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Acanthamoeba Keratitis among Rigid Gas Permeable Contact Lens Wearers, United States, 2005–2011

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Abstract

Objective—To describe the clinical presentation and outcomes of *Acanthamoeba* keratitis (AK) in rigid gas permeable (RGP) contact lens wearers and identify modifiable risk factors.

Design—A case-control investigation.

Participants—Case-patients were RGP contact lens-wearing U.S. residents with a diagnosis of AK during 2005–2011. Controls were RGP contact lens wearers with no history of AK and at least 12 years of age.

Methods—Case-patients were identified during two multi-state AK outbreak investigations. Controls from the first investigation in 2007 were identified using a reverse address directory. In the second investigation, controls were recruited from participating ophthalmology and optometry practices. Case-patients and controls were interviewed by phone using a standardized questionnaire. Odds ratios (ORs) and Fisher's exact *P*-values were calculated to assess risk factors associated with infection.

Main Outcome Measures—AK, a rare eye disease primarily affecting contact lens wearers, is caused by free-living amebae, *Acanthamoeba* spp.

Results—We identified 37 case-patients in the two investigations, 10 (27%) from the 2007 investigation and 27 (73%) from 2011. There were 17 healthy controls, 9 (53%) from 2007 and 8 (47%) from 2011. Among case-patients, 9 (24%) wore RGP lenses for orthokeratology or therapeutic indication; no controls wore RGP lenses for these indications. Significant risk factors for AK were wearing lenses for orthokeratology (OR undefined, P=0.02), sleeping while wearing lenses (OR 8.00, P=0.04), storing lenses in tap water (OR 16.00, P=0.001), and topping off contact lens solution in the case (OR 4.80, P=0.01). After stratifying by use of RGP lenses for orthokeratology, storing lenses in tap water and topping off remained significant exposures.

Conclusions—Nearly a quarter of case-patients were orthokeratology wearers. Using tap water to store RGP lenses and topping off solution in the lens case were modifiable risk behaviors

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identified in RGP wearers who wore lenses for both orthokeratology and non-orthokeratology indications. RGP wearers should avoid exposing their lenses to tap water and should empty their cases and use fresh lens solution each time they take out their lenses.

Acanthamoeba keratitis (AK) is a severe infection of the eye with significant risk of vision loss due to corneal ulceration and scarring. *Acanthamoeba* species are free-living amebae ubiquitous in the environment and found in water and soil. Wearing soft contact lenses (SCL) is a well-documented risk factor for *Acanthamoeba* eye infection[1]; however, AK reports in patients who wear rigid contact lenses, such as rigid gas permeable (RGP) contact lenses , are limited and risk factors for developing AK among RGP wearers have not been previously described.

In the United States, RGP lenses are used by a small proportion of contact lens wearers for the correction of simple refractive error. The most recent estimates suggest that RGP lenses comprise approximately 6.5% of the 40.9 million contact lens wearers in the United States.[2] Soft contact lenses are much more comfortable, especially on initial fitting, and are available in a wide range of powers accommodating mild to moderate amounts of astigmatism. RGP lenses are often used in the setting of high astigmatism, irregular astigmatism and for orthokeratology (the practice of using RGP lenses to temporarily reshape the cornea to reduce refractive errors).

Among soft contact lens wearers, case-control studies have shown several behaviors to be risk factors for AK. These include use of homemade saline, suboptimal disinfection of lenses, and “topping off” (adding new solution to an existing volume of used solution in the lens case).[1, 3, 4] Reported cases of *Acanthamoeba* infection in RGP wearers have been few, primarily in orthokeratology patient case reports and case series.[5-9] However, to our knowledge, no controlled studies assessing risk factors for AK among RGP wearers have been published.

In 2007 and 2011, the U.S. Centers for Disease Control and Prevention (CDC) conducted multi-state investigations of nationwide AK outbreaks. From these investigations, we present the largest case series to date of AK in rigid lens wearers, a description of clinical outcomes, and analyses of risk factors for infection using healthy RGP wearer controls.

METHODS

Case-patients and controls for this analysis were identified during two multi-state outbreak investigations conducted by CDC in 2007 and 2011. The goal of these investigations was to determine clinical characteristics, risk factors, diagnostic modalities and outcomes of AK cases. Methods for the 2007 investigation have been described previously.[4] Briefly, case-patients with confirmed AK (defined as AK with onset of symptoms on or after January 1, 2005; diagnosed by an ophthalmologist; and confirmed by cultures of corneal specimens) were solicited from ophthalmologists, laboratories, and public health officials nationwide. Controls were recruited via random-digit dialing and were restricted to persons who had no history of AK.

For the 2011 investigation, case-patients with confirmed AK (defined as AK with onset of symptoms between January 1st, 2008 and June 12th, 2011; diagnosed by an ophthalmologist; and confirmed by culture, histology or confocal microscopy) were identified from a sentinel network of 15 reference laboratories and ophthalmologic institutions formed in response to the 2007 investigation or new collaborations with additional institutions.[10] Because control recruitment via random-digit dialing had been resource-intensive in the 2007 investigation, controls were recruited from patients of optometrists and ophthalmologists located in the same states of residence as case patients. Controls wore contact lenses and had no history of AK.

Both investigations were conducted as part of an urgent public health response and as such, were deemed non-research by the Human Research Protection Coordinator and not subject to Institutional Review Board approval. Both cases and controls provided informed consent to be interviewed. Excepting basic demographic and clinical characteristics, the data derived from RGP case-patient and control interviews used in this study have not been published previously.

For both outbreak investigations, case-patients and controls were interviewed by phone with a standardized questionnaire that assessed contact lens use, contact lens care behaviors and risk factors, and demographics. To gather more information about their illness, case-patients were also asked about their symptoms. In addition, standardized chart abstraction forms were sent to the case-patients' ophthalmologists in order to collect information on presenting signs and symptoms, disease progression, diagnosis, treatment and outcome.

This analysis was restricted to case-patients and controls who reported wearing RGP lenses. Data from phone interviews and chart abstraction forms were analyzed using SAS 9.3 © (SAS Institute Inc., Cary, NC, USA). Odds ratios (ORs) and p-values were calculated to assess exposures associated with case-control status. Because of the small numbers in this analysis, exact p-values were calculated using Fisher's exact test in place of confidence intervals. Results were considered statistically significant at $P<0.05$. Additionally, because of the small numbers in this analysis, multivariable logistic regression was not conducted. Instead, to examine differences in exposures between orthokeratology patients and non-orthokeratology patients, stratified analyses were conducted.

RESULTS

We identified 37 case-patients in the two investigations, 10 (27%) from the 2007 investigation and 27 (73%) from 2011. There were 17 healthy RGP-wearing controls, 9 (53%) from 2007 and 8 (47%) from 2011. The most frequently reported symptoms among case-patients were redness, sensitivity to light, and increased tearing (Table 1). The median time from onset of symptoms to initiation of anti-ameba treatment was 40 days (range 13–1154 days). At the time of data collection, 10 (30.3%) of 33 case-patients with known outcome had undergone keratoplasty after failing anti-ameba therapy and 18 (56.3%) of 32 had a visual acuity of 20/200 or worse with best correction (i.e. legally blind) in the affected eye.

Demographic features of the cases and controls are summarized in Table 2. Among the 37 RGP wearers with AK, a minority (10 cases, 27%) were male and most (23 cases, 62%) were over 55 years of age. Among controls, 1 respondent (6%) was male and half (8 controls, 50%) were over 55 years of age. Among cases, 9 (24%) wore RGP lenses for orthokeratology (8 cases) or therapeutic indication (1 case); no controls wore RGP lenses for these indications. Most cases (81%) and all controls (100%) had worn contact lenses for more than 10 years.

Table 2 shows the prevalence and unadjusted odds ratios for exposures. In univariable analyses, cases had higher odds of being 25 years of age or less (vs. being 26-55 years of age) when compared with controls (OR undefined, P=0.04). Cases were more likely to wear lenses for orthokeratology or therapeutic indication (OR undefined, P=0.02), wear lenses for less than 12 hours per day (OR 3.66, P=0.04), or sleep in their contact lenses (OR 8.00, P=0.04) in comparison with controls.

Cases had elevated odds of having municipal water as their tap water source (vs. a private well) compared with controls (P=0.02). Cases also had significantly higher odds of ever storing their lenses in tap water (OR 16.00, P=0.001) and of topping off solution (OR 4.80, P=0.01). Forty-five percent of case-patients who used municipal water reported storing their lenses in water compared with 10% of controls. Among users of private well water, 66.7% of case-patients reported storing their lenses in water compared with none of the controls.

To examine differences in exposures between orthokeratology wearers and others, we stratified results by use of rigid lenses for orthokeratology or therapeutic use. Among rigid lens wearers who did not wear lenses for orthokeratology or therapeutic indication (wore for vision correction only), being age ≤ 25 years, reporting duration of wear < 12 hours per day, and wearing lenses overnight were no longer significantly associated with case status, despite remaining elevated (Table 3). Because no controls were orthokeratology patients, we were unable to further compare exposures among RGP wearers who were orthokeratology patients.

DISCUSSION

This analysis of the largest case series of AK in RGP contact lens wearers in the United States identified important characteristics of clinical presentation and outcomes, along with significant differences in exposures between case-patients and controls. Case-patients had elevated odds of two potentially modifiable behaviors, storing lenses in tap water and topping off lens solution in the case. A notable finding of this study was that nearly a quarter of AK case-patients were orthokeratology wearers.

Cases and case series of AK among orthokeratology wearers have been reported in the literature previously.[6-9, 11] However, to our knowledge, this analysis is the first to examine exposure to orthokeratology in a case-control study of AK. The only other study to date that has looked at orthokeratology as a risk factor for microbial keratitis used a retrospective cohort design and found that the risk of microbial keratitis in orthokeratology wearers was similar to other overnight modalities.[12] No cases of AK were reported in that study.

Although a quarter of AK case-patients in this analysis were orthokeratology wearers, no controls were, and an odds ratio assessing the risk of wearing RGP lenses for orthokeratology in AK case-patients could not be calculated. However, a recent survey of contact lens prescribing trends in the United States found that an average of 4.5% of rigid lens fits were for orthokeratology.[13] If 4.5% of the controls in this analysis had been orthokeratology wearers, case-patients would have 6.8 times the odds of being an orthokeratology wearer when compared with controls.

Orthokeratology wearers could be at greater risk of developing AK. However, orthokeratology wearers as a group differ from other RGP wearers in several ways and potential for confounding exists. Orthokeratology wearers tend to be younger on average, and younger age has been associated with poorer contact lens hygiene.[14] Sleeping in contact lenses, which is usually how orthokeratology lenses are prescribed, is a known risk factor for microbial keratitis, but has not been a consistent risk factor for either amebic or fungal keratitis among soft contact lens wearers.[15-18] However, sleeping in contact lenses when tear production is physiologically decreased, regardless of the material, potentiates changes in the cornea that can result in corneal epithelial microtrauma that puts the contact lens wearer at higher risk for keratitis.[19] Additionally, orthokeratology lenses are fit with a different lens/cornea relationship than non-orthokeratology lenses.[20] This fit leads to a greater bearing on the central cornea which may compromise the corneal epithelial barrier and exposes the cornea to several hours of hypoxia leading to a higher risk of infections.[21] Other therapeutic indications that mold the corneal surface might also increase the risk of corneal microtrauma**.** As a result, contact lens wearers of any type should consider minimizing contact lens wear while sleeping. For those patients in whom overnight wear for orthokeratology is considered, strict adherence to good contact lens hygiene practices and avoidance of tap water for storage (no FDA-approved care regimen recommends tap water storage) should be highly recommended in order to minimize risk of AK or other types of microbial keratitis. Furthermore, the appearance of keratitis in an individual using contact lenses for orthokeratology should trigger concern for the possibility of AK.

Younger age, wearing lenses for less than 12 hours per day, and overnight contact lens wear were found to be significant risk factors in the overall analysis. Based on characteristics of typical orthokeratology patients (younger patients, wearing lenses overnight for <12 hours), we hypothesized that these risk factors were actually markers for orthokeratology. When analyses were restricted to non-orthokeratology wearers, odds of age <25 years, duration of wear <12 hours per day, and overnight lens wear were still elevated but no longer statistically significant in case-patients. Younger age may be associated with poorer contact lens hygiene and overnight contact lens wear has been previously associated with microbial keratitis.[14, 16] Wearing lenses <12 hours per day has not been previously reported as a risk factor, to our knowledge, but could perhaps be associated with longer time in the lens case (i.e., prolonged exposure to a potentially contaminated lens case) or be a marker for uses of lenses for orthokeratology (i.e. wearing only while sleeping overnight which would typically amount to <12 hours of wear).

Case-patients were 16 times more likely than controls to store their lenses in tap water. This modifiable risk factor for AK has been reported previously and has clear biologic

plausibility.[22-25] *Acanthamoeba* is a hardy, chlorine-resistant organism that thrives in the nutrient-poor setting of drinking water distribution systems and premise plumbing.[26] *Acanthamoeba* is a frequent inhabitant of biofilms in pipes and was found in 51% of households in an Ohio study, 9.3% of household samples in West Virginia and 13% of drinking water distribution systems in Virginia.[27-30] Thus, recommendations to contact lens wearers to avoid tap water exposure are a refrain that echoes back to some of the first investigations of *Acanthamoeba* keratitis in contact lens wearers in the 1980's.[3] That 50% of case-patients in this analysis reported storing their lenses in tap water is perhaps an indication of the need for continued reiteration of this recommendation.

Although rinsing lenses with tap water was not significantly associated with case status in this analysis, case-patients were twice as likely than controls to rinse their lenses in tap water (OR 2.04, p=0.1984). While lens storage in tap water likely represents a much more prolonged, intense exposure to *Acanthamoeba* compared with rinsing lenses in tap water, the small number of participants in this analysis mean that an elevated risk for *Acanthamoeba* keratitis among contact lens wearers who rinse their lenses with tap water cannot be ruled out.

Some RGP cleaning systems continue to recommend the use of tap water for the rinsing step.[31] Based on instructions that state to rinse with tap water, RGP wearers might assume that storage in tap water is acceptable as well. To avoid mixed public health messaging, it might be preferable to advise RGP wearers to avoid tap water in all steps of the cleaning process and storage of their lenses. The use of commercial saline as a rinse may be a reasonable alternative to tap water.

While the association of AK and contact with tap water is clear, the association between the type of water source and AK is less so. Case-patients were more likely to have municipal water (vs. a private well) than controls. Among case-patients, 8.6% of respondents identified a private well as their drinking water source, while 37.5% of controls had well water. The prevalence of well water use among the 17 controls in this study is higher than that found in the general U.S. population (approximately 12% of households are supplied by a private well).[32] *Acanthamoeba* spp. are a common microbial inhabitant of water sources, including wells and groundwater sources[28, 33, 34] and studies have shown an increased risk for AK associated with showering, using hot tubs, and swimming with contact lenses.[35, 36] Other studies have shown associations with AK and water quality, case-patient geography, and water storage practices.[22, 36, 37] The role of biofilm formation in water systems, methods of water treatment, and their contribution to the presence of *Acanthamoeba* in tap water is still not clear and requires further study.

Case-patients were more likely to report topping off. This modifiable risk factor has been previously identified in soft contact lens wearers in two multistate outbreaks of microbial keratitis, one involving *Acanthamoeba* and the other, *Fusarium*.[4, 38] Contact lens solution in the lens case can become contaminated (e.g., by organisms on contact lenses or transferred via fingers when placing lenses in the case). Topping off may also promote the formation of biofilm, which is a food source for *Acanthamoeba*.[39] As the solution is exposed to more organic material, the disinfectant is consumed, leaving less disinfectant available to

inactivate pathogens.[40-42] Subsequently, when a fraction of new disinfectant is added to the old, inactive solution ("topping off"), the active disinfectant concentration is diluted significantly, allowing pathogens to proliferate on the lens and in the case. Therefore, rigid lens wearers should avoid topping off the disinfecting solution in the lens storage case.

RGP wearers with AK had similar presenting symptoms to soft contact lens wearers with AK identified in the 2007 outbreak investigation.[4] While the median time from onset of symptoms to initiation of anti-ameba therapy was no longer in RGP case-patients compared with soft contact lens wearers in the 2007 investigation (40 days vs. 49 days)[4], some RGP case-patients did not receive treatment until over a year after symptom onset, potentially leading to worse outcomes. A similar proportion of RGP wearers required keratoplasty (30% vs 29%) but a higher proportion had a best corrected visual acuity of 20/≥200 in the affected eye (56% vs. 41%) compared with soft contact lens wearers from the 2007 investigation.[4] The diagnosis of AK should be considered early in a patient with keratitis to ensure the best chance for full recovery.

The findings of this analysis are subject to several limitations, including both those present in the larger case-control investigations from which these case-patients and controls were derived as well as those inherent to this particular analysis. Limitations of the larger 2007 and 2011 investigations included recall bias related to participants' limited recollection of behaviors during the 2 years before the investigations. Additionally, selection bias might have been present among controls given the low response rate among controls and the use of ophthalmology and optometry office-based controls. In this particular analysis, our findings are limited by the small sample size of RGP wearers, likely reducing the statistical power to detect smaller differences among the case-patients and controls as well as prohibiting the use of a multivariable model to control for confounding. Furthermore, we were not able to assess age of RGP lenses as a risk factor for AK as this data was not collected during the multi-state investigations. In spite of these limitations, this case-control study of AK in RGP wearers fills a gap in the contact lens literature.

Overall, our findings indicate that modifiable risk factors for AK among RGP wearers who wear lenses for vision correction are similar to those for soft contact lens wearers, namely avoiding exposure to tap water and practicing good contact lens wear and care habits. Therefore, prevention messages should be broadly applicable to all contact lens wearers. Public health messaging that encompasses risk factors for both rigid and soft contact lenses and for bacterial, fungal and amebic infections is likely to be the most effective. The most important of these messages include minimizing overnight wear, reducing exposure of lenses to tap water, not topping off contact lens solutions, and frequent replacement of the contact lens case. Providers should also carefully evaluate candidates for orthokeratology to ensure they can comply with hygiene recommendations. For more information on healthy contact lens wear and care, visit http://www.cdc.gov/contactlenses.

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Glossary

AK	Acanthamoeba keratitis
RGP	Rigid gas permeable
OR	Odds ratio
CDC	Centers for Disease Control and Prevention

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Table 1

Clinical characteristics and outcomes of *Acanthamoeba* keratitis infection among rigid gas-permeable lens wearers — United States, 2005–2011

Eye Affected (n=37)	
Left eye affected	21 (56.8)
Right eye affected	14 (37.8)
Both	2 (5.4)
Symptoms (n=37)	
Redness	31 (83.8)
Sensitivity to light	27 (73.0)
Increased tearing	25 (67.6)
Foreign body sensation	24 (64.9)
Eye pain	24 (65.9)
Blurred vision	17 (45.9)
Eye discharge	10 (27.0)
Outcome (n=33)	
Resolved	13 (39.4)
Still on anti-ameba therapy, no keratoplasty performed	9 (27.3)
Keratoplasty after failed therapy	10 (30.3)
Transplant planned	1 (3.0)
Best corrected visual acuity in the affected eye (n=32)	
20/20	3 (9.4)
20/25 – 20/50	7 (21.9)
20/60 – 20/100	4 (12.5)
20/200 – 20/400	12 (37.5)
20/800 – 20/1200	5 (15.6)
Light perception	0 (0)
No light perception or enucleated	1 (3.1)

Table 2

Prevalence and odds ratio of demographic characteristics and potential risk factors for infection in *Acanthamoeba* keratitis cases and controls who wore rigid gas-permeable lenses — United States, 2005 – 2011

Demographic characteristic or exposure	Cases (N=37) n (%)	Controls (N=17) n (%)	Unadjusted odds ratio (p-value)*
Age			
25 years or younger	6/36 (16.2)	0	undefined (p=0.04) **
26–55 years	8/36 (21.6)	8/16 (50.0)	referent
56 years or older	23/36 (62.2)	8/16 (50.0)	2.88 (p=0.09)
Male	10/37 (27.0)	1/16 (6.3)	5.42 (p=0.08)
Non-Hispanic ethnicity	34/36 (94.4)	14/16 (87.5)	2.42 (p=0.36)
Non-white race	4/35 (11.4)	1/16 (6.3)	1.94 (p=0.49)
Eye injury in month before symptoms began	4/36 (11.1)	NA	
Any immunocompromising condition	3/37 (8.1)	1/17 (5.9)	1.41 (p=0.63)
Indications for RGP use			
Vision correction	28/37 (75.7)	17/17 (100)	referent
Orthokeratology/therapeutic †	9/37 (24.3)	0 (0)	undefined (p=0.02) **
Length of prior contact lens wear			
<1 year	2/37 (5.4)	0 (0)	undefined (p=0.42)
1-5 years	4/37 (10.8)	0 (0)	undefined (p=0.19)
6-10 years	1/37 (2.7)	0 (0)	undefined (p=0.65)
>10 years	30/37 (81.1)	17/17 (100)	referent
Duration of daily lens wear			
<12 hrs./day	18/37 (48.7)	4/17 (23.5)	3.66 (p=0.04) **
>12-16 hrs./day	16/37 (43.2)	13/17 (76.5)	referent
>16 hrs./day	3/37 (8.1)	0 (0)	undefined (p=0.20)
Overnight contact wear			
Never slept with lenses in	24/36 (66.7)	16/17 (94.1)	referent
Slept with lenses in some nights ††	6/36 (16.7)	1/17 (5.9)	4.00 (p=0.19)
Slept with lenses in every night ††	6/36 (16.7)	0 (0)	undefined (p=0.06)
Any sleeping with lenses in ††	12/36 (33.3)	1/17 (5.9)	8.00 (p=0.04) **
Smoking			
Ever smoked	16/36 (44.4)	5/17 (29.4)	1.92 (p=0.23)
Current smoker	7/37 (18.9)	1/17 (5.9)	3.73 (p=0.21)
Tap water source			
Municipal water	32/35 (91.4)	10/16 (62.5)	17.78 (p=0.02) **
Private well	3/35 (8.6)	6/16 (37.5)	referent
Tap water exposure			

Demographic characteristic or exposure	Cases (N=37) n (%)	Controls (N=17) n (%)	Unadjusted odds ratio (p-value)*
Used tap water to rinse lens case	23/37 (62.2)	12/17 (70.6)	0.68 (p=0.39)
Used tap water to clean lens case	18/37 (48.7)	12/17 (70.6)	0.39 (p=0.11)
Used tap water to rinse lenses	17/37 (46.0)	5/17 (29.4)	2.04 (p=0.20)
Ever used tap water to store lenses	18/36 (50.0)	1/17 (5.9)	16.00 (p=0.001) **
Lens hygiene			
Ever topped off solution in lens case	24/36 (66.7)	5/17 (29.4)	4.80 (p=0.01) **
Always washed hands before inserting lenses	21/36 (58.3)	11/17 (64.7)	0.76 (p=0.77)
Recreational water			
Any hot tub use while wearing lenses in previous month	2/37 (5.4)	2/17 (11.8)	0.43 (p=0.37)
Any swimming while wearing lenses in previous month	3/37 (8.1)	1/17 (5.9)	1.41 (p=0.63)
Showering			
Ever showered while wearing lenses	17/37 (46.0)	10/17 (58.8)	0.60 (p=0.28)
Ever washed their face while wearing lenses	31/36 (86.1)	13/17 (76.5)	1.91 (p=0.31)

* Because of the small numbers in this analysis, exact p-values were calculated using Fisher's test in place of confidence intervals

** Significant at 95% confidence level. If OR was undefined, no controls had this exposure, thus the OR ((number of exposed cases/number of unexposed cases)/(number of exposed controls/number of unexposed controls) could not be calculated because division by zero is undefined.

† Includes 8 orthokeratology patients and 1 patient who reported used a contact for therapeutic reasons. This patient did report sleeping in their lenses every night, but no additional data was available to explain the therapeutic lens wear for this patient.

†† Includes patients who wore lenses for orthokeratology and therapeutic reasons

Table 3

Prevalence and odds ratio of demographic characteristics and potential risk factors for infection in *Acanthamoeba* keratitis cases and controls who wore rigid gas-permeable lenses, stratified by orthokeratology or therapeutic use — United States, 2005–2011

	Non-Orthokeratology			Orthokeratology	
	Cases (N=28)	Controls (N=17)		Cases (N=9)	Controls (N=0)
Demographic characteristic or exposure	**n (%)**	**n (%)**	**Unadjusted odds ratio (p-value)***	**n (%)**	**n (%)**
Age					
25 years or younger	2/28 (7.1)	0	undefined (p=0.23)	4/9 (44.4)	0
26–55 years	6/28 (21.4)	8/16 (50.0)	referent	2/9 (22.2)	0
56 years or older	20/28 (71.4)	8/16 (50.0)	3.3 (p=0. 07)	3/9 (33.3)	0
Duration of daily lens wear					
<12 hrs./day	12/28 (42.9)	4/17 (23.5)	2.8 (p=0.12)	6/9 (66.7)	0
>12-16 hrs./day	14/28 (50.0)	13/17 (76.5)	referent	2/9 (22.2)	0
>16 hrs./day	2/28 (7.1)	0	undefined (p=0.30)	1/9 (11.1)	0
Overnight contact wear					
Never slept with lenses in	22/27 (81.5)	16/17 (94.1)	referent	2/9 (22.2)	0
Slept with lenses in some nights	5/27 (18.5)	1/17 (5.9)	3.6 (p=0.24)	1/9 (11.1)	0
Slept with lenses in every night	0	0		6/9 (66.7)	0
Tap water source					
Municipal water	25/27 (92.6)	10/16 (62.5)	7.5 (p=0.02)**	6/8 (87.5)	0
Private well	2/27 (7.4)	6/16 (37.5)	referent	1/8 (12.5)	0
Tap water exposure					
Ever used tap water to store lenses	14/27 (51.9)	1/17 (5.9)	17.2 (p=0.002)**	4/9 (44.4)	0
Lens hygiene					
Ever topped off solution in lens case	18/27 (66.7)	5/17 (29.4)	4.8 (p=0.02)**	7/9 (77.8)	0