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The ROYAL COLLEGE of OPHTHALMOLOGISTS

ARTICLE

Slit lamps and lenses: a potential source of nosocomial infections?

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Abstract

Purpose The aim of the study was to evaluate the bacterial contamination level of contact surfaces on slit lamps and the grip areas of lenses.

Methods Within unannounced audits, two regions of the slit lamps (headrest and joystick), indirect ophthalmoscopy devices, and ultrasound probes were obtained with rayon-tipped swab. Non-contact lenses used for indirect fundoscopy were pressed on RODAC (Replicate Organism Detection and Counting) plates. One hundred and eighty-one surfaces were sampled. The total number of colony-forming units was assessed and bacterial species were identified. Spa-typing and antimicrobial susceptibility testing were performed from *Staphylococcus aureus* isolates.

Results Among the total bacterial isolates from ophthalmological equipment (lenses: 51 of 78, slit lamps: 43 of 88, ophthalmoscopy helmets: 3 of 8, ultrasound probes: 2 of 7), coagulase-negative staphylococci (CNS) was most frequently found, followed by *Micrococcus* spp. (lenses vs. slit lamps: $P < 0.001$ and $P = 0.01$, respectively). The bacterial contamination of lenses (76%) was significantly higher than that of slit lamps (54%) ($P < 0.003$). A significantly higher contamination with CNS was observed on lenses from residents vs. from consultants (78% vs. 35%, $P = 0.01$). A total of seven different spa-types of *S. aureus* were isolated. No correlation was found between *S. aureus* contamination of different ophthalmological equipments (Spearman's rank correlation coefficient, $\rho = 0.04$, $P = 0.75$). Methicillin-resistant *S. aureus* was not detected.

Conclusion Bacterial species of the normal skin flora were isolated from the ophthalmological equipment. The bacterial contamination of the portable devices was significantly higher than that of slit lamps. Therefore, proper hygiene of the mobile instruments should be monitored in order to prevent transmission of bacteria in residents and consultants.

Introduction

Health-care-associated infections (HAIs) or nosocomial infections are not present at the time of first contact or admission and include infections appearing after discharge, which were acquired by patients in hospital or other health-care facilities (World Health Organization). They are a common cause of mortality and morbidity as well as one of the most common adverse events in health care. In addition, HAIs lead to high financial costs. According to the Center for Disease Prevention and Control in the United States and Europe, 4.5 and 6% of patients are infected with at least one HAI during a hospital stay [1]. In a multistate point-prevalence survey of HAIs, 5.6% of patients had eye, ear, nose, throat, or mouth infection [2]. The most common nosocomial infections in eye hospitals are acute conjunctivitis, followed by upper respiratory tract infections and endophthalmitis. [3]. In patients with postoperative endophthalmitis, the most frequently isolated bacteria were coagulase-negative staphylococci (CNS), including *Staphylococcus epidermidis* [3, 4]. Further, ocular infections caused by methicillin-resistant *Staphylococcus aureus* (MRSA) appear to be increasing in incidence, prevalence, and also resistance to other antibiotics, especially fluoroquinolones and erythromycin [5–12].

Potential reservoirs of HAIs are different surfaces including stethoscopes [13, 14], bed rails [15], faucet handles [16], and ophthalmic equipments, such as slit lamps [17], operating microscopes [18], tonometer tips [19–22], and felt-tipped marker pens [23]. In the digitial medicine also mobile phones [24] and computer keyboards [16]

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become more relevant vehicles for the transmission of pathogenic microorganisms. Other potential vectors for nosocomial infections are inappropriately or unsuccessfully decontaminated surgical instruments [25] or reusable laser-protective eyeware [26], and reuse of contaminated eye drops [27, 28]. Besides, microbial hand contamination during an eye examination contributes to the risk of transmission not only due to contact with the patient's skin but also due to direct contact with the patient's eye discharge and tears [29]. Further, ophthalmologists with conjunctivitis may spread infections, too [30].

However, the small and often personalized equipment of ophthalmologists must not be forgotten as potential vehicles for transmission of bacteria. Previous studies did not include the handheld lenses [17–19, 29], although frequent disinfection of this equipment between patients in accordance to standardized hygiene guidelines appears very unlikely. The endeavors to improve the discipline of hand hygiene would be irrelevant if the contact areas would be ignored [29].

Due to the rise of multi-drug resistance, bacterial contamination has to be taken seriously, just as the risk of adenoviral keratoconjunctivitis. [31]. Therefore, the aim of this study was to evaluate the bacterial contamination level of the whole spectrum of the ophthalmological equipment: lenses, slit lamps, indirect ophthalmology helmets, and handheld ultrasound probes.

Materials and methods

Setting

The study was conducted at a tertiary center and teaching hospital (Center for Ophthalmology, Eberhard-Karl University, Tuebingen, Germany). The hospital offers accommodation with 76 beds (7000 inpatient treatments per year and 94,300 outpatient cases per year). This work adhered to the tenets of the Declaration of Helsinki, and the Institutional Ethics Committee of the University of Tuebingen granted approval with a waiver of informed consent for this study. The samples were pseudonymized and de-identified prior to analysis. According to the disinfection recommendations, all devices used in this study should be cleaned with non-woven wipes distributed with didecyldimethyl ammonium chloride and quaternary ammonium compounds, benzyl-C12-16-alkyldimethyl, chlorides.

Sample collection

Samples were taken from the slit lamps, non-contact lenses used for indirect fundoscopy, indirect ophthalmology helmets, and ultrasound probes within an unannounced audit by one qualified person (between 11 a.m. and 1 p.m.). We examined all diagnostic (non-contact) lenses used for indirect fundoscopy, which were found in the workplace. Most physicians carried 90 D (and similar) and 20 D lenses with them ($n = 20$). Different variants and commercial versions providing slight differences of magnification or visual field (Superfield NC®, SuperPupil®, Super Vitreo-fundus®, Digital Wide-Field®, Digital High Mag®, 66 D, 78 D) were analyzed within this subgroup. Only a small group of personal contact lenses (Goldmann three-mirror contact lens, Super Quad®, $n = 3$) was tested. Two surfaces of the slit lamps, headrests and joysticks, were chosen for microbiological examination due to direct contact with the skin of the patients and with the ophthalmologists' hands, respectively (interim wipe disinfection not applied). Due to the use of chin papers, this part of the slit lamps was not examined. Two surfaces of the slit lamps, the headrest and the joystick, as well as the indirect ophthalmoloscopy helmets and ultrasound probes were obtained using rayon-tipped swabs (plastic stick rayon-tipped Venturi Transystem™ Amies with charcoal sterilized by ionizing radiation, BD, made by COPAN, Italy). Sampling of the lenses was conducted by gently pressing on RODAC (Replicate Organism Detection and Counting) plates (24 cm^2) for 5 s [32].

Culture

All specimens were delivered to the laboratory immediately after collection. RODAC plates with inhibitors against disinfecting agents (Oxoid) and Columbia sheep blood (Oxoid) plates were incubated aerobically at 37 °C for 48 h. The total number of colony-forming units (CFU) was assessed and bacterial species were examined following a standardized operational procedure. This included preliminary identification using catalase test and DiaMondiaL Staph Plus Kit, followed by MALDI-TOF-MS (Axima Assurance, Shimadzu) where appropriate. *Staphylococcus aureus* isolates were further characterized as for their spa-types (Staphylococcus protein A) and using the Ridom SpaServer (Ridom).

Statistical analysis

Data are presented as median and ranges. The bacterial contamination of lenses and slit lamps was compared using Wilcoxon's signed-rank tests for continuous variables and with χ^2 analysis for categorical variables. Correlation between the bacterial contamination of different ophthalmological equipments was measured by Spearman's correlation coefficient. A P value <0.05 was defined as statistically significant. All statistical analyses were performed using commercial software (SPSS version 22.0, SPSS Inc.).

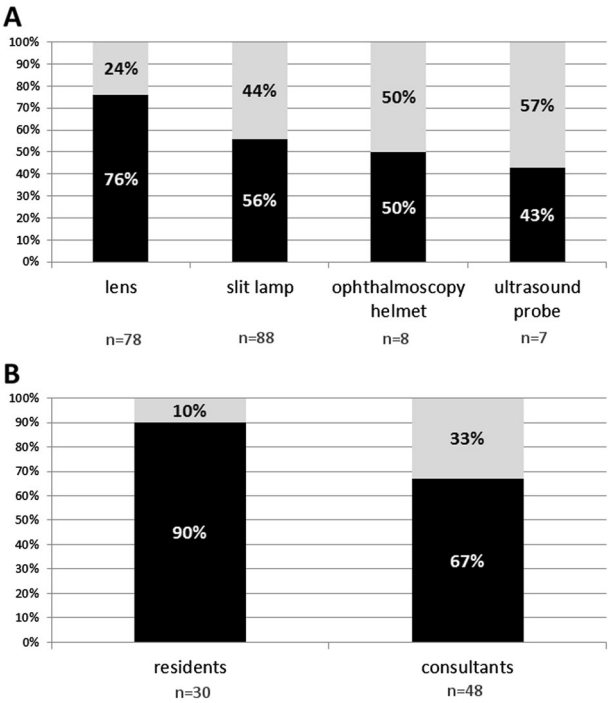

Fig. 1 **a** A total of bacterial contamination of lenses ($n = 78$), slit lamps ($n = 88$), ophthalmoscopy helmets ($n = 8$), and handheld ultrasound probes ($n = 7$); **b** A total of bacterial contamination of lenses in residents ($n = 30$) and consultants ($n = 48$) (black—percentage of samples with bacterial contamination, gray—percentage of samples without bacterial contamination)

Results

Seventy-eight samples from lenses (30 from residents and 48 from consultants), 88 samples from slit lamps, 8 samples from indirect ophthalmology helmets, and 7 samples from ultrasound probes. The slit lamps were in 40 different rooms and lenses came from 39 doctors (18 residents and 21 consultants). A total of 181 samples were analyzed for the presence of microorganisms.

Out of the total samples, bacteria were isolated from 59 (76%) of 78 lenses and 56 (54%) of 103 devices other than lenses (slit lamps: 49 of 88, ophthalmoscopy helmets: 4 of 8, handheld ultrasound probes: 3 of 7) (Fig. 1a).

Among the total bacterial isolates from lenses, CNS 51 (86%) were followed by *Micrococcus* spp. 20 (34%), other aerobic bacteria 10 (17%), and *S. aureus* 7 (12%). In addition, two (3%) non-fermenting bacteria and molds were found (Fig. 2).

In the slit lamp samples together with indirect ophthalmology helmets and ultrasound samples, CNS 48 (86%) were followed by *Micrococcus* spp. 13 (23%), other aerobic bacteria 6 (11%), *S. aureus* 4 (7%), and molds 2 (4%) (Fig. 2).

The maximum contamination of lenses was 71 CFU, followed by slit lamps (3 CFU), indirect ophthalmology helmets (2 CFU), and ultrasound probes (1 CFU) (Table 1).

The bacterial contamination of lenses was significantly higher as compared to the bacterial contamination of slit lamps ($P = 0.003$). CNS (lenses vs. slit lamps: median 2 (0–71) CFU/24 cm^2 vs. median 0 (0–3) CFU/24 cm^2, $P < 0.001$) and *Micrococcus* spp. (lenses vs. slit lamps: median 0 (0–36) CFU/24 cm^2 vs. median 0 (0–1) CFU/24 cm^2, $P = 0.015$) were the most frequently isolated bacteria from the grip areas of lenses (Table 1). No correlation was found between contamination with CNS ($\rho = 0.13$, $P = 0.27$), *Micrococcus* spp. ($\rho = 0.06$, $P = 0.59$), and *S. aureus* ($\rho = 0.04$, $P = 0.75$) of slit lamps and lenses.

A significant difference in contamination with CNS was observed on lenses from residents vs. from consultants (78% vs. 35%, $P = 0.01$). A statistical trend toward significance was observed in total of bacterial contamination between lenses from residents and consultants ($P = 0.058$) (Fig. 1b, Table 2).

A total of seven different spa-types of *S. aureus* were isolated. Two types (t1827 and t2387) were found in different slit lamps and lenses. *Staphylococcus aureus* t1827 was isolated from two lenses, which belonged to the same doctor, and *S. aureus* t2387 was isolated from one lens of another doctor and from two different slit lamps.

MRSA was not detected in this study.

Discussion

This study evaluated, within unannounced audits, 181 samples from lenses, 2 regions of slit lamps (headrest and joystick), sections of indirect ophthalmoscopy devices, and ultrasound probes in order to estimate the contamination rate and spectrum of the microorganisms on these surfaces. The major findings of this study are: (1) CNS were the most frequently isolated microorganisms in all evaluated ophthalmological equipment; (2) the bacterial contamination of lenses was significantly higher in comparison to the slit lamps; (3) the bacterial contamination of lenses from residents showed a statistical trend toward significance in comparison to the lenses from consultants; (4) a significant contamination with CNS was observed in lenses from residents vs. lenses from consultants.

The vast majority of all bacterial species found in this study were part of the resident skin flora. The skin seems to be the most common determinant of ophthalmological equipment contamination. CNS were the most common microorganisms isolated from the slit lamps, including indirect ophthalmology helmets and ultrasounds probes, and lenses which is in accordance with studies on mobile phones [24]. The second most common bacteria isolated

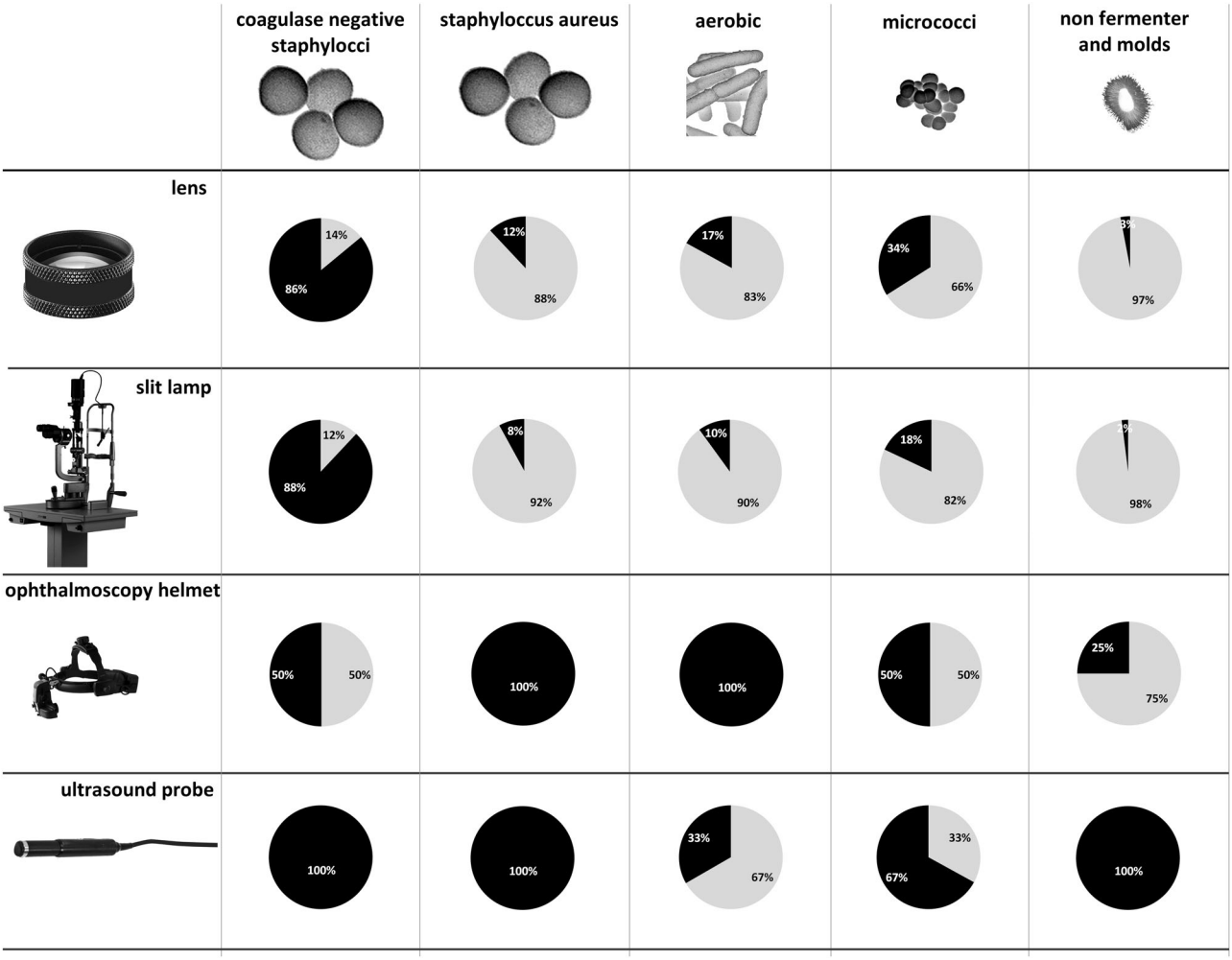

Fig. 2 Spectrum of bacteria implicated in contamination of lenses, slit lamps, ophthalmoscopy helmets, and ultrasound probes (black—percentage of samples with bacterial contamination, gray—percentage of samples without bacterial contamination)

from the ophthalmological equipment were *Micrococcus* spp., which is also present on normal skin [33] and in the inanimate environment, and does only rarely lead to infections in immunocompromised patients [34]. The third most common isolated bacteria were aerobic bacteria, which are predominant inhabitants of the skin, and are involved in different infections [29]. *Staphylococcus aureus* was least often found in our study, and no MRSA were cultured. However, the presence of *S. aureus* spa-types t1827 on two lenses from the same doctor and t2387 on a lens and two different slit lamps suggests that hands may be a source of bacterial cross-contamination. However, no relation was found between *S. aureus* contamination of different ophthalmological equipments.

In our study, the bacterial contamination of lenses was significantly higher in comparison to the slit lamps. Furthermore, the significant contamination levels with CNS were observed in lenses compared to the slit lamps, and also in lenses from residents vs. lenses from consultants. This observation suggests a better hygienic practice of slit lamps than lenses. It has to be pointed out that no lens cleaning instructions existed, and the lenses are not routinely cleaned, in particular not subsequent to every examination. However, considering the results of our study and the fact that lenses are very frequently used, in virtually every eye examination, the optimal method of disinfection should be determined. In addition, considerable variation in the lens contamination, ranging from 0 to 71 CFUs, was observed in this study. These differences in the bacterial contamination level may be associated with the frequency of lens use and disinfection and also the storage of the devices between the eye examinations. A wide discrepancy in the frequency of bacterial contamination was also reported in studies on stethoscope contamination [14].

In addition, a significant contamination level with CNS was observed in the sample from 18 residents (number of lenses: 30) in comparison to lenses from 21 consultants (number of lenses: 48). The results seem to be unrelated to

Table 1 Spectrum of bacteria implicated in contamination of lenses, slit lamps, ophthalmoscopy helmets, and ultrasound probes

Bacterial contamination	Lenses	Slit lamps	Ophthalmoscopy helmets	Ultrasound probes
CNSA: median	2	0	0	0
CNSA: mean	5	1	1	0
CNSA: range	0–71	0–3	0–2	0–1
SA: median	0	0	0	0
SA: mean	0	0	0	0
SA: range	0–7	0–3	0	0
Micr.: median	0	0	0	0
Micr.: mean	1	0	0	0
Micr.: range	0–36	0–1	0–1	0
Aerob.: median	0	0	0	0
Aerob.: mean	0	0	0	0
Aerob.: range	0–3	0–1	0–1	0–1

Aerob. aerobic bacteria, *CNSA* coagulase-negative *Staphylococcus aureus*, *Micr.* Micrococcus, SA *Staphylococcus aureus*

Table 2 Spectrum of bacteria implicated in contamination of lenses in residents and consultants

Bacterial contamination	Lenses from residents	Lenses from consultants
CNSA: median	4	1
CNSA: mean	9	3
CNSA: range	0–71	0–26
SA: median	0	0
SA: mean	0	0
SA: range	0–7	0–6
Micr.: median	0	0
Micr.: mean	0	0
Micr.: range	0–3	0–1
Aerob.: median	1	0
Aerob.: mean	0	2
Aerob.: range	0–9	0–36

Aerob. aerobic bacteria, *CNSA* coagulase-negative *Staphylococcus aureus*, *Micr.* Micrococcus, SA *Staphylococcus aureus*

the number of doctors or to the number of patients seen in the offices. The residents usually examine a smaller number of patients per day than consultants.

Furthermore, every resident and consultant have their own lenses. As the lenses sometimes lie around next to each other, it occurs that lenses were shared; however, all physicians preferably use their own private lens. Neither residents nor consultants have been reminded or instructed to routinely clean their lenses in the path. Nevertheless, all physicians undertake regular training to improve hygiene education to prevent nosocomial infections, for example, training in hand hygiene. In addition, screening tests are performed to detect carriage of problem germs in physicians as part of the hygiene monitoring program.

Several limitations of this study have to be considered. First, the study was not multicenter. However, the number of samples was not small. Second, we did not investigate the bacterial contamination of physicians' hands [29, 35]. Third, the lenses often have soft linings, which are impossible to clean.

The risk factors for transmission of pathogens to patients are rare hand disinfection and sharing lenses with colleagues, which are an implication of lack of hygiene awareness and wrong personal behavior like "scratching your hair or nose with your finger" [36]. Thus, it is not only sufficient to wear short-sleeved shirts and ban ties but also to remain aware of others routes of cross-contamination [37].

In conclusion, bacterial species of the normal skin flora were isolated from the ophthalmological equipment and the bacterial contamination of the lenses was significantly higher than that of slit lamps. Furthermore, the grip areas of lenses from residents were significantly contaminated with CNS compared to lenses from consultants, although all residents own and use their own lenses and usually examine a smaller number of patients than consultants. Therefore, better hygiene education and determination of cleaning method for lenses could reduce a risk of spreading potential nosocomial pathogens.

Summary

What was known before

- Potential reservoirs of HAIs are different surfaces including stethoscopes, bed rails, medical charts, faucet handles, and ophthalmic equipments, such as slit lamps, operating microscopes, tonometer tips, and felt-tipped marker pens.
- In the digitial medicine also mobile phones and computer keyboards become more relevant vehicles for the transmission of pathogenic microorganisms.
- Other potential vectors for nosocomial infections are inappropriately or unsuccessfully decontaminated surgical instruments or reusable laser-protective eyeware, and reuse of contaminated eye drops.

What this study adds

- Previous studies did not include the handheld lenses.
- The bacterial contamination of lenses (76%) was significantly higher than that of slit lamps (54%) ($P < 0.003$).
- A significantly higher contamination with CNS was observed on lenses from residents vs. from consultants (78% vs. 35%, $P = 0.01$).

- Better hygiene education and determination of cleaning method for lenses could reduce a risk of spreading potential nosocomial pathogens.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no competing interests.

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