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BASIC SCIENCE

Characterizing the microbiota of instrumentation in ophthalmology clinics during and beyond the COVID-19 pandemic

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Abstract

Purpose Increased ophthalmology-specific risk of novel coronavirus 2019 (SARS-CoV-2) transmission is well-established, increasing the fear of infection and causing associated decreased rates of procedures known to save vision. However, the potential transmission from exposure to clinic instrumentation is unknown, including which additional pathogens may be spreading in this context. This study seeks to fill this gap by characterizing the microbiota of instrumentation in ophthalmology clinics during the COVID-19 pandemic and identifying potential sources of pathogenic spread encountered by patients and healthcare workers.

Methods Thirty-three samples were captured using standard cultures and media. Ten positive and negative controls were used to confirm proper technique. Descriptive statistics were calculated for all samples. Samples were collected from the retina ($N=17$), glaucoma ($N=6$), cornea ($N=6$), and resident ($N=4$) clinics with rigorous disinfection standards at a tertiary academic medical center. Standard media cultures and/or polymerase chain reaction (PCR) was performed for each sample.

Results From 33 samples, more than half (17/33, 51.5%) yielded bacterial growth. Using two different molecular methods, three samples (3/33, 9%) tested positive for SARS-CoV-2 (cycle thresholds 36.48, 37.14, and 37.83). There was no significant difference in bacterial growth (95% confidence interval [95% CI]: − 0.644–0.358, $p=0.076$) among different clinics (retina, glaucoma, cornea, resident). *Staphylococcus (S.) epidermidis* grew most frequently (12/35, 34%), followed by *S. capitis* (7/35, 20%), *Micrococcus luteus* (2/35, 5.7%), *Corynebacterium tuberculostearicum* (2/35, 5.7%), and *Cutibacterium ([C.], Propionibacterium) acnes* (2/35, 5.7%). *C. acnes* growth was more frequent with imaging device forehead rests (2/7, 28.6%) than other surfaces (0/26, 0%, 95% CI: 0.019–0.619, $p=0.040$). No samples isolated fungus or adenovirus.

Conclusions Most samples across subspecialty clinic instrumentation grew bacteria, and several tested positive for SARS-CoV-2. Many isolated pathogens have been implicated in causing infections such as endophthalmitis, conjunctivitis, uveitis, and keratitis. The clinical implications of the ophthalmology microbiome for transmitting nosocomial infections warrant optimization of disinfection practices, strategies for mitigating spread, and additional study beyond the pandemic.

Key messages

- It is known that ophthalmologists are at an increased risk of COVID-19 transmission.
- Various commensal and pathogenic bacteria as well as SARS-CoV-2 were found on ophthalmologic instruments throughout ophthalmology clinics at one hospital.
- These findings may indicate a need for increased disinfection in ophthalmology clinics.

Keywords COVID-19 · SARS-CoV-2 · Instrumentation · Pathogens · Bacteria

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Introduction

Decreases in critical procedures known to preserve vision in the pandemic have been attributed to fear of infection [1], intensifying concerns for safety among patients and healthcare workers inherent to ophthalmological care. Maintaining proper disinfection in the clinical setting is crucial for mitigating these concerns as well as safety itself. This concept becomes increasingly relevant with interaction proximity, as occurs between ophthalmologists and patients for example, during slit lamp examination. One study done among 34 ophthalmology clinics in 2005 showed remnant bacteria and fungi on biometry equipment, indicating inadequate elimination during cleaning [2]. Another reported an adenovirus outbreak in neonatal intensive care unit with equipment contaminated from retinopathy of prematurity screening [3]. However, these studies were both performed before the COVID-19 pandemic.

Now that disinfection processes are largely replaced by heightened infection control practices [4], it is crucial to evaluate potential risks of pathogenic spread during ophthalmology visits. Increased relative risk of SARS-CoV-2 transmission for ophthalmologists [5, 6] is well-established, but a gap remains in knowledge regarding which microbes may still be spreading. This investigation seeks to fill this gap by characterizing the microbial profile of different ophthalmology clinics.

Methods

To assess for the presence of bacteria, fungi, adenovirus, and SARS-CoV-2, we captured samples using COPAN ESwabs™ (Murrieta, CA, USA). The sampling process occurred between 3/9/2021 and 3/30/21 at the Wilmer Eye Institute at Johns Hopkins Hospital in Baltimore, MD, USA. The sampling occurred at 6 am, before any staff or patients entered the rooms, and after being cleaned the previous night. Infection control standards in the clinic included utilizing PDI (Professional Disposables International, Inc.) germicidal disinfectant wipes on surfaces in between patient encounters. Several minutes were allowed for air drying surfaces after PDI wipe use. This study complied with the Declaration of Helsinki and did not require Institutional Review Board approval because it did not involve human subjects.

Thirty-three surfaces or instruments were surveyed in four ophthalmology subspecialty clinics and imaging suites including resident (general eye service), retina, glaucoma, and cornea (Table 1). Ten positive and negative controls were also sampled (Table 1). Samples were assessed for bacteria and fungi on standard media including blood agar plates (BAP), chocolate agar (CHOC), colistin nalidixic agar (CNA), MacConkey agar (MAC), inhibitory mold agar (IMA), and brain heart infusion agar (BHI). SARS-CoV-2 presence was determined via two different molecular methods including polymerase chain reaction (PCR). Cycle threshold (Ct) was determined for each positive SARS-CoV-2 sample.

Descriptive statistics were calculated for all samples using Microsoft Excel (Seattle, WA, USA). The associations between type of surfaces, instruments, or subspecialty clinics with bacterial growth or SARS-CoV-2 positivity were examined using Fisher's exact tests, and the Pearson correlation coefficients or polychoric correlation coefficients were reported when appropriate. All the analyses were carried out in Stata version 16.1 (College Station, TX, USA), and $p \leq 0.05$ was considered significant.

Results

Samples included 33 unique surfaces among 4 clinics. All 10 controls yielded expected results. Saliva and nares from two authors (HM1, MPB) grew an abundance of bacteria but no fungi (Table 1).

From 33 samples, more than half (17/33, 51.5%) yielded bacterial growth. eTable 1 shows 15 different species that grew on surfaces 35 times total. Among these, *Staphylococcus (S.) epidermidis* grew most frequently (12/35, 34%), followed by *S. capitis* (7/35, 20%), *Micrococcus luteus* (2/35, 5.7%), *Corynebacterium (C.) tuberculostearicum* (2/35, 5.7%), and *Cutibacterium (Propionibacterium) acnes* (2/35, 5.7%) (eTable 1).

No fungus or adenovirus was isolated. Three samples (3/33, 9%) tested positive for SARS-CoV-2 virus (retina slit lamp chin rest [Ct 36.48], retina SPECTRALIS [Heidelberg, Germany] Heidelberg optical coherence tomography [OCT] chin rest [Ct 37.14], and cornea Oculus [Wetzlar, Germany] Pentacam forehead rest [Ct 37.83]) (Table 1). Bacterial growth (95% confidence interval [95% CI] − 0.644–0.358, $p = 0.076$) and SARS-CoV-2 positivity (95% CI − 0.438–0.735, $p = 0.948$) did not vary by clinic (Table 2). Imaging suites and examination rooms were also similar in bacterial (95% CI − 0.134–0.523, $p = 0.220$) and SARS-CoV-2 positivity (95%CI − 0.199–0.473, $p = 0.389$) (Table 2). *C. acnes* was isolated on imaging device forehead rests more frequently than other surfaces (95% CI 0.019–0.619, $p = 0.040$) (Table 3). SARS-CoV-2 was identified on 3 surfaces (2 chin rests) (eTable 2).

Table 1 Bacteria, fungi, adenovirus, and SARS-CoV-2 presence in controls and samples

Sample	Adenovirus	SARS-COVID-2	Bacterial growth	Fungal growth
Controls				
S.# aureus culture	N/A	Not done	*S. aureus*	No growth (NG)
Candida albicans culture	N/A	Not done	NG	*Candida albicans*
Study team member 1, saliva	N/A	Negative	*Neisseria flavescens, Streptococcus mitis, Streptococcus parasanguinis, Rothia aeria, Haemophilus parainfluenzae, Rothia dentocariosa*	NG
Study team member 1, R nares	N/A	Negative	*S. aureus, S. epidermidis, Klebsiella pneumoniae*	NG
Study team member 2, saliva	N/A	Negative	*S. aureus, Neisseria flavescens, Streptococcus mitis, Streptococcus salivarius, Rothia mucilaginosa, Rothia aeria, Lautropia mirabilis*	NG
Study team member 2, R nares	N/A	Negative	*K.pnemoniae, S.lugdunensis, C.** amycolatum, S. epidermidis*	NG
PDI germicidal disinfectant wipe	N/A	Negative	NG	NG
PDI germicidal disinfectant solution	N/A	Negative	NG	NG
Water, retina clinic room sink	N/A	Negative	NG	NG
Distilled water	N/A	Not done	NG	NG
Samples				
Retina clinic, lens kit	N/A	Negative	*C. mucifaciens*	NG
Retina clinic, indirect ophthalmoscope	N/A	Negative	*S. capitis, S. pasteuri*	NG
Retina clinic, patient seat	N/A	Negative	NG	NG
Retina clinic, handheld eye occluder	N/A	Negative	NG	NG
Retina clinic, keyboard and mouse	N/A	Negative	NG	NG
Retina clinic, patient room light switch	N/A	Negative	*S. epidermidis, C. minutissimum, C. amycolatum, Micrococcus luteus, C. tuberculostearicum, C. ureicelerivorans*	NG
Retina clinic room A, slit lamp chin rest	N/A	Positive; Cycle threshold (CT) = 36.48	NG	NG
Retina clinic room A, slit lamp forehead rest	N/A	Negative	NG	NG
Retina clinic room B, slit lamp chin rest	Negative	Negative	*C. tuberculostearicum, C. singulare*	NG
Retina clinic room C, slit lamp chin rest	Negative	Negative	NG	NG
Retina clinic room D, slit lamp chin rest	Negative	Negative	*Mixta calida*	NG
Retina clinic room E, slit lamp chin rest	Negative	Negative	NG	NG
Retina clinic room F, slit lamp chin rest	Negative	Negative	NG	NG
Retina imaging suite, SPECTRALIS® Heidelberg OCT chin rest	Not done	Positive; CT = 37.14	*S. capitis, S. epidermidis*	NG
Retina imaging suite SPECTRALIS® Heidelberg OCT forehead rest	Negative	Negative	*S. capitis, S. epidermidis, Cutibacterium acnes*	NG
Retina imaging suite Optos® chin rest	Negative	Negative	*S. epidermidis*	NG
Retina imaging suite Optos® forehead rest	Not done	Negative	*S. capitis, S. epidermidis, C. kroppenstedtii*	NG
Glaucoma imaging suite OCT chin rest	Negative	Negative	*S. epidermidis*	NG
Glaucoma imaging suite OCT forehead rest	Negative	Negative	*S. hominis, Cutibacterium acnes, S. epidermidis*	NG
Glaucoma imaging suite Humphrey® Field Analyzer chin rest	Negative	Negative	*S. epidermidis, S. capitis, Micrococcus luteus*	NG
Glaucoma imaging suite Humphrey® Field Analyzer forehead rest	Negative	Negative	*Moraxella osloensis, S. capitis*	NG
Glaucoma clinic room A slit lamp chin rest	Negative	Negative	NG	NG

Table 1 (continued)

Sample	Adenovirus	SARS-COVID-2	Bacterial growth	Fungal growth
Glaucoma clinic room B slit lamp chin rest	Negative	Negative	*S. epidermidis*	NG
GES (general eye service) A slit lamp chin rest	Not done	Negative	*S. epidermidis*	NG
GES (general eye service) B slit lamp chin rest	Negative	Negative	*S. epidermidis*	NG
GES (general eye service) imaging suite Cirrus OCT chin rest	Negative	Negative	NG	NG
GES (general eye service) imaging suite Cirrus OCT forehead rest	Negative	Negative	NG	NG
Cornea imaging suite Pentacam® chin rest	Not done	Negative	*S. epidermidis, S. capitis*	NG
Cornea imaging suite Pentacam® forehead rest	Not done	Positive; CT = 37.83	NG	NG
Cornea imaging suite IOL Master® chin rest	Negative	Negative	NG	NG
Cornea imaging suite IOL Master® forehead rest	Negative	Negative	NG	NG
Cornea clinic room A slit lamp chin rest	Negative	Negative	NG	NG
Cornea clinic room B slit lamp chin rest	Negative	Negative	NG	NG

S.# = *Staphylococcus*

*C.*** = *Corynebacterium*

*Imaging machines include ultra-widefield fundus cameras (Optos, Marlborough, MA, USA), OCT machines (including Cirrus, Zeiss, Oberkochen, Germany; Spectralis, Heidelberg, Germany), Humphrey® Field Analyzer (Zeiss), Pentacam® (Oculus, Wetzlar, Germany), and IOL Master® (Zeiss) machines

Table 2 Bacterial growth and SARS-CoV-2 among subspecialty clinics and room types

	Bacterial growth				Positive for SARS-CoV-2			
	Yes	No	*P* value	Correlation coefficient (95% confidence interval (CI))	Yes	No	*P* value	95% CI
Subspecialty clinics								
Retina, *N* = 17	9	8	0.076	−0.143 (−0.644, 0.358)	2	15	0.948	0.148 (−0.438, 0.735)
Glaucoma, *N* = 6	5	1			0	6		
Cornea, *N* = 6	1	5			1	5		
GES*, *N* = 4	2	2			0	4		
Room type								
Imaging suite, *N* = 14	9	5	0.220	0.219 (−0.134, 0.523)	2	12	0.389	0.155 (−0.199, 0.473)
Clinic room, *N* = 19	8	11			1	18		

**GES* general eye service (resident clinic)

Table 3 Presence of *Cutibacterium acnes* among surfaces

	Presence of *Cutibacterium acnes*			
	Yes	No	*P* value	95% CI
Imaging device forehead rest, *N* = 7	2	5	0.040	0.355 (0.019, 0.619)
All other surfaces, *N* = 26	0	26		

Discussion

To our knowledge, this surveillance is the first of its kind during the COVID-19 pandemic, an era when disinfection practices have been amplified. PDI (Professional Disposables International, Inc.) germicidal disinfectant wipes are universally used across surfaces in ophthalmology examination and imaging suites between patient encounters. These wipes are bactericidal, viricidal (including

SARS-CoV-2), and tuberculocidal, requiring 2 min with complete drying. Despite these measures, numerous pathogens were found in this microbiome. The last surveillance appears documented in 2005 [2] and it is evident that many pathogens remain pervasive. It is still unknown the extent with which these pathogens may be spreading among patients and healthcare workers.

The isolation of *C. acnes* (formerly *Propionibacterium acnes)* on multiple chin rests is alarming. *C. acnes* is well-established as a cause of postoperative, chronic endophthalmitis requiring repeated intravitreal antibiotics, and occasionally surgical removal of contaminated intraocular lenses [7, 8]. This bacteria may also cause dacryocystitis [9]. *Micrococcus luteus*, isolated here, can form biofilms implicated in prosthetic valve endocarditis, a life-threatening condition [10]. Many samples grew *Corynebacterium* species, which can cause granulomatous mastitis. These infections have reportedly poor outcomes and may be difficult to treat due to the lipophilic nature of associated granulomas [11].

While *S. epidermidis* was seen among the commensal bacteria in study team member samples, it was also the most frequently grown bacterium among all samples. This bacterium is one of the most common causes of post-intraocular surgical infection [12]. In addition to *S. epidermidis, S. capitis* is implicated with surface infections such as chronic blepharitis, suppurative keratitis, and purulent conjunctivitis [13]. These findings, then, are suggestive of an uncontrolled vector for these nosocomial infections. While specific adherence to infection control protocols was not assessed here, it is important to evaluate the regularity of execution and effectiveness of individual existing procedures for optimizing antisepsis.

One study showed that SARS-CoV-2 half-life on plastic surfaces was 5.3 h with infectivity exceeding 120 h [14]. The alarming finding of 3 positive SARS-CoV-2 samples on plastic surfaces of ophthalmology equipment indicates an unmet need and opportunity for reducing potential infectious spread. For example, copper exhibits antiviral activity by causing irreversible fragmentation of the genome through reactive oxygen species [15]. Therefore, copper chin and forehead rests for slit lamp and imaging machines may be a useful and relatively convenient protective measure. Additionally, UV-C irradiation may decrease SARS-CoV-2 loads on plastic within 21 s [14], and may provide an alternative for maximizing antisepsis. Regardless, current disinfection practices appear deficient for preventing instances of SARS-CoV-2 isolation in ophthalmology clinics.

This study has some limitations, including the challenge of directly linking bacteria and SARS-CoV-2 to clinical infection as they can be more insidious than adenovirus[2], for example. Just as *S. epidermidis* does not always cause infection, other pathogens may act similarly. Future studies are needed to elucidate infection rates following ophthalmology visits. Though these findings may indicate a need for increased disinfection, the potential costs such as environmental impact and risks must be weighed, including greater waste products in the form of PDI wipes. Furthermore, samples were derived from one hospital where the disinfection technique is similar between clinics. Some samples were inadequate for testing adenovirus. Expanding surveillance to other sites would be helpful. Still, we would expect negligible microbial growth during the COVID-19 pandemic with increased disinfection practices, which reinforces these findings.

In conclusion, we found the majority of sampled surfaces in ophthalmology clinics yielded bacterial growth, and some samples tested positive for SARS-CoV-2 despite rigorous antisepsis. These findings suggest an opportunity for reevaluating disinfection techniques across subspecialties. Future studies are necessary to clarify instances of infection after an ophthalmology appointment.

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Author contribution Each author contributed to the manuscript as follows: design and conduct of the study (HM, SXZ, WM, HM, MPB); collection, management, analysis, and interpretation of the data (HM, SXZ, JW, WM, HM, MPB); preparation, review, or approval of the manuscript and decision to submit for publication (HM, SXZ, WM, MPB). At least 2 authors (HM, SXZ, JW, WM, MPB) had full access to all the data in the study and take responsibility for the integrity of the data and the accuracy of the data analysis.

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Declarations

Ethics approval This article does not contain any studies with human participants or animals performed by any of the authors.

Conflict of interest The authors declare no competing interests.

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