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The Disinfecting Potential of Contact Lens Soutions used by Sultan Qaboos University Students

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قدرة التطهير لمحاليل العدسات اللاصقة لدى طلاب جامعة السلطان قابوس

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الملخص: **الهدف**: دراسة قدرة التطهير لبعض محاليل العدسات اللاصقة لدى طلاب جامعة السلطان قابوس. **الطريقة**: تمت هذه الدراسة في الفترة من يناير إلى يونيو 2010 بقسم الأحياء الدقيقة والمناعة في كلية الطب والعلوم الصحية بجامعة السلطان قابوس. تم جمع 50 محلولا من المحاليل المصنعة من قبل شركات مختلفة والمستخدمة لحفظ العدسات اللاصقة من طلاب جامعة السلطان قابوس، وقمنا بفحص الجراثيم المتواجدة في المحاليل عن طريق زرعها في أوساط مخبرية متعددة. تم التعرف على أنواع الجراثيم والفطريات بطرق معملية معينة. **النتائج**: تم التعرف على 98 سلالة من الجراثيم والفطريات المختلفة، منها (23.5%) كانت لبكتيريا السيودوموناس اريجينوسا، و(13%) للبنسليوم و (9.2%) لكل من فطريات الكانديدا والمكورات السبحية غير الفارزة لأنزيم التخثر، و (6.1%) لسيراتيا مار سيسينس و(5.1%) لكل من العصيات والاسبيرجلس فلافس و(4.1%) لكل من سيراتيا ليكويفاسينس وسيودومونا فلوريسنس وانترباكتز كلويكيا واسبرجلس نيجر، و (3.1%) لكل من كريسوموناس ليوتولا و كريسوموناس اندولوجينس، و (2%) لكل من ستينوتروفومانس مالتوفيليا وسيراتيا اودوريفيرا و (1%) لكل من انتيروباكتر اريجونيس وكليبسيللا نيومونيا . لوحظ أن أكثر من (65%) من سلالات الجراثيم كانت من المحاليل المحتوية على بوليهكساتيد **الخلاصة**: أوضحت الدراسة أن المحاليل المستخدمة لحفظ العدسات اللاصقة تحوي نفس المكونات ولكنها مصنعة من عدة شركات لها قدرات تطهير مختلفة.

مفتاح الكلمات: عدسات، تطهير، تلوث، فطريات، عُمان.

abstract: ***Objectives:*** This study aimed to determine the disinfecting potential of some contact lens solutions used by some university students in Oman. ***Methods:*** This work was carried out from January to June 2010 in the Department of Microbiology & Immunology, College of Medicine and Health Sciences, Sultan Qaboos University, Oman. Fifty disinfecting solutions, in which contact lenses were disinfected according to the manufacturers' instructions, were collected from the students and plated on various microbiological culture media. Bacterial isolates were identified by API-20E, API-20NE and Phoenix automated systems while fungi were identified by their cultural characteristics and biochemistry. ***Results:*** From 98 isolates, *Pseudomonas aeruginosa* was 23.5%; *Penicillium*, 13%; *Candida* species, 9.2%; coagulase negative staphylococci, 9.2%; *Serratia marcescens*, 6.1%; *Bacillus*, 5.1%; *Aspergillus flavus*, 5.1%; *Serratia liquefaciens*, *Pseudomonas fluorescens*, *Enterobacter cloacae* and *Aspergillus niger*, 4.1% each; *Chryseomonas luteola* and *Chryseomonas indologenes*, 3.1% each; *Stenotrophomonas maltophilia*, *Serratia odorifera*, 2.0% each; *Enterobacter aerogenes* and *Klebsiella pneumoniae*, 1% each. Most isolates (65%) came from polyhexanide containing solutions. ***Conclusion:*** Contact lens disinfecting solutions with the same formulations, but manufactured by different companies, possessed different disinfecting potentials.

Keywords: Lenses; Disinfecting; Bacteria; Contamination; Fungi; Oman

Advances in knowledge

1. *This is the first time this type of study has been done at Sultan Qaboos University.*
2. *It was observed that different disinfecting solutions for contact lenses are used by students at Sultan Qaboos University.*
3. *Contact lens disinfecting solutions with the same formulation, but manufactured by different companies, possessed different disinfecting activity.*
4. *There is great need to revisit the US Food and Drug Administration guidelines on the use of multipurpose disinfecting solutions for contact lenses and storage cases.*

Application to patient care

1. *Manufacturers' guidelines for the decontamination of contact lenses and storage cases should be rigorously followed by the wearers.*

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2. *Wearers of contact lenses should be aware of the risk of developing microbial keratitis and corneal ulcers.*
3. *Good personal hygiene during decontamination of lenses and storage cases and during removal or placement of lenses on the eyes is essential.*

The soft contact lens industry has expanded rapidly over the past four decades because of the demand for a convenient alternative to wearing spectacles for various purposes. Contact lenses wear can be for correction of eye defects (myopia, hypermetropia, astigmatism and presbyopia), may be cosmetic (decorative) or therapeutic (for the treatment and management of bullous keratopathy, dry eyes, corneal ulcers and keratitis).[1] It is estimated that 125 million people worldwide use contact lenses of which 28–38 million are from USA and 13 million from Japan.[1] Soft hydrogel contact lenses are categorised according to their structure, water content, oxygen permeability and mode of wearing (daily wear, removed each night), extended wear (worn for 6 nights) and continuous wear (worn for 30 consecutive nights).[1-2] Their ability to aid vision, give comfort to the wearer and prevent microbial keratitis is highly advocated.[2-3] Silicone hydrogel contact lenses were introduced in 1999 for this purpose. Unfortunately, they are not better than other soft contact lenses for controlling microbial keratitis. Corneal infections continue to be the most serious complication of wearing contact lenses.[4-10]

However, many people who wear contact lenses are unaware of the likelihood of developing eye infections for some bacteria colonise and form biofilms inside lens storage cases.[3] In this state, they become resistant to disinfecting solutions.[11-12]

A study on 252 soft contact lenses, lens storage cases and disinfecting liquids found that 84.1% of the contact lenses, 80.9% of the lens storage cases and 63.1% of the disinfecting liquids were contaminated by *Staphylococcus aureus, Staphylococcus epidermidis, Viridans streptococci, Klebsiella pneumoniae, Pseudomonas aeruginosa, Pseudomonas fluorescens, Citrobacter amalonaticus* and *Stenotrophomonas maltophilia*.[13] Another study found 9% of lenses, 34% of lens storage cases and 11% of lens solutions contained *Serratia* spp, *S. aureus,* coagulase negative staphylococci and *P. aeruginosa*.[14] The contamination was traceable to users' dirty hands, or the tap water used to rinse the lens storage cases, and/or air contamination during drying of the cases.

Flynn *et al*[15] found contact lenses to harbour mostly Gram negative and coagulase negative staphylococci. Their mode of adhesion to lenses was through deposits of proteins, mucins, lipids and inorganic compounds produced by the eye.[16-19]

However, the results of studies on the efficacy of some contact lens solutions as effective disinfectants are conflicting.[20-21] The Federal Drug Administration (FDA) recommended the mode of assessing the efficacy of multipurpose contact lens disinfecting solutions using 'stand alone' (ISO/CD 14729) testing procedures. In this procedure, all multipurpose solutions are required to ensure a 3-log reduction in numbers on three bacterial strains (*S. aureus* (ATCC 6538), *Serratia marcescens* (ATCC 13880) and *P. aeruginosa* (ATCC 9027), 1-log reduction on *Candida albicans* (ATCC 10231) and *Fusarium solani* (ATCC 36031).[22] Although the recommendation ensured good disinfection of lenses by achieving 3-log reduction in cell numbers,[21,23] some researchers found many laboratory isolates viable in the solution[20,24,25] while others observed that many microbes associated with microbial keratitis were not represented in the approved panels of microbes used for the test.[26-27]

Disinfecting solutions containing polyhexanide were found to kill *Escherichia coli, S. epidermidis, P. aeruginosa, and S. marcescens* while solutions containing biguanides killed *E. coli* and *S. epidermidis,* but not *C. albicans*.[28] The reduced efficiency of some disinfecting solutions may be attributable to their formulations and mode of use.[29]

The aim of this study was to assess the disinfecting potential of some contact lens solutions used by some students at Sultan Qaboos University. It is envisaged that the results of this investigation can help establish the type of microbes in the solutions so that wearers can appropriately be advised.

Methods

This study was carried out from January to June 2010 in the Department of Microbiology & Immunology, College of Medicine and Health Sciences, Sultan Qaboos University, Oman. Fifty disinfecting solutions, in which contact lenses were disinfected according to the manufacturers' instructions, were collected from the students and plated on various microbiological culture media. No patient or patient's sample was utilised.

Each contact lens user was given three sterile bijou bottles, one for the disinfecting solution for the contact lens of the right eye, the second for the left eye, while the third served as a control (same as solution for disinfecting right or left eye lenses). This was done to check the degree of sterility of the solutions before immersion of the lenses. The lenses were immersed in the solutions at night and brought to the laboratory in the morning. Twelve brands of disinfecting solutions marketed by different manufacturers were investigated. The solutions were coded 1-12 to mask the manufacturers' names and to avoid brand name promotion.

INOCULATION OF MEDIA

Fifty microlitres of each solution were streaked on blood agar (BA, Oxoid, UK), cystine electrolyte deficient (CLED, H-Media Laboratories, India), and Sabouraud (SAB, Biotec, UK). All the plates were incubated at 37^{0}C for 48 hrs except Sabouraud plates which were incubated at room temperature for one week. Bacterial growths on the plates were identified using API 20-E, 20-NE (Biomerieux, France) and Phoenix automated system (Bacton Dickinson, Maryland, USA) while fungal growths were identified by their growth characteristics, the colour of aerial spores and structural differences using lactophenol cotton blue.

The FDA mode of testing disinfecting solutions for contact lenses (ISO/CD 14729) was not followed because of non-availability of the test organisms. However, any solution that allows growth of any microbe was regarded as contaminated and the contaminating organism was identified.

Table 1: Active agents in some contact lens disinfecting solutions and organisms isolated from them

Solutions (code)	Active agent	Samples (N)	Growth (N)	Isolate
Code 1	Polyhexanide (0.0001%)	15	7	*P. aeruginosa* *S. liquefaciens* *C. indologenes*
Code 2	Polyhexanide (0.0001%)	14	4	*P. aeruginosa* *S. marcescens* *Penicillium* species
Code 3	Polyhexamethylene biguanide (0.0001%)	1	1	*P. aeruginosa*
Code 4	Tetronic sulfactant	2	2	*P. aeruginosa* *A. flavus* *A. niger*
Code 5	Boric acid	2	1	*A. niger*
Code 6	Polydronium chloride (0.001%)	2	2	*P. aeruginosa*
Code 7	Hydroxyethyl methacrylate	1	0	No growth
Code 8	Polyaminopropyl Biguanide	6	0	No growth
Code 9	Polyhexanide (0.0001%)	4	2	*Bacillus, Penicillium* species
Code 10	Polyaminopropyl biguanide (0.0001%)	1	1	*Penicillium*
Code 11	Polyhexamethylene biguanide	1	0	No growth
Code 12	Polyhexamethylene biguanide	1	0	No growth
Totals		**50**	**20 (40%)**	

Table 2: Microbes isolated from various solutions

Solution used for right eye lenses	Solution used for left eye lenses	Control solutions
Coagulase negative staphylococci	Coagulase negative staphylococci	*P. aeruginosa* *Candida spp*
E. aerogenes *P. aeruginosa,* *C. luteola*	*E. cloacae* *P. aeruginosa* *C. luteola*	*C. indolegenes* *S. marcescens* *Penicillium*
C indolegenes, *Candida spp*	*K. pneumoniae* *S. marcescens*	*A. flavus* *S. liquefaciens*
A. flavus	*Candida spp*	*A. niger*
S. hominis *Bacillus* *S. liquefaciens* *Penicillium*	*E. cloacae* *A. flavus* *S. liquefaciens* *Candida spp*	*Bacillus spp*
S. marcescens *C. indolegenes* *S. marcescens*	*S. odorifera* *S. marcescens* *C. indolegenes*	
A. niger *A. flavus*	*A. niger* *Bacillus* *Penicillium spp*	
P. fluorescens *P. fluorescens* *S. odorifera* *E. cloacae*	*P. fluorescens* *S. maltophilia*	

Results

Although the sample sizes of the solutions were small and their manufacturers different, the same formulations marketed by different manufacturers gave different results [Table 1]. Forty percent (40%) of the solutions showed growth of various types of microbes. Solutions containing polyhexanide had 65% growth and were used by 66% of the students. This was followed by polyaminopropyl biguanide with 5% growth and used by 14% of the students. All the microbes contaminating control solutions were present in the solutions used for the right or left contact lenses, but not all the isolates contaminating the right or left contact lenses solutions were present in the control solutions [Table 2]. However, where the lens solutions and their aliquots (controls) were sterile, no organism was found. *P. aeruginosa* (23.5%) and *Penicillium* spp. (13.3%) were the most common isolates while *Klebsiella pneumoniae* and *Enterobacter aerogenes* were the least, 1% each [Table 3].

Discussion

Soft hydrogel contact lenses are used for various purposes (corrective, cosmetic or therapeutic) and are either for daily, extended or continuous wear. Users are advised to clean their contact lens cases and change disinfecting solutions daily except if they are silicone hydrogels for extended or continuous wear. Contact lenses offer some advantages over spectacles in terms of convenience and better visual acuity. However, the wearing of contact lenses may lead to serious complications including microbial keratitis and corneal ulcers which may lead to blindness.[7-9,30-31]

In this experiment, polyhexanide containing solutions, although greater in number, were the most contaminated. In contrast, polyaminopropyl and polyhexamethylene biguanides inhibited the growth of some microbes and allowed growth of others. Though their sample sizes were few, they possessed more antimicrobial properties than polyhexanides. This finding agrees with Santos *et al.*[3] and Hume *et al.*,[23] but disagrees with Cano-Parro *et al.*[28] who found polyhexanides better than biguanides.

In this study, *P. aeruginosa* had a prevalence of 23.5%. The factors contributing to its survival in some lens disinfecting solutions were traceable

to its adaptability to adverse environmental conditions and capability to attach easily to corneas and contact lenses (rigid, hydrogel, high and low water content contact lenses).[16,32-33]

In contrast, *Enterobacter, Serratia* and *Klebsiella* species which are usually of faecal origin can be transferred to the disinfectants by the wearers during the process of immersion or removal of the lenses from the solutions. In addition, some of the organisms like *Serratia* and *Pseudomonas* species are resistant to some disinfecting solutions.[20] Fungi like *Candida, Penicillium* and *Aspergillus* species are adaptive to diverse environments and require little moisture and organic substrate for growth. They are likely to come from poor or inadequate cleaning of contact lens cases since bacteria interacting with contact lens storage cases form biofilms that make them resistant to disinfecting solutions.[17] The nutrients for growth are acquired from lipids, proteins and glycoproteins present in the tears of the eyes.[35] However, when they are present on the lenses and lens cases, the efficacy of the disinfecting solution can be neutralised by their presence.[11] The isolates contaminating the control solutions also contaminated the solutions used for disinfecting left and right eye lenses. This indicates that the solutions were contaminated before the immersion of the lenses. In this study, it is observed that some control solutions were sterile although microbes were isolated from their aliquots used for disinfecting the right or left lenses [Table 2]. Such contamination is inferred to originate from the user (poor hand hygiene), the lenses or from the storage cases. Some researchers observed that non-compliance with the guidelines for caring for contact lenses and lens cases was a major issue in the use of contact lenses.[32] Their observation was supported by the finding that 11% of the contamination of solutions was due to poor hand hygiene, 13% to inadequate disinfection of lenses, and 61% to inappropriate cleaning practices of storage cases.[31,32] From whatever source and by whatever means, the organisms got into the solutions and some of the disinfectants could not eliminate the organisms. This experiment appears to establish the fact that disinfecting solutions for lenses are not sterilising solutions, but agents meant to reduce the microbial numbers on lenses and cases

Conclusion

Twelve disinfecting solutions for soft hydrogel contact lenses were examined for growth of microbes after lenses were removed from the eyes and immersed overnight in the disinfecting solutions. Forty percent (40%) of the solutions grew some microbes, with polyhexanide containing solutions showing highest growth (65%). The least growth (5% and 5% respectively) came from polyhexamethylene and polyaminopropyl biguanides. Because of the small and unequal number of samples investigated, it is statistically difficult to state which is the best disinfecting solution.

The small number of samples used in this study limits the outcome of the investigation. Further work using larger samples and looking for parasites like *Acanthamoeba* is necessary. However, it is of importance that multipurpose solutions which clean, disinfect and rinse contact lenses and their cases be used for all contact lenses.[17,21,24,] The lenses should be stored dry in their cases after disinfection. Before removing the lenses from the eyes, the user should wash his/her hands thoroughly in soapy water. If a multipurpose solution containing hydrogen peroxide is used for disinfecting the lenses, the lenses should be rinsed several times in saline solution to get rid of the hydrogen peroxide which is toxic to the eyes.[35] It should be borne in mind by all contact lens users that the disinfecting solutions do not sterilise contact lenses and lens cases, but only reduce the microbial load on them. The reduction is only possible if the organisms to be reduced are susceptible to formulations in the disinfecting solutions. Currently, the performance of disinfecting solutions for all types of contact lenses is being re-visited and various formulations are being suggested.[20,21]

CONFLICT OF INTEREST

The authors reported no conflict of interest.

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Table 3: Percentage distribution of isolates from all solutions

No.	Organisms	No. of isolates	Percentage
1	*P. aeruginosa*	23	23.5%
2	*Penicillium* spp.	13	13.3%
3	*Candida* spp.	9	9.2%
4	Coagulase negative staphylococci	9	9.2%
5	*S. marcescens*	6	6.1%
6	*Aspergillus flavus*	5	5.1%
7	*Bacillus*	5	5.1%
8	*S. liquefaciens*	4	4.1%
9	*P. fluorescens*	4	4.1%
10	*E. cloacae*	4	4.1%
11	*Aspergillus niger*	4	4.1%
12	*C. luteola*	3	3.1%
13	*C. indolegenes*	3	3.1%
14	*Stenotrophomonas maltophilia*	2	2.0%
15	*S. odorifera*	2	2.0%
16	*E. aerogenes*	1	1.0%
17	*K. pneumoniae*	1	1.0%
Total		**98**	**100%**

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