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Care practices of contact lens solutions and microbial contamination among wearers in Ghana

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ABSTRACT

Purpose: This study sought to assess contact lens solutions care practices, and their microbial contamination among contact lens wearers in Ghana and to profile their antibiotic susceptibility pattern.
Methods: The study employed a biphasic approach which involved a cross-sectional design that investigated participants' habits related to care for the solutions with a two-part questionnaire and a microbiological analysis of samples of contact lens care solutions of the participants for microbial contamination. A snowball sampling method provided access to 32 different contact lens wearers in four care facilities in Ghana. In most cases, the participants had no pre-existing familial relationship with each other or with the care facilities.
Results: Out of 32 samples of contact lens solutions, 30 were tested for microbial contamination. A total of 23 (76.67 %) samples of contact lens solution were found to be contaminated with *Enterobacter* sp. (34.80 %), *Pseudomonas* sp. (21.70 %), *Bacilli* sp. (21.70 %), *Klebsiella* sp. (17.20 %), and *Escherichia coli* (4.60 %). The duration of solution storage in the open bottle and nonadherence to manufacturer instructions for solution storage showed a statistically significant association with microbial contamination ($p \leq 0.05$).
Conclusion: Contact lens care solutions have been found to harbour multiple antibiotic-resistant bacteria that are potentially pathogenic to the corneal surface. The contamination is associated with some unhealthy solution-care practices among wearers.

1. Introduction

Contact lens (CL) wear is the leading risk factor for the development of microbial keratitis in otherwise healthy eyes [1]. The lens biomaterial serves as a substrate for the adherence of microorganisms increasing the risk for ocular surface infections [2]. More than half (approximately 56 %–65 %) of lenses are found to contain microorganisms, mostly bacterial when aseptically removed from the eye [3]. Some of the factors accountable for the development of microbial keratitis include the type of lens material [4], wearing schedule [5,6], adherence of microorganisms to the lens [7], and microbial contamination of lens care solutions [8,9].

Contamination of lens care solutions is of significant concern in contact lens wear [10], particularly in developing countries such as Ghana, where poor hygiene practices and limited access to clean water [11] can increase the risk of microbial contamination. In contrast to lens contamination, which is almost exclusively bacterial, the microorganisms involved in solution contamination found in lens cases or on the internal wells are usually a mixture of bacteria, fungi, and protozoa [12,13]. Studies involving patients with contact lens-associated microbial keratitis have demonstrated contamination of the lens care solutions [14,15]. All types of solutions are at risk of microbial contamination, in experienced and compliant users [16] and even in unopened, factory-sealed bottles (an incidence of 11.15 %) [17]. Contact lens cases or cleaning solutions have been found to be contaminated by *Acanthamoeba* sp. and other microbial organisms as a result of poor hand hygiene [18]. Microbial organisms that are responsible for the contamination of lens care systems can serve as a source of nutrition for other harmful organisms, including *Acanthamoeba* sp. [19]. Microbial contamination of the care system may result in the production of toxins that affect the eye [20]. In rabbits, intrastromal injection of endotoxins present in the cell walls of gram-negative bacteria has been linked to

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corneal ring infiltrates [21].

Several previous studies have established the risk of contamination of contact lens care solutions [22–24]. Taking into consideration hot and humid climates that promote the proliferation of bacterial populations, it is of utmost importance to frequently monitor the degree of microbial contamination in lens care solutions among contact lens wearers [10]. This study therefore aimed to assess contact lens care solution care practices and their microbial contamination among contact lens wearers in Ghana and to profile their antibiotic susceptibility pattern.

2. Materials and methods

2.1. Data collection procedure

This biphasic study employed a cross-sectional approach to investigate factors that influence contamination of contact lens solutions, and a laboratory analysis to assess the microbial contamination profile of contact lens care solutions. A two-part questionnaire was used to collect data on patient demographics, which included age, sex, and occupation, as well as information on habits related to caring for the solutions. The second phase involved the collection of in-use contact lens solutions from the identified wearers using a snowball approach. As an exclusion criterion, bottles with less than 1 ml of solution (almost finished) were not collected. No special instructions were given, and the participants were not informed beforehand that they would be recruited into the second phase of the study to avoid a possible modification in their solution care practices. A 2 ml sterile syringe was used to aspirate samples from the residual lens care solutions in the bottles into sterile vacuum tubes, which were then capped effectively and preserved under cold conditions (2–4 °C). Processing of the samples took place within a 12-hour window. Control samples were obtained from unopened containers at the designated sites, for comparative purposes. Samples were collected between March and August 2023.

2.2. Participant selection

Eye care practitioners in Ghana have been reported to provide limited contact lens services [25], resulting in only a handful of eye care facilities and optometric practices offering contact lens services to the public.

The study therefore utilized snowball sampling to recruit 32 contact lens wearers. The snowball sampling method provided access to 32 contact lens wearers who were associated with four care facilities in Accra, Kumasi, and Cape Coast. A visit was made to each of the contact lens care facilities. The first contact lens patients identified in the facilities were first asked for their consent to participate in the study, and then, to refer the investigators to other contact lens wearers. In most cases, the participants had no pre-existing relationship with each other or with the care facilities. The contact lens wearers were recruited from four distinct eye care facilities in the country as a result of the dearth in the number of eye care facilities that offer contact lens services to the public. Inclusion criteria were applied stringently to individuals aged 18 and above, without gender bias, who had sought treatment at these facilities. Active use of contact lens solutions during the study period (had to wear CLs at least once a week either for vision correction or for cosmetic reasons) was also a crucial consideration. During the study, individuals experiencing symptoms such as redness and discharges indicative of bacterial corneal or conjunctival infections related to contact lens wear were also excluded to ensure that the investigation remained focused on the contamination of contact lens solutions.

2.3. Culturing and identification of microbes

A range of culture media, including nutrient agar and peptone water agar, was prepared meticulously and precisely following manufacturer instructions (Thermo Fisher Scientific, San Jose, CA, USA) to guarantee sterility. Additional media, including triple sugar iron agar, citrate agar, and motility agar, were employed to evaluate microbial biochemical activity. Mueller-Hinton agar (Thermo Fisher Scientific, San Jose, CA, USA) was used for culture and sensitivity tests and was prepared as contained in the manufacturer's instructions. To ensure accurate processing of the contact lens solution, 1 ml of each sample was pipetted and inoculated into a sterile Petri dish containing approximately 20 ml of culture media. The plates were gently swirled to ensure even distribution before solidifying. Subsequently, the plates underwent incubation: 24 h at 37 °C for bacteria and 120 h at 25 °C for fungi. Following this period, the visible colonies were enumerated, scrutinized for morphological traits, and categorized. Selected colonies were then segregated and re-cultured in nutrient agar for future identification. Microorganism isolates were identified through an array of measures encompassing biochemical, morpho-cultural characteristics, and Gram staining. The morpho-cultural properties were established by assessing the colony appearance on nutrient agar. Gram-negative bacteria were identified through biochemical tests, including catalase, indole, triple sugar iron reduction, citrate, and motility tests. Gram-positive bacteria, on the other hand, were identified using catalase, motility, and indole tests.

2.4. Antimicrobial susceptibility testing

The bacteria under observation underwent susceptibility testing to a range of antibacterial agents using the disc diffusion method. Antifungal susceptibility testing was not performed since no fungal contaminant was isolated. Mueller-Hinton agar served as the medium in combination with antibacterial discs. The antibacterial agents included Tetracycline (10 μg), Gentamicin (10 μg), Ciprofloxacin (5 μg), Amoxiclav (30 μg), Ampicillin (30 μg), Amikacin (30 μg), Vancomycin (30 μg), Ceftriaxone (30 μg), Chloramphenicol (30 μg), and Cefuroxime (30 μg) which were imported from Scientific Laboratory Supplies, United Kingdom.

2.5. Data analysis

The study data was transferred to the Statistical Package for Social Science (SPSS) software, version 26.0 for Windows (Chicago, USA) for statistical analysis. To ensure reliability, all reported values were thoroughly examined for missing variables, outliers, and normal distribution. Owing to the small sample size, the Monte Carlo exact test at a 99 % confidence interval for 10,000 samples was applied. The Monte Carlo exact test was used to determine factors associated with contamination of contact lens solutions, and provided an unbiased estimate of the exact p-value, without the requirements of the asymptotic method. Univariate and multivariate logistic regression were run to screen for predictors of the likelihood of contamination, and odds ratios (cOR: Crude Odds Ratio; aOR: Adjusted Odds Ratio) with 95 % confidence intervals (CI) were utilized. Following the purposeful selection of variables procedure [26], variables found to be associated with contamination of lens care solutions from the Monte Carlo exact test were included in the univariate logistic regression model, and afterwards, the multivariate logistic regression model. The model for the multivariate logistic regression was adjusted for "The duration solution has remained in the bottle" and "Storage of solution according to instructions", and interactions were not explored. A statistically significant result was obtained with $p \leq 0.05$.

2.6. Ethical consideration

The study protocol was approved by the institutional review board of the University of Cape Coast (UCCIRB/CHAS/2023/77). The samples were sent to the microbiology laboratory of the Department of Biomedical Sciences, University of Cape Coast, where they were assayed. Biosafety guidelines for the protection of personnel in the laboratory were observed.

3. Results

3.1. Characteristics of study participants

Thirty contact lens solutions were analysed, with an equal distribution of 15 samples each from male and female patients. The age range of the participants was 22–48 years, with a mean age of 30.93 ± 7.37 years.

3.2. Microbial profile of contact lens solutions

In all, 32 samples of contact lens solutions were collected from the participants. Contact lens solutions from two participants were excluded because the volume of residual solutions was less than 1 ml. Out of the 30 samples of contact lens solution that were tested for microbial contamination, 23 (76.67 %) were found to be contaminated while the remaining 7 (23.33 %) were not. The control samples, on the other hand, did not exhibit any contamination. During the study, participants only had access to multipurpose and saline contact lens solutions. The bottles of contact lens solutions had been open for varying durations, ranging from 3 to 212 weeks, with a mean duration of 46.47 ± 45.03 weeks (95 % CI 29.65–63.28). No fungal growth was observed in any of the samples examined during the investigation. Further analysis of the contaminated samples identified the presence of five different genera of bacteria. These bacteria were identified as *Enterobacter* sp., *Pseudomonas* sp., *Bacilli* sp., *Klebsiella* sp., and *Escherichia coli* (Table 1). Most of the contact lens care solutions were found to be contaminated with at least one genus of bacteria and a maximum of three bacterial contaminants (Fig. 1).

3.3. Factors associated with contact lens solution contamination

The factors associated with bacterial contamination of the CL solution are presented in Table 2. The duration of solution storage in the open bottle showed a statistically significant association with microbial contamination, as did nonadherence to manufacturer instructions for solution storage. Storage of contact lens solutions always according to manufacturer instructions was not found to be a significant predictor of the likelihood of contamination of contact lens solutions, as determined by univariate (cOR: 0.00 [95 % CI: 0.00–0.00], p = 1.00) logistic regression. A duration of opening of less than 3 months (90 days) was found to be associated with a 91 % lower likelihood of contamination of contact lens solutions, as determined by univariate logistic regression (cOR: 0.09 [95 % CI: 0.02–0.56], p = 0.01), and an 88 % lower likelihood of contamination of contact lens solutions as determined by multivariate logistic regression (aOR: 0.12 [95 % CI: 0.02–0.95], p = 0.04). The other variable included in the multivariate logistic regression was “Storage of contact lens solutions always according to manufacturer instructions”. The contamination rate was slightly skewed towards the male population, although a statistically significant relationship between sex and microbial contamination was not demonstrated.

3.4. Antimicrobial susceptibility testing

The isolates were subjected to a susceptibility test using a standard antibiotic disc. This classified each isolate as resistant, intermediate, or susceptible to the antibiotics present on the disc. Table 3 presents a summary of the antimicrobial susceptibility test results for the isolated bacteria. All isolates were susceptible to Gentamicin 10 μg, Ciprofloxacin 5 μg, Amoxiclav 30 μg, Vancomycin 30 μg and Amikacin 30 μg. However, they were resistant to Ampicillin 10 μg, Ceftriaxone 30 μg and Cefuroxime 30 μg. *Bacilli* sp. isolates were the most susceptible, with susceptibility to all antibiotics except Ampicillin 10 μg, Ceftriaxone 30 μg, and Cefuroxime 30 μg.

Table 1
Incidence of microbial contaminants in lens solutions isolated from collected samples.

Organisms	N (%)
Bacilli sp.	5 (21.70)
Pseudomonas sp.	5 (21.70)
Enterobacter sp.	8 (34.80)
Klebsiella sp.	4 (17.20)
Escherichia coli	1 (4.60)

4. Discussion

Despite their long history of use and proven disinfectant efficacy, lens care solutions themselves can be easily contaminated and become a reservoir of microbes that can contaminate lens storage cases, adhere to the lens, cause an inflammatory reaction, or infect the cornea [27]. This study hence sought to assess contact lens care solution care practices, microbial contamination among contact lens wearers in Ghana, and their antibiotic susceptibility profile pattern.

Microbial contamination of contact lens care solutions was found to be common in this study, as most of the contact lens care solutions were found to be contaminated with at least, one genus of bacteria (Fig. 1). The multipurpose solution was found to be the most commonly used among the participants, while the use of saline solution was from a participant who had possibly deviated from the instructions from the eye care professional pertaining to contact lens care. The bioburden of contamination in this study is significantly higher than the incidence rates of contamination of preserved lens care solutions reported in similar studies (contamination rates of up to 30 %) [28,29]. In contrast to this study where lens care solutions were stored for a minimum of approximately 29 weeks, the maximum duration of storage in the study by Sweeney et al. [27] was 28 days. The survival and replication of bacteria in contact lens solutions may lead to the formation of biofilm in contact lens cases [30].

The duration of solution storage in the open bottle showed a statistically significant association with microbial contamination, as did adherence to manufacturer instructions for solution storage. Also, a duration of opening of less than 3 months (90 days) was found to be associated with a lower likelihood of contamination of contact lens solutions. Lens care solutions were found to be stored for a minimum of approximately 29 weeks, suggesting that contact lens wearers change their solutions infrequently possibly due to infrequent lens wear. The length of time since a bottle was opened and used has been demonstrated in previous studies to influence the degree of contamination [10]. In a study by Donzis et al. [31], a used bottle were shown to harbour organisms five (5) days after opening. It has been recommended that solution manufacturers begin labelling solution bottles with a discard date (usually within 90 days of opening), as the activity of most lens care solutions against microbes falls with time [10]. The majority of patients are non-compliant in the use of contact lens care solutions and maintenance regimens [4,32]. In a study that evaluated microbial contamination of contact lens care accessories and compliance with care regimens in Nepal, subjects with medium or low compliance had highly significant rates of contamination both in CL cases and solutions than to subjects with high compliance [29]. Collins & Carney [33] correlated the presence of contact lens-related signs and symptoms with care and maintenance regimen compliance and found a positive relationship between poor compliance and the presence of lens-wearing complications such as corneal staining, lens deposition, and subjective symptoms. Improving compliance with lens care practices is crucial in reducing complications and enhancing the patients’ success with contact lens wear [34]. Eye care practitioners should provide clear, concise, and detailed guidance on lens care and maintenance [35]. They should also follow up with patients to ensure compliance with the recommended regimen [35].

Contaminants identified in this study comprised pathogens that have

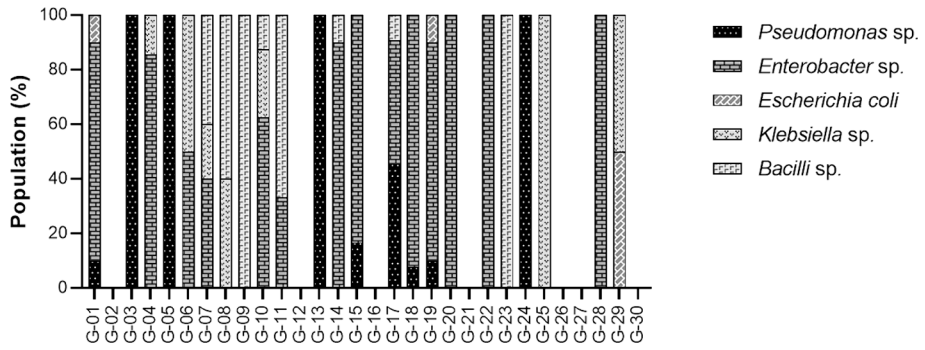

Fig. 1. Population of bacteria isolated from the various contact lens solutions G-01 through G-30 represent the samples of contact lens care solutions obtained from the participants.

Table 2
Factors associated with the contamination of contact lens solutions.

	Contaminated (%)	Sterile (%)	*P**	cOR	CI	*P*
Sex			1.00	–	–	–
Male	12(52.20)	3(42.90)				
Female	11(47.80)	4(57.10)				
Type of solution			1.00	–	–	–
Multipurpose solution	22(95.70)	7(100.00)				
Saline	1(4.30)	0(0.00)				
Handwashing before handling the solution			1.00	–	–	–
Always	14(60.90)	5(71.40)				
Sometimes	9(39.10)	2(28.60)				
Never	0(0.00)	0(0.00)				
Frequency of disinfection			0.46	–	–	–
Always	16(69.60)	7(100.00)				
Sometimes	4(17.40)	0(0.00)				
Never	3(130.00)	0(0.00)				
Sharing of solution			0.66	–	–	–
Always	1(4.30)	0(0.00)				
Sometimes	3(13.00)	0(0.00)				
Never	19(82.60)	7(100.00)				
Reuse of previously used solution			0.46	–	–	–
Always	1(4.30)	0(0.00)				
Sometimes	6(26.10)	0(0.00)				
Never	16(69.60)	7(100.00)				
Storage of solution according to instructions			**0.01**	0.00	0.00 – 0.00	1.00
Always	10(43.50)	7(100.00)				
Sometimes	13(59.50)	0(0.00)				
Recap of solution bottle tightly after use			1.00	–	–	–
Always	21(91.30)	7(100.00)				
Sometimes	2(8.70)	0(0.00)				
Never	0(0.00)	0(0.00)				
Topping up care solution			1.00	–	–	–
Always	2(8.70)	0(0.00)				
Sometimes	0(0.00)	0(0.00)				
Never	21(91.30)	7(100.00)				
Checking of expiry date regularly			0.53	–	–	–
Always	14(60.90)	6(85.70)				
Sometimes	6(26.10)	1(14.30)				
Never	3(13.00)	0(0.00)				
Rinsing contact lenses with water			1.00	–	–	–
Always	0(0.00)	0(0.00)				
Sometimes	2(8.70)	0(0.00)				
Never	21(91.30)	7(100.00)				
The duration solution has remained in the bottle			**0.01**	**0.09**	**0.02–0.95**	**0.04**
< 3 months (within 90 days)	3(13.00)	5(71.40)				
3 months to 1 year	11(47.80)	2(28.6)				
> 1 year	9(39.1)	0(0.00)				
Contact lens wear experience			0.13	–	–	–
< 2 years	16(69.60)	5(71.40)				
> 2 years	7(30.40)	2(28.60)				

*P**: p-values obtained from Monte Carlo exact test at a 99 % confidence interval for 10,000 samples.
P: p-values obtained from univariate logistic regression.

the potential to induce microbial keratitis associated with contact lenses, normal flora from the ocular surface, the gastrointestinal tract, the skin, as well as the surrounding environment. The strains of bacteria obtained from the contaminated samples included *Enterobacter* sp., *Pseudomonas* sp., *Bacilli* sp., *Klebsiella* sp., and *Escherichia coli. Bacilli* sp. Isolates were resistant to Ampicillin, Ceftriaxone, and Cefuroxime but most

Table 3
Antibiotic susceptibility pattern of the isolated bacteria.

Organism	GEN 10 µg	TET 10 µg	CIP 5 µg	CHL 30 µg	AMC 30 µg	AMP 10 µg	VA 30 µg	AMK 30 µg	CTX 30 µg	CRX 30 µg
Bacilli sp.	S	S	S	S	S	R	S	S	R	R
Pseudomonas sp.	S	I	S	R	S	R	S	S	R	R
Enterobacter sp.	S	S	S	R	S	R	S	S	R	R
Klebsiella sp.	S	R	S	I	S	R	S	S	R	R
Escherichia coli	S	I	S	R	S	R	S	S	R	R

AMP: ampicillin, CRX: cefuroxime, GEN: gentamicin, CIP: ciprofloxacin, CHL: chloramphenicol, AMC: amoxiclav, VA: vancomycin, AMK: amikacin, TET: tetracycline, CTX: ceftriaxone, R: resistant, S: susceptible, I: intermediate.

susceptible to Gentamicin, Ciprofloxacin, Amoxiclav, Vancomycin, and Amikacin. In a study by Sweeney et al. [36] on the bioburden of bacteria in preserved lens care solutions, coagulase-negative staphylococcus, *Bacilli* sp, *Corynebacteria* sp. and *Pseudomonas* sp. were found to be prevalent. However, whereas samples were aspirated from the residue of the lens care solution bottles in this study, the samples were collected from the nozzles and contents of the bottles in that study [36].

The ability of the isolated bacteria to thrive is based on the fact that the activity against them may fall during the storage of multipurpose solutions (MPS) [10]. In addition, some organisms may be able to utilize lens solution ingredients as nutrients for growth [10]. The presence of Gram-negative bacteria, even in small numbers, is considered an important bioburden, since these species are reported to be linked with corneal infection, swelling, and perforation, and are hardly ever isolated in asymptomatic subjects [37].

The limitation of this study was a lack of information on the type of multipurpose solution used, particularly, the types of active microbial components used, and therefore, it is recommended that future studies take into account the types of active microbial components used.

In light of the findings of this study, it is recommended that practitioners counsel their patients to follow the manufacturer's instructions for storage and disposal (after 90 days of use) of contact lens solutions and to practice proper hand hygiene before handling contact lens solutions and systems. In Ghana, many contact lens wearers only attend yearly follow-up visits [25], which undermines the importance of regular follow-up, especially considering the high contamination rate of contact lens solutions. Therefore, it is recommended that eye care practitioners counsel their patients to attend follow-up visits frequently. This will allow the practitioners to regularly reinforce the need for solution compliance and potentially reduce contamination.

5. Conclusion

Contact lens care solutions have been found to harbour multiple antibiotic-resistant bacteria that are potentially pathogenic to the corneal surface. The contamination is associated with some unhealthy solution-care practices among wearers. It is recommended that patients should be instructed to establish and maintain a lens-care regimen that adheres to the guidelines provided by the manufacturer of the products they utilize.

Conflict of Interest Statement

The authors declare no conflict of interest

References

[1] Dart JK, Radford CF, Minassian D, Verma S, Stapleton F. Risk factors for microbial keratitis with contemporary contact lenses: a case-control study. Ophthalmology 2008;115(10):1647–54. https://doi.org/10.1016/j.ophtha.2008.05.003.

[2] Kodjikian L, Burillon C, Roques C, Pellon G, Renaud FN, Hartmann D, et al. Intraocular lenses, bacterial adhesion and endophthalmitis prevention: a review. Biomed Mater Eng 2004;14(4):395–409.

[3] Szczotka-Flynn LB, Pearlman E, Ghannoum M. Microbial contamination of contact lenses, lens care solutions, and their accessories: a literature review. Eye Contact Lens 2010;36(2):116–29. https://doi.org/10.1097/ICL.0b013e3181d20cae.

[4] Yee A, Walsh K, Schulze M, Jones L. The impact of patient behaviour and care system compliance on reusable soft contact lens complications. Cont Lens Anterior Eye 2021;44(5):101432. https://doi.org/10.1016/j.clae.2021.02.018.

[5] Abdelkader A. Cosmetic soft contact lens associated ulcerative keratitis in southern Saudi Arabia. Middle East Afr J Ophthalmol 2014;21(3):232–5. https://doi.org/10.4103/0974-9233.134677.

[6] Rahim N, Bano H, Naqvi BS. Bacterial contamination among soft contact lens wearer. Pak J Ophthalmol 2008;24(2).

[7] Onurdağ FK, Özkan S, Özgen S, Olmuş H, Abbasoğlu U. Candida albicans and Pseudomonas aeruginosa adhesion on soft contact lenses. Graefes Arch Clin Exp Ophthalmol 2011;249(4):559–64. https://doi.org/10.1007/s00417-010-1595-3.

[8] Ismail LA, Rampal L, Omar N, Rahman HA, Midi H, Ariffin AE. Visual status following contact lens related microbial keratitis. Malays J Med Health Sci 2016;12(2):24–9.

[9] Stellwagen A, MacGregor C, Kung R, Konstantopoulos A, Hossain P. Personal hygiene risk factors for contact lens-related microbial keratitis. BMJ Open Ophthalmol 2020;5(1):e000476. https://doi.org/10.1136/bmjophth-2020-000476.

[10] Yung MS, Boost M, Cho P, Yap M. Microbial contamination of contact lenses and lens care accessories of soft contact lens wearers (university students) in Hong Kong. Ophthalmic Physiol Opt 2007;27(1):11–21. https://doi.org/10.1111/j.1475-1313.2006.00427.x.

[11] Adams EA, Boateng GO, Amoyaw JA. Socioeconomic and demographic predictors of potable water and sanitation access in Ghana. Soc Indic Res 2016;126(2):673–87. https://doi.org/10.1007/s11205-015-0912-y.

[12] Kuzman T, Kutija MB, Juri J, Jandroković S, Škegro I, Olujić SM, et al. Lens wearers non-compliance—is there an association with lens case contamination? Cont Lens Anterior Eye 2014;37(2):99–105. https://doi.org/10.1016/j.clae.2013.08.004.

[13] Willcox M, Sharma S, Naduvilath TJ, Sankaridurg PR, Gopinathan U, Holden BA. External ocular surface and lens microbiota in contact lens wearers with corneal infiltrates during extended wear of hydrogel lenses. Eye Contact Lens 2011;37(2):90–5. https://doi.org/10.1097/ICL.0b013e31820d12db.

[14] Lim CH, Carnt NA, Farook M, Lam J, Tan DT, Mehta JS, et al. Risk factors for contact lens-related microbial keratitis in Singapore. Eye (Lond) 2016;30(3):447–55. https://doi.org/10.1038/eye.2015.250.

[15] Booranapong W, Prabhasawat P, Kosrirukvongs P, Tarawatcharasart Y. Risk factors for contact lens related microbial keratitis: A case-control study. J Med Assoc Thai 2012;95(5):693–8.

[16] Al-Hilli FA. Study of microbial contamination of some commercial contact lens solutions. Iraqi J Pharm Sci. 2021;30(2):214-8 (P-ISSN. 3597 E-ISSN; 1683. p. 2521-3512).

[17] Durbán JJ, Villaverde EH, Monteoliva-Sanchez M, Ramos-Cormenzana A. Bacterial contamination of hydrophilic contact lens solutions marketed in Spain. Optom vis Sci 1996;73(8):529–32.

[18] McMonnies CW. Hand hygiene prior to contact lens handling is problematical. Cont Lens Anterior Eye 2012;35(2):65–70.

[19] Macharia ZW. Acanthamoeba-associated Pseudomonas species at Kenyatta National Hospital, Intensive Care Unit, Kenya ([Doctoral dissertation]. University of Nairobi).

[20] O'Callaghan RJ. The pathogenesis of Staphylococcus aureus eye infections. Pathogens 2018;7(1):9. https://doi.org/10.3390/pathogens7010009.

[21] Livingston ET, Mursalin MH, Callegan MC. A pyrrhic victory: the PMN response to ocular bacterial infections. Microorganisms 2019;7(11):537. https://doi.org/10.3390/microorganisms7110537.

[22] Midelfart J, Midelfart A, Bevanger L. Microbial contamination of contact lens cases among medical students. CLAO J 1996;22(1):21–4.

[23] Velasco J, Bermudez J. Comparative study of the microbial flora on contact lenses, in lens cases, and in maintenance liquids. ICLC 1996;23(2):55–8. https://doi.org/10.1016/0892-8967(96)00004-1.

[24] Rosenthal RA, Stein JM, McAnally CL, Schlech BA. A comparative study of the microbiologic effectiveness of chemical disinfectants and peroxide-neutralizer systems. CLAO J 1995;21(2):99–110.

[25] Ocansey S, Ovenseri Ogbomo GO, Abu EK, Morny EKA, Adjei-Boye O. Profile, knowledge, and attitude of contact lens users regarding contact lens wear in Ghana. Cont Lens Anterior Eye 2019;42(2):170–7. https://doi.org/10.1016/j.clae.2018.10.012.

[26] Bursac Z, Gauss CH, Williams DK, Hosmer DW. Purposeful selection of variables in logistic regression. Source Code Biol Med 2008;3:1–8.

[27] Udomwech L, Karnjana K, Jewboonchu J, Rattanathamma P, Narkkul U, Juhong J, et al. Bacterial microbiota of the contact lens surface and associated care

behaviours. Heliyon 2022;8(3):e09038. https://doi.org/10.1016/j.heliyon.2022.e09038.
[28] Sweeney DF, Stapleton F, Leitch C, Taylor J, Holden BA, Willcox MD. Microbial colonization of soft contact lenses over time. Optom vis Sci 2001;78(2):100–5. https://doi.org/10.1097/00006324-200102000-00010.
[29] Sweeney D, Holden B, Evans K, Ng V, Cho P. Best practice contact lens care: a review of the Asia Pacific Contact Lens Care Summit. Clin Exp Optom 2009;92(2):78–89. https://doi.org/10.1111/j.1444-0938.2009.00353.x.
[30] Dosler S, Hacioglu M, Yilmaz FN, Oyardi O. Biofilm modelling on the contact lenses and comparison of the in vitro activities of multipurpose lens solutions and antibiotics. PeerJ 2020;24(8):e9419. https://doi.org/10.7717/peerj.9419.
[31] Donzis PB, Mondino BJ, Weissman BA, Bruckner DA. Microbial contamination of contact lens care systems. Am J Ophthalmol 1987;104(4):325–33. https://doi.org/10.1016/0002-9394(87)90219-4.
[32] McMonnies CW. Improving patient education and attitudes toward compliance with instructions for contact lens use. Cont Lens Anterior Eye 2011;34(5):241–8. https://doi.org/10.1016/j.clae.2011.06.007.
[33] Collins MJ, Carney LG. Compliance with care and maintenance procedures amongst contact lens wearers. Clin Exp Optom 1986;69(5):174–7. https://doi.org/10.1111/j.1444-0938.1986.tb04586.x.
[34] Donshik PC, Ehlers WH, Anderson LD, Suchecki JK. Strategies to better engage, educate, and empower patient compliance and safe lens wear: compliance: what we know, what we do not know, and what we need to know. Eye Contact Lens: Sci Clin Pract 2007;33(6):430–3.
[35] Ayatollahi A, Mirfendereski SA, Shahcheraghi SH. Patient compliance in a contact lens wearing-population. Med Res Chronicles 2015;2(6):712–9.
[36] Sweeney DF, Willcox MD, Sansey N, Leitch C, Harmis N, Wong R, et al. Incidence of contamination of preserved saline solutions during normal use. CLAO J 1999;25(3):167–75.
[37] Jabir DM, Wathah EF. Isolation and diagnosis of the bacteria causing corneal ulceration associated with ocular myiasis infection. Indian J Forensic Med Toxicol 2022;16(1).