The Efficacy of *Acanthamoeba* Cyst Kill and Effects Upon Contact Lenses of a Novel Ultraviolet Lens Disinfection System

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• PURPOSE: **To assess the efficacy of a novel ultraviolet (UV) lens device on the killing of *Acanthamoeba* cysts and the impact of efficacious doses of UV upon soft contact lens parameter and material characteristics.**

• DESIGN: **Prospective, in vitro, experimental study of a device.**

• METHODS: **A UV lens device was constructed and used to expose *Acanthamoeba* cysts to various levels of UV irradiation. Once an efficacious dose, as defined by a greater than 3 log reduction, was determined (130 mJ/cm^2), 6 soft contact lens materials (etafilcon A, senofilcon A, galyfilcon A, lotrafilcon A, polymacon, and comfilcon A) were exposed to that dose for 30 cycles and tested for visual parameters, mechanical parameters, and cytotoxicity.**

• RESULTS: **The UV device produced an average log reduction of over 3.5 log of *Acanthamoeba* cysts when the lens and solution inside of the inset case was irradiated with 130 mJ per cm^2 of UV or greater. After 30 cycles of 130 mJ per cm^2 UV dose each, no gross changes were observed in mechanical properties or cytotoxicity tests in any soft contact lenses tested. In visual parameters, polymacon and lotrafilcon A exhibited a shift in sphere power and diameter, respectively.**

• CONCLUSIONS: **The novel UV lens device was able to provide a marked log reduction to *Acanthamoeba* cysts, one of the most resistant ocular disease–causing organisms found in lens cases, without a detrimental effect on many lens materials. (Am J Ophthalmol 2014;158: 460–468. © 2014 by Elsevier Inc. All rights reserved.)**

CONTACT LENS WEAR IS THE MOST COMMON RISK factor for the development of microbial keratitis (MK).[1,2] Microbial contamination of contact lens cases by bacteria, fungi, and amoebae is common.[3,4] These microbes can adhere to the contact lens and are then transported onto the surface of the cornea when the user inserts his or her lens.[5] Studies have shown that microorganisms isolated from the corneal ulcers of contact lens wearers were the same strains as those isolated from the patients' lens case, strongly suggesting that contact lens cases are a source of potential pathogenic microbes.[6,7]

Most cases of contact lens–related MK are attributable to bacteria, with *Pseudomonas* and *Staphylococcus* strains being the most common microbes involved.[1,8] In recent years, however, there has been an increase in the number of cases of keratitis caused by the free-living amoeba *Acanthamoeba* in the United States. Although relatively rare, *Acanthamoeba* keratitis (AK) is potentially blinding, and approximately 90% of AK patients are contact lens wearers.[9] *Acanthamoeba* are virtually ubiquitous in nature and are commonly found in dust, soil, swimming pools, air conditioning systems, and domestic tap water.[10] *Acanthamoeba* exist as a dimorphic organism: the trophozoite, which is the motile, feeding, and replicating form, and the cyst, which is the dormant, resistant form.[11] *Acanthamoeba* transform into the cyst form (encyst) in unfavorable conditions, such as starvation, exposure to biocides, and changes in osmolarity.[12] Cysts are highly resistant to chemical disinfection, desiccation, and extremes of temperature and can remain viable and pathogenic after decades in storage.[13–15]

Following an outbreak of AK in soft contact lens wearers in the United States starting in 2004, epidemiology studies found that 21 of the 39 AK cases were found to be associated with the use of a single multipurpose solution (MPS), which resulted in the manufacturer's voluntary global recall of the product in May 2007.[16–18] Since the 2007 product recall, the incidence of AK in the United States still remains elevated above previous baseline levels, indicating that additional risk factors are involved in the recent increase in cases of AK, such as users having poor lens care practices (Brown AC. Elevated Acanthamoeba keratitis incidence despite a 2007 outbreak-associated product Recall—A multi-state investigation, 2008–2011. Presented at CDC EIS Conference. April 16, 2012; Atlanta, Georgia.)

Although compliance in lens case hygiene is clearly important, the recent outbreak of AK highlights the need for improved contact lens disinfection systems, in particular against the more resistant cyst form of the organism. MPSs are currently the most common systems used for

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TABLE 1. Contact Lens Materials and Parameters Used in Study of *Acanthamoeba* Cyst Kill and the Effects Upon Contact Lenses of a Novel Ultraviolet Lens Disinfection System

Material	Power (Diopter)	Diameter (mm)	Base Curve (mm)	Purchased From
etafilcon A	−1.00	14.0	8.7	Johnson & Johnson Vision Care (Jacksonville, Florida, USA)
senofilcon A	−1.00	14.0	8.4	Johnson & Johnson Vision Care (Jacksonville, Florida, USA)
galyfilcon A	−1.00	14.0	8.3	Johnson & Johnson Vision Care (Jacksonville, Florida, USA)
lotrafilcon A	−1.00	13.8	8.4	Ciba Vision (Duluth, Georgia, USA)
polymacon	−1.00[a]	14.0	8.4	Bausch & Lomb (Rochester, New York, USA)
comfilcon A	−1.00	14.0	8.6	Cooper Vision (Fairport, New York, USA)

[a] −3.00 diopter lenses were used for parameters testing for polymacon only, owing to lack of availability of -1.00 diopter lenses at the time of testing.

the care of soft contact lenses, being complex formulations of buffering, chelating, surfactant, wetting, and antimicrobial agents that can vary significantly from one MPS to another.[19] Studies have shown that MPSs can vary in their disinfection efficacy against *Acanthamoeba*, and this efficacy also varies depending on the strain tested.[20–23] Some of this variation could, however, be attributable to significant interlaboratory variation, as the current microbiological requirements for contact lens care products do not include efficacy against *Acanthamoeba*[24] and there are currently no standardized test methods for the evaluation of contact lens disinfectant solutions against *Acanthamoeba*.

Ultraviolet (UV) light has been proposed as a method for disinfecting contact lenses. Although reports have shown successful UV disinfection of bacteria-contaminated contact lenses,[25] lenses directly exposed to disinfecting levels of UV often exhibit changes in their properties.[26] To remedy the issue of direct UV-induced changes, a commercially available UV device that exposes only the solution to UV while protecting the lens from direct irradiation has been created.[27] The efficacy of this device was shown to be high for bacteria; however, the device exhibited low efficacy against *Acanthamoeba* cysts.[27,28] Striking a balance between the germicidal dose of UV light and its ability to alter the polymer of soft contact lenses is a great challenge to the successful use of UV as a contact lens disinfecting agent.

The purpose of this study was to assess the disinfection efficacy of a novel directly irradiating germicidal UV device against *Acanthamoeba castellanii* ATCC 50370 cysts, while in the presence of a contact lens. A secondary objective was to assess the impact of efficacious (greater than 3 log reduction) doses of UV on soft contact lens parameters and material characteristics. Previous studies have shown that UV treatment on its own is ineffective in killing all *Acanthamoeba* cysts in a single exposure and that cysts are resistant to UVB up to 800 mJ per cm^2.[12,28,29] The results of this study showed that the novel UV device produced over 3 log reduction of *Acanthamoeba* cysts when the lens and solution inside of the inset case was irradiated with 130 mJ per cm^2 of UV or greater. This study also highlights methodology that can be used to assess the efficacy of contact lens disinfecting solutions or devices in a regimen assay against *Acanthamoeba*.

METHODS

THIS STUDY WAS A PROSPECTIVE, IN VITRO, EXPERIMENTAL study of a novel UV contact lens disinfection device.

• **MATERIALS:** For the construction and testing of the novel UV device, National Institute of Standards and Technology (NIST)-certified UV germicidal detector PMA2122 and data logger PMA2100 were purchased from Solar (Glenside, Pennsylvania, USA). UV bulbs were purchased from LCD Lighting (Orange, Connecticut, USA). Teflon was purchased from Industrial Plastics and Machine (Houston, Texas, USA) and Achieve 1605 polypropylene homopolymer was purchased from ExxonMobil Chemical (Irving, Texas, USA).

For contact lens testing, Table 1 shows the lenses that were used.

Phosphate-buffered saline (PBS), Eagle's minimal essential medium (EMEM), and fetal bovine serum (FBS) were purchased from Mediatech (Manassas, Virginia, USA). V79-4 cells (CCL-93), *Escherichia coli* (8739), and *Acanthamoeba castellanii* (50370) were purchased from ATCC (Manassas, Virginia, USA). TableCurve2D was purchased from Systat Software (San Jose, California, USA). Flat-bottomed 24- and 96-well tissue culture treated microtiter plates were purchased from Helena Biosciences (Tyne and Wear, UK). Hemocytometers were purchased from Hawksley (Sussex, UK) and all other materials were purchased from VWR (Atlanta, Georgia, USA) or Fisher (Leicestershire, UK).

• **NOVEL DEVICE CONSTRUCTION:** A circular custom-made germicidal UV bulb was made by LCD Lighting (Orange, Connecticut, USA) to allow for a uniform distribution of UV light to both surfaces of the lenses. A Teflon