use of dental handpieces in the operative environment. *J Am Dent Assoc* 2020;151:660-7

60. Interim Guidance on Ending Isolation and Precautions for Adults with COVID-19. *Center of Disease Control and Prevention: COVID-19, Healthcare Workers*, <https://www.cdc.gov/coronavirus/2019-ncov/hcp/duration-isolation.html> (accessed 21 June 2021)

61. Goswami M, Chawla S. Time to restart: a comparative compilation of triage recommendations in dentistry during the COVID-19 pandemic. *J Oral Biol Craniofacial Res* 2020;10:374-84

62. Asadi S, Cappa CD, Barreda S, Wexler AS, Bouvier NM, Ristenpart WD. Efficacy of masks and face coverings in controlling outward aerosol particle emission from expiratory activities. *Sci Rep* 2020;10:15665

63. Vaidya M, Gangakhedkar G, Shetty A, Wagalkar P. A rare occurrence of accidental exposure to UV radiation among operating theatre personnel. *Indian J Anaesth* 2020;64:230-32

64. Association AD. American dental association responds to world health organization recommendation: dentistry is essential health care. *News Release*, <https://www.ada.org/en/press-room/news-releases/2020-archives/august/american-dental-association-dentistry-is-essential-health-care> (accessed 10 July 2021)

65. Corum J, Grady D, Wee S, Zimmer C. Corona virus tracker. *N Y Times* 2020. <https://www.nytimes.com/interactive/2021/us/covid-cases.html>

66. Knoll MD, Wonodi C. Oxford-AstraZeneca COVID-19 vaccine efficacy. *Lancet* 2021;397:72-4

67. Polack FP, Thomas SJ, Kitchin N, Absalon J, Gurtman A, Lockhart S, Perez JL, Pérez Marc G, Moreira ED, Zerbini C, Bailey R, Swanson KA, Roychoudhury S, Koury K, Li P, Kalina WV, Cooper D, Frenck RW, Hammitt LL, Türeci Ö, Nell H, Schaefer A, Ünal S, Tresnan DB, Mather S, Dormitzer PR, Sahin U, Jansen KU, Gruber WC. Safety and efficacy of the BNT162b2 mRNA COVID-19 vaccine. *N Engl J Med* 2020;384:1576-77

68. Baden LR, El Sahly HM, Essink B, Kotloff K, Frey S, Novak R, Diemert D, Spector SA, Rouphael N, Creech CB, McGettigan J, Khetan S, Segall N, Solis J, Brosz A, Fierro C, Schwartz H, Neuzil K, Corey L, Gilbert P, Janes H, Follmann D, Marovich M, Mascola J, Polakowski L, Ledgerwood J, Graham BS, Bennett H, Pajon R, Knightly C, Leav B, Deng W, Zhou H, Han S, Ivarsson M, Miller J, Zaks T. Efficacy and safety of the mRNA-1273 SARS-CoV-2 vaccine. *N Engl J Med* 2021;384:403-16