How Could Contact Lens Wearing Be at Risk of Acanthamoeba Infection? A Review
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ABSTRACT
Contact lens wear is highly influential on the incidence of ulcerative keratitis worldwide, particularly in developed countries. The association between Acanthamoeba keratitis and contact lens wear is firmly established; it may account for up to 95% of the reported cases. Before the popularisation of soft contact lens wear, Acanthamoeba keratitis was extremely rare. In 2000 it was estimated that the number of contact lens wearers worldwide was about 80 million, out of whom 33 million were in the United States and 90% of them wore hydrogel soft lenses. Contact lens-related problems depend on many factors, such as lens material, wearing modality, lens hygiene, type of lens-caring solution, the degree of compliance of the lens user with lens wear and care procedures, lens overwear, sleeping in lenses, rate of changing lenses, and lens case hygiene. This paper is a thorough review of the literature aiming to highlight the role of one of the main risk factors of infectious keratitis, contact lens wear, and also to show the responsibility of lens users in aggravating this risk.

Received: 4 September 2008
Revised: 1 March 2009
Accepted: 2 March 2009

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doi:10.3921/joptom.2009.60
to the development of keratitis. Corneal abrasion was absolutely essential for the induction of *Acanthamoeba* keratitis in hamsters infected with contaminated contact lenses.\(^{25}\)

Corneal epithelial defects make it possible for the *Acanthamoeba* protozoan to attach to the epithelium and to subsequently invade the rest of the underlying stromal layers. Corneal injury exposes protein sites known as mannose glycoproteins on the surface of injured corneas. The adhesion of the *Acanthamoeba* to the corneal epithelial cells is the result of mutual interaction between corresponding mannose-binding glycoproteins on the adjacent surface membranes.\(^{5,10,17}\) Sugar inhibition assays\(^{26,18}\) revealed how *Acanthamoeba* can selectively bind with high affinity to mannose saccharides and not to non-mannosylated neoglycoproteins, such as galactose, fucose, galactosamine or lactose. The corneal surface mannose receptors stimulate *Acanthamoeba* to secrete pathogenic proteases\(^{16}\) which, in turn, induce epithelium apoptosis\(^{19}\) and facilitate amoeba invasion to the underlying stroma. Alizadeh et al.\(^{20}\) showed that contact lens wear exacerbated *Acanthamoeba* keratitis through the secretion of mannose-induced protease 133. In addition, the attachment of *Acanthamoeba* to corneal epithelial cells helps the phagocytosis and digestion of bacteria\(^{21}\) that provide an important nutrition source for *Acanthamoeba*. However, Sharma et al.\(^{22}\) found no difference between the adherence ability of *Acanthamoeba* to corneal epithelial cells of normal non-lens wearers and that of asymptomatic contact lens wearers.

**Indirect Traumatic Effect of Lenses.** Contact lens wear is usually associated with corneal epithelial hypoxia and hypercapnia, particularly when sleeping in lenses or when using lenses having low oxygen transmissibility.\(^{11}\) Carbon dioxide accumulation alters the normal metabolic pathways, which leads to a series of micro-structural changes affecting all corneal layers, such as epithelial microcysts, depletion of epithelial glycogen storage, lactic acid accumulation, corneal acidosis, epithelial oedema,\(^{11}\) decreased mitotic rate, increased central corneal thinning,\(^{23}\) corneal hypoesthesia,\(^{24}\) compromised junctional integrity, increased epithelial cells permeability,\(^{25}\) increased cellular epithelial fragility, epithelial punctuation, microscopic abrasion, sloughing of the epithelium and, eventually, corneal ulceration. In addition, changes in tear film thickness and stability\(^{26}\) and alteration of the normal profile of conjunctival commensals\(^{27}\) have been recognised. All these changes collectively breach the natural extra ocular protective mechanisms, rendering the cornea an easy target to a wide array of pathogens, including the *Acanthamoeba*.

**Attachment of Acanthamoeba to Contact Lenses**

Contact lenses serve as a vehicle for the harbouring, transmission and delivery of microorganisms to the eye. *Acanthamoeba* has a high affinity for contact lens surfaces, a property that plays an important role in the pathogenesis of *Acanthamoeba* keratitis and creates an actual threat to contact lens wearers.\(^{28}\) The adherence of *Acanthamoeba* trophozoites and cysts to contact lenses can be detected and quantified using different methods and techniques.\(^{5,29-31}\) The ability of *Acanthamoeba* to attach to contact lenses is influenced by several factors:

**Contact Lens Material, Ionicity, and Water Content.** The manufacturing material affects contact lens ability as a mechanical host allowing attachment and transfer of *Acanthamoeba* trophozoites or cysts onto the corneal surface. The incidence of *Acanthamoeba* keratitis is much lower with rigid lenses, as compared with the soft type. The lower incidence of *Acanthamoeba* keratitis found in the Netherlands\(^{32}\) was attributed to the greater proportion of Dutch contact lens wearers that used rigid gas-permeable lenses. Rigid gas-permeable lenses were recommended to hospital staff members wearing lenses, with the aim of minimising the risk of infectious keratitis, due to the easy removal of the attached *Acanthamoeba* trophozoites and cysts from the surface of this type of contact lenses.\(^{33}\) Kilvington et al.\(^{34}\) showed that cyst attachment occurred only for soft lenses, but not for gas-permeable ones. However, a significant adherence of trophozoites was detected in the case of rigid gas-permeable lenses, as compared with soft contact ones\(^{35}\), with greater affinity for the silicone acrylate material of rigid lenses than for the fluoropolymer material of those same lenses.\(^{36}\)

The greater affinity of *Acanthamoeba* trophozoites for silicone hydrogel lenses, as compared with conventional hydrogel lenses (\(P<0.001\)) was attributed to the attachment characteristics of the polymer of silicon type.\(^{57,58}\) The attachment of *Acanthamoeba* trophozoites to different soft contact lens materials, such as polymacon, etafilcon A, lidofilcon A, and bufilcon A varied significantly, with the greatest adherence being observed for lidofilcon A and the least for the etafilcon A lenses.\(^{29}\) Adherence of cysts and trophozoites was found to be higher for the non-ionic than for the ionic disposable lenses.\(^{38}\) Simmons et al.\(^{39}\) suggested that the attachment of *Acanthamoeba* was highly dependant on the ionic nature and the water content of soft contact lenses. Collectively, these reasons could explain why *Acanthamoeba* adherence is higher for disposable and extended-wear soft lenses than for the conventional soft daily and rigid lenses.

**Duration of Exposure and Protozoon Concentration.** Both cysts and trophozoites showed an immediate adherence to contact lenses, which was observed to happen within 10 seconds after exposure.\(^{33}\) *Acanthamoeba* adherence to lens surface increased significantly for longer exposure durations and for higher concentrations of inoculum.\(^{39,40}\) The higher water content of disposable soft contact lenses allows longer time of lens wear and, in turn, gives enough time of exposure for the lenses to be loaded with *Acanthamoeba*. This could add to the reasons why disposable soft contact lenses are at greater risk of suffering from *Acanthamoeba* keratitis than those wearers of other types of contact lenses. However, Sharma et al.\(^{22}\) found no difference in *Acanthamoeba* adherence to different contact lenses with increasing exposure time.

**Acanthamoeba-Life Stage.** *Acanthamoeba* trophozoite shows a greater tendency to adhere to contact lenses, as compared with the cystic form.\(^{39,36,40-42}\) In contrast to the cystic form, Sharma et al.\(^{36}\) noticed more adherence of trophozoites to rigid gas-permeable lenses than to soft ones. Similarly, Kelly et al.\(^{29}\) observed more preference of trophozoites to adhere
to rigid gas-permeable lenses and polymethylmethacrylate (PMMA) contact lenses compared with the cystic form, which showed non specific similar rates of adherence to a variety of lenses, such as rigid gas-permeable, PMMA, daily and disposable soft lenses.

**Lens Surface Deposits.** Attachment of trophozoites and cysts to contact lenses is highly influenced by the presence of protein deposits on the lens surface. Protein deposits on contact lens surface increase the adhesion of other bacterial microbes like *Pseudomonas aeruginosa*, on which *Acanthamoeba* feeds. Protein and lipid deposition on lens surface is mediated by the chemical structure of the lens material and its water content. The high water content and the ionic material of some disposable soft lenses allow for more deposition of proteins, a fact that could explain the greater affinity of the *Acanthamoeba* protozoan for worn lenses than for unworn ones. Jones et al. reported significant deposition of low levels of lysozyme and high levels of lipid on silicone hydrogel contact lens materials, as compared with ionic contact lens materials. The adhesion of *Acanthamoeba* in unwashed worn versus unwashed unworn contact lenses showed a significantly lower adherence of *Acanthamoeba* to new lenses. The serine protease subtilisin A enzyme used for protein removal from contact lenses has been found to have no cysticidal action even after 24 hours of exposure. However, it could lower the number of protozoa attached to lens surface through protein removal.

**Mechanical Ways Used in Contact Lens Care.** While shaking showed no significant effect on adherence, a post-incubation wash using phosphate buffered saline decreased the number of adherent cysts and trophozoites.

Several studies suggested that a wash significantly decreased the adherence of trophozoites and cysts to the contact lens surface, though one study suggested that washing had no effect on either *Acanthamoeba* stage. Rinsing contact lenses in saline using the flow method was significantly more effective than the immersion technique in removing adherent *Acanthamoeba* trophozoites from rigid gas-permeable lenses. Wiping, rinsing, and rubbing of contact lenses and lens cases with multipurpose disinfecting solutions dislodged adherent cysts and trophozoites and reduced the associated microbiological load. Recent studies, showed that multipurpose contact lens solutions that employed a manual rub regimen were more effective in removing adherent loosely-bound deposits and different pathogenic microbes from soft hydrogel lenses than rinsing or soaking alone.

**Associated Bacterial Organisms.** The contamination of lens care systems with bacteria is an essential association in the development of *Acanthamoeba* keratitis. The bacterial microorganisms that adhere to the surfaces of contact lenses provide a good medium that facilitates attachment, feeding, survival, and growth of *Acanthamoeba*. *Acanthamoeba* can easily attach and grow on a lens surface previously loaded with bacterial microorganisms. Gorlin et al. found that about 50% of the eyes infected with *Acanthamoeba* had positive cultures for bacteria. Other study showed that 85% of contact lens systems infected with *Acanthamoeba* were contaminated with bacterial strains, mainly with the aerobic gram-negative bacterial *P. aeruginosa* and *Xanthomonas maltophilia*.

Other bacterial microorganisms, such as *Flavobacterium breve*, *P. paucimobili*, *P. fluorescens*, *Staphylococcus aureus*, *Staphylococcus epidermidis*, *Esherichia coli*, *Enterobacter agglomerans*, *Flavobacterium indolgenes*, *Salmonella enterica*, *Corynebacterium xeroticus*, *Serratia marcescens* and *Klebsiella pneumoniae* were isolated in patients with *Acanthamoeba* keratitis. Alizadeh et al. showed that *Acanthamoeba* could secrete increased amounts of pathogenic mannose-induced protease 133 upon exposure to *C. xeroticus*. *Acanthamoeba* trophozoites and cysts could retain viable bacteria with human pathogenic potential. Intra-*Acanthamoeba* detection, survival, growth, and multiplication of salmonellae and *P. aeruginosa* were reported, with the possibility of reisolating from contact lenses. The combination of *P. aeruginosa* and *Acanthamoeba* was assumed to be selectively exclusive, causing potentially devastating ocular infections in contact lens wearers. Sodium salicylate reduced trophozoite attachment to hydrogel lenses when inoculated with *P. aeruginosa*. This effect was attributed to the inhibition of bacterial biofilm formation, interference with the biofilm-amoebal attachment, or modification of the lens surface.

**Contact Lens Disinfecting Solutions.** The use of ineffective contact lens disinfecting solutions is strongly linked to the threat of *Acanthamoeba* infection in contact lens wearers. A 10-year survey (1994-2004) showed that *Acanthamoeba* was isolated in contact lenses and contact lens disinfecting solutions in all cases of *Acanthamoeba* keratitis. The one-step 3% hydrogen peroxide and multipurpose solutions were found to be ineffective in killing *Acanthamoeba* cysts and trophozoites, as well as bacteria and fungi. However, in addition to the broad antimicrobial activity of multipurpose solutions, they were found to be capable of reducing the adherence capability of *Acanthamoeba* to contact lenses. Opti-Free express multipurpose solution significantly reduced the adherence of trophozoites and cysts when used to clean, rinse, and soak contact lenses. Complete Easy Rub multipurpose solution was effective in removing bacteria, fungi and *Acanthamoeba* from silicone hydrogel lenses.

**Problems Caused by Contact Lens Wearers**

**Contact Lens Overwear**

Corneal overwear-related problems could develop in the long term for any type of contact lenses, including those designed for extended wear. The overwear problems were influenced by the rate of oxygen transmission and permeability through the lens material, lens thickness, lens type, wearing modalities, replacement schedule, repeated wear of disposable lenses, and overnight sleep in lenses. A lower incidence of microbial keratitis was reported for silicone hydrogel lenses with high oxygen permeability than for other soft lenses having low oxygen permeability used with an extended


correlation the safety of the overnight wear to the high oxygen permeability. A significantly higher risk of bacterial keratitis among the users of extended wear lenses was not a reliable predictor of ocular complications. No significant difference was recognised in the bacterial binding ability to the corneal epithelium between the overnight wear of either conventional or hyper-oxygen transmissible rigid contact lenses. Other surveys suggested the high risk of microbial keratitis among the overnight wearers of orthokeratology contact lenses. However, Brennan et al. suggested that neither the level of overnight corneal swelling nor the period between removals could influence the incidence or the severity of corneal problems of extended wear lenses.

Non-Compliant Contact Lens Users

The compliance of contact lens wearers with the recommended lens care hygiene procedures is crucial to reduce the risk of serious infections. D’Aversa et al. reviewed the medical records of 12 patients and found that substandard lens-care methods were used in 13 out of 14 (92.9%) eyes infected with Acanthamoeba. The use of tap water for the care of contact lenses was widely accepted as the main risk factor in Acanthamoeba infection. The non-compliance of contact lens users could occur due to the increased lens surface tear and wear-related scratches or to the accumulated deposits. The multipurpose solutions replaced the need for the use of saline and chlorine-based solutions.

The compliance of contact lens users with the recommended care procedures is ineffective if these solutions do not manage to kill Acanthamoeba. To avoid the persistent use of non-sterile solutions by non-compliant lens wearers, Moore recommended heat disinfection of lenses—between 70 and 80°C for 10 minutes—and the use of 3% hydrogen peroxide for 2-3 hours, 0.001% thimerosal with edetate for 4 hours, 0.005% benzalkonium chloride with edetate for 4 hours, 0.001% chlorhexidine for 4 hours or 0.004% chlorhexidine for 1 hour. Better compliance of contact lens wearers was achieved with the introduction of multipurpose solutions. The multipurpose solutions replaced the need for an additional rinsing solution, offering a single solution for the cleaning, disinfection and contact lens storage. The multipurpose solutions provided potent antimicrobial protection with less toxic and less allergenic effects.

The non-compliance of contact lens users could occur in the case of deliberate reuse of daily disposable contact lenses, when wearing expired lenses without replacement or if using cheap contact lenses purchased from unlicensed vendors. Old contact lenses could colonise more microorganisms due to the increased lens surface tear and wear-related scratches or to the accumulated deposits. The relationship between repeated use of daily disposable lenses
and risk of *Acanthamoeba* and microbial keratitis is well established. Daily disposable lenses were designed for single use only, where a new sterile set should be opened every morning and discarded in the evening. This wear modality aimed to divert the attention of professionals from considering *Acanthamoeba* infection in daily disposable contact lens wearers. A delay of 17 days before starting the anti-*Acanthamoeba* treatment was reported.

Radford et al. stated that the low care philosophy of daily disposable lens use has resulted in an absolute absence of care, and emphasised the importance of warning patients against the increased risk of infection upon reuse of daily disposable contact lenses. The non-compliance of contact lens users has been attributed to the convenience of using multipurpose or one-step solutions instead of using two-step hydrogen peroxide solutions. Financial savings achieved by reusing daily disposable contact lenses is another factor.

**CONCLUSION**

Contact lens wear is the main cause of ulcerative keratitis, which can get seriously complicated with corneal scarring and lead to permanent vision loss. The association between *Acanthamoeba* keratitis and contact lens wear is firmly established. Contact lenses have a great impact on corneal epithelium and lead to permanent vision loss. The vision loss was less likely to occur for reusable soft lens wearers, though no significant reduction in the risk of microbial keratitis was found for users of daily disposable and silicone hydrogel lenses. However, the assumed lens wearers’ compliance could sometimes divert the attention of professionals from considering *Acanthamoeba* infection in daily disposable contact lens wearers. A delay of 17 days before starting the anti-*Acanthamoeba* treatment was reported.

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