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UV Protection with Contact Lenses

Sunlight is the primary source of radiation reaching the human eye. The solar ultraviolet (UV) radiation spectrum is typically classified according to wavelength into the following based on biological effect: UVA (400-320nm), UVB (320-290nm) and UVC (290-100nm).[1] Whilst UV is important for some biological processes, it can also be harmful to the human body and, in particular, the eyes. This article will discuss the impact of UV exposure on ocular tissue and the need for adequate UV protection, with particular emphasis on UV-blocking contact lenses (CLs).

KEY POINTS

- Both acute and chronic UV exposure can lead to various ophthalmic pathologies; exposure over long periods can result in cataracts and pterygium
- It is important to protect the eyes from childhood – eye damage from UV is cumulative; 80% of children in an Australian study showed UV-induced damage by the age of 15 years
- Many sunglasses do not prevent the peripheral light focussing effect in which tangential UV rays are focussed and concentrated on the nasal aspect of the eye; notably the nasal limbus where pterygia are more common and the nasal lens cortex, the most likely site for cortical cataracts
- When UV-blocking contact lenses are worn the peripheral light focussing effect is significantly reduced, suggesting that the risk of eye diseases such as pterygium and cortical cataracts may be reduced
- Contact lenses that offer UV protection are labelled as Class I or Class II. Class I offers the highest level of protection, blocking more than 90% UVA and 99% UVB, and is currently found in five silicone hydrogels, all ACUVUE® Brand contact lenses
- There is a huge opportunity to educate all patients on ocular UV protection and UV-blocking contact lenses should be considered for a large number of patients
- A large body of evidence supports the benefit of wearing UV-blocking contact lenses to prevent detrimental ocular damage associated with UV exposure
- The most complete measure of UV protection is achieved with the combination of UV-blocking sunglasses, a wide-brimmed hat and UV-blocking contact lenses.
- Use of UV-blocking contact lenses can provide practitioners, patients and parents with the reassurance that the wearers have at least some protection if the supplemental protection of hat and sunglasses are not worn

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Solar UV that reaches the Earth's surface is comprised of approximately 95% UVA and 5% UVB.[1] UVA exposure produces tanning of the skin and photosensitivity reactions. UVB radiation has important influences on biological processes, and is strongly absorbed by atmospheric ozone (in both the stratosphere and the lower atmosphere). Reductions in stratospheric ozone are therefore important because of the corresponding increase in the highly damaging UVB radiation reaching the Earth's surface. UVC wavelengths are completely filtered by the ozone layer such that they are effectively not found in nature. While some UV radiation is needed to synthesize vitamin D, which is necessary for human health, increases in UV radiation are also harmful for human health. High levels of UV radiation can damage a wide range of organic molecules, including DNA, and generally leads to harming a diverse range of biological and physical processes.

It is well established that both acute and chronic UV exposure can lead to various ophthalmic pathologies. The type and extent of damage from UV radiant energy is associated with the wavelength, duration, intensity and size of the exposure.

The biology of UV-induced tissue damage

UV radiation is invariably damaging to ocular tissue by many mechanisms such as protein cross-linking, dysfunction of enzymes, ion pump inhibition, genetic mutations and membrane damage.[2,3] These effects of UV may be due to direct or indirect damage. In indirect reactions, UV-activated intermediates such as free radicals mediate the effects of UV. This results in the formation of reactive oxygen species (ROS), including peroxides, superoxides, anions and hydroxyl radicals. Production of these 'free radicals' neutralises antioxidant defences and cause cellular damage.[2,3] Direct UV damage to pyrimidines in DNA and RNA can lead to potentially mutagenic pyrimidine dimers and (6,4) -photoproducts.[2,3] All cells possess some ability to repair themselves following UV exposure, but often UV irradiation can lead to programmed cell death.[2,3] The eye is particularly susceptible to photochemical reactions due to the high concentration of pigmented molecules including the visual pigments.[4] Damage can occur from either acute or chronic exposure, and the degree of damage is dependent on the wavelength and exposure time of radiation.

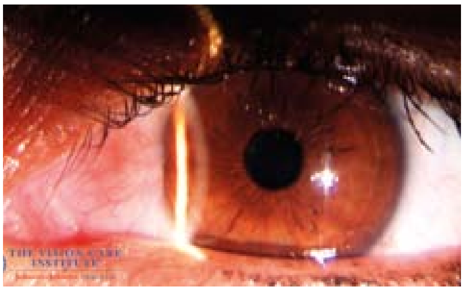
UV-induced ocular changes

The eye is shielded from ambient UV by the brow and eyelids, so that over land about 5% of ambient UV reaches the unprotected eye.[5,6] However, exposure to UV radiation also occurs through indirect sources such as radiation reflected off surfaces such as snow and water, and scattered sources such as high cloud cover. Also, it is difficult to predict when eyes are most at risk as the greatest exposure to ocular tissue has been shown to occur at unlikely times, both in terms of the time of day and the months of the year,[7] making patient education on the need for all-year round protection very important.

Repeated exposure of the eyes to UV radiation causes both short-term eye conditions and permanent eye damage. Short-term complaints include mild irritations such as excessive blinking, swelling or difficulty looking at strong light. UV exposure can also cause acute photokeratopathy, such as snow blindness or welder's flash burns.[1]

Exposure to UV radiation over long periods can result in more serious damage to the eyes. This includes cataracts (*Figure 1*), pterygium (*Figure 1*), solar keratopathy, conjunctival cancer and skin cancer of the eyelids and around the eyes.[1,8-12] It is estimated that almost half of the 8,600 cases of pterygium treated annually in Australia are caused by sun exposure.[13,14] In more temperate climates, such as the north eastern United States, a significant relationship has been found between the cumulative dose of solar UVA and UVB and the prevalence of pterygium.[1,8,9] The World Health Organisation (WHO) suggest that up to 20% of cataracts may be caused by over-exposure to UV radiation and are therefore avoidable.[15] WHO estimates that every year, some 16 million people in the world suffer from blindness due to a loss of transparency in the lens. It was been estimated that 10% of cortical cataracts in Australia are potentially due to average annual ocular UVB exposure to the eye.[16] An analysis of data that controlled for age, sex, race, income and medical practices, found that the probability of cataract surgery increases by 3% for every degree south in latitude in the USA.[17] It has been estimated that by 2050, assuming a 5-20% ozone depletion, there will be 167,000-830,000 more cases of cataract in the United States, resulting in an increase in cataract operations and additional costs of $563 million to $2.8 billion.[18,19] In Australia, approximately 160,000 cataracts are treated annually at a cost in excess of $320 million.[20] Such data demonstrating UV-induced anterior

__Figure 1.__ Examples of the UV-associated ocular pathologies: cortical cataract (top) and pterygium (bottom).



segment pathologies are convincing, as they have been derived from a number of different study designs, in different populations, with varying levels of other known risk factors.

Most UV radiation is absorbed by the cornea, aqueous humour, and crystalline lens, with less than 1% of radiation below 340nm reaching the retina compared to over 10% of incident light at the 400nm wavelength reaching the retina.[21] Despite this, all UV radiations are genotoxic and UVB exposure can alter the function of the retina.[22] This makes aphakic or pseudophakic eyes more vulnerable to UV induced retinal damage. While an association between UV radiation and age-related macular degeneration (AMD) is tenuous, it is possible that damage to the retina may be indirectly associated with UV exposure. Aside from induction of DNA fragmentation, one potential role for UV-induced cell death involves production of ROS.[23] The retina is an ideal environment for generation of ROS; oxygen consumption is high, photoreceptors are composed of polyunsaturated fatty acids readily oxidized, RPE cells contain an abundance of photosensitisers, and photoreceptor phagocytosis processes generate high levels of ROS by itself. Although the aetiological mechanisms underlying AMD continue to elude, there is a growing body of evidence implicating oxidative stress and/or cumulative blue light damage in the process.[24,25] While currently unsupported by scientific studies, it is possible that UV-induced generation of ROS may indirectly contribute to AMD formation or progression.

UV exposure and children

As eye damage from UV radiation is cumulative, it is important to maximally protect the eyes beginning in childhood. A recent study in Australia found that 80% of children have signs of UV-induced damage by the age of 15 years.[26] Exposure of very young children to UV radiation should be limited, especially when UV levels are moderate or high. Children are particularly vulnerable to UV damage because they have larger pupils and have clearer lenses.[27,28] In the crystalline lens, 75% of UV radiation is transmitted in children under the age of 10 years, compared to 10% transmittance for individuals older than 25 years;[28,29] this is due to the UV absorbing effects of an increasingly yellow crystalline lens.

In addition, children tend to spend more time outdoors than adults, exposing them to higher levels of UV. Recent studies estimated that only 3% of children regularly wear sunglasses and that 23% of lifetime UV exposure occurs by the age of 18 years.[30,31]

During times of UV exposure, it is important that all children wear sun protection. Once children are old enough to manage wearing sunglasses and UV-blocking CLs they should be encouraged to do so if they are outside during daylight hours.

UV protection from sunglasses

Ocular exposure to UV can be substantially reduced through personal protection, such as wearing a hat with a brim and sunglasses.[5,6] Unfortunately, most individuals do not realize that the majority of sunglasses do not prevent all UV rays from reaching the eyes. While well-made sunglasses will block nearly all UV light that enters through the lenses, only goggles and extreme wrap-around styles have lenses that provide complete coverage. Also, some research has suggested that dark sunglasses may undermine UV protection by disabling the eye's natural reactions to sunlight, such as squinting, and may initiate counter-productive responses such as pupil dilation.[32,33] Most other sunglass styles allow direct and reflected light to enter the eye from the sides, top and bottom of the glasses, with the result that some sunglasses block as little as 50% of UV rays.[6,32,36] This can result in the peripheral light focusing effect where tangential light rays will be directed onto the nasal aspect of the eye.[10,35] Unfortunately, these peripheral UV rays can be very damaging to the eye. The intensity of radiation passing through most sunglasses is 20 times stronger at the nasal limbus and up to 5 times stronger at the nasal lens cortex.[35-37] Studies have shown that the UV rays entering the eye from the side or top of sunglasses are focused at the nasal limbus and coincide with where pterygia most frequently occur and the nasal lens cortex, the most likely site for cortical cataracts. When UV-blocking CLs are used, they can help to absorb the peripheral light that sunglasses cannot block (*Figure 2*).[36,38,39] Kwok and colleagues demonstrated a significant decrease in the intensity of peripheral light focused on the nasal limbus when UV-blocking CLs were worn.[36]

In addition, UV-blocking CLs cover the limbal region including the Palisades of Vogt. As a result, these lenses can help to protect the vital corneal and conjunctival stem cells in this region against tangential and temporal UV rays.

UV protection from contact lenses

Currently, silicone hydrogel (SiH) CLs account for more than half of all prescribed soft lenses.[40] SiHs that offer UV-protection are labelled as Class I and Class II, with each of the different classes indicating the level of UV protection. Class II UV-blocking polymers have been available in CLs for several years; most recently Class I UV-blocking SiH polymers have been introduced, providing the highest level of UV protection. Previously, little data concerning the UV-blocking characteristics of SiH materials was available;[39,41] however, measurements from a recent study found that the SiH materials senofilcon A and galyfilcon A could effectively reduce UV radiation to safe levels.[42]

According to the American National Standards Institute's (ANSI) standard for aphakic and cosmetic CL wear, Class I CLs block 90% of UVA (316–400nm wavelengths) and 99% of UVB (280–315nm wavelengths). Class II CLs must block at least 70% of UVA and 95% of UVB radiation. Non-UV blocking CLs have been documented to absorb only 10% of UVA and 30% of UVB, on average. It is thought that the unique materials found within Class I and II could provide protection relative to UV-induced ophthalmic exposures.[43-50] In this regard, a soft CL is in intimate contact with the ocular surface, therefore potentially protecting the surface it covers in addition to the internal structures of the eye that are vulnerable to UV-induced damage. Currently there are five Class I SiH CLs that have received the American Optometric Association (AOA) seal of acceptance based on FDA standards (ACUVUE® OASYS®, ACUVUE® OASYS® for ASTIGMATISM, ACUVUE® ADVANCE®, ACUVUE® ADVANCE® for ASTIGMATISM and *1•DAY* ACUVUE® TruEye™). According to a Brand Health Monitoring Survey performed in 2005 by Vistakon in USA, 57% of respondents did not know if their current CLs provided UV protection and 39% believed that all CLs provided appropriate UV protection. In a 2006 Gallup survey, 57% of CL considerers rated UV protection as the most desired feature in a CL.[51] This data provides strong incentive to educate CL consumers on appropriate UV protection and UV-blocking CLs.

Figure 2a. *Relative intensity of peripherally focused UVB measured using a mannequin head model in three insolation conditions. In all environments, the UV-blocking CL produced significantly lower intensities compared with no eyewear.[36]*

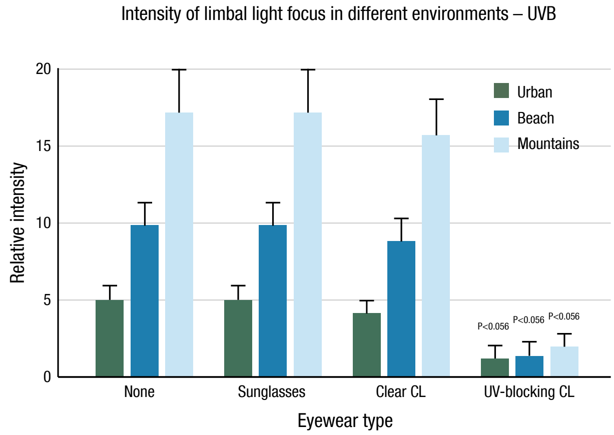
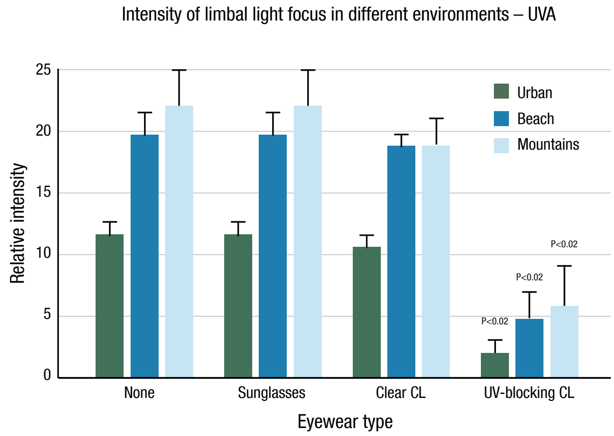


Figure 2b. *Relative intensity of peripherally focused UVA measured using a mannequin head model in three insolation conditions. In all environments, the UV-blocking CL produced significantly lower intensities compared with no eyewear.[36]*



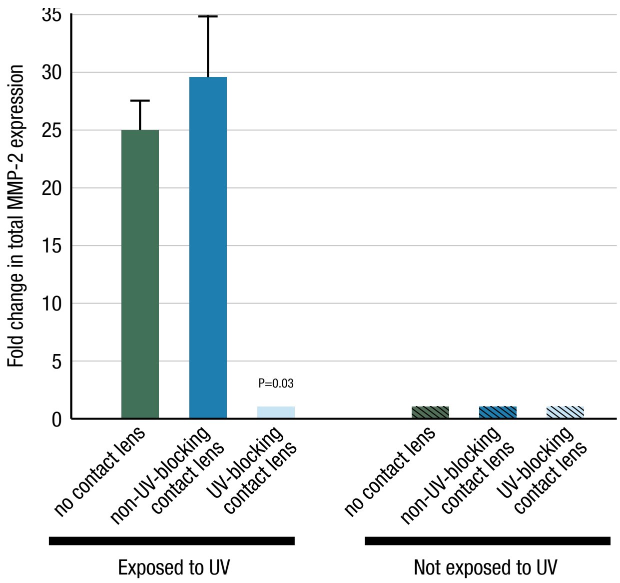
Research on UV-blocking contact lenses

UV exposure is based on a number of factors such as environmental conditions (altitude, geography, cloud cover) and personal factors (extent and nature of outdoor activities). UV-blocking CLs help provide protection against such exposure to harmful UV radiation. Recent studies support the hypothesis that UV-blocking CLs can attenuate the amount of peripherally focused UV light, suggesting that the risk of eye diseases such as pterygium and cortical cataracts may be reduced through use of UV-blocking CLs.[36,38] Due to their smaller diameter, rigid gas permeable CLs capable of blocking UV radiation can only protect the central cornea from UV exposure; the peripheral cornea is left exposed and research has demonstrated evidence of UV-induced damage in such situations.[46] Soft CLs cover the entire cornea and limbus, increasing the potential for protection from UV exposure. This is of considerable significance since this is the location of epithelial stem cells that continuously repopulate the corneal epithelium. Concern over increased corneal damage due to the combination of CL wear and UV exposure has been minimized by previous studies.[47,48] Ahmedbhai[48] demonstrated that removal of a rigid CL from a CL adapted eye did not increase the risk of damage to that eye compared to the non-adapted eye subjected to the same exposure of UV.[48] It was noted that biomicroscopic differences in the appearance of the ocular reaction, damage and recovery were similar.[48] A second study determined that eyes exposed to UV while wearing soft CLs were at no greater risk than eyes not wearing CLs.[47] Such data supports the use of UV-blocking CLs to protect the ocular surface.

Several scientific studies have demonstrated that following acute UV exposure, the cornea is particularly vulnerable to UV-induced damage.[44-50] Following irradiation, corneas not protected by UV-blocking CLs had pronounced corneal haze and oedema within the endothelium and stroma due to changes in corneal hydration.[44] Use of UV-blocking CLs not only prevented these changes but also negated degeneration and fragmentation of corneal epithelial cells and keratocytes.[44] Expression of proteins associated with inflammation and cell death have been observed in corneas exposed to acute UV irradiation.[50] In earlier research studies, UVB has been shown to induce matrix metalloproteinases (MMPs) in human corneal cells.[52] This UV induction of MMP production and activation likely plays a role in initiating or maintaining enhanced proteolytic activity in corneas with keratitis. Furthermore, inflammatory cells recruited due to keratitis undoubtedly sustain and amplify MMP activity. New data demonstrates that use of UV-blocking SiH CLs significantly reduced expression of these potentially detrimental protesases (*Figure 3*).[50]

Programmed cell death through apoptotic mechanisms is frequently observed in corneas that receive exposure to UVB. The use of UV-blocking CLs has been shown to significantly reduce levels of UV-induced cell death in the cornea, likely due to prevention of apoptosis, compared to eyes wearing non-UV-blocking CLs.[50] Further experimentation has found that irradiated eyes wearing UV-blocking CLs maintained normal corneas, while eyes wearing standard hydrogel lenses showed pronounced cell loss and changes in the epithelial, stromal and endothelial cells.[45]

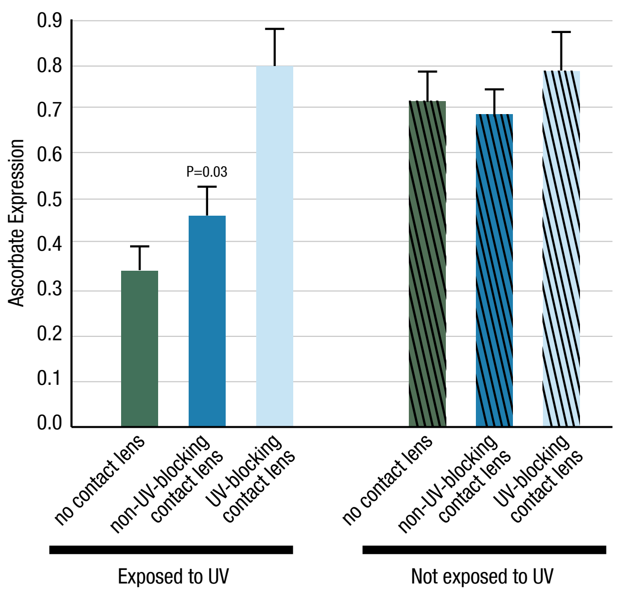
Figure 3. *Matrix metalloproteinases (MMP) expression following UV exposure.[50] A significant increase in MMP expression was found in corneas exposed to UV wearing non-UV-blocking CLs compared to corneas exposed to UV but wearing UV-blocking CLs.*



While full recovery from UV-induced damage is possible in the corneal epithelium, damage to the stromal keratocytes and endothelium is considered permanent. This has implications on how the cornea can deal with future trauma or surgery. Cumulative examination of data relating to UV- induced corneal changes suggests that long-term exposure to solar UV could be a major factor in the aetiology of certain keratopathies and might be responsible for premature age-related corneal changes.[9] This provides further justification for protecting the cornea with UV-blocking CLs.

In addition to corneal changes, damage associated with UV exposure has been noted in the aqueous humour and crystalline lens. UV-induced reduction of aqueous humour ascorbate levels, an antioxidant know to protect the crystalline lens, was minimized in rabbits wearing UV-blocking CLs (*Figure 4*).[50] This shielding of aqueous humour antioxidant levels will likely aid in protection against cataractogenesis. While UV-associated cataract formation requires

Figure 4. *Aqueous humor ascorbate levels following UV exposure.[50] A significant decrease in ascorbate was observed in eyes exposed to UV while wearing non-UV-blocking CLs compared with UV exposed eyes wearing UV-blocking CLs.*



chronic exposure, a recent study utilising acute UV demonstrated that UV-blocking CLs were capable of decreasing lens epithelial cell death.[50] This is one factor known to contribute to cataract formation. Bergbauer[49] found that longer UV exposure to guinea pig eyes resulted in changes that occur during human lens ageing and cataractogenesis, such as increased pigmentation, fluorescence and disulfide crosslinking,[49] with eyes that wore UV-blocking CLs showing reduced UV-associated damage. To date, neither chronic nor clinical studies in humans have been performed to demonstrate that wearing UV-blocking CLs reduce the risk of developing cataracts or other ocular disorders.

Conclusions and future directions

A large body of evidence supports the benefit of wearing UV-blocking CLs to prevent detrimental ocular damage associated with acute UV exposure. While it is very likely that UV-blocking CLs can mitigate the effects of UV irradiation over longer periods of time, additional research must be performed to confirm this hypothesis. Despite the lack of conclusive biologic or clinical evidence, UV protecting CLs should be considered for a large number of patients. Myopic, hyperopic, or even emmetropic, children may benefit from UV-blocking CLs by reducing lifetime ocular UV exposure. Other instances where a UV-blocking CL would be indicated include aphakia or those who have received refractive surgery, as the removal of stromal thickness might alter the corneas ability to naturally filter UV light.

It is important to note that UV-blocking CLs should not be viewed as a stand-alone solution since they do not protect the eyelids, face or areas of the eye not covered by the lens. Hence, the most complete measure of UV protection can be achieved with a combination of UV-blocking sunglasses, a wide-brimmed hat and UV-blocking CLs. Use of UV-blocking CLs will, as a minimum, provide practitioners, patients and parents with the reassurance that the wearers have at least some protection without the supplemental protection of hats and sunglasses. Additionally, protection from the UV-blocking CLs is present all day long, allowing the wearer a level of UV protection with minimal effort and obstruction to daily life.

Increasing public and practitioner awareness is of critical importance. Emphasis on the importance of UV ocular safety and education on UV protection in all forms should be strongly encouraged.

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