

Should we be advising our patients about the need for ocular protection?

Professor James Wolffsohn reviews the latest evidence to help us understand the need to raise awareness of UV exposure on the eye and with advise options for protection.

There can't be too many people who would dispute the adverse effects of sunlight exposure to the skin and would advise those around them on the need for protection. Hence it is important to examine the level and type of evidence in the peer reviewed literature on the effects of ocular damage from UV exposure. This evidence will help us understand the need to raise awareness of UV exposure on the eye and the subsequent issues with our patients and help them to protect their eyes.

In the journal *Eye and Contact Lens* last year, a series of review articles were published on this topic by 13 respected authors, including: public health aspects of UV exposure

and the need for protection; ozone depletion; diurnal and seasonal variations in ocular UV exposure; anterior eye UV induced conditions and the peripheral light focusing factor; phototoxicity and the retina; the role of UV in age-related macular degeneration (AMD); and the best ocular protection for UV. The authors had all been invited to participate in a symposium sponsored by the journal and the Contact Lens Association of Ophthalmologists, Inc. (CLAO), which was funded by an educational grant from Johnson and Johnson Vision Care. This article aims to draw out the key points from the 104 pages of amassed evidence and a few papers published since this symposium.

KEY POINTS SUMMARY

- Public health campaigns on UV dangers to skin has decreased skin cancer incidence
- Although UV exposure may have some beneficial effects (i.e. vitamin D synthesis protecting against certain systemic diseases), there are no known benefits of UV ocular exposure
- Unlike skin damage (mainly from direct UV exposure), the eye is at risk from UV exposure all day and all year round due to light scatter and reflections
- The publicised UV index is misleading for ocular damage; UV exposure with limited effect on the skin may damage internal ocular tissues
- UV exposure implicated in pathogenesis of a range of ophthalmohelioses including photokeratitis, pinguecula, pterygium, squamous cell carcinoma, cortical cataract and macular degeneration
- Peripheral light focusing (PLF) effect can by-pass natural stem cell protection mechanisms and increase light intensity to nasal limbus 20 fold, affecting conjunctiva and crystalline lens
- The young retina is particularly at risk of damage from UV exposure
- There are a range of options for protection from ocular UV exposure
 - Hats and umbrellas help protect from overhead solar energy, yet don't limit significant ocular UV exposure from light scatter and when sun is close to horizon.
 - Spectacle and sunglass UV protection depends mainly on frame design – side shields are critical, particularly due to PLF effect
 - Class 1 and 2 UV-blocking contact lenses cover the cornea, limbus and much of bulbar conjunctiva, providing an ideal solution for all day, year round protection
- Eye-care practitioners have a duty of care to:
 - warn patients of the potential damage from ocular UV exposure
 - communicate ways to help patients protect their eyes using a combination of a hat, wrap-around sunglasses and Class 1 or 2 UV-blocking contact lenses

Public Health

Eye care professionals have a role not just in correcting refractive error and providing information on the range of correction options that will optimise the patient's visual quality of life, but they also have a key role concerning eye health. Not only does ocular disease need to be detected and treated, but the highest ideal of any health strategy is prevention. The patient history should be used to identify risk factors such as smoking (obviously some are non-modifiable such as gender!) and advise on their impact so patients can make informed choices on their lifestyle.

Many countries have developed highly promoted sun protection programs over the past few decades, spurred on by rapidly increasing skin cancer incidence and concerns about stratospheric ozone depletion increasing UVB (280-315nm) at the earth's surface.¹ While the adverse effects of too much UV to the skin are well known, there are some positive aspects to UV exposure such as the endogenous synthesis of vitamin D and with low vitamin D linked to a wide variety of cancers, autoimmune diseases such as multiple sclerosis and diabetes type 1, infections such as influenza and tuberculosis, psychiatric diseases and cardiovascular diseases.² Regulation of the sleep cycle (circadian rhythm) through relatively recently identified suppression of the melatonin retinal receptors (also linked with cancer incidence and progression) is also a positive benefit, although this is mediated through blue rather than UV light.^{3,4} These conflicting health concerns make the public message such as Australia's slip (on a shirt), slap (on a hat) slop (on sunscreen) less robust (expanded with 'seek' shade and 'slide' on sunglasses in 2007).⁵ However, it is unclear whether a similar dilemma exists for UV-related eye conditions.

The World Health Organisation published a study on the global burden of disease due to UV radiation in 2006.⁶ Based on the evidence available to them they estimated that 25% of the total burden of disease resulting from cataracts was caused by cortical cataracts (assuming a causal link between UV radiation and cortical cataract) and that the total cataract disease burden could be reduced by 5% if exposure to UV radiation to the eye was avoided. In his review, Lucas⁷ challenged some of the limitations of the model such as the lack of consideration of regional variations in population demographics, lifestyle, socioeconomic status and ambient UV radiation, as well as the epidemiological evidence that cataract-induced vision loss is a risk factor for premature mortality.⁸

Declining or plateauing incidence rates of UV-related cancers provides some evidence for the effectiveness of sun protection focused public health programmes which

influence, at least in the short term, sun safety knowledge and behaviour.⁹ However, although it seems plausible that wearing UV blocking sunglasses and/or a hat should decrease the risk of UV-induced eye diseases, there is currently a limited evidence-basis. Indeed, it has been surmised that promoting sunglasses in high UV environments could increase UV-induced eye damage,¹⁰ through negating natural 'defence' mechanisms of pupil contraction and squinting.¹¹

Diurnal and Seasonal UV Exposure

Solar UV levels are known to generally be greater at low latitudes,^{12,13} in the summer season, and from 10am to 2pm everyday.¹⁴ The World Health Organization in collaboration with partners across the world developed the UV index, a 0 to 10 linear scale based on the intensity of UV present under standardised conditions (although ozone depletion is now resulting in values above 10 as it is related to the UV radiance, weighted for wavelength). Their aim was to better communicate the need for the general public to adopt skin protection measures when the UV is high.¹⁵ The index is based on skin erythema dose, for whom, most exposure to UV radiation is direct from overhead. However, for the eye, direct exposure is less common due to the shielding from the ocular brow and eyelids.¹¹ Sasaki and colleagues found the UV index differed so much from their measures of ocular exposure that they considered it invalid as a determiner of eye risk, warning it could be seriously misleading. For example in Japan during September, facing towards the sun, the maximum intensity at the ocular surface occurred at about 9am and 2-3pm in a bimodal distribution.¹⁶

Thus, light scatter and reflection are more of a concern for the eye than direct exposure. In addition, the cornea and crystalline lens focus incoming light on the retina increasing the gain by as much as 100 fold.¹⁷ Thus even UV radiation doses that have limited effect of the skin may be capable of damaging internal ocular tissues. Protection just in summer months or around midday is inadequate as UV exposure can occur all day and all year.

UV Radiation and the Anterior Eye

Conditions in which sunlight has been implicated in the pathogenesis have been termed the "ophthalmohelioses"¹⁸ Current evidence indicates that UV radiation exposure to the eye causes only adverse effects. There is strong evidence that acute high dose exposure to UV radiation causes photokeratitis and photoconjunctivitis, while even low dose chronic exposure to UV radiation is a risk factor for cataract (Figure 1), pterygium and squamous cell carcinoma of the cornea and conjunctiva.

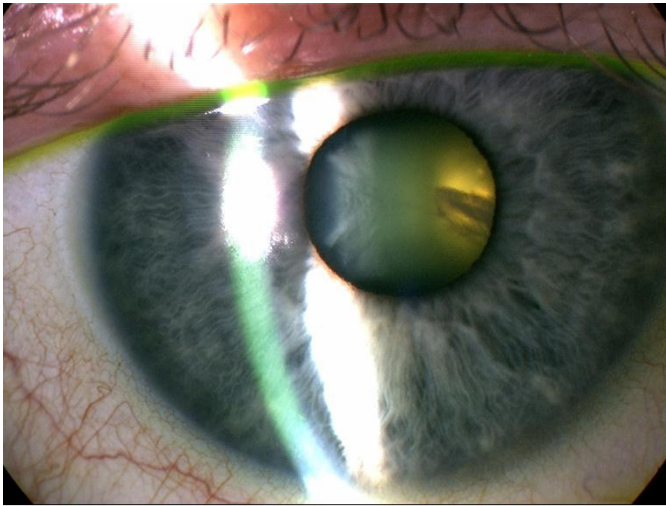


Figure 1:
Cortical cataract (with kind permission of David Ruston)

There is currently less clear cut evidence in relation to other conditions, including ocular melanoma and age-related macular degeneration (Figure 2). Ultraviolet radiation related eye diseases are common (Table 1), disabling, and cause a considerable disease burden worldwide.



Figure 2:
Age-related macular degeneration (with kind permission of Professor Christina Grupcheva)

The peripheral light focusing effect (Figures 3 and 4) explains why pterygia occur more commonly on the nasal rather than the more exposed temporal conjunctiva. It has been shown by careful observation and ray tracing that the anterior eye, acting as a side-on lens, focuses light across the anterior chamber onto the opposite side of the eye, most noticeably to the distal (nasal) limbus. The peripherally focused light avoids the normal protection of the superficial stem cells by striking the basal, relatively unprotected, stem cells.¹⁹ This also accounts for why cortical cataracts tend to be most severe in the lower nasal region.²⁰ The degree of

limbal focusing is partly determined by the corneal shape, the anterior chamber depth and focusing on the crystalline lens, perhaps explaining why some individuals are more susceptible than others in the same environment. The peak light intensity at the distal limbus is approximately 20 times that of the incident light intensity and occurs at an incident angle of 104 degrees, creating a complex arc focal shape.^{21,22}

Eyelid	Wrinkles
	Sunburn
	Photosensitivity reactions
	Cicatricial ectropion
	Dermatochalasis
	Pre-malignant changes
	Malignant changes (basal cell carcinoma)
	Squamous cell carcinoma
	Primary acquired melanosis
	Melanoma
Ocular surface	Pinguecula
	Pterygium
	Climatic keratopathy
	Actinic granuloma
	Photokeratitis
	Arcus
	Bank keratopathy
	Corneal endothelial polymorphism
	Reactivation of herpetic keratitis
	Scleritis in porphyria
	Senile sclera plaques
	Post photorefractive keratectomy haze
	Dysplasia and malignancy of the cornea or conjunctiva
	Vernal catarrh
Crystal-line lens	Cataract
	Anterior capsular herniation
	Early presbyopia
	Capsular pseudoexfoliation
	Subluxation in Marfan syndrome
	Intraocular lens dysphotopsia
Uvea	Melanoma
	Miosis
	Pigment dispersion
	Uveitis
Vitreous	Blood-ocular barrier incompetence
Retina	Liquification
	Photic maculopathy
	Erythropsia
	Macular degeneration
	Choroidal melanoma
	Visual loss with photostress in carotid stenosis
Circadian rhythm disturbances	

Table 1:
Ophthalmic conditions where sunlight has been implicated in the pathogenesis

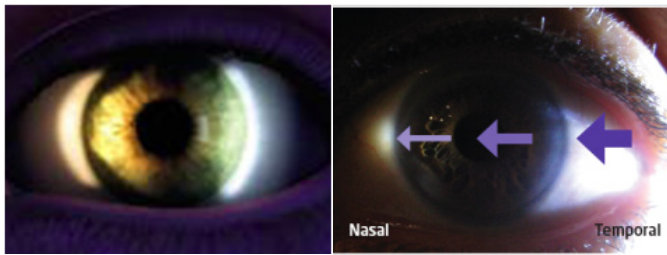


Figure 3:
Peripheral light focussing effect

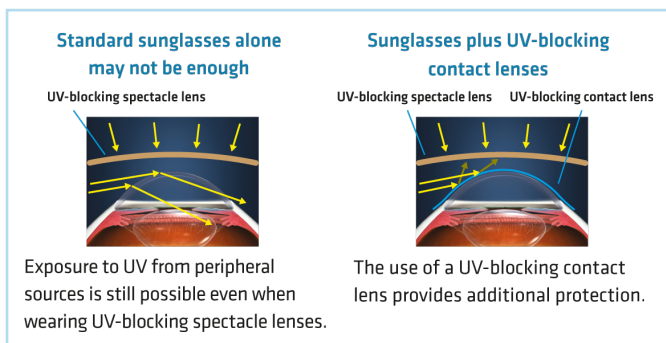


Figure 4:
Graphical demonstration of peripheral light focussing effect (PLF)

As long as the crystalline lens with its yellow pigments of 3-hydroxy kynurenine and its glucosides are present, relatively little UVA or UV-B reaches the retina. However, intense acute UV radiation or chronic UV exposure will lead to the formation of cataracts as there is little protein turnover in the lens fibre cells so damage accumulates through life.²³ Both in-vitro and in-vivo studies support the hypothesis that light penetration into the eye is a significant contributory factor in the genesis of cataracts, the major effect being through photochemical generation of reactive oxygen species resulting in oxidative stress to the tissue.²⁴ The young retina is at particular risk for damage from UV exposure as the young lens has not as yet synthesized the yellow pigment that prevents UV transmission to the retina.^{25,26}

UV Radiation and the Posterior Eye

While the adult crystalline lens effectively shields the retina from wavelengths less than 360 nm, the spectral band from 360 to approximately 550 nm does penetrate to the retina and contains photons with sufficient energy to produce photochemical damage. Depending on the wavelength and exposure duration, light interacts with tissue by three general mechanisms: thermal, mechanical, or photochemical. Natural light sources, such as the sun, emit relatively longer wavelength UV photons, which typically induce photochemical damage as the energy is not confined within the retinal layers (which would result in thermal or mechanical damage). Photochemical damage in the retina proceeds through direct reactions involving proton or electron transfers and reactions involving reactive oxygen species mechanisms. Commonly used drugs, such as

certain antibiotics, non-steroidal anti-inflammatory drugs, psychotherapeutic agents, and even herbal medicines, may act as photosensitizers that promote retinal UV damage if they are excited by UVA or visible light with sufficient retinal penetration.²⁷

The retinal pigment epithelium and choroid contain melanin, which absorbs UV and protects the retina against UV-induced damage. However, with age, ocular melanin is photo-bleached, decreasing its effectiveness in protecting against UV damage.²⁸ In those over the age of about 50 years, short wavelength blue light of around 430 nm causes an additional hazard through a photo-oxidation reaction.^{29,30} Lipofuscin, which accumulates with age, produces singlet oxygen in response to blue light, superoxide, and free radicals which damage the retinal pigment epithelium.³¹⁻³² The rods and cones eventually die as they are no longer being nourished by the retinal pigment epithelium, speculated to lead to age-related macular degeneration (AMD). Macular pigments such as lutein and zeaxanthin offer some protection against inflammatory and photooxidative damage, but decline with age.^{33,34}

Long-term exposure to short wavelength light in animal models leads to retinal damage similar to that seen in patients with AMD. The epidemiologic evidence for light exposure as a cause of AMD is currently inconclusive.³⁵ Some clinical studies found a positive association between sun exposure and AMD, such as the amount of time spent outdoors was related to the development of AMD in the Beaver Dam Study in the USA³⁶ and exposure to blue and short wavelength light was associated with AMD in two Australian studies.³⁷⁻³⁸ However, others have failed to show an association between sunlight exposure and AMD.³⁹⁻⁴² A study to prove UV protection reduces the rate of macular degeneration could take a lifetime to complete, although retrospective analysis of UV protection over a period of around 5 years has recently been shown to result in higher levels of macular pigment optical density which has previously been linked to less AMD.⁴³

Ocular UV Protection

A number of alternatives potentially could provide UV protection to the eye. Hats and umbrellas may provide some protection from overhead solar energy, reducing glare. However, as has been highlighted, they don't avoid the significant ocular UV exposure from light scatter and when the sun is closer to the horizon. The last three articles in the special issue of Eye & Contact Lens cover the other alternatives of UV protection from spectacles, sunglasses and contact lenses.⁴⁴⁻⁴⁶ Although there is not scope within this article to comprehensively cover all the issues they raise,

there are a number of key points. The protection offered by sunglasses assessed by mannequin dosimetry studies all show that the frame design plays an all-important role,⁴⁷⁻⁵² but this has traditionally been ignored in sunglass standards.^{53,54} The same issues will arise in spectacle lenses. However, the reduction of visible light passing through sunglasses is likely to enlarge the pupil size and prevent squinting, two of the eyes protection mechanisms against intense solar exposure. Studies have consistently suggested a typical biologically weighted UV exposure of approximately 20 per cent of ambient light reaches the eye for conventional sunglass designs that have no peripheral protection.⁴⁷⁻⁵² This, together with the peripheral light focusing effect described earlier, emphasise the importance of close fitting side-shields. However, these are rarely fitted to spectacles or sunglasses. Hence the benefits of UV blocking soft contact lenses that cover the cornea, limbus and much of the bulbar conjunctiva would appear to be an ideal solution; Class 1 lenses block at least 99 per cent UVB and 90 per cent UVA, with Class 2 blocking at least 95 per cent UVB and 50 per cent UVA. When combined with a hat and sunglasses, UV-blocking contact lenses can offer comprehensive protection from all sources of UV exposure, whether direct, reflected or refracted.

A couple of recent research papers since the Eye & Contact Lens and CLAO symposium have specifically looked at the UV-blocking effects of modern contact lens materials. Andley and colleagues examined the effect of a non-UV blocking silicone hydrogel lens compared to the silicone hydrogel lens senofilcon A (ACUVUE® OASYS®) which has Class 1 UV-blocking⁵⁵ showing the latter completely protected in-vitro epithelial cell cultures and human donor crystalline lenses from UVB radiation induced damage, whereas the former was not protective.⁵⁶ In an in-vivo animal model, the same two silicone hydrogels were compared to a no-contact lens exposure of high dose UVB for 30 minutes. Eyes irradiated with no contact lens on the ocular surface showed crystalline lens anterior sub-capsular opacification, corneal vacuole formation and corneal epithelial cell loss and swelling as well as DNA single-strand breaks. The non-UV-blocking contact lens showed similar effects whereas the senofilcon A UV-blocking contact lens protected the eye almost completely from all the UVB adverse effects.⁵⁷

Conclusion

Reviewing the articles from the 2011 special issue of Eye & Contact Lens and more recent papers, it is clear that there is a strong association between anterior eye tissue damage and sunlight exposure, with still more research to be done to conclusively prove a direct link between age-related conditions such as AMD and chronic environmental UV

irradiation. However, as there is no evidence that blocking UV exposure to the eye would be of harm, it would seem reasonable to suggest eye-care practitioners have a duty of care to encourage ocular UV protection strategies where possible.

Practitioners should warn patients of the damage that can occur to their eyes from UV exposure and communicate ways in which they can protect their eyes using a combination of a hat, wrap-around sunglasses and Class 1 or 2 UV-blocking contact lenses. As the UV-index is not a good indicator of ocular UV exposure, all-day, all-year round protection with UV-blocking contact lenses could even be considered as a good reason to suggest starting wearing contact lenses to a non-contact lens wearer.

About the Author

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