Contact Lens and Anterior Eye 43 (2020) 196–203

Contents lists available at ScienceDirect

Contact Lens and Anterior Eye

journal homepage: www.elsevier.com/locate/clae

The COVID-19 pandemic: Important considerations for contact lens practitioners

Lyndon Jones[a,*], Karen Walsh[b], Mark Willcox[c], Philip Morgan[d], Jason Nichols[e]

[a] School of Optometry & Vision Science, Centre for Ocular Research & Education (CORE), University of Waterloo, Waterloo, Ontario, Canada
[b] Centre for Ocular Research & Education (CORE), University of Waterloo, Waterloo, Ontario, Canada
[c] School of Optometry and Vision Science, UNSW, Sydney, Australia
[d] The University of Manchester, Manchester, UK
[e] University of Alabama at Birmingham, Birmingham, AL, USA

ARTICLE INFO

Keywords:
COVID-19
contact lens
lens care
lens wear

ABSTRACT

A novel coronavirus (CoV), the Severe Acute Respiratory Syndrome Coronavirus - 2 (SARS-CoV-2), results in the coronavirus disease 2019 (COVID-19). As information concerning the COVID-19 disease continues to evolve, patients look to their eye care practitioners for accurate eye health guidance. There is currently no evidence to suggest an increased risk of contracting COVID-19 through contact lens (CL) wear compared to spectacle lens wear and no scientific evidence that wearing standard prescription spectacles provides protection against COVID-19 or other viral transmissions.

During the pandemic there will potentially be significant changes in access to local eyecare. Thus, it is imperative CL wearers are reminded of the steps they should follow to minimise their risk of complications, to reduce their need to leave isolation and seek care. Management of adverse events should be retained within optometric systems if possible, to minimise the impact on the wider healthcare service, which will be stretched. Optimal CL care behaviours should be the same as those under normal circumstances, which include appropriate hand washing (thoroughly with soap and water) and drying (with paper towels) before both CL application and removal. Daily CL cleaning and correct case care for reusable CL should be followed according to appropriate guidelines, and CL exposure to water must be avoided. Where the availability of local clinical care is restricted, practitioners could consider advising patients to reduce or eliminate sleeping in their CL (where patients have the appropriate knowledge about correct daily care and access to suitable lens-care products) or consider the option of moving patients to daily disposable lenses (where patients have appropriate lens supplies available). Patients should also avoid touching their face, including their eyes, nose and mouth, with unwashed hands and avoid CL wear altogether if unwell (particularly with any cold or flu-like symptoms).

1. Introduction

A novel coronavirus (CoV), the Severe Acute Respiratory Syndrome Coronavirus - 2 (SARS-CoV-2), results in the coronavirus disease 2019 (COVID-19). The World Health Organisation (WHO) declared the rapid spread of cases of COVID-19 a pandemic on 11th March, 2020. The global response to COVID-19 has resulted in substantial changes to business and social practices around the world. With concerns existing around the pandemic, many reports relating to how best to limit the chance of infection have been shared via various news outlets and on social media, with significant amounts of misinformation and speculation being reported [1]. Among these, recent rumours have circulated stating that contact lens wear is unsafe, that wearers of contact lenses are more at risk of developing COVID-19, that certain contact lens materials are more "risky" than others and that contact lens wearers should immediately revert to spectacle wear to protect themselves. How true are these statements, and are they supported by evidence? Importantly, are contact lens wearers increasing their risk of contracting COVID-19 by wearing contact lenses? Furthermore, what are the ramifications of a potential reduction in the availability of local ophthalmic care for contact lens wearers during this pandemic?

Before answering these questions, it first is important to review the known structural biology and pathophysiological mechanism of an infection caused by SARS-CoV-2. All CoVs contain ribonucleic acid (RNA)

* Corresponding author.
E-mail addresses: lwjones@uwaterloo.ca (L. Jones), karen.walsh@uwaterloo.ca (K. Walsh), m.willcox@unsw.edu.au (M. Willcox), philip.morgan@manchester.ac.uk (P. Morgan), jjn@uab.edu (J. Nichols).

https://doi.org/10.1016/j.clae.2020.03.012
Received 26 March 2020; Received in revised form 29 March 2020; Accepted 29 March 2020
1367-0484/

as their genetic material, which is surrounded by a protein shell called a nucleocapsid. Like other CoVs, SARs-CoV-2 is an enveloped virus, meaning its nucleocapsid is surrounded by a lipid bilayer. SARs-CoV-2 has three proteins which are anchored into and protrude from the envelope, including an envelope, membrane and spike proteins [2]. These proteins form the corona that can be seen by electron microscopy and gives the name to the CoVs. The spike proteins are glycoproteins that have high affinities for angiotensin converting enzyme 2 (ACE2), a component of the renin-angiotensin system (RAS) found in many human tissues [3]. This affinity is believed to allow entry of the virus into host cells, where the virus releases its RNA into the host cell, leading to viral replication and further infection. Patients taking ACE inhibitors for hypertension may be at increased risk for adverse outcomes as taking this medication may increase ACE2 in cardiac tissues [4]; there may also be concerns about patients with chronic renal disease [5]. While many components of the RAS are found in the eye and many of its tissues, there appears to be inconsistency in the literature regarding ACE2, and more specifically, if it is present in the cornea, conjunctiva, or tears [6–9]. This may relate to the infrequent findings to date of SARS-CoV-2 presence in COVID-19 disease on the cornea, conjunctiva, or tear film of humans that is discussed later in this review. It is acknowledged that CoVs can cause a variety of ocular pathologies in animals, including conjunctivitis, anterior uveitis, retinitis, and optic neuritis, many of which are severe [10].

1.1. Coronavirus and contact lens wear

Contact lenses represent a highly effective form of vision correction for an estimated 140 million people worldwide, with a very low incidence of either microbial keratitis or symptomatic inflammatory keratitis in strict daily wear of contact lenses [11,12]. It is well established that contact lens wear, and particularly overnight contact lens wear, increases the risk of bacterial keratitis [12–16]. It is also well established that viral conjunctivitis is the overall most common type of conjunctivitis [17]. Yet, the eye, ocular surface and tear film employ a variety of host-defense mechanisms such as physical barriers and immunological strategies that help reduce the chance of infection in the cornea and conjunctiva.

A PubMed search on 24th March 2020 found no evidence that contact lens wearers are more likely to contract COVID-19 than spectacle wearers. The likely belief for this being a concern relates to the fact that SARS-CoV-2 has been isolated in tears, albeit to date, infrequently [18] and also that the virus is known to be transferred by hand contact, and thus could be transferred to contact lenses during their application and removal. In one report, positive tear and conjunctival secretions occurred in a single patient who developed conjunctivitis from a cohort of thirty patients with novel coronavirus pneumonia [18]. In another report, [19] 64 samples of the tear film from 17 patients with COVID-19 showed no evidence of SARS-CoV-2 by viral culture or reverse transcriptase polymerase chain reaction (RT-PCR). Further, the frequency of conjunctivitis in patients with COVID-19 reported to date is low, at $<3\%$ [18,20], although it has been suggested that CoVs could possibly be transmitted by aerosol contact with the conjunctiva in patients with active disease [18,20–24]. However, the question of whether COVID-19 can occur through conjunctival exposure remains unknown [7]. Recent papers concluded that *"The eye is rarely involved by human CoV infection, nor is it a preferred gateway of entry for human CoVs to infect the respiratory tract* [25]." and that *"The results from this study suggests that the risk of SARS-CoV-2 transmission through tears is low* [19]." Thus, to date, there are no findings that support concerns that healthy patients are more at risk of contracting COVID-19 if they are contact lens wearers.

It could be argued that COVID-19 is so new that such data would not yet exist. However, the lack of evidence from previous outbreaks of coronavirus disease, including SARS, suggests that the risk of developing COVID-19 from contact lens wear is low. It is informative to consider viral diseases that are transmitted by direct contact and which could be used as a surrogate for evaluating the risks of COVID-19 in contact lens wearers. Viruses that are associated with human infections have been found on ocular surface tissues or in the tear film. These include, but are not limited to, both DNA and RNA viruses such as adenovirus, other coronaviruses, herpes virus, human immunodeficiency virus, influenza virus, and Zika virus [18,22,26–29]. That said, these viruses are typically found at low levels and it is generally believed that they are not transmitted from the ocular surface (with the exception of adenoviral infections).

One ocular viral infection to consider is epidemic keratoconjunctivitis (EKC), caused by the non-enveloped DNA virus adenovirus. This disease is highly contagious, spreads rapidly through direct contact, accounts for 65-90% of viral conjunctivitis cases [30,31] and has been implicated in actively transmitted disease in eyecare clinics and other common healthcare settings where there is close contact between healthcare providers and patients [32–38]. A review of the literature appears to show no increased risk for EKC in those wearing contact lenses versus non-lens wearers, with a reported frequency of 3-15% in contact lens wearers [32,36]. Indeed, it has been proposed that bandage silicone hydrogel contact lenses can be used to help treat adenoviral infection in patients [39]. There are conflicting data on herpes simplex keratitis (HSK, another DNA virus, but one that is enveloped) and contact lens wear. One prospective cohort study and one retrospective case control study showed no association between contact lens wear and HSK occurrence or reoccurrence, whereas one retrospective study and a case report did suggest an association [40–43].

Another virus for which there has been concern as it relates to the ocular surface is the human immunodeficiency virus (HIV), which causes acquired immunodeficiency syndrome (AIDS), with an estimated prevalence of 1.1 million in the US [44]. HIV is an RNA virus, but a different form of RNA virus called a retrovirus, and has an envelope. HIV has been detected in most ocular tissues, including the cornea, conjunctiva and tear film of patients with AIDS [45]. It has also been recovered from the surface of a contact lens [46]. It is presently believed, however, that HIV has not been transmitted via ocular surface tissues or the tear film. The CDC specifically states, *"HIV is not spread by saliva, tears, or sweat that is not mixed with the blood of an HIV-positive person."* [47] Research has also indicated that with appropriate rubbing of contact lenses, most contact lens care systems would likely prevent the chance of the lens transferring the virus to the eye and resulting in HIV [48]. However, because of the immunodeficiency and compromise, it is recognized that AIDS is associated with opportunistic infections that can put an individual at risk for ocular infection [49]. HIV has been identified as a risk factor for hospitalization for corneal ulceration. While daily contact lens wear (not overnight wear) can be safe in a patient with AIDS, it is important that the eyecare practitioner play an active role in managing the patient and their ocular health as it relates to safe contact lens wear. A CD4+ count indicating immunocompetence may be key in guiding these decisions. On March 20, 2020, the CDC released information related to patients with AIDS and precautions as it relates to COVID-19 [50]. Of course, there are many differences in these viruses in terms of their structural biology, vectors and other factors. However, with limited current data comparing contact lens wearers versus non-lens wearers in patients with COVID-19, this remains the best evidence available of disease spread via viral contaminants that are highly infectious and potentially spread by direct contact, and an exhaustive literature search would not support the apprehension that contact lens wear is a concern.

Coronaviruses are capable of producing a wide spectrum of ocular disease, including anterior segment diseases such as conjunctivitis and anterior uveitis, and posterior segment conditions like retinitis and optic neuritis [51]. Current understanding about how SARS-CoV-2 spreads is based largely on what is known about other similar coronaviruses. Currently, two types of SARS-CoV-2 have been detected (L and S) [52]. The L form is suspected to be the derived variant of the ancestral S type, and is suggested to be more aggressive and is significantly more prevalent in Wuhan, China (where COVID-19 was first reported) than other places, although its frequency of isolation has decreased since January 2020 [52]. The virus spreads primarily via person-to-person contact through respiratory droplets produced when an infected person coughs or sneezes [53,54]. However, it also could be spread if people touch an object or surface with virus present from an infected person, and then touch mucosal surfaces such as their mouth, nose or eyes [54–56]. Given that contact lens wearers must touch their eyes when applying and removing their contact lenses, it is understandable this has been raised as a potential concern for increasing their risk of exposure to the virus. The consistent, unambiguous advice to protect individuals from the virus is to employ frequent handwashing with soap and water. The lipid envelope of the virus can be emulsified by surfactants such as those found in simple soap, which kills the virus [54,57]. Best practice advice for contact lens wearers includes the same instructions that should be imparted under all situations, regardless of the COVID-19 pandemic. When using contact lenses, careful and thorough hand washing with soap and water followed by hand drying with unused paper towels (generally known as 'kitchen roll' in the United Kingdom) is paramount. For contact lens wearers, this should occur before every contact lens application and removal, and such practice reduces the risks of infection and inflammatory responses and is highly effective [58]. It follows that as long as contact lens wearers are using correct hand hygiene techniques, they should be limiting any virus transmission to their ocular surface, and indeed, as already stated, there is currently no evidence that they are at any higher risk of developing COVID-19 infection than non-wearers.

1.2. Coronavirus and spectacle lens wear

A systematic review of the literature shows that there is no scientific evidence that wearing spectacles provides protection against SARS-CoV-2 or other viral transmissions, although this concept has been recently proposed in the media [59–61]. This belief around the safety of spectacles likely exists because of the guidance to use approved personal protective eyewear (medical masks, goggles or face shields) in certain settings involved in the care of infected patients [62]. However, these goggles and shields provide very different protection to that afforded by standard spectacles, a difference recognised by the U.S. Centers for Disease Control and Prevention (CDC), who state that *"personal eyeglasses are NOT considered adequate eye protection* [63]*."*

Despite the CDC's clear delineation between standard spectacles and approved personal protective eyewear, it is understandable that a misplaced belief still exists for spectacles being preferable to contact lenses. There are a number of confounding factors, however, which do not support this theory. Consider firstly, part-time wearers of spectacles who only use their spectacles for occasional distance use or for reading. Their assumed 'protection' is intermittent, and additionally their increased frequency of putting on and removing their spectacles adds to the potential of touching their face each time, possibly in the absence of hand washing. Another point to consider is that some viruses such as SARS-CoV-2 can remain on hard plastic surfaces (similar to those found in spectacle frames and lenses) for hours to days [64–67]. Upon touching their spectacles, any virus particles could potentially be transferred to the wearers' fingers and face and thus adequate hand hygiene practices should also extend to the regular handling of spectacle and sunglass frames to prevent transmission of viral particles to the fingers and subsequently to the face. Spectacles should be regularly cleaned with soap and water and dried with paper towel to remove any adhered viral particles.

1.3. The importance of hand hygiene

Hands are a common vector for the transmission of respiratory infection [68,69]. An observational study of medical students examined the frequency with which they touched their face [70]. On average, each of the students touched their face 23 times per hour. Of all face touches, 44% involved contact with a mucous membrane (eyes, nose or mouth) versus 56% that involved contact with non-mucosal areas (ears, cheeks, chin, forehead or ear). Of the mucous membrane touches, 36% involved the mouth, 31% the nose, 27% the eyes, and 6% were a combination of these regions. Given this very high number of face touches, hand washing becomes extremely important as a method to prevent transmission of any pathogenic organism from the fingers to the mucous membranes of the face. It is also important to remember that the generally younger demographic of contact lens wearers are often seen to practice more "risky" behaviors (such as the non-observance of social distancing seen recently during Spring break in the US) [71], which poses an inherent increased risk for SARS-CoV-2 infection. Hence, it remains important to remind this age group of the role of hand hygiene in preventing both ocular and systemic infection, regardless of their mode of vision correction.

In addition to commons soaps used in hand washing, the SARS-CoV-2 virus is very likely susceptible to the same alcohol- and bleach-based disinfectants that eye-care practitioners commonly use to disinfect ophthalmic instruments and office furniture [66]. To prevent SARS-CoV-2 transmission, the same disinfection practices already used to prevent office-based spread of other viral pathogens are recommended before and after every patient encounter. Many of these steps have been summarised in a recent editorial [72], which covers a number of important considerations for conducting safe clinical practice during the pandemic.

The CDC and WHO recommend that people clean their hands often to reduce their risk of contracting the virus. Specifically, they advise all people to:

- Wash their hands often with soap and water for at least 20 seconds especially after they have been in a public place, or after blowing their nose, coughing, or sneezing.
- If soap and water are not readily available, they should use a hand sanitizer that contains at least 60% alcohol. They should cover all surfaces of their hands and rub them together until they feel dry.
- They should avoid touching their eyes, nose, and mouth with unwashed hands.

1.4. Contact lens material considerations

The use of daily disposable contact lenses substantially reduces the risks of many inflammatory complications [73]. Contact lens wearers should always either dispose of their daily disposable lenses each evening, or regularly disinfect their monthly or two-week lenses according to manufacturer and eye care professional instructions.

A point to consider is whether there are differences in the risk of SARS-CoV-2 infection between the various contact lens materials available. Suggestions have been made that siloxane-based materials (silicone hydrogels) are more likely to bind SARS-CoV-2 than hydrogels, [61] and that these contact lens materials are particularly "risky" to wear. A recent study showed that the aerosol and surface stability of both SARS-Cov-2 and its predecessor, SARS-CoV-1 (the viral strain associated with the prior SARS epidemic of 2002 and 2003) was similar [74]. Specifically, both viruses could be detected in aerosols for up to three hours, on cardboard for 24 hours, and on plastic and stainless steel for 2-3 days. To date, there have been no laboratory studies reported on the ability of coronaviruses to adhere to contact lenses, and none on the ability of disinfectants to kill coronaviruses adhered to contact lenses.

There is no evidence of the presence of SARS-CoV-2 in the tears or conjunctival tissue of asymptomatic patients and even in those with confirmed disease, the presence of SARS-CoV-2 on the ocular surface is low [18–20]. Thus, binding of SARS-CoV-2 to contact lenses from the ocular surface in asymptomatic wearers would be unlikely. It is advisable that patients with COVID-19 should not wear contact lenses and if a patient were to develop COVID-19 any contact lenses that were being worn at that time should be immediately disposed of as should any remaining disinfecting solutions and contact lens cases that the patient possess, the patient must revert to spectacle lens wear and when fully recovered should recommence wear with a new pair of lenses.

The issues that influence bacterial, viral, fungal and amoebic binding to contact lens materials are highly complex and variable, with confounding data on the factors that impact microbial binding [75–80]. To date, no studies have addressed this issue specifically for the virus that causes COVID-19. A recent paper [66] has been cited as suggesting that silicone hydrogels are more likely to bind SARS-CoV-2 than hydrogels [61]. However, this paper did not examine contact lens materials. The inanimate surfaces described in the paper [66] which most closely resemble contact lens materials were "plastic" and silicon rubber [64,81,82]. Neither of these materials appropriately represents the complex bulk and surface chemistry of contemporary contact lens materials [83–85] and cannot be used to reflect the likely binding of any pathogenic organism to modern day contact lenses. Soft lens material surfaces are far more hydrophilic than the plastic and silicon rubber surfaces examined in this manuscript and the binding of virus particles to substrates is complex, depending upon the charges and topographic characteristics of the virus and the characteristics of the surface in question [86]. The factors governing the binding of SARS-CoV-2 to inanimate surfaces are so far unknown, but for a variety of waterborne viruses the major driving factors were electrostatic interactions (charge driven), followed by hydrophobic interactions, with only minor impact from van der Waals interactions [86].

Other factors of note in the paper by Kampf et al. are that the high concentration of inoculum used to examine the potential viral binding rates ($10^3 – 10^5$) are likely very much higher than those encountered on the ocular surface in asymptomatic wearers, and potentially much higher than that encountered following contamination transferred via fingertip application or removal of contact lenses. The viability time quoted is that found at room temperature, but the time for which viruses remain viable at ocular surface temperatures is significantly lower [81,82] and to date the time for which SARS-CoV-2 remains viable on hydrophilic substrates such as contact lens materials remains unknown. Finally, these studies took place in a dry, static environment, which in no way reflect the moist condition of the ocular surface and did not take into consideration the impact of blinking on removal of potential viral contaminants from a lens surface. Furthermore, no evidence exists that would support the contention that silicone hydrogel lenses are more likely to be contaminated with SARS-CoV-2 (or indeed any virus) than hydrogel lenses.

To date, no evidence exists of the ability of currently marketed contact lens solutions to disinfect SARS-CoV-2, and evidence concerning the ability of contemporary care solutions to disinfect viruses remains equivocal [87,88] and future work in this area is required. Over 30 years ago it was recognized that contact lens care systems of that time, based on chemical and thermal disinfection approaches, were effective at inactivating both herpes simplex and human immunodeficiency virus (HIV) [89,90]. Another study showed that common commercial contact lens care systems were capable of "safely decontaminating" HIV-1 from contact lenses, particularly when a rub step was included [48]. A recent paper showed that benzalkonium chloride, a common ophthalmic preservative, could slow or halt adenovirus [91]. Another paper reported that a rub-and-rinse technique was more effective at removing viruses from contact lenses than one in which no rubbing occurred [88]. Most modern lens care systems include a surfactant [92], and given that SARS-CoV-2 has a lipid envelope, it is plausible that a rub-and-rinse of the lens with such a care system may well be effective at killing the virus, but further work in this area is required to confirm this. Finally, one study demonstrated that thorough cleansing of virus-infected contact imaging lenses (such as retinal and fundus lenses) with both bleach and water/detergent was possible [93], although this is not suggested as a suitable option for contact lens disinfection.

A potentially important finding from the review paper by Kampf et al. [66] was their investigation of the inactivation of coronaviruses by various biocidal agents. These studies included examining the effect of disinfectants such as benzalkonium chloride, chlorhexidine digluconate, hydrogen peroxide and povidone iodine, which are (or have been) used in contact lens solutions. Chlorhexidine digluconate was a relatively weak biocide when tested against mouse hepatitis virus or canine coronavirus, benzalkonium chloride had improved activity, 0.5% hydrogen peroxide (a concentration substantially less than that used in contact lens solutions) caused a $>4 \log_{10}$ reduction in human coronavirus within 1 minute, and povidone iodine at concentrations as low as 0.23% (much less than found in contact lens disinfection systems) caused $>4\log_{10}$ reduction in the coronaviruses that cause SARS or MERS (middle east respiratory syndrome) within 15 seconds.

1.5. Areas for further study

Clearly, this is a fast moving situation, with information and advice being produced based on the best available evidence at the time each manuscript, news report and social media post is written. There are many areas where further study could extend current knowledge of the interaction of SARS-CoV-2 with both the ocular surface and contact lenses. Already mentioned above, further study is required to investigate the interaction of SARS-CoV-2 with contact lens materials, and the ability of contact lens disinfecting systems to kill the virus. The tear film is another area of interest. The tear film has antiviral properties [94,95] and it is plausible that the tear film could inactivate viruses that were to come in contact with the tears. For instance, the tear film contains the protein lactoferrin, which is thought to prohibit adenoviral entry into corneal epithelial cells [96]. However, this is unknown for SARS-CoV-2, but given the low frequency thus far of patients infected with COVID-19 that demonstrate the virus in the tears [19] this is an area also worthy of study. What is missing at this time is the minimum infectious dose of SARS-CoV-2 that can cause COVID-19 and such information would be valuable. This dose would likely differ depending upon where that viral dose was delivered (for example, on the conjunctiva versus into the respiratory tract), or indeed whether there is true evidence to date that COVID-19 could indeed occur through conjunctival transmission [7].

1.6. Access to clinical care and considerations for contact lens wear during the pandemic

The evidence presented in this paper suggests the safety of contact lens wear has not altered due to the pandemic and that appropriate hygiene considerations for contact lens wear and care should be the same as that always recommended. However, with local access to eyecare being different at this time of social distancing, and potentially severely compromised during the height of the pandemic, what should eye care professionals bear in mind when discussing contact lens wear with their patients?

A key consideration is for practitioners to be cognizant of local clinical care facilities during the course of the pandemic and to act to minimise the impact of contact lens-related adverse events on the wider healthcare system, which may be very stretched as staff are moved from providing ophthalmic care to other areas more directly related to COVID-19 patients. The implications here will necessarily vary according to local and regional considerations. For example, as of March 24, 2020, routine eyecare has been suspended in many countries, with optometric practices moving to provide scaled-back provision, telephone-only consultations and/or emergency services. For example, in the United Kingdom, practitioners should work to manage cases within an optometric framework rather than refer into the National Health Service where possible. This could include telephone contact with patients reporting contact lens problems and/or a video consultation using a suitable mobile phone app to enable rapid triage and management, reducing the need for burdening other clinical colleagues. Some cases may be best managed by referral to optometric colleagues licensed to practice as Independent Prescribers (therapeutically qualified optometrists) and who can treat more significant contact lens adverse events. In other cases, local Minor Eye Conditions Services (MECS) may be an alterative care pathway. Under this service patients are sent to local optometrists who have undergone accredited training in advanced optometric care that can triage whether referral to ophthalmology is required and, where possible and within their scope of practice, treat minor eye conditions. It is imperative that eyecare professionals avail themselves of the relevant options as early as possible in order to act quickly in the interests of both their patients and the wider healthcare system, and not begin to investigate the possibilities only after a contact lens wearer reports having some form of adverse event.

In North America, Australia and other regions/countries, therapeutically-endorsed optometrists are more likely to be the first port of call for contact lens patients with clinical adverse events, although again, most health authorities have required deferral of non-emergent, routine care. Here also, appropriate pathways need to be considered and enacted where a reduced level of routine eyecare is available. In countries where contact lens fitters and practitioners are less likely to offer clinical care to patients with clinically significant adverse events, management pathways and advice should again be considered to minimise the impact on the wider healthcare system.

It is particularly imperative during the ongoing pandemic that practitioners redouble their efforts to provide clinical advice to their patients to minimise contact lens complications, not least because many parts of the world are in forms of 'lockdown' and even leaving home to seek attention may not be straightforward. The simplest approach, as recommended by the American Academy of Ophthalmology, would be to cease contact lens wear and return to spectacles during this time [97]. However, given the personal motivation individuals may have for wearing contact lenses, or indeed those wearing lenses for a clinical reason (keratoconus for example), this suggestion is likely not practical for many contact lens wearers. In the UK, the General Optical Council have taken a pragmatic approach to contact lens wear and supply during the pandemic. Releasing a joint statement with a number of other health care regulators, they recognise the highly challenging circumstances and the need to depart from established procedures [98]. They have offered guidance which enables practitioners to exercise their professional judgement on whether patients need to be seen, or whether, following remote consultation, that the best course of action is to continue to supply lenses, even in the case of an expired specification [98]. This action will act to ensure a continual supply of new lenses to wearers and significantly reduce any temptation from patients to use lenses beyond the recommended replacement interval. Practitioners should also act to ensure patients receive a supply of their prescribed lens type and communicate this appropriately, to dissuade patients from sourcing alternative (non-prescribed) lens brands via online lens retailers.

It is important to remember that by any absolute measure, contact lens wear is a safe form of vision correction for millions of people around the world. A review of 1,276 soft contact lens wearers records, across 4,120 visits, found eighty-two percent did not present with any complications during the observation period of more than two years [99]. The frequency of more significant complications such as corneal infiltrative events (CIEs) and microbial keratitis are well understood. The annual incidence of symptomatic CIEs in daily reusable soft lens wear is around 3%, and nearly zero in daily disposable wear [100]. The incidence of symptomatic CIEs in extended wear is higher, with a 2-7x increased risk compared to daily wear [101–103]. Annual incidence of microbial keratitis (MK) varies by modality, and is around 2 per 10,000 wearers with daily wear of soft lenses, [13,15,104] increasing to around 20 per 10,000 wearers in extended soft lens wear, irrespective of material type [13,14,105,106].

However, a valid concern arises that any contact lens complication that warrants a visit to a healthcare facility at this time of limited resources is potentially an issue. To put these risks into context it is helpful to consider the incidence of contact lens issues in relation to accidental home-based injuries that also require medical care. In the U.S in 2012, a total of 19.4 million home injuries occurred that required medical attention, representing a rate of 24.17 per 100,000 of population [107]. A study across two years in Belgium estimated the annual incidence of home incidents requiring management by general practitioners to be 2,194 per 100,000 people [108]. Within the context of these figures, contact lens wear, with a rate for microbial keratitis of 0.2-2 per 100,000 (i.e. 2-20 per 10,000) wearers does not represent a significant additional burden on the healthcare system compared to the inherent dangers of living within the home, which based on their incidence as quoted above, would result in a far greater number of injuries that may require medical attention during the pandemic.

How could the risks of contact lens wear be further minimised to reduce any potential burden on hospital visits at this time? The risk factors that result in CIEs and infectious keratitis are well understood. The relative risks of developing CIEs are summarised in the comprehensive review by Steele and Szczotka-Flynn, [11] and include non-modifiable factors such as younger age (1.75-2.61x), higher prescription ($\geq$5D) (1.21-1.6x) and history of a previous event (2.5-6.1x), along with modifiable risks such as overnight wear (2.5-7x), bacterial bioburden on the lens and lid margins (5-8x), and lens replacement schedule - reusable compared to daily disposable (12.5x). MK is associated with many similar factors, including overnight wear [13,105,106], and for daily wear, poor lens and storage case hygiene, infrequent lens case replacement, exposure to water and smoking [109,110]. Risk factors for MK in daily disposable wearers are more frequent use, any overnight wear, less frequent handwashing, and smoking [111]. While it is not possible to change a non-modifiable risk factor such as the age of a patient, there are significant opportunities to address modifiable behaviours. Given the reduced incidence of CIEs in wearers of daily disposable lenses [99,100], this form of lens wear seems ideal in a time of reduced clinical provision. Some patients hold supplies of both reusable and daily disposable contact lenses, with the latter normally used for sports or holidays. With appropriate practitioner discussion, a move to using daily disposable lenses could be recommended at the current time.

Ceasing planned or accidental overnight wear significantly lowers the risk of contact lens complications. Some patients may principally use their lenses on an extended wear basis for occupational reasons and the same benefits may no longer be present if they are currently working from home. In such situations, reverting to a daily wear schedule could be merited – although only if the patient has an appropriate care regimen and is suitably compliant in its correct use. In the same way, patients who habitually alter from daily wear to extended wear over time (for work or other reasons) could be advised to adopt a routine daily wear modality until normal clinical provision is available. Such changes to contact lens wearing schedules should be undertaken only after consultation between the patient and their contact lens practitioner.

Scrupulous hand hygiene along with correct use of multipurpose solutions with rub and rinse cleaning of reusable lenses, daily case cleaning and regular replacement of the lens case are all positive changes about which eye care professionals should remind their patients at the current time. Likewise, an important point is to counsel on the avoidance of contact with water to reduce the risk of microbial keratitis, especially *Acanthamoeba* keratitis which has been increasing in recent years [112,113].

Adherence to compliant lens wear and care practices is an important aim for the profession all of the time, however, it can be argued during the current outbreak of SARS-CoV-2 this should be an area of heightened focus. The attention on thorough hand washing is welcome and an important start, but for eye care practitioners it is reasonable to use this time to go much further, revisiting patient education on safe wear and care practices with the aim of reducing the chance of developing contact lens-related complications requiring clinical care.

2. Conclusions

In conclusion, to date no evidence suggests that contact lens wearers who are asymptomatic should cease contact lens wear due to an increased risk of developing COVID-19, that wearing prescription spectacles provides protection against SARS-CoV-2 or that any one form of contact lens material is more likely to enhance or reduce the risk of future COVID-19 infection. However, information concerning this novel coronavirus is evolving at a rapid rate and eye care practitioners must remain attentive to new findings as they emerge.

Practitioners must remain vigilant about reminding contact lens wearers of the need to maintain good hand hygiene practices when handling lenses. A focus on fully compliant contact lens wear and especially on the modifiable risk factors associated with contact lens complications are especially important during the height of the pandemic, where access to primary and secondary optometric care may be substantially different to normal, and practitioners should act to minimise the burden on the wider healthcare system by considering their local clinical pathway options. Patients must be reminded of the need to dispose of daily disposable lenses upon removal, the need for appropriate disinfection with reusable lenses, including the use of a rub-and-rinse step where indicated, and appropriate case cleaning and replacement. Finally, consistent with guidance for other types of illness, particularly those of the respiratory tract [114–116], no contact lens wearer with active COVID-19 should remain wearing their contact lenses. This is the time to cease contact lens wear and revert to spectacles.

Declaration of Competing Interest

Lyndon Jones and Karen Walsh are employees of the Centre for Ocular Research & Education (CORE) at the University of Waterloo. Over the past 3 years CORE has received research support or lectureship honoraria from the following companies: Alcon, Allergan, CooperVision, GL Chemtec, iMed Pharma, Johnson & Johnson Vision Care, Lubris, Menicon, Nature's Way, Novartis, Ote, PS Therapy, Safilens, Santen, Shire, SightGlass and Visioneering.

Lyndon Jones is a consultant and/or serves on an advisory board for Alcon, CooperVision, Johnson & Johnson Vision Care, Novartis and Ophtecs.

Karen Walsh has received honoraria from Alcon, CooperVision and Johnson & Johnson.

Mark Willcox is a consultant for Johnson & Johnson Vision Care, CooperVision and Ophtecs. In the past three years he has received research funding or honoraria from Alcon, Allergan, CooperVision, Ophtecs, Australian Biotechnologies, Lumicare, Botanix and EcoAid.

Philip Morgan is Director of Eurolens Research at the University of Manchester. In the past three years, Eurolens Research has received research funding and/or honoraria from: Alcon, AMCo, CooperVision, Essilor, Johnson & Johnson Vision, Menicon, RB, Shire and Ultravision.

Jason Nichols declares Alcon (research, consultant), Bruder Healthcare (research; spouse-consultant), Allergan (spouse-consultant, spouse-research), Kala pharmaceuticals (spouse-research, spouse-consultant), Olympic Ophthalmics (consultant), Shire (consultant), Johnson and Johnson Vision Care (research), Sun Pharmaceuticals (spouse-consultant), ScienceBased Health (spouse-consultant), Oyster Point (spouse-consultant), Sight Sciences (spouse-consultant), Silk Technologies (spouse-consultant), Topivert (spouse-consultant), TearSolutions (spouse-research), Tearfilm Innovations (spouse-stock/other equity).

References

[1] G. Miller, Researchers are tracking another pandemic, too—of coronavirus misinformation, (2020) Accessed 24 Mar 2020 https://www.sciencemag.org/news/2020/03/researchers-are-tracking-another-epidemic-too-misinformation.

[2] C. Wu, Y. Liu, Y. Yang, P. Zhang, W. Zhong, Y. Wang, Q. Wang, Y. Xu, M. Li, X. Li, M. Zheng, L. Chen, H. Li, Analysis of therapeutic targets for SARS-CoV-2 and discovery of potential drugs by computational methods, Acta Pharmaceutica Sinica B In press (2020).

[3] Y. Chen, Y. Guo, Y. Pan, Z.J. Zhao, Structure analysis of the receptor binding of 2019-nCoV, Biochem Biophys Res Commun In press (2020).

[4] L. Perico, A. Benigni, G. Remuzzi, Should COVID-19 Concern Nephrologists? Why and to What Extent? The Emerging Impasse of Angiotensin Blockade, Nephron (2020) 1–9.

[5] J.H. Diaz, Hypothesis: angiotensin-converting enzyme inhibitors and angiotensin receptor blockers may increase the risk of severe COVID-19, J Travel Med In press (2020).

[6] A.J. White, S.C. Cheruvu, M. Sarris, S.S. Liyanage, E. Lumbers, J. Chui, D. Wakefield, P.J. McCluskey, Expression of classical components of the renin-angiotensin system in the human eye, J Renin Angiotensin Aldosterone Syst 16 (1) (2015) 59–66.

[7] Y. Peng, Y.H. Zhou, Is novel coronavirus disease (COVID-19) transmitted through conjunctiva? J Med Virol In press (2020).

[8] M. Holappa, H. Vapaatalo, A. Vaajanen, Many Faces of Renin-angiotensin System - Focus on Eye, Open Ophthalmol J 11 (2017) 122–142.

[9] A. Sharma, D.I. Bettis, J.W. Cowden, R.R. Mohan, Localization of angiotensin converting enzyme in rabbit cornea and its role in controlling corneal angiogenesis in vivo, Mol Vis 16 (2010) 720–728.

[10] I. Seah, R. Agrawal, Can the Coronavirus Disease 2019 (COVID-19) Affect the Eyes? A Review of Coronaviruses and Ocular Implications in Humans and Animals, Ocul Immunol Inflamm (2020) 1–5.

[11] K.R. Steele, L. Szczotka-Flynn, Epidemiology of contact lens-induced infiltrates: an updated review, Clin Exp Optom 100 (5) (2017) 473–481.

[12] F. Stapleton, L. Keay, K. Edwards, B. Holden, The epidemiology of microbial keratitis with silicone hydrogel contact lenses, Eye Contact Lens 39 (1) (2013) 79–85.

[13] F. Stapleton, L. Keay, K. Edwards, T. Naduvilath, J.K. Dart, G. Brian, B.A. Holden, The incidence of contact lens-related microbial keratitis in Australia, Ophthalmology 115 (10) (2008) 1655–1662.

[14] J.K. Dart, C.F. Radford, D. Minassian, S. Verma, F. Stapleton, Risk factors for microbial keratitis with contemporary contact lenses: a case-control study, Ophthalmology 115 (10) (2008) 1647–1654 1654 e1-3.

[15] K.H. Cheng, S.L. Leung, H.W. Hoekman, W.H. Beekhuis, P.G. Mulder, A.J. Geerards, A. Kijlstra, Incidence of contact-lens-associated microbial keratitis and its related morbidity, Lancet 354 (9174) (1999) 181–185.

[16] O.D. Schein, R.J. Glynn, E.C. Poggio, J.M. Seddon, K.R. Kenyon, The relative risk of ulcerative keratitis among users of daily-wear and extended-wear soft contact lenses. A case-control study. Microbial Keratitis Study Group, N Engl J Med 321 (12) (1989) 773–778.

[17] A.A. Azari, N.P. Barney, Conjunctivitis: a systematic review of diagnosis and treatment, JAMA 310 (16) (2013) 1721–1729.

[18] J. Xia, J. Tong, M. Liu, Y. Shen, D. Guo, Evaluation of coronavirus in tears and conjunctival secretions of patients with SARS-CoV-2 infection, J Med Virol In press (2020).

[19] I. Jun, D.E. Anderson, A.E. Kang, L.-F. Wang, P. Rao, B.E. Young, D.C. Lye, R. Agrawal, Assessing Viral Shedding and Infectivity of Tears in Coronavirus Disease 2019 (COVID-19) Patients, Ophthalmology In press (2020).

[20] W.J. Guan, Z.Y. Ni, Y. Hu, W.H. Liang, C.Q. Ou, J.X. He, L. Liu, H. Shan, C.L. Lei, D.S.C. Hui, B. Du, L.J. Li, G. Zeng, K.Y. Yuen, R.C. Chen, C.L. Tang, T. Wang, P.Y. Chen, J. Xiang, S.Y. Li, J.L. Wang, Z.J. Liang, Y.X. Peng, L. Wei, Y. Liu, Y.H. Hu, P. Peng, J.M. Wang, J.Y. Liu, Z. Chen, G. Li, Z.J. Zheng, S.Q. Qiu, J. Luo, C.J. Ye, S.Y. Zhu, N.S. Zhong, C. China Medical Treatment Expert Group for, Clinical Characteristics of Coronavirus Disease 2019 in China, N Engl J Med In press (2020).

[21] D. Bonn, SARS virus in tears? Lancet Infect Dis 4 (8) (2004) 480.

[22] W.M. Chan, K.S. Yuen, D.S. Fan, D.S. Lam, P.K. Chan, J.J. Sung, Tears and conjunctival scrapings for coronavirus in patients with SARS, Br J Ophthalmol 88 (7) (2004) 968–969.

[23] S.C. Loon, S.C. Teoh, L.L. Oon, S.Y. Se-Thoe, A.E. Ling, Y.S. Leo, H.N. Leong, The severe acute respiratory syndrome coronavirus in tears, Br J Ophthalmol 88 (7) (2004) 861–863.

[24] America Academy of Ophthalmology, Alert: Important coronavirus updates for ophthalmologists, AAO Alerts, (2020) Accessed 24 Mar 2020 https://www.aao.org/headline/alert-important-coronavirus-context.

[25] C. Sun, Y. Wang, G. Liu, Z. Liu, Role of the Eye in Transmitting Human Coronavirus: What We Know and What We Do Not Know, Preprints In press (2020).

[26] H.M. Creager, A. Kumar, H. Zeng, T.R. Maines, T.M. Tumpey, J.A. Belser, Infection and Replication of Influenza Virus at the Ocular Surface, J Virol 92 (7) (2018).

[27] S.A. Nordbo, T. Nesbakken, K. Skaug, E.F. Rosenlund, Detection of adenovirus-specific immunoglobulin A in tears from patients with keratoconjunctivitis, Eur J Clin Microbiol 5 (6) (1986) 678–680.

[28] M. Ramchandani, M. Kong, E. Tronstein, S. Selke, A. Mikhaylova, A. Magaret, M.L. Huang, C. Johnston, L. Corey, A. Wald, Herpes Simplex Virus Type 1 Shedding in Tears and Nasal and Oral Mucosa of Healthy Adults, Sex Transm Dis

43 (12) (2016) 756–760.
[29] J.J.L. Tan, P.K. Balne, Y.S. Leo, L. Tong, L.F.P. Ng, R. Agrawal, Persistence of Zika virus in conjunctival fluid of convalescence patients, Sci Rep 7 (1) (2017) 11194.
[30] V. Jhanji, T.C. Chan, E.Y. Li, K. Agarwal, R.B. Vajpayee, Adenoviral kerato-conjunctivitis, Surv Ophthalmol 60 (5) (2015) 435–443.
[31] D. Garcia-Zalisnak, C. Rapuano, J.D. Sheppard, A.R. Davis, Adenovirus Ocular Infections: Prevalence, Pathology, Pitfalls, and Practical Pointers, Eye Contact Lens 44 (Suppl 1) (2018) S1–S7.
[32] A.J. Mueller, V. Klauss, Main sources of infection in 145 cases of epidemic kera-toconjunctivitis, Ger J Ophthalmol 2 (4-5) (1993) 224–227.
[33] T.J. Doyle, D. King, J. Cobb, D. Miller, B. Johnson, An outbreak of epidemic keratoconjunctivitis at an outpatient ophthalmology clinic, Infect Dis Rep 2 (2) (2010) e17.
[34] K. Yong, M. Killerby, C.Y. Pan, T. Huynh, N.M. Green, D.A. Wadford, D. Terashita, Outbreak of Epidemic Keratoconjunctivitis Caused by Human Adenovirus Type D53 in an Eye Care Clinic - Los Angeles County, 2017, MMWR Morb Mortal Wkly Rep 67 (48) (2018) 1347–1349.
[35] M.P. Muller, N. Siddiqui, R. Ivancic, D. Wong, Adenovirus-related epidemic ker-atoconjunctivitis outbreak at a hospital-affiliated ophthalmology clinic, Am J Infect Control 46 (5) (2018) 581–583.
[36] E. Marinos, M. Cabrera-Aguas, S.L. Watson, Viral conjunctivitis: a retrospective study in an Australian hospital, Cont Lens Anterior Eye 42 (6) (2019) 679–684.
[37] J.S. Sammons, E.H. Graf, S. Townsend, C.L. Hoegg, S.A. Smathers, S.E. Coffin, K. Williams, S.L. Mitchell, U. Nawab, D. Munson, G. Quinn, G. Binenbaum, Outbreak of Adenovirus in a Neonatal Intensive Care Unit: Critical Importance of Equipment Cleaning During Inpatient Ophthalmologic Examinations, Ophthalmology 126 (1) (2019) 137–143.
[38] J.D. Gottsch, J.W. Froggatt 3rd, D.M. Smith, D.M. Dwyer, P. Borenstein, L.V. Karanfil, S. Vitale, M.F. Goldberg, Prevention and control of epidemic kera-toconjunctivitis in a teaching eye institute, Ophthalmic Epidemiol 6 (1) (1999) 29–39.
[39] O. Ucakhan, O. Yanik, The Use of Bandage Contact Lenses in Adenoviral Keratoconjunctivitis, Eye Contact Lens 42 (6) (2016) 388–391.
[40] B.M. Brandt, J. Mandleblatt, P.A. Asbell, Risk factors for herpes simplex-induced keratitis: a case-control study, Ann Ophthalmol 26 (1) (1994) 12–16.
[41] J.J. Mucci, V.M. Utz, A. Galor, W. Feuer, B.H. Jeng, Recurrence rates of herpes simplex virus keratitis in contact lens and non-contact lens wearers, Eye Contact Lens 35 (4) (2009) 185–187.
[42] A. Hamroush, J. Welch, Herpes Simplex epithelial keratitis associated with daily disposable contact lens wear, Cont Lens Anterior Eye 37 (3) (2014) 228–229.
[43] Herpetic Eye Disease Study Group, Psychological stress and other potential trig-gers for recurrences of herpes simplex virus eye infections, Herpetic Eye Disease Study Group, Arch Ophthalmol 118 (12) (2000) 1617–1625.
[44] Centers for Disease Control and Prevention, Estimated HIV Incidence and Prevalence in the United States 2010–2016, (2019) Accessed 24 Mar 2020 https://www.cdc.gov/hiv/pdf/library/reports/surveillance/cdc-hiv-surveillance-supplemental-report-vol-24-1.pdf.
[45] D.V. Ablashi, S. Sturzenegger, E.A. Hunter, A.G. Palestine, L.S. Fujikawa, M.K. Kim, R.B. Nussenblatt, P.D. Markham, S.Z. Salahuddin, Presence of HTLV-III in tears and cells from the eyes of AIDS patients, J Exp Pathol 3 (4) (1987) 693–703.
[46] T. Tervo, J. Lahdevirta, A. Vaheri, S.L. Valle, J. Suni, Recovery of HTLV-III from contact lenses, Lancet 1 (8477) (1986) 379–380.
[47] Centers for Disease Control and Prevention, HIV Transmission, (2020) Accessed 24 Mar 2020 https://www.cdc.gov/hiv/basics/transmission.html.
[48] R.M. Amin, M.T. Dean, L.E. Zaumetzer, B.J. Poiesz, Virucidal efficacy of various lens cleaning and disinfecting solutions on HIV-I contaminated contact lenses, AIDS Res Hum Retroviruses 7 (4) (1991) 403–408.
[49] R. Lee, E.E. Manche, Trends and Associations in Hospitalizations Due to Corneal Ulcers in the United States, 2002-2012, Ophthalmic Epidemiol 23 (4) (2016) 257–263.
[50] Centers for Disease Control and Prevention, Information from CDC's division of HIV/AIDS prevention, (2020) Accessed 22 Mar 2020 https://www.cdc.gov/hiv/policies/dear-colleague/dcl/032020.html.
[51] I. Seah, X. Su, G. Lingam, Revisiting the dangers of the coronavirus in the oph-thalmology practice, Eye (Lond) In press (2020).
[52] J. Lu, J. Cui, Z. Qian, Y. Wang, H. Zhang, Y. Duan, X. Wu, X. Yao, Y. Song, X. Li, C. Wu, X. Tang, On the origin and continuing evolution of SARS-CoV-2, National Science Review In press (2020).
[53] P. Habibzadeh, E.K. Stoneman, The Novel Coronavirus: A Bird's Eye View, Int J Occup Environ Med 11 (2) (2020) 65–71.
[54] D. Wu, T. Wu, Q. Liu, Z. Yang, The SARS-CoV-2 outbreak: what we know, Int J Infect Dis In press (2020).
[55] S.P. Adhikari, S. Meng, Y.J. Wu, Y.P. Mao, R.X. Ye, Q.Z. Wang, C. Sun, S. Sylvia, S. Rozelle, H. Raat, H. Zhou, Epidemiology, causes, clinical manifestation and diagnosis, prevention and control of coronavirus disease (COVID-19) during the early outbreak period: a scoping review, Infect Dis Poverty 9 (1) (2020) 29.
[56] H.A. Rothan, S.N. Byrareddy, The epidemiology and pathogenesis of coronavirus disease (COVID-19) outbreak, J Autoimmun In press (2020) 102433.
[57] World Health Organization, Coronavirus disease (COVID-19) advice for the public, (2020) Accessed 24 Mar 2020 https://www.who.int/emergencies/diseases/novel-coronavirus-2019/advice-for-public.
[58] D. Fonn, L. Jones, Hand hygiene is linked to microbial keratitis and corneal in-flammatory events, Cont Lens Anterior Eye 42 (2) (2019) 132–135.
[59] J. Feldman, How Ditching Contacts For Glasses Can Protect You From The Coronavirus, (2020) Accessed 24 Mar 2020 https://www.huffingtonpost.ca/entry/how-ditching-contacts-for-glasses-protect-coronavirus_l_5e78e283c5b6f5b7c5489e44.
[60] S. Weiss, Does wearing glasses help protect you against coronavirus? (2020) Accessed 24 Mar 2020 https://nypost.com/2020/03/10/does-wearing-glasses-help-protect-you-against-coronavirus/.
[61] Anon, Experts do not recommend using contact lenses for coronavirus, (2020) Accessed 24 Mar 2020 https://www.newsmaker.news/a/2020/03/experts-do-not-recommend-using-contact-lenses-for-coronavirus.html.
[62] World Health Organization, Rational use of personal protective equipment for coronavirus disease 2019 (COVID-19), (2020) Accessed 24 Mar 2020 https://apps.who.int/iris/bitstream/handle/10665/331215/WHO-2019-nCov-IPCPPE_use-2020.1-eng.pdf.
[63] Centers for Disease Control and Prevention, Interim Infection Prevention and Control Recommendations for Patients with Suspected or Confirmed Coronavirus Disease 2019 (COVID-19) in Healthcare Settings, COVID-19, (2020) Accessed 24 Mar 2020 https://www.cdc.gov/coronavirus/2019-ncov/infection-control/control-recommendations.html.
[64] S.L. Warnes, Z.R. Little, C.W. Keevil, Human Coronavirus 229E Remains Infectious on Common Touch Surface Materials, mBio 6 (6) (2015) e01697–15.
[65] N. Ikonen, C. Savolainen-Kopra, J.E. Enstone, I. Kulmala, P. Pasanen, A. Salmela, S. Salo, J.S. Nguyen-Van-Tam, P. Ruutu, P. consortium, Deposition of respiratory virus pathogens on frequently touched surfaces at airports, BMC Infect Dis 18 (1) (2018) 437.
[66] G. Kampf, D. Todt, S. Pfaender, E. Steinmann, Persistence of coronaviruses on inanimate surfaces and their inactivation with biocidal agents, J Hosp Infect 104 (3) (2020) 246–251.
[67] S.W.X. Ong, Y.K. Tan, P.Y. Chia, T.H. Lee, O.T. Ng, M.S.Y. Wong, K. Marimuthu, Air, Surface Environmental, and Personal Protective Equipment Contamination by Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2) From a Symptomatic Patient, JAMA In press (2020).
[68] D. Pittet, B. Allegranzi, H. Sax, S. Dharan, C.L. Pessoa-Silva, L. Donaldson, J.M. Boyce, W.A.f.P.S. Who Global Patient Safety Challenge, Evidence-based model for hand transmission during patient care and the role of improved prac-tices, Lancet Infect Dis 6 (10) (2006) 641–652.
[69] A.E. Macias, A. de la Torre, S. Moreno-Espinosa, P.E. Leal, M.T. Bourlon, G.M. Ruiz-Palacios, Controlling the novel A (H1N1) influenza virus: don't touch your face!, J Hosp Infect 73 (3) (2009) 280–281.
[70] Y.L. Kwok, J. Gralton, M.L. McLaws, Face touching: a frequent habit that has implications for hand hygiene, Am J Infect Control 43 (2) (2015) 112–114.
[71] U. Khatri, A. Agarwal, Hey, millennials and Gen Z, this isn't spring break. It's a pandemic, (2020) Accessed 24 Mar 2020 https://www.inquirer.com/health/coronavirus/coronavirus-covid-19-millennials-spring-break-social-distancing-20200323.html.
[72] F. Zeri, S.A. Naroo, Contact lens practice in the time of COVID-19, Cont Lens Anterior Eye In press (2020).
[73] R.L. Chalmers, L. Keay, J. McNally, J. Kern, Multicenter case-control study of the role of lens materials and care products on the development of corneal infiltrates, Optometry and vision science : official publication of the American Academy of Optometry 89 (3) (2012) 316–325.
[74] N. van Doremalen, T. Bushmaker, D.H. Morris, M.G. Holbrook, A. Gamble, B.N. Williamson, A. Tamin, J.L. Harcourt, N.J. Thornburg, S.I. Gerber, J.O. Lloyd-Smith, E. de Wit, V.J. Munster, Aerosol and Surface Stability of SARS-CoV-2 as Compared with SARS-CoV-1, N Engl J Med In press (2020).
[75] P.A. Simmons, A. Tomlinson, D.V. Seal, The role of Pseudomonas aeruginosa biofilm in the attachment of Acanthamoeba to four types of hydrogel contact lens materials, Optometry and vision science : official publication of the American Academy of Optometry 75 (12) (1998) 860–866.
[76] L.N. Subbaraman, R. Borazjani, H. Zhu, Z. Zhao, L. Jones, M.D. Willcox, Influence of protein deposition on bacterial adhesion to contact lenses, Optometry and vi-sion science : official publication of the American Academy of Optometry 88 (8) (2011) 959–966.
[77] D. Dutta, N. Cole, M. Willcox, Factors influencing bacterial adhesion to contact lenses, Mol Vis 18 (2012) 14–21.
[78] M.D. Willcox, Microbial adhesion to silicone hydrogel lenses: a review, Eye Contact Lens 39 (1) (2013) 61–66.
[79] G.H. Lee, J.E. Lee, M.K. Park, H.S. Yu, Adhesion of Acanthamoeba on Silicone Hydrogel Contact Lenses, Cornea 35 (5) (2016) 663–668.
[80] J. Dantam, L.N. Subbaraman, L. Jones, Adhesion of Pseudomonas aeruginosa, Achromobacter xylosoxidans, Delftia acidovorans, Stenotrophomonas maltophilia to contact lenses under the influence of an artificial tear solution, Biofouling 36 (1) (2020) 32–43.
[81] K.H. Chan, J.S. Peiris, S.Y. Lam, L.L. Poon, K.Y. Yuen, W.H. Seto, The Effects of Temperature and Relative Humidity on the Viability of the SARS Coronavirus, Adv Virol 2011 (2011) 734690.
[82] N. van Doremalen, T. Bushmaker, V.J. Munster, Stability of Middle East re-spiratory syndrome coronavirus (MERS-CoV) under different environmental con-ditions, Euro Surveill 18 (38) (2013).
[83] J.H. Teichroeb, J.A. Forrest, V. Ngai, J.W. Martin, L. Jones, J. Medley, Imaging protein deposits on contact lens materials, Optometry and vision science : official publication of the American Academy of Optometry 85 (12) (2008) 1151–1164.
[84] A. Mann, B. Tighe, Contact lens interactions with the tear film, Experimental eye research 117 (2013) 88–98.
[85] B.J. Tighe, A decade of silicone hydrogel development: surface properties, me-chanical properties, and ocular compatibility, Eye Contact Lens 39 (1) (2013) 4–12.
[86] A. Armanious, M. Aeppli, R. Jacak, D. Refardt, T. Sigstam, T. Kohn, M. Sander,

Viruses at Solid–Water Interfaces: A Systematic Assessment of Interactions Driving Adsorption, Environmental Science & Technology 50 (2) (2016) 732–743.

[87] R.P. Kowalski, C.V. Sundar-Raj, E.G. Romanowski, Y.J. Gordon, The disinfection of contact lenses contaminated with adenovirus, Am J Ophthalmol 132 (5) (2001) 777–779.

[88] W. Heaselgrave, J. Lonnen, S. Kilvington, J. Santodomingo-Rubido, O. Mori, The disinfection efficacy of MeniCare soft multipurpose solution against Acanthamoeba and viruses using stand-alone biocidal and regimen testing, Eye Contact Lens 36 (2) (2010) 90–95.

[89] M.D. Rohrer, M.A. Terry, R.A. Bulard, D.C. Graves, E.M. Taylor, Microwave sterilization of hydrophilic contact lenses, Am J Ophthalmol 101 (1) (1986) 49–57.

[90] J.S. Pepose, Contact lens disinfection to prevent transmission of viral disease, The CLAO journal: official publication of the Contact Lens Association of Ophthalmologists, Inc 14 (3) (1988) 165–168.

[91] D.R. Lazzaro, K. Abulawi, M.E. Hajee, In vitro cytotoxic effects of benzalkonium chloride on adenovirus, Eye Contact Lens 35 (6) (2009) 329–332.

[92] C.J. Kuc, K.A. Lebow, Contact Lens Solutions and Contact Lens Discomfort: Examining the Correlations Between Solution Components, Keratitis, and Contact Lens Discomfort, Eye Contact Lens 44 (6) (2018) 355–366.

[93] A.M. Abbey, N.Z. Gregori, K. Surapaneni, D. Miller, Efficacy of detergent and water versus bleach for disinfection of direct contact ophthalmic lenses, Cornea 33 (6) (2014) 610–613.

[94] V.J. Smith, E.A. Dyrynda, Antimicrobial proteins: From old proteins, new tricks, Mol Immunol 68 (2 Pt B) (2015) 383–398.

[95] J. Malaczewska, E. Kaczorek-Lukowska, R. Wojcik, A.K. Siwicki, Antiviral effects of nisin, lysozyme, lactoferrin and their mixtures against bovine viral diarrhoea virus, BMC Vet Res 15 (1) (2019) 318.

[96] J.L. Flanagan, M.D. Willcox, Role of lactoferrin in the tear film, Biochimie 91 (1) (2009) 35–43.

[97] American Academy of Ophthalmology, Coronavirus eye safety, (2020) Accessed 24 Mar 2020 https://www.aao.org/eye-health/tips-prevention/coronavirus-covid19-eye-infection-pinkeye.

[98] General Optical Council, Joint statement and advice for eye care practitioners, (2020) Accessed 24 Mar 2020 https://www.optical.org/en/news_publications/Publications/joint-statement-and-guidance-on-coronavirus-covid19.cfm.

[99] R.L. Chalmers, L. Keay, B. Long, P. Bergenske, T. Giles, M.A. Bullimore, Risk factors for contact lens complications in US clinical practices, Optometry and vision science: official publication of the American Academy of Optometry 87 (10) (2010) 725–735.

[100] R.L. Chalmers, S.B. Hickson-Curran, L. Keay, W.J. Gleason, R. Albright, Rates of adverse events with hydrogel and silicone hydrogel daily disposable lenses in a large postmarket surveillance registry: the TEMPO Registry, Invest Ophthalmol Vis Sci 56 (1) (2015) 654–663.

[101] R.L. Chalmers, H. Wagner, G.L. Mitchell, D.Y. Lam, B.T. Kinoshita, M.E. Jansen, K. Richdale, L. Sorbara, T.T. McMahon, Age and other risk factors for corneal infiltrative and inflammatory events in young soft contact lens wearers from the Contact Lens Assessment in Youth (CLAY) study, Invest Ophthalmol Vis Sci 52 (9) (2011) 6690–6696.

[102] P.B. Morgan, N. Efron, N.A. Brennan, E.A. Hill, M.K. Raynor, A.B. Tullo, Risk factors for the development of corneal infiltrative events associated with contact lens wear, Invest Ophthalmol Vis Sci 46 (9) (2005) 3136–3143.

[103] C.F. Radford, D. Minassian, J.K. Dart, F. Stapleton, S. Verma, Risk factors for nonulcerative contact lens complications in an ophthalmic accident and emergency department: a case-control study, Ophthalmology 116 (3) (2009) 385–392.

[104] D.S. Lam, E. Houang, D.S. Fan, D. Lyon, D. Seal, E. Wong, G. Hong Kong Microbial Keratitis Study, Incidence and risk factors for microbial keratitis in Hong Kong: comparison with Europe and North America, Eye (Lond) 16 (5) (2002) 608–618.

[105] O.D. Schein, J.J. McNally, J. Katz, R.L. Chalmers, J.M. Tielsch, E. Alfonso, M. Bullimore, D. O'Day, J. Shovlin, The incidence of microbial keratitis among wearers of a 30-day silicone hydrogel extended-wear contact lens, Ophthalmology 112 (12) (2005) 2172–2179.

[106] P.B. Morgan, N. Efron, E.A. Hill, M.K. Raynor, M.A. Whiting, A.B. Tullo, Incidence of keratitis of varying severity among contact lens wearers, Br J Ophthalmol 89 (4) (2005) 430–436.

[107] A.C. Gielen, E.M. McDonald, W. Shields, Unintentional home injuries across the life span: problems and solutions, Annu Rev Public Health 36 (2015) 231–253.

[108] D. Devroey, V. Van Casteren, D. Walckiers, The added value of the registration of home accidents in general practice, Scand J Prim Health Care 20 (2) (2002) 113–117.

[109] F. Stapleton, K. Edwards, L. Keay, T. Naduvilath, J.K. Dart, G. Brian, B. Holden, Risk factors for moderate and severe microbial keratitis in daily wear contact lens users, Ophthalmology 119 (8) (2012) 1516–1521.

[110] M. Arshad, N. Carnt, J. Tan, I. Ekkeshis, F. Stapleton, Water Exposure and the Risk of Contact Lens-Related Disease, Cornea 38 (6) (2019) 791–797.

[111] F. Stapleton, T. Naduvilath, L. Keay, C. Radford, J. Dart, K. Edwards, N. Carnt, D. Minassian, B. Holden, Risk factors and causative organisms in microbial keratitis in daily disposable contact lens wear, PLoS One 12 (8) (2017) e0181343.

[112] N. Carnt, J.M. Hoffman, S. Verma, S. Hau, C.F. Radford, D.C. Minassian, J.K.G. Dart, Acanthamoeba keratitis: confirmation of the UK outbreak and a prospective case-control study identifying contributing risk factors, Br J Ophthalmol 102 (12) (2018) 1621–1628.

[113] A.C. Randag, J. van Rooij, A.T. van Goor, S. Verkerk, R.P.L. Wisse, I.E.Y. Saelens, R. Stoutenbeek, B.T.H. van Dooren, Y.Y.Y. Cheng, C.A. Eggink, The rising incidence of Acanthamoeba keratitis: A 7-year nationwide survey and clinical assessment of risk factors and functional outcomes, PLoS One 14 (9) (2019) e0222092.

[114] P. Sankaridurg, B. Holden, I. Jalbert, Adverse events and infections: Which ones and how many? in: D. Sweeney (Ed.), Silicone hydrogels: Continuous wear contact lenses, Butterworth-Heinemann, Oxford, 2004, pp. 217–274.

[115] D. Sweeney, R. du Toit, L. Keay, I. Jalbert, P. Sankaridurg, J. Stern, C. Skotnitsky, A. Stephensen, M. Covey, B. Holden, G. Rao, Clinical performance of silicone hydrogel lenses, in: D. Sweeney (Ed.), Silicone hydrogels: Continuous wear contact lenses, Butterworth-Heinemann, Oxford, 2004, pp. 164–216.

[116] M. Willcox, P. Sankaridurg, H. Zhu, E.B. Hume, N. Cole, T. Conibear, M. Glasson, N. Harmis, F. Stapleton, Inflammation and infection and the effects of the closed eye, in: D. Sweeney (Ed.), Silicone hydrogels: Continuous wear contact lenses, Butterworth-Heinemann, Oxford, 2004, pp. 90–125.