SPECIAL COMMUNICATION

Dental Care and Oral Health under the Clouds of COVID-19

Y.F. Ren[1], L. Rasubala[1], H. Malmstrom[1], and E. Eliav[1]

Abstract: *Coronavirus disease 2019 (COVID-19), caused by the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), has caused much anxiety and confusion in the community and affected the delivery of vital health care services, including dental care. We reviewed current evidence related to the impact of SARS-CoV-2/COVID-19 on dental care and oral health with the aim to help dental professionals better understand the risks of disease transmission in dental settings, strengthen protection against nosocomial infections, and identify areas of COVID-19–related oral health research. When compared with other recent pandemics, COVID-19 is less severe but spreads more easily, causing a significantly higher number of deaths worldwide. Protection of dental patients and staff during COVID-19 is challenging due to the existence of patients who are infectious yet asymptomatic. Dental professionals are ill prepared for the pandemic, as they are not routinely fitted for the N95 respirators now required for preventing contagion during dental treatments. Biological and clinical evidence supports that oral mucosa is an initial site of entry for SARS-CoV-2 and that oral symptoms, including loss of taste/smell and dry mouth, might be early symptoms of COVID-19, presenting before fever, dry cough, fatigue, shortness breath, and other typical symptoms. Oral health researchers may play a more active role in early identification and diagnosis of the disease through deciphering the mechanisms of dry mouth and loss of taste in patients with COVID-19. Rapid testing for infectious diseases in dental offices via saliva samples may be valuable in the early identification of infected patients and in disease progress assessment.*

Knowledge Transfer Statement: *This commentary provides a timely evidence-based overview on the impact of COVID-19 on dental care and oral health and identifies gaps in protection of patients and staff in dental settings. Oral symptoms are prominent before fever and cough occur. Dental professionals may play an important role in early identification and diagnosis of patients with COVID-19.*

Keywords: SARS-CoV-2, dental facility, urgent care, airborne transmission, dry mouth, ageusia

Coronavirus disease 2019 (COVID-19), caused by the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), has spread rapidly across the globe since it was first reported in China in December 2019. As of April 15, 2020, SARS-CoV-2 has infected >2 million individuals and resulted in 132,000 deaths in 185 countries/regions. While government agencies, health care facilities, and medical professionals worldwide mobilize to contain the virus, mitigate the transmission of the disease, and save the lives of patients with COVID-19, dental care and oral health research have rightfully taken a backseat during the pandemic to preserve scarce personal protective equipment (PPE), observe social distancing, and protect the employees and patients from risks of potential exposure and illness. With the rapid increase in confirmed cases of COVID-19 in the United States, the Centers for Disease Control and Prevention (CDC), American Dental Association (ADA), and state dental boards and associations have all issued guidance to advise dentists to halt elective dental services and treat only patients requiring emergency dental procedures.

SARS-CoV-2 differs significantly from the 2003 SARS-CoV and Middle East

DOI: 10.1177/2380084420924385. [1]Eastman Institute for Oral Health, University of Rochester, Rochester, NY, USA. Corresponding authors: Y.F. Ren, Eastman Institute for Oral Health, University of Rochester, 625 Elmwood Ave, Rochester, NY 14620, USA. Email: yanfang_ren@urmc.rochester.edu. E. Eliav, Eastman Institute for Oral Health, University of Rochester, 625 Elmwood Ave, Rochester, NY 14620, USA. Email: eli_eliav@urmc.rochester.edu.

respiratory syndrome coronavirus (MERS-CoV) not only in genome sequence but also in its spike protein structures (Kandeel et al. 2020; Ren et al. 2020), which exhibit higher affinity to the cellular entry receptor angiotensin-converting enzyme 2 (ACE2), rendering it much easier for SARS-CoV-2 to enter human cells than SARS-CoV and MERS-CoV. Consequently, COVID-19 spreads much faster than SARS and MERS and has caused more deaths than SARS and MERS combined. Rapid transmission of the disease and exponential increase in number of confirmed cases—coupled with evolving but limited information about the transmission, prevention, diagnosis, treatment, and prognosis of the disease—have caused much anxiety and confusion in the community and affected the delivery of vital health care services, including dental treatments for those who need emergency care.

Reports from Wuhan, China, the epicenter of the pandemic, indicated that SARS-CoV-2 infections did occur in a small percentage of dental professionals, and face masks and gloves were credited for effectively preventing further spread of the infections among colleagues in close contact (Meng et al. 2020). These authors state that dental staff should be provided adequate PPEs when providing dental emergency services, including N95 masks, gloves, isolation gowns, protective eye goggles, face shields, and head and shoe covers (Meng et al. 2020). Such measures of personal protection were effective, as no transmission from patients to dental staff was reported in China. However, these PPEs are at present in critical short supply in the United States, even for medical staff who provide direct care to patients with COVID-19 in hospital emergency rooms and intensive care units, and it is practically impossible for dental providers to acquire and utilize the full list of PPEs included in this recommendation. The Pennsylvania state health department issued guidance that initially required using PPEs similar to this list and engineering control, such as negative-pressure isolation rooms with HEPA filtration (high-efficiency particulate air), when treating dental emergency patients, which essentially precluded all dental clinics in the state to provide dental emergency care, as none of the available dental facilities could meet such stringent requirement. This guidance was later revised to allow urgent or emergency dental treatments with PPEs and disinfection procedures consistent with usual standard of care in patients not suspected of having COVID-19 (Pennsylvania Department of Health 2020).

Dental emergency services are vital to the community in the time of the COVID-19 pandemic, which puts a heavy strain on critical health care resources. Aside from life-threatening dental emergencies, such as uncontrolled oral tissue bleeding, head and neck fascial space infection, or facial trauma that may compromise the patient's airway, patients with severe dental pain that cannot be controlled with over-the-counter analgesics or patients with minor dental trauma may clog hospital emergency rooms that are already overburdened with patients with COVID-19 or other medical emergencies. The ADA (2020c) developed guidance on dental emergency and nonemergency dental procedures, which includes a rather inclusive list of urgent dental care treatments aiming at minimizing pain, preventing infections, and reducing discomforts. As dental professionals treating emergency patients in the time of uncertainty in the midst of the COVID-19 pandemic, it is urgent that we develop adequate understanding of the disease, especially its modes of transmission, and adopt prudent measures to protect our patients and our staff to the best of our capacity. We therefore provide the following overview on SARS-CoV-2/COVID-19 and its impact on oral health and dental care. We fully understand that knowledge about the virus and the disease is rapidly evolving, and we advise caution and reference to the most up-to-date evidence from peer-reviewed scientific publications. This overview focuses on issues important to dental care and oral health and is not intended to be a comprehensive review of SARS-CoV-2 and COVID-19.

Bare Basics of SARS-CoV-2

SARS-CoV-2 is an enveloped positive-stranded RNA virus, which is a betacoronavirus within the Nidovirales order of viruses (Gorbalenya et al. 2020). The host-derived membrane is studded with glycoprotein spikes and surrounds the RNA genome. Replication of viral RNA occurs in the host cytoplasm through the action of RNA polymerase. The spike protein projects through the viral envelope and mediates ACE2 receptor binding and fusion with the host cell membrane (Xu, Chen, et al. 2020). In more simple terms, SARS-CoV-2 can be described as a piece of genetic material (RNA) wrapped in a coat of proteins that have spikes helping the virus enter human cells and hijack them, creating copies of itself and eventually killing the host cells. It is of practical importance to understand that the virus is only "alive" when inside the cells and that it is inert and cannot replicate itself when outside the body (Koonin and Starokadomskyy 2016). While outside the body, the protein structure of SARS-CoV-2 can be easily unwrapped or disassembled by common disinfectants within 5 min (Chin et al. 2020), which effectively render the virus harmless since it will not be able to enter the cells and replicate without the protein coat and spikes.

Spread of SARS-CoV-2 from Human to Human

Though SARS-CoV-2 was generally considered a novel coronavirus transmitted from bat to human via an intermediate host, such as a pangolin (Lam et al. 2020; Li, Giorgi, et al. 2020) or other animals (Li, Zai, et al. 2020; Luan et al. 2020) in a wet market in Wuhan, China, a group of leading virologists from the United States, United Kingdom, and Australia recently described that this virus may have been circulating in

human populations for an extended period before it acquired the ability of causing human diseases through genomic adaptations during undetected human-to-human transmissions (Andersen et al. 2020). These researchers analyzed available genomic sequence data of known coronavirus strains and determined that the receptor-binding domain sections of SARS-CoV-2 spike proteins could become so effective in binding to ACE2 only through a long process of natural selections. Clinical and epidemiologic studies suggest that human-to-human transmission is most frequently realized through direct or indirect contact with virus-laden respiratory droplets discharged from infected individuals while coughing and sneezing (Chen 2020; Wu et al. 2020). These droplets vary in size, from a few micrometers to a hundred, and may travel in air for distances from a few feet to several meters (Kunkel et al. 2017; Liu et al. 2017). In theory, smaller droplets (5 to 10 µm) or droplet nuclei (<5 µm) produced by coughing or sneezing can be inhaled by a person in very close proximity and directly cause transmission of the disease, as they may float in the air for an extended period, especially in a closed space with poor ventilation (An et al. 2020). SARS-CoV-2 transmission may also occur indirectly, when a person comes into contact with fomites, such as the hand or clothes of an infected patient or the door handles, counter surfaces, dinning utensils, and other objects touched, used, or soiled by respiratory droplets from an infected patient. It is believed that SARS-CoV-2 cannot penetrate the keratin layer of intact human skin but may enter human body through mucosal surfaces when contaminated hands touch the mouth, noses, and eyes.

The possibility for airborne transmission of SARS-CoV-2 remains an item of debate among infectious disease experts. SARS-CoV-2 virus was found to remain in floating aerosols for up to 3 h in a laboratory experimental study (van Doremalen et al. 2020). Some studies found that the viral RNA of SARS-CoV-2 is present in air samples in isolation rooms and quarantine facilities (Santarpia et al. 2020) and in and around hospitals and department store entrances (Liu et al. 2020), while other studies did not find the viral RNA in air samples where the patients with COVID-19 were treated (Cheng et al. 2020; Ong et al. 2020). In a scientific brief published March 27, 2020, the World Health Organization (2020) stated that there is no sufficient evidence that SARS-CoV-2 is airborne and that presence of the virus RNA in aerosols does not indicate that viable virus is transmissible. To date, infectious disease experts and policy makers in countries such as China and South Korea are convinced that SARS-CoV-2 is transmissible by air, like other infectious respiratory diseases. As such, they have stringent face mask policies in place for citizens in public spaces and for health care workers in medical facilities. Yet, the World Health Organization and policy makers in the United States and some European countries have taken a more evidence-based approach while awaiting more concrete findings on the effectiveness of universal masking, namely by insisting that only patients with confirmed or suspected COVID-19 wear face masks as well as the health care workers who treat them. As emerging evidence supports that SARS-CoV-2 is transmissible by air during normal talking and breathing (Asadi et al. 2020), more stringent face mask policies in health care facilities and public spaces are likely to come.

Though fecal-oral transmission has been proposed as a possibility because the viral RNA was detectable in stools and anal swabs (Gu et al. 2020; Zhang et al. 2020), a recent study indicated that no viable virus could be isolated from stool samples (Wölfel et al. 2020). The clinical and public health significance of fecal-oral transmission is therefore unclear and needs confirmatory studies.

In summary, SARS-CoV-2 is most frequently transmitted from human to human through direct contact with respiratory droplets and through indirect contact with fomites. Airborne transmission and fecal-oral transmission are also likely, but concrete confirmatory evidence is lacking.

Transmission from Asymptomatic or Presymptomatic Patients with COVID-19

As mentioned earlier, SARS-CoV-2 spreads much faster than SARS-CoV and MERS-CoV, which can partially be explained by a higher binding efficiency of SARS-CoV-2 spike protein to human ACE2 receptors (Walls et al. 2020). With increased understanding about the natural course of the disease, including its virologic and clinical manifestations, we now know that COVID-19 is less severe overall, having a lower fatality rate (2%) than SARS (10%) or MERS (34%; Mahase 2020), and that many patients with COVID-19 have mild or no symptoms, especially at early stages of the disease. Virologic studies show that viral load is highest in the first week of COVID-19, when the symptoms are generally mild (To, Tsang, Leung, et al. 2020; Wölfel et al. 2020). Some individuals infected with SARS-CoV-2 may never show symptoms themselves but become the source of the disease transmission within close contacts (Hu et al. 2020). A recent epidemiologic study indicated that nearly 17% of the patients with COVID-19 are asymptomatic and that the transmission rate from asymptomatic patients (4.1%) is statistically similar to that from symptomatic patients (6.3%; Chen, Wang, et al. 2020). These findings suggest that transmission from asymptomatic patients to healthy individuals is likely a hallmark of COVID-19 that distinguishes it from SARS and MERS and contributes to rapid spread of the disease in the community. Reports from Japan show that 18% to 30% of the infected patients were asymptomatic (Mizumoto et al. 2020; Nishiura et al. 2020). With escalating rates of screening and testing, emerging data from European countries and the United States point to even higher proportions of asymptomatic patients with COVID-19. News media reported

on April 2, 2020, that nationwide data from Iceland showed that 50% of those who tested positive said that they were asymptomatic, and the CDC director stated that an estimated 25% of coronavirus carriers in the United States have no symptoms (CNN 2020).

"Asymptomatic patients" reported in scientific literature and mass media refer to individuals who test positive for SARS-CoV-2 RNA but do not have any of the hallmark symptoms of COVID-19 at the time of the test. Some patients may never show symptoms, but others may develop symptoms later and are more accurately defined as "presymptomatic" (Kimball et al. 2020). Such distinction is important only in statistical terms, as they are counted as different types of patients. In reality, asymptomatic and presymptomatic patients are both major sources of SARS-CoV-2 transmission, as they are covert and show no warning signs to health care workers or laypersons at the time of contact.

Oral Health Implications of SARS-CoV-2 and COVID-19

Oral mucosa has been implicated as a potential route of entry for SARS-CoV-2 (Peng et al. 2020). The SARS-CoV-2 cellular entry receptor ACE2 was found in various oral mucosal tissues, especially in the tongue and floor of the mouth (Xu, Zhong, et al. 2020). ACE2-positive cells were also detected in buccal and gingival epithelial cells. The presence of ACE2 receptors in oral tissues suggests that it is biologically plausible for the oral cavity to be the initial site of entry for SARS-CoV-2. Habitual and unintentional hand-mouth contact is a common phenomenon in social and private settings, which is consistent with the mode of transmission of SARS-CoV-2 described earlier. In addition to inadequate hand hygiene and possible direct transmission through hand-mouth contact, oral ingestion of food contaminated by infected patients might be a possibility in regions where dinning from shared dishes with friends and family is customary. Dinning with family or friends was reported to be a risk factor of transmission from symptomatic and asymptomatic patients in China (Chen, Wang, et al. 2020).

Loss of taste (ageusia) has been reported in patients with COVID-19 (Chen, Zhao, et al. 2020; Gautier and Ravussin 2020; Giacomelli et al. 2020). Approximately 50% of the patients reported loss of taste (Chen, Zhao, et al. 2020; Giacomelli et al. 2020). It is particularly interesting that loss of taste occurred before hospitalization in the early stage of the disease in 91% of these patients and that this symptom is persistent (Giacomelli et al. 2020). Using the COVID Symptom Tracker app developed in King's College London, researchers found that loss of taste and smell is a key symptom for patients with COVID-19. The app tracked 1,702 patients tested for COVID-19, with 579 positive results and 1,123 negative, and showed that 59% of patients who were COVID-19 positive reported loss of taste and smell, as compared with only 18% of those who tested negative. Self-reported loss of taste and smell is much stronger in predicting a positive COVID-19 diagnosis than self-reported fever (King's College London 2020). Taste organs are widely distributed in oral tongue, where 96% of the oral ACE2-positive cells reside (Xu, Zhong, et al. 2020). Loss of taste as an early symptom of COVID-19 before fever and other symptoms occur lends support to the hypothesis that oral cavity, particularly tongue mucosa, might be an initial site of infection by SARS-CoV-2.

SARS-CoV-2 has been consistently detected in whole saliva at an early stage of the disease (To, Tsang, Chik-Yan Yip, et al. 2020) and in saliva collected from the duct opening of the salivary glands at a late stage (Chen, Zhao, et al. 2020). It has been shown that ACE2-positive salivary gland epithelial cells are early targets of SARS-CoV in nonhuman primates and that salivary gland functions may be affected at an early stage of the disease (Liu et al. 2011). At 48 h after intranasal viral challenges, viral loads of SARS-CoV were significantly higher in saliva than in blood samples (Liu et al. 2011). These findings suggest that oral symptoms may occur due to impediment of salivary flow in these patients. A cross-sectional survey of 108 patients with confirmed COVID-19 in Wuhan indeed found that 46% of the patients reported dry mouth as one of their symptoms (Chen, Zhao, et al. 2020). However, the temporal sequence of oral dryness and COVID-19 diagnosis is not clear and warrants further exploration.

In summary, empirical, biological, and clinical evidence supports that oral mucosa is an initial site of entry for SARS-CoV-2 and that oral symptoms, including loss of taste/smell and dry mouth, might be early symptoms of COVID-19 before fever, dry cough, fatigue, shortness breath, and other typical symptoms occur. The mechanism and prognosis of oral symptoms of COVID-19 are not clear. Dentists and dental researchers could play a more active role in the early diagnosis, prevention, and treatment of COVID-19 and its related research.

Provision of Dental Care during the COVID-19 Pandemic

In response to the rapid spread of COVID-19 across the country, the ADA issued its initial recommendation on March 16, 2020, for dentists nationwide to postpone elective dental procedures and focus on emergency dental care only for 3 wk. This recommendation was extended to April 30, 2020, when the ADA announced the publication of detailed interim guidance on the management of emergency and urgent dental care (ADA 2020a) as a complement to the list of emergency and urgent dental procedures published earlier (ADA 2020c).

Howitt Dental Urgent Care (HDUC) at the University of Rochester Eastman Institute for Oral Health (UR-EIOH) is a 7-operatory clinic dedicated to treating patients who have dental emergencies and are in need of urgent care. Since March 16, 2020, the UR-EIOH started to postpone and cancel scheduled visits at general dentistry and specialty

clinics and adopted policies to provide only urgent care following the ADA guidance. Some patients who are in need of urgent dental care are therefore diverted from HDUC to general dentistry and specialty care clinics to reduce waiting room crowding and patient and staff densities in the clinic. Patient visits to the UR-EIOH were reduced by approximately 85%, to a total of about 80 urgent care visits per day. Most of the patients (96%) seen in the urgent care clinic had moderate to severe pain associated with pulpal or periapical inflammation, dentoalveolar infections, and trauma. These types of pain could not be managed with over-the-counter analgesics, and many patients require antibiotics, prescription analgesics, and/or definitive treatment, such as tooth extraction, incision and drainage, or root canal therapy, to eliminate the disease and prevent spread of the infection. Had the dental urgent care service not been available, these patients would have likely visited the hospital emergency department for pain management, adding strains to the already overburdened emergency rooms from COVID-19 and other medical emergencies. Dental urgent care service is especially important at a time when most dental clinics are closed following the ADA guidance. We anticipate that some of the clinics will not be able to provide urgent care services to their patients due to staffing issues or lack of adequate PPEs.

With the extension of the urgent care–only guidance period, we expect that more and more patients will need definitive treatments, as dental pain or infection cannot be managed with medications long-term. Though we have, to a great extent, avoided aerosol-generating procedures—such as those needing the use of a high-speed handpiece due to the lack of adequate PPEs at the earlier stage (hoping that the pandemic would be over soon and we could resume routine care in a few weeks)—we now know that we need to adjust our plan and be prepared to perform the procedures that carry risks but benefit our patient long-term. During the first 2 wk after the ADA published its urgent care recommendation, approximately 30% of patients at HDUC received tooth extraction and incision and drainage, and 70% received palliative treatments and prescription of antibiotics. This is a significant reversal from the time before COVID-19, when 70% of our patients received definitive treatments and 30% received palliative treatments and prescriptions (unpublished data). With improved availability of PPEs and publication of the ADA guidance on minimizing risk of COVID-19 transmission, we should be able to improve our ability to provide the best care possible for our patients.

Protection of Patients and Staff in Dental Urgent Care Settings

In its interim guidance on minimizing risk of COVID-19 transmission in dental offices, the ADA (2020b) provided 3 algorithms to assist dentists in making decisions on patient triage, evaluating for COVID-19, and minimizing risks for patients and staff during emergency or urgent dental treatments. The goal is to minimize risks of transmission while allowing the provision of needed urgent care. Though the risk to patients and staff should be small if the guidance is followed, uncertainties exist given the high number of asymptomatic patients and the possibility of airborne transmission. Screening for fever and contact history may not be productive because many patients who are infected with the virus can be asymptomatic or undiagnosed (Bwire and Paulo 2020; Hu et al. 2020; Quilty et al. 2020) and can equally transmit the disease as the symptomatic cases (Chen, Wang, et al. 2020). The prevalence of COVID-19 in the community remains to be low in many areas, but it may change rapidly with time. Therefore, we may soon face the question if we should assume that every patient who comes to a dental office is a patient with COVID-19 and, if so, what preventive and protective measures during dental treatments are appropriate for the safety of the patients and staff.

According to the ADA and CDC guidance, patients with active COVID-19 infection should not be seen in dental settings. Patients who present for emergency and urgent dental care should be evaluated for signs and symptoms of COVID-19 and for determination of whether they can be seen in a dental office. For patients who have fever and signs and symptoms of acute respiratory infection or have no fever but signs and symptoms of acute respiratory infection, the ADA guidance states that they need to go to the hospital emergency department for treatment and the doctor needs to page infection control. If patients have neither fever nor signs and symptoms or have only fever, they can be seen at the dental setting as the fever might be caused by dental infections. Patients not suitable to be seen in the dental setting include those who had exposure to an individual with suspected or confirmed COVID-19 infection, traveled to countries currently under a travel ban, or were exposed to confirmed SARS-CoV-2 biologic material directly or indirectly, because risk of transmission increases with these exposures (ADA 2020a). This guidance will be able to minimize the risk of exposures in dental offices provided that the number of asymptomatic patients with COVID-19 is negligible and that the number of confirmed, suspected, or potentially exposed patients is low in the surrounding communities. Otherwise, this screening strategy will not work because it cannot identify asymptomatic patients or those exposed to asymptomatic patients and it adds burden to emergency departments that are struggling to save lives of the seriously ill. An ideal solution is to provide rapid COVID-19 testing in the dental urgent care clinic with the available point-of-care test kit that produces results in minutes. This can be a great opportunity for dental professionals to contribute to the fight against COVID-19 by expanding the

testing capacity and identifying patients early. This may be difficult to realize at this time due to the shortage of testing equipment but should be considered if the equipment becomes available.

According to the interim guidance of the ADA (2020a, 2020b), if patients have no known exposure to COVID-19, recently tested negative, or recovered from COVID-19 infection, they can be treated in the dental office if they have a dental emergency or urgent condition that cannot be postponed without causing significant pain or distress. Protection and prevention measures depend on if the treatment procedures will produce aerosols. For non–aerosol-generating procedures, surgical face masks and basic clinical PPE (including eye protection) are adequate, and approved disinfection procedures should be performed immediately after every procedure. For aerosol-generating procedures, fitted N95 respirators, full-face shields, and basic clinical PPE (including eye protection) are required, and approved disinfection procedures should be performed immediately after every procedure. If fitted N95 respirators and full-face shields are not available, there might be moderate to high risks of exposure, and the dental team may need to be put into a 14-d quarantine after the aerosol-generating procedure due to the existence of asymptomatic patients. We believe that these guidelines are judicious and useful, but the requirement "You and your staff have N95 respirators fitted to your face" may deserve further explanation. Does this mean that dentists and staff need to be formally fit tested for using the N95 respirators? Or is it acceptable to just use an N95 respirator that you feel fits? In addition to improved filtration efficiency, the main advantage of an N95 respirator over a surgical mask is that it can achieve a tight seal that prevents air leakage around the edges. Appropriate use of N95 respirators requires an annual fit test via a standard protocol that includes a pass/fail result that relies on the individual's sensory (taste or smell) detection of a test agent, such as Saccharin (sweetener) or Bitrex (bitter) solutions (CDC and National Institute for Occupational Safety and Health 2020). As there are many models and different sizes of N95 respirators, a successful fit test only qualifies you to use the specific brand and size of respirator that you wore during that test (CDC and National Institute for Occupational Safety and Health 2020). Therefore, it should be apparent that "N95 respirators fitted to your face" mean that you and your staff have been fit tested for an N95 respirator that you use in your clinic or facility. However, this requirement probably will preclude most, if not all, dentists in private practices from participating in providing urgent care services during the COVID-19 pandemic, as an annual N95 fit test is not part of the dental practice routine. At the UR-EIOH, residents and faculty members who have clinical privileges at the medical center are fitted for N95 respirators annually, but those who work in the dental clinic alone have not been fit tested. Though we are working with the medical center to have all residents and faculty members fitted for the N95 respirators, it takes time to complete the test. In the mean time, we have to minimize the number of aerosol-generating procedures to protect the faculty and resident providers and staff.

N95 respirators, gloves, full-face shields, eye protection goggles with side shields, isolation gowns, and head covers were recommended for aerosol-generating procedures by the state health commission in China and proven effective, as no staff or patients were infected with the disease in dental clinics throughout the country (Meng et al. 2020; Peng et al. 2020; Yang et al. 2020; Zhang and Jiang 2020). Face shields and eye protection goggles are considered essential in dental procedures that produce spatter or aerosol because ocular exposure is likely a route of transmission for the SARS-CoV-2 virus (Li, Lam, et al. 2020; Lu et al. 2020).

As described earlier, the SARS-CoV-2 virus does not replicate or "grow" outside the body, and its protein structure can be disrupted by many common disinfectants. However, the virus may retain viability for an extended period, from several hours to several days, and on different surfaces, such as metal, glass, plastic, wood, or paper (Kampf et al. 2020; van Doremalen et al. 2020), but it can be effectively inactivated in 1 to 5 min by many disinfectants, including 70% ethanol, 0.1% sodium hypochlorite, 1% povidone-iodine, and 0.5% hydrogen peroxide (Chin et al. 2020; Kampf et al. 2020). Povidone-iodine mouthwash has been shown to have strong viricidal activities against SARS-CoV and MERS-CoV after 15 s of exposure (Eggers et al. 2018). The CDC (2020) has published an interim infection prevention and control guidance for dental settings during the COVID-19 response and lists >300 products approved for SARS-CoV-2 disinfection. For aerosol-generating procedures, patients should be instructed to use 1% povidone-iodine or 1.5% hydrogen peroxide mouth rinses for 1 min before the procedure, and a rubber dam should be used to reduce saliva contamination and aerosol generation during the procedure. After the procedure, all exposed surfaces of the operatory, including chairs, desks, cabinets, and door handles, should be cleaned with 0.1% sodium hypochlorite. Though these steps are all helpful in reducing the risks of nosocomial infections in dental offices, adequate hand washing with soap between patients and after touching any nonsterile objects remains the most effective way to prevent the transmission of COVID-19.

In summary, protection of patients and staff during COVID-19 is challenging due to the existence of patients who are infectious yet asymptomatic. Dental clinics and dental professionals are not well prepared to perform aerosol-generating procedures at the time of the infectious respiratory disease pandemic, as they are not routinely fitted for the N95 respirators required for these procedures. It is fortunate that SARS-CoV-2 is sensitive to many common disinfectants and that the risks for dental providers and patients are small if prudent measures are taken

following the ADA and CDC guidance, including frequent hand washing and judicious use of PPEs.

Looking Ahead

The COVID-19 pandemic has exposed significant gaps in the collective response of global health care systems to a public health emergency. Though dentistry is a relatively small part in the COVID-19 response, dental professionals should take this opportunity to assess the role of dental care in a public health emergency, look into the future, and determine what we can improve to better serve our patients and protect our staff should a similar event happen again. With the successive emergence of SARS-CoV in 2003, H1N1 in 2009, MERS in 2012, Ebola in 2018, and SARS-CoV-2 in 2020, global public health emergencies and pandemics of infectious diseases are no longer rare, once-in-a-lifetime events. Dentistry as an integral part of the health care system should be prepared to play a more active role in the fight against emerging life-threatening diseases. Dental education, research, clinical practices, and public health should consider the following aspects during and after the COVID-19 pandemic:

- Improve public health emergency preparedness throughout the dental health care system. Proper donning and doffing of N95 respirators, surgical masks, and isolation gowns may need to be included in the dental training curriculum and dental practice routine.
- Explore the value of rapid testing for infectious diseases in dental offices via saliva samples. The best way to fight against the COVID-19 pandemic or similar outbreaks is to rapidly test the population, identify those who are infected but asymptomatic, trace those in close contact with the patients, and isolate them to prevent further spread of disease. Rapid testing in dental offices via saliva samples could contribute to disease containment as well as protect dental staff from accidental exposures. With the progression of the pandemic, testing for antibodies against SARS-CoV-2 will help us to identify those who have already developed immunity to the disease through covert infections.
- Increase research efforts in aerosol control in dental offices, including improving engineering control in dental office design. Negative-pressure rooms are effective in reducing risks of transmission for infectious respiratory diseases. It may be time to consider negative-pressure dental operatories, at least in academic health centers and dental school clinics, in the era of frequent respiratory disease pandemics.
- Initiate and participate in scientific research projects to discover the impact of COVID-19 and other infectious diseases on oral health. Preliminary data indicate that oral symptoms are prominent in many patients with COVID-19, especially in the early stages before other symptoms occur. Dental and oral health researchers may play a more active role in early identification and diagnosis of the disease through deciphering the mechanisms of dry mouth and loss of taste and smell in patients with COVID-19.

Author Contributions

Y.F. Ren, contributed to conception, design, and data analysis, drafted the manuscript; L. Rasubala, contributed to data analysis, critically revised the manuscript; H. Malmstrom, contributed to data analysis and interpretation, critically revised the manuscript; E. Eliav, contributed to conception, design, data analysis, and interpretation, drafted the manuscript. All authors gave final approval and agree to be accountable for all aspects of the work.

Acknowledgments

The authors received no financial support and declare no potential conflicts of interest with respect to the authorship and/or publication of this article.

ORCID iD

Y.F. Ren https://orcid.org/0000-0001-6428-2252

References

American Dental Association. 2020a. ADA interim guidance for management of emergency and urgent dental care [accessed 2020 Apr 3]. https://www.ada.org/~/media/CPS/Files/COVID/ADA_Int_Guidance_Mgmt_Emerg-Urg_Dental_COVID19.pdf?utm_source=cpsorg&utm_medium=covid-cps-virus-lp&utm_content=cv-pm-ebd-interim-flowchart&utm_campaign=covid-19

American Dental Association. 2020b. ADA interim guidance for minimizing risk of COVID-19 transmission [accessed 2020 Apr 3]. https://www.ada.org/~/media/CPS/Files/COVID/ADA_COVID_Int_Guidance_Treat_Pts.pdf?utm_source=cpsorg&utm_medium=covid-cps=virus-lp&utm_content=cv-pm-ebd-interim-response&utm_campaign=covid-19

American Dental Association. 2020c. What constitutes a dental emergency? [accessed 2020 Apr 2]. https://success.ada.org/~/media/CPS/Files/Open%20Files/ADA_COVID19_Dental_Emergency_DDS.pdf?_ga=2.78740951.215793349.1585680652-310524266.1585339538

An N, Yue L, Zhao B. 2020. Droplets and aerosols in dental clinics and prevention and control measures of infection. Zhonghua Kou Qiang Yi Xue Za Zhi. 55:E004.

Andersen KG, Rambaut A, Lipkin WI, Holmes EC, Garry RF. 2020. The proximal origin of SARS-CoV-2. Nat Med. 26(4):450–452.

Asadi S, Bouvier N, Wexler AS, Ristenpart WD. 2020. The coronavirus pandemic and aerosols: does COVID-19 transmit via expiratory particles? Aerosol Sci Technol. doi:10.1080/02786826.2020.1749229

Bwire GM, Paulo LS. 2020. Coronavirus disease-2019: is fever an adequate screening for the returning travelers? Trop Med Health. 48:14.

Centers for Disease Control and Prevention. 2020. Interim infection prevention and control guidance for dental settings during the COVID-19 response [accessed 2020 Apr 6]. https://www.cdc.gov/coronavirus/2019-ncov/hcp/dental-settings.html

Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health. 2020. The need for fit testing during emerging infectious disease outbreaks [accessed 2020 Apr 7]. https://blogs.cdc.gov/niosh-science-blog/2020/04/01/fit-testing-during-outbreaks/

Chen J. 2020. Pathogenicity and transmissibility of 2019-nCoV—a quick overview and

comparison with other emerging viruses. Microbes Infect. 22(2):69–71.

Chen L, Zhao J, Peng J, Li X, Deng X, Geng Z, Shen Z, Guo F, Zhang Q, Jin Y, et al. 2020. Detection of 2019-nCoV in saliva and characterization of oral symptoms in COVID-19 patients [epub ahead of print 19 Mar 2020]. https://ssrn.com/abstract=3557140. doi:10.2139/ssrn.3557140

Chen Y, Wang A, Yi B, Ding K, Wang H, Wang J, Shi H, Wang S, Xu G. 2020. The epidemiological characteristics of infection in close contacts of COVID-19 in Ningbo City [article in Chinese]. Chinese Journal of Epidemiology. http://html.rhhz.net/zhlxbx/028.htm.

Cheng VCC, Wong SC, Chen JHK, Yip CCY, Chuang VWM, Tsang OTY, Sridhar S, Chan JFW, Ho PL, Yuen KY. 2020. Escalating infection control response to the rapidly evolving epidemiology of the coronavirus disease 2019 (COVID-19) due to SARS-CoV-2 in hong kong. Infect Control Hosp Epidemiol [epub ahead of print 5 Mar 2020] in press. doi:10.1017/ice.2020.58

Chin A, Chu J, Perera M, Hui K, Yen H-L, Chan M, Peiris M, Poon L. 2020. Stability of SARS-CoV-2 in different environmental conditions [epub ahead of print 2 Apr 2020] in press. Lancet Microbe. doi:10.1016/S2666-5247(20)30003-3

CNN. 2020. US coronavirus cases pass 200,000: more states are saying stay at home [accessed 2020 Apr 2]. https://www.cnn.com/2020/04/01/health/us-coronavirus-updates-wednesday/index.html.

Eggers M, Koburger-Janssen T, Eickmann M, Zorn J. 2018. In vitro bactericidal and virucidal efficacy of povidone-iodine gargle/mouthwash against respiratory and oral tract pathogens. Infect Dis Ther. 7(2):249-259.

Gautier JF, Ravussin Y. 2020. A new symptom of COVID-19: loss of taste and smell. Obesity (Silver Spring) [epub ahead of print 1 Apr 2020] in press. doi:10.1002/oby.22809

Giacomelli A, Pezzati L, Conti F, Bernacchia D, Siano M, Oreni L, Rusconi S, Gervasoni C, Ridolfo AL, Rizzardini G, et al. 2020. Self-reported olfactory and taste disorders in SARS-CoV-2 patients: a cross-sectional study. Clin Infect Dis [epub ahead of print 26 Mar 2020] in press. doi:10.1093/cid/ciaa330

Gorbalenya AE, Baker SC, Baric RS, de Groot RJ, Drosten C, Gulyaeva AA, Haagmans BL, Lauber C, Leontovich AM, Neuman BW, et al. 2020. The species severe acute respiratory syndrome-related coronavirus: classifying 2019-nCoV and naming it SARS-CoV-2. Nat Microbiol. 5(4):536–544.

Gu J, Han B, Wang J. 2020. COVID-19: gastrointestinal manifestations and potential fecal-oral transmission. Gastroenterology [epub ahead of print 3 Mar 2020] in press. doi:10.1053/j.gastro.2020.02.054

Hu Z, Song C, Xu C, Jin G, Chen Y, Xu X, Ma H, Chen W, Lin Y, Zheng Y, et al. 2020. Clinical characteristics of 24 asymptomatic infections with COVID-19 screened among close contacts in nanjing, china. Sci China Life Sci [epub ahead of print 4 Mar 2020] in press. doi:10.1007/s11427-020-1661-4

Kampf G, Todt D, Pfaender S, Steinmann E. 2020. Persistence of coronaviruses on inanimate surfaces and their inactivation with biocidal agents. J Hosp Infect. 104(3):246–251.

Kandeel M, Ibrahim A, Fayez M, Al-Nazawi M. 2020. From SARS and MERS CoVs to SARS-CoV-2: moving toward more biased codon usage in viral structural and nonstructural genes. J Med Virol [epub ahead of print 11 Mar 2020] in press. doi:10.1002/jmv.25754

Kimball A, Hatfield KM, Arons M, James A, Taylor J, Spicer K, Bardossy AC, Oakley LP, Tanwar S, Chisty Z, et al. 2020. Asymptomatic and presymptomatic SARS-CoV-2 infections in residents of a long-term care skilled nursing facility—King County, Washington, March 2020. MMWR Morb Mortal Wkly Rep. 69(13):377–381.

King's College London. 2020. Loss of smell and taste a key symptom for COVID-19 cases [accessed 2020 Apr 3]. https://www.kcl.ac.uk/news/loss-of-smell-and-taste-a-key-symptom-for-covid-19-cases.

Koonin EV, Starokadomskyy P. 2016. Are viruses alive? The replicator paradigm sheds decisive light on an old but misguided question. Stud Hist Philos Biol Biomed Sci. 59:125–134.

Kunkel SA, Azimi P, Zhao H, Stark BC, Stephens B. 2017. Quantifying the size-resolved dynamics of indoor bioaerosol transport and control. Indoor Air. 27(5):977–987.

Lam TT, Shum MH, Zhu HC, Tong YG, Ni XB, Liao YS, Wei W, Cheung WY, Li WJ, Li LF, et al. 2020. Identifying SARS-CoV-2 related coronaviruses in malayan pangolins. Nature [epub ahead of print 26 Mar 2020] in press. doi:10.1038/s41586-020-2169-0

Li JO, Lam DSC, Chen Y, Ting DSW. 2020. Novel coronavirus disease 2019 (COVID-19): the importance of recognising possible early ocular manifestation and using protective eyewear. Br J Ophthalmol. 104(3):297–298.

Li X, Giorgi EE, Marichann MH, Foley B, Xiao C, Kong X-P, Chen Y, Korber B, Gao F. 2020. Emergence of SARS-CoV-2 through recombination and strong purifying selection. bioRxiv [epub ahead of print 22 Mar 2020] in press. doi:10.1101/2020.03.20.000885

Li X, Zai J, Zhao Q, Nie Q, Li Y, Foley BT, Chaillon A. 2020. Evolutionary history, potential intermediate animal host, and cross-species analyses of SARS-CoV-2. J Med Virol [epub ahead of print 27 Feb 2020] in press. doi:10.1002/jmv.25731

Liu L, Li Y, Nielsen PV, Wei J, Jensen RL. 2017. Short-range airborne transmission of expiratory droplets between two people. Indoor Air. 27(2):452–462.

Liu L, Wei Q, Alvarez X, Wang H, Du Y, Zhu H, Jiang H, Zhou J, Lam P, Zhang L, et al. 2011. Epithelial cells lining salivary gland ducts are early target cells of severe acute respiratory syndrome coronavirus infection in the upper respiratory tracts of rhesus macaques. J Virol. 85(8):4025–4030.

Liu Y, Ning Z, Chen Y, Guo M, Liu Y, Gali NK, Sun L, Duan Y, Cai J, Westerdahl D, et al. 2020. Aerodynamic characteristics and rna concentration of SARS-CoV-2 aerosol in Wuhan hospitals during COVID-19 outbreak. bioRxiv. doi.org/10.1101/2020.03.08.982637

Lu CW, Liu XF, Jia ZF. 2020. 2019-nCoV transmission through the ocular surface must not be ignored. Lancet. 395(10224):e39.

Luan J, Jin X, Lu Y, Zhang L. 2020. SARS-CoV-2 spike protein favors ace2 from bovidae and cricetidae. J Med Virol [epub ahead of print 1 Apr 2020] in press. doi:10.1002/jmv.25817

Mahase E. 2020. Coronavirus COVID-19 has killed more people than SARS and MERS combined, despite lower case fatality rate. BMJ. 368:m641.

Meng L, Hua F, Bian Z. 2020. Coronavirus disease 2019 (COVID-19): emerging and future challenges for dental and oral medicine. J Dent Res [epub ahead of print 12 Mar 2020] in press. doi:10.1177/0022034520914246

Mizumoto K, Kagaya K, Zarebski A, Chowell G. 2020. Estimating the asymptomatic proportion of coronavirus disease 2019 (COVID-19) cases on board the Diamond Princess cruise ship, Yokohama, Japan, 2020. Euro Surveill. 25(10). doi:10.2807/1560-7917.ES.2020.25.10.2000180.

Nishiura H, Kobayashi T, Suzuki A, Jung SM, Hayashi K, Kinoshita R, Yang Y, Yuan B, Akhmetzhanov AR, Linton NM, et al. 2020. Estimation of the asymptomatic ratio of novel coronavirus infections (COVID-19). Int J Infect Dis [epub ahead of print 13 Mar 2020] in press. doi:10.1016/j.ijid.2020.03.020

Ong SWX, Tan YK, Chia PY, Lee TH, Ng OT, Wong MSY, Marimuthu K. 2020. Air, surface

environmental, and personal protective equipment contamination by severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) from a symptomatic patient. JAMA [epub ahead of print 4 Mar 2020] in press. doi:10.1001/jama.2020.3227

Peng X, Xu X, Li Y, Cheng L, Zhou X, Ren B. 2020. Transmission routes of 2019-nCoV and controls in dental practice. Int J Oral Sci. 12(1):9.

Pennsylvania Department of Health. 2020. Revised guidance on COVID-19 for dental health care personnel in Pennsylvania [accessed 2020 Apr 2]. https://www.health.pa.gov/topics/disease/coronavirus/Pages/Dental-Care.aspx.

Quilty BJ, Clifford S, Flasche S, Eggo RM. 2020. Effectiveness of airport screening at detecting travellers infected with novel coronavirus (2019-nCoV). Euro Surveill. 25(5). doi:10.2807/1560-7917.ES.2020.25.5.2000080

Ren LL, Wang YM, Wu ZQ, Xiang ZC, Guo L, Xu T, Jiang YZ, Xiong Y, Li YJ, Li XW, et al. 2020. Identification of a novel coronavirus causing severe pneumonia in human: a descriptive study. Chin Med J (Engl) [epub ahead of print 11 Feb 2020] in press. doi:10.1097/CM9.0000000000000722

Santarpia JL, Rivera DN, Herrera V, Morwitzer MJ, Creager H, Santarpia GW, Crown KK, Brett-Major D, Schnaubelt E, Broadhurst MJ, et al. 2020. Transmission potential of SARS-CoV-2 in viral shedding observed at the University of Nebraska Medical Center. medRxiv. doi:10.1101/2020.03.23.20039446

To KK, Tsang OT, Chik-Yan Yip C, Chan KH, Wu TC, Chan JMC, Leung WS, Chik TS, Choi CY, Kandamby DH, et al. 2020. Consistent detection of 2019 novel coronavirus in saliva. Clin Infect Dis [epub ahead of print 12 Feb 2020] in press. doi:10.1093/cid/ciaa149

To KK, Tsang OT, Leung WS, Tam AR, Wu TC, Lung DC, Yip CC, Cai JP, Chan JM, Chik TS, et al. 2020. Temporal profiles of viral load in posterior oropharyngeal saliva samples and serum antibody responses during infection by SARS-CoV-2: an observational cohort study. Lancet Infect Dis [epub ahead of print 23 Mar 2020] in press. doi:10.1016/S1473-3099(20)30196-1

van Doremalen N, Bushmaker T, Morris DH, Holbrook MG, Gamble A, Williamson BN, Tamin A, Harcourt JL, Thornburg NJ, Gerber SI, et al. 2020. Aerosol and surface stability of SARS-CoV-2 as compared with SARS-CoV-1. N Engl J Med. 382(16):1564–1567.

Walls AC, Park YJ, Tortorici MA, Wall A, McGuire AT, Veesler D. 2020. Structure, function, and antigenicity of the SARS-CoV-2 spike glycoprotein. Cell [epub ahead of print 6 Mar 2020] in press. doi:10.1016/j.cell.2020.02.058

Wölfel R, Corman VM, Guggemos W, Seilmaier M, Zange S, Müller MA, Niemeyer D, Jones TC, Vollmar P, Rothe C, et al. 2020. Virological assessment of hospitalized patients with COVID-2019. Nature [epub ahead of print 1 Apr 2020] in press. doi:10.1038/s41586-020-2196-x

World Health Organization. 2020. Modes of transmission of virus causing COVID-19: implications for IPC precaution recommendations 2020 [accessed 2020 Apr 2]. https://www.who.int/publications-detail/modes-of-transmission-of-virus-causing-covid-19-implications-for-ipc-precaution-recommendations.

Wu Y-C, Chen C-S, Chan Y-J. 2020. The outbreak of COVID-19: an overview. J Chin Med Assoc. 83(3):217–220.

Xu H, Zhong L, Deng J, Peng J, Dan H, Zeng X, Li T, Chen Q. 2020. High expression of ACE2 receptor of 2019-nCoV on the epithelial cells of oral mucosa. Int J Oral Sci. 12(1):8.

Xu X, Chen P, Wang J, Feng J, Zhou H, Li X, Zhong W, Hao P. 2020. Evolution of the novel coronavirus from the ongoing Wuhan outbreak and modeling of its spike protein for risk of human transmission. Sci China Life Sci. 63(3):457–460.

Yang Y, Soh HY, Cai ZG, Peng X, Zhang Y, Guo CB. 2020. Experience of diagnosing and managing patients in oral maxillofacial surgery during the prevention and control period of the new coronavirus pneumonia. Chin J Dent Res. 23(1):57–62.

Zhang W, Du RH, Li B, Zheng XS, Yang XL, Hu B, Wang YY, Xiao GF, Yan B, Shi ZL, et al. 2020. Molecular and serological investigation of 2019-nCoV infected patients: implication of multiple shedding routes. Emerg Microbes Infect. 9(1):386–389.

Zhang W, Jiang X. 2020. Measures and suggestions for the prevention and control of the novel coronavirus in dental institutions. Frontiers of Oral and Maxillofacial Medicine. doi:10.21037/fomm.2020.02.01