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Epidemiology of *Pseudomonas aeruginosa* keratitis in contact lens wearers

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SUMMARY

This study evaluated the epidemiology of *Pseudomonas aeruginosa* keratitis in contact lens (CL) wearers; the relationships between CL storage case contamination and CL hygiene practice and between CL hygiene and the development of keratitis. Sixteen CL wearers with keratitis were compared with 44 asymptomatic controls. Lens hygiene practice was assessed and CL care materials, domestic water sites and endogenous sites were evaluated microbiologically. Poor CL hygiene was not associated with *Ps. aeruginosa* keratitis. There was an association between keratitis and bacterial contamination of the CL and storage case ($P < 0{\cdot}0005$). Lens and storage case contamination were not significantly associated with poor hygiene. No domestic or endogenous source for *Ps. aeruginosa* was found. Causative organisms may be derived from other sources, but CLs and CL storage cases provide a favourable environment for *Ps. aeruginosa* colonization. Changing the CL care environment to one less favourable for *Ps. aeruginosa* may help to eliminate this problem.

INTRODUCTION

Ulcerative keratitis is a rare but potentially sight threatening complication of cosmetic contact lens (CL) wear. Prior to the widespread use of CLs for the correction of low refractive errors, ulcerative keratitis was rare in normal eyes, occurring mainly with trauma, previous surgery or ocular surface disease and in therapeutic or aphakic CL wearers [1]. A recently published case control study [2], has shown that CL wear for the correction of low refractive errors now accounts for 65% of all new cases of microbial keratitis at Moorfields Eye Hospital. The majority of these cases have been attributed to hydrogel CL wear, particularly with overnight use.

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The spectrum of microbes differs significantly between CL and non-CL related keratitis. Keratitis in cosmetic CL users is commonly caused by *Pseudomonas aeruginosa*, which has been implicated in up to 70% of culture-proven infections [3–5]. Other causative organisms include Gram negative species, such as *Serratia marcescens* [6], *Proteus* sp. [7], and other *Pseudomonas* sp. [8]. Of the Gram positive species, *Staphylococcus* sp. and *Streptococcus* sp. predominate [9]. Amongst aphakic lens wearers, *Staphylococcus* and *Streptococcus* sp. are the most frequently implicated organisms with *Ps. aeruginosa* accounting for 25% of culture-proven ulcers [5]. Less commonly, CL related keratitis may be attributed to *Acanthamoeba* sp. or fungi.

In CL related keratitis, the CL storage case is frequently contaminated with the causative organism [10]. However the endogenous and exogenous sources of these organisms have not been investigated.

The aims of this study were to investigate the epidemiology of *Ps. aeruginosa* infections; the relationship of CL storage case contamination to CL hygiene practice; and the relationship between CL hygiene practice and the development of keratitis. Possible sources of *Ps. aeruginosa* were investigated to identify the causative organism. The lens care material, including CL, lens storage case and all solutions used, plus the domestic water environment were sampled for bacterial contamination. Endogenous sources were sampled (throat, finger, toe web and stool) in wearers with culture-proven keratitis to assess their carrier status for *Ps. aeruginosa*.

SUBJECTS

Subjects

The study population comprised new attenders to the casualty department of Moorfields Eye Hospital, who wore lenses for the correction of low refractive errors only.

Cases

Sixteen CL wearers attended the casualty department between 22 April 1988 and 23 May 1991 with a diagnosis of *Ps. aeruginosa* keratitis, which had been confirmed with a corneal culture.

Controls

Forty-four contemporaneous CL wearing controls were identified. Controls were defined as wearers without a CL related disorder, who presented immediately subsequent to a wearer with keratitis, and who were willing to be visited at home.

METHODS

Lens hygiene

Data on CL type and hygiene was abstracted from a questionnaire completed by all CL wearers. Hygiene scores were based on the frequency of CL cleaning, CL disinfection and use of enzyme tablets, as described previously [2, 11]. A maximum score of 18 for daily wear CL users is achieved with daily cleaning scoring 7, daily disinfection scoring 7 and weekly use of enzyme tablets scoring 4. Hygiene scores for extended wear soft CL users were based on the level of hygiene

which occurred each time the CLs were removed. Good hygiene, with a score of 14 or greater, was assumed to require a minimum of lens cleaning and disinfection, in accordance with manufacturers' instructions, each time the lenses were removed.

Lens care material sampling

Samples were collected from all CL care materials, including CLs, CL storage cases and care solutions. Lens storage case wells were sampled using sterile swabs and 3 ml of each solution used was sampled. Lenses were either agitated in a vortex mixer or manually shaken in 3 ml of phosphate buffered saline. Care material samples were collected from 16 wearers with *Ps. aeruginosa* keratitis and 44 asymptomatic controls.

Domestic environment and lens care materials were sampled on one occasion and all samples were cultured on multiple solid media, including 4% blood agar (Oxoid Ltd, UK), cetrimide agar [Pseudomonas agar (Oxoid UK, Ltd) plus CFC supplement (Difco UK, Ltd)].

RESULTS

Lens hygiene

Good hygiene was reported in 9/16 wearers with keratitis, with a further 3 reportedly fully compliant disposable extended wear soft lens users, and in 16/43 controls. Hygiene information was unavailable from one control wearer. An association could not be found between poor hygiene and *Ps. aeruginosa* keratitis ($P = 0{\cdot}288$), and a significant trend was not present (χ^2 test).

Lens care material contamination

Table 1 shows the breakdown by lens type for each of the 60 CL wearers evaluated. Of the 16 wearers with culture-proven *Ps. aeruginosa* infections, 3 wore disposable extended wear CLs with *Ps. aeruginosa* contamination of the CL. Of the 13 wearers of reuseable CLs, 11 had co-contamination of the lens storage case and 2 had contamination of the CL, CL storage case and care solutions. One rigid CL wearer had *Ps. aeruginosa* contamination of the CL wetting solution only. In one patient with keratitis, contamination could not be found from any of the lens care material sampled. Where *Ps. aeruginosa* was isolated from the care materials of patients with culture-proven keratitis, antibiotic susceptibility testing demonstrated similar antibiograms to the respective corneal isolate. However, these may not necessarily be identical strains.

Table 2 shows the frequency of organisms isolated from the lens care materials from wearers with keratitis ($n = 16$) and controls ($n = 44$). Compared with control wearers, both CL and CL storage case contamination were strongly associated with culture-proven keratitis ($P < 0{\cdot}0005$). Contamination of commercial lens solutions, however, did not occur more frequently amongst wearers with keratitis; a similar range of care systems were used by the wearers with keratitis and controls. The hydrogel disinfection systems used by the study group were a range of cold chemical systems, including two stage hydrogen peroxide, chlorine release and thiomersal and chlorhexidine preserved systems. However, the sample group was too small to enable detailed comparisons between care system types.

Table 1. *Comparison of lens type for wearers with keratitis and asymptomatic controls*

Lens type	*Pseudomonas* keratitis	Controls
Soft lenses		
DW-SCL*	6	29
EW-SCL†	3	2
Disp DW-SCL‡	3	0
Disp EW-SCL§	3	0
Rigid lenses		
PMMA-HCL‖	0	7
RGP-HCL¶	1	6

* DW-SCL, Daily wear soft contact lenses.
† EW-SCL, Extended wear soft contact lenses.
‡ Disp DW-SCL, Disposable daily wear soft contact lenses.
§ Disp EW-SCL, Disposable extended wear soft contact lenses.
‖ PMMA-HCL, Polymethylmethacrylate hard contact lenses.
¶ RGP-HCL, Rigid gas permeable hard contact lenses.

Table 2. *Frequency of contamination of the CL, CL storage cases and commercial solutions from wearers with* Ps. aeruginosa *keratitis* (n = 16) *and asymptomatic controls* (n = 44)

	Wearers with *Ps. aerug** keratitis			Controls		
	CL	Case†	Soln‡	CL	Case†	Soln‡
*Ps. aerug**	7	5	3	0	0	0
*Ps. aerug** and other Gram negative rods	5	5	0	0	0	0
Ps. fluor§ and *E. coli*‖	1	1	0	0	0	0
Coliforms	0	0	2	10	13	7
S. aureus¶ and coliforms	0	0	0	0	1	1
CNS** and *micrococci*	0	0	0	0	1	0
CNS** and coliforms	0	0	0	1	1	1
Total positive cultures	13	11	5	11	16	9
Total sampled	14	13	24	42	44	108

* *Ps. aerug*, *Pseudomonas aeruginosa*.
† Case, CL storage case.
‡ Soln, Commercial solution.
§ *Ps. fluor*, *Pseudomonas fluorescens*.
‖ *E. coli*, *Escherichia coli*.
¶ *S. aureus*, *Staphylococcus aureus*.
** CNS, Coagulase negative staphylococci.

Two wearers in the control group used home made saline (as a diluent for protein removal tablets). Both solutions were found to be contaminated with non-lactose fermenting Gram negative organisms. *Ps. aeruginosa* was not isolated from the care materials used by asymptomatic wearers.

Hygiene results for wearers with and without storage case contamination were compared for all wearers with keratitis ($n = 16$) and asymptomatic controls ($n = 43$). Poor CL hygiene (hygiene practice scores of less than 14) was not found to be associated with more frequent CL or CL storage case contamination either

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for wearers with *Ps. aeruginosa* keratitis ($P = 0{\cdot}55$) or asymptomatic wearers ($P = 0{\cdot}39$). A similar analysis was performed for daily wear soft lens users only, and no association was found between bacterial contamination and poor hygiene for either cases ($n = 9$) or controls ($n = 29$).

Domestic environment sampling

Ps. aeruginosa was not isolated from any of the domestic sites sampled. Bacterial contamination rates were similar for wearers with keratitis and controls. Of the 10 wearers with keratitis, lactose and non-lactose fermenting Gram negative rods were isolated from 6 bathroom cold taps, 7 bathroom basin drains and 4 kitchen cold taps. Of the 44 controls, Gram negative rods were isolated from 25 bathroom taps, 34 bathroom basin drains and 22 kitchen cold water taps. Apparently similar environmental Gram negative and coliform organisms were cultured from both domestic water sites and lens storage cases in 3/10 wearers with culture-proven keratitis and in 15/44 controls.

Endogenous sampling

Personal carriage of *Ps. aeruginosa* was not detected in 12 wearers with culture-proven keratitis.

DISCUSSION

Ps. aeruginosa is the organism most frequently associated with CL related keratitis, although the epidemiology of this organism in CL wearers is not always clear. This study has examined possible endogenous and exogenous sources of *Ps. aeruginosa* in lens wearers.

Using a small sample of wearers with proven *Ps. aeruginosa* keratitis, this study has failed to demonstrate an association between poor hygiene practices and culture-proven keratitis. However, a larger population study has demonstrated a weak association between infrequent lens disinfection and microbial keratitis amongst DW-SCL users only [2]. An association or trend between poor hygiene and keratitis has not been found for EW-SCL users, despite a higher risk of keratitis for overnight lens use [2, 13]. Similar findings were reported by Mondino and colleagues in 1986 [14], where keratitis was found to occur despite good lens hygiene amongst EW-SCL users.

In addition, the current study has failed to demonstrate an association between contamination of either the CL or CL storage case with poor lens hygiene in either asymptomatic wearers or those with keratitis. This confirms the implications of these previous studies that good hygiene practice does not necessarily result in contamination free CLs and CL storage cases [15]. This may suggest that either methods for assessing hygiene compliance are imprecise or more probably that CL care systems are less than effective in the hands of the user.

The finding of an association between CL or CL storage case contamination and *Ps. aeruginosa* keratitis agrees with results from previous studies [8, 10, 14]. However, several studies have shown that microbial contamination of the lens storage case may also be present in 50% of asymptomatic wearers [16, 17]. Using a control group of asymptomatic wearers, this study has shown that bacterial contamination of the lens storage case is significantly associated with *Ps.*

aeruginosa keratitis. The control group was however, too small to control for CL type and CL care system, a larger control group would be required in order to explore these variables. The association between CL storage case contamination and *Ps. aeruginosa* keratitis does not explain the development of keratitis in all subjects. In this study, keratitis has been reported in three reportedly compliant wearers using extended wear disposable lenses, and in one other user without co-existing contamination of the lens care materials.

It is particularly interesting that *Ps. aeruginosa* was not cultured from any source in the asymptomatic control wearers, despite a high rate of CL case contamination with other organisms in this group (16/44). It is possible that only those unfortunate enough to acquire *Ps. aeruginosa* contamination by serendipity, will develop keratitis. This high rate of bacterial contamination in asymptomatic wearers, with environmental lactose and non-lactose fermenting Gram negative organisms, may contribute to the development of sterile keratitis possibly due to bacterial antigens and toxins [11] and in CL related acute red eye [18].

Laboratory studies have demonstrated that *Ps. aeruginosa* will readily adhere to a variety of polymer surfaces [19, 20]. This adherence and subsequent biofilm formation by micro-organisms is a common strategy for survival in natural ecosystems [21]. It may also explain the persistence of this organism on lenses and in lens cases from wearers with culture-proven infections [15, 22]. The role of the CL and CL storage case may be to amplify the inoculum of organisms. Further study is necessary to elucidate the mechanisms involved and the relationship to both the pathogenesis of CL related infections and to the persistence of organisms in CL storage cases in reportedly compliant, asymptomatic CL wearers.

Ps. aeruginosa may be derived from various endogenous and environmental sources. The conjunctiva may be a possible source of organisms although several studies have shown no difference in the conjunctival flora of CL users compared with non-CL users [23–25]. Other studies however, have shown an increased rate of isolation of organisms [26–28] in contact lens wearers. One study has related the conjunctival flora to the CL storage case contaminants [25]. Endogenous sources include the human gut and upper respiratory tract [29]. Environmental sources include water, soil and vegetation [29].

In this study, similar strains of *Ps. aeruginosa* to the corneal isolate were not found amongst the domestic sites sampled. It is possible that the sampling technique for tap swabs was not sufficiently sensitive to detect small numbers of organisms which may be present in the water supply. A more sensitive technique for recovery of small numbers of organisms would involve filtration of water samples [30]. However, one study has demonstrated that *Ps. aeruginosa* is rare in the domestic environment [31], being present in only 6% of samples from domestic taps and drains.

Personal carriage of *Ps. aeruginosa* was not detected in the small group of patients sampled on one occasion only. Previous studies have estimated that *Ps. aeruginosa* is present in the throat and stool of 2–10% of normal individuals [29]. A larger sample group or repeated sampling may have confirmed this, but this study has shown that individuals with *Ps. aeruginosa* keratitis are not invariably colonized with this organism and other sources are more likely.

Contact lens and CL storage case contamination with *Ps. aeruginosa* are not

invariably secondary to obvious sources of this organism. Contamination presumably results from transient sources of *Ps. aeruginosa* either in the environment or endogenously. A change in the CL care environment to one less favourable for *Ps. aeruginosa* may help to eliminate this problem.

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