

# Maximizing Protection from Ultraviolet Radiation Hazards: Assessing the Risks; Finding Solutions

Exposure to the ultraviolet component of sunlight causes damage to ocular tissues that can accumulate over a lifetime. This chronic ultraviolet radiation (UVR) exposure has been associated with pterygium, cataract, climatic droplet keratopathy, and other serious ocular conditions. As a result, many spectacle lenses now offer effective blocking of UVR transmission. However, recent work by Karl Citek, OD, PhD, and others has found that UVR can be reflected from the backside of clear, photochromic, and tinted/polarized lenses; and that No-Glare (antireflective, or AR) technology actually increases the level of backside UVR reflection. Maximum protection from UVR requires that all lenses—including clear lenses intended primarily for indoor wear—effectively shield wearers from both transmitted and reflected UVR. This is now possible with Essilor's new Crizal® UV lenses with patented Broad Spectrum Technology; these lenses maximize long-term eye health by shielding eyes from exposure to transmitted and reflected UVR.

## INTRODUCTION

Sunlight is the primary source of ultraviolet radiation (UVR) to which humans are exposed. Although a portion of the sun's UVR is absorbed by the ozone layer of the atmosphere, significant UVR penetrates the ozone to strike the surface of the earth. For most people, the total amount of UVR received (the cumulative dose) increases linearly over time.<sup>1</sup>

Documentation that cumulative sunlight exposure causes irreversible eye damage has been part of the medical literature for more than 100 years, but public awareness of the need to protect eyes from sunlight has lagged far behind. And new findings about the nature of solar UVR hazards underscore the importance of continuous UVR protection, which for eyeglass wearers is possible only if every pair incorporates effective UVR protection.

For example, we now know that a significant portion of the solar UVR incident on the cornea comes from indirect sources, including UVR striking from the side rather than the front (called "albedo") and UVR reflected by

This paper will further document that the problem of reflected UVR is not limited to sunglass wearers. Rather, studies have found that, on average, people receive over 40% of their annual UVR dose at times of day when they are unlikely to wear sunglasses; and up to 23% of people never protect their eyes from the sun at all (Table 1).<sup>2</sup> Clearly, eyeglass wearers need both their everyday glasses and their sunglass lenses to provide complete UVR protection.

## CHRONIC UVR EXPOSURE AND LONG-TERM EYE HEALTH

Although acute photokeratitis can occur from a single very high dose of UVR (eg, from skiing without eye protection) most UVR damage is cumulative—it is chronic UVR exposure and the lifetime UVR dose that are of greatest importance in UVR-associated diseases. This is as true with eyes as it is with skin, where solar UVR is known to contribute to aging and the development of cancer.

UVR that reaches the eye can cause serious damage. Epidemiologic studies have linked chronic UVR exposure

TABLE 1 Sources of UVR Exposure

Condition	Sunlight Exposure (Lx)	Percent of Annual UVR exposure
Indoor	500	~7%
Cloudy sky	5,000	5%
Clear sky	25,000	30%
Summer sky	100,000	58%
TOTAL		100%

the backside of spectacle lenses. (All types of spectacle lenses can reflect UVR, including clear, photochromic, and tinted/polarized lenses). As this paper will document, the hazard to eyes from UVR reflected by the backside of spectacle lenses is a serious problem that until now has had no solution.

with serious ocular pathology, including climatic droplet keratopathy, pterygium, cortical cataract, and pinguecula (Table 2). Although the relationship has not been definitively proved, solar UVR exposure has also been implicated in the development of age-related macular degeneration (AMD).

**UVR EXPOSURE AND THE EYE**

It was once thought that ocular UVR exposure rose and fell in parallel with the intensity of ambient UVR — as is true of skin exposure — but this is not the case. Set deep within the orbit, the eye is effectively shaded by the brow and upper lid when the sun is directly overhead. Thus, when the sun reaches its zenith at solar noon (and ambient UVR peaks), only a fraction of this radiation reaches the eye.<sup>3</sup>

Sasaki and colleagues demonstrated this relationship between solar angle and the quantity of solar radiation striking the eye by using a specially designed mannequin with UVR sensors installed on both the top of the head and within the eye socket at the position of the cornea. As expected, UVR exposure at the top of the head rose and fell with solar angle, but the in-eye sensor registered the highest levels of UVR in the mid-morning (from 8:00AM to 10:00AM) and mid-afternoon (2:00PM to 4:00PM), leading these researchers to conclude that UVR exposure in the eye peaks at times other than solar noon and suggests a need for all-day UVR protection.<sup>4</sup>

Ocular anatomy has other effects on UVR exposure. The human skull is configured to allow a large temporal field of vision. As a result, a significant amount of sunlight can strike the eye from the side. This exposure to oblique light creates a particularly significant hazard due to the peripheral light focusing (PLF) effect, also known as the Coroneo effect.<sup>5,6</sup>

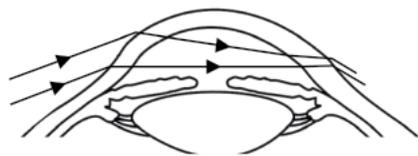


Figure 1 Focused peripheral light reaches the nasal limbus.

In PLF, light incident from the side is refracted by the peripheral cornea, which focuses it on the nasal limbus where the corneal stem cells reside (Figure 1). Although the limbal stem cells are protected by the sclera from direct UVR exposure, PLF bypasses this protection and concentrates sunlight (including its UVR component)

TABLE 2 Ophthalmic conditions associated with UVR/sun exposure

Eyelid	Basal cell carcinoma; squamous cell carcinoma; wrinkles; sunburn; photosensitivity reactions
Ocular Surface	Pterygium; climatic droplet keratopathy; photokeratitis (“snow blindness”); pinguecula; dysplasias and malignancies of the cornea and conjunctiva
Crystalline Lens	Cortical cataract
Uvea	Melanoma; pigment dispersion; uveitis; blood/ocular barrier incompetence
Vitreous	Liquifaction
Retina	Age-related macular degeneration (not definitely proved)

at the nasal limbus, increasing exposure there as much as twenty-fold.<sup>5</sup> Epidemiologic evidence indicates that this concentrated sunlight plays a critical role in the development of pterygium.<sup>7</sup>

**BACKSIDE UVR REFLECTIONS: A NEWLY RECOGNIZED HAZARD**

Antireflective lens technology (sometimes referred to as “No-Glare” or “AR” technology) is widely used in

**CONTRIBUTION OF LIGHT SCATTERING AND REFLECTION**

Short wavelengths of solar radiation, including UVR, are scattered by clouds and by particles in the atmosphere—this scattering of blue wavelengths makes the sky appear blue. High levels of UVR can also be reflected from surfaces such as sand, snow, water, and grass (See Table). This reflected and scattered UVR accounts for more than half of the UVR that strikes the cornea.<sup>8</sup>

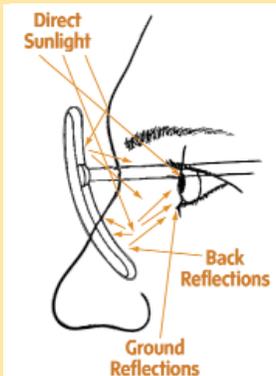
At times close to solar noon, when the brow and upper eyelid shield the eye from direct sunlight, scattered and reflected sunlight becomes the primary source of ocular UVR exposure. This scattered and reflected UVR can strike the eye from any direction, including directions that bypass spectacle frames and lenses (see Figure). (The exception is full-wrap sunglasses and goggles.)

If the individual is wearing glasses, a significant portion of this UVR can be reflected directly into the eye by the backside of the lenses. This is true whether the lenses are clear, photochromic, or tinted/polarized.

Depending on the geometry of the lens, the frame, and environmental conditions, up to 50% of UVR exposure comes from the back and sides of the lens. Thus, even if the lens is capable of blocking 100% of UVR transmission, the eye can still receive a substantial dose of UVR due to side and back exposure. This light scattering (which enables UVR to come at the eye from the side and behind) and reflection from the backside of spectacle lenses must be taken into account in any consideration of UVR protection.

UVR Reflectance of Different Surfaces

Surface	UVA	UVB
Snow	94%	88%
Sand	13%	9%
Water	7%	5%
Grass	2%	2%



UVR can still reach the cornea, even if the patient is wearing a UVR-blocking lens.

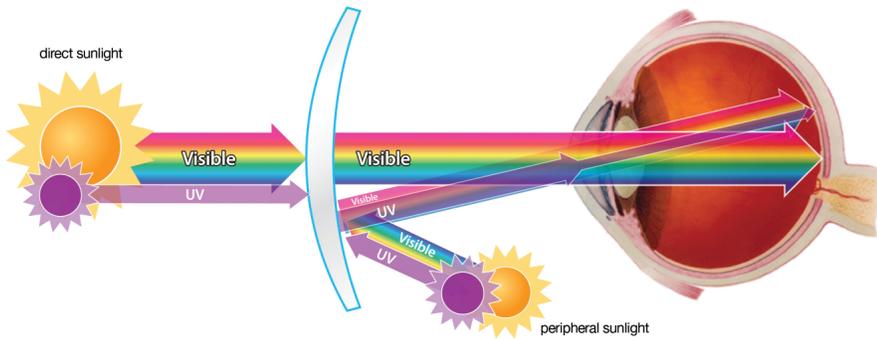


Figure 2 Antireflective lenses that are not Crizal® UV reflect UVR off the backside, so significant UVR can strike the cornea (even if the lens protects against transmitted UVR). Today, only Crizal® UV lenses (Crizal Forte® UV, Optifog™ with Crizal® UV, Crizal Sun™ UV, Optifog Sun™ with Crizal® UV) protect against reflected UVR.

spectacle lenses to enhance the cosmetic and optical performance of the lens by increasing light transmission and eliminating visible reflections and glare. Unexpectedly, Antireflective treatments have recently been found to increase the reflectance of UVR. While clear lenses without antireflective treatment reflect approximately 4% to 6% of UVA (380-315 nm) and UVB (315-280 nm), antireflective lenses reflect an average of 25% of most UVR wavelengths.<sup>9</sup> And

some AR lenses reflect close to 90% of individual UVR wavelengths.<sup>9</sup>

This high level of UVR reflectance makes scattered and reflected UVR a particular concern since they can strike the back surface of a spectacle lens and be reflected into the eye (Figure 2). UVR reflected by the backside of a lens can enter through the central cornea. It can also reach the temporal limbus and do harm through the PLF mechanism.

Heretofore, backside reflection could

be prevented only by goggles or high-wrap frame designs that allow little or no light to strike the back surface of the lens. Current photochromic, sun lenses, and clear lenses do not address this particular hazard. Some clear lenses (eg, those made from polycarbonate) and all photochromic lenses block transmission of 100% of UVR that is directly incident on the front of the lens; materials that do not inherently absorb UVR can be treated to block UVR transmission. However, the backside reflection of UVR remains the Achilles heel of UVR protection and safer vision.

**NEW CRIZAL® UV LENSES ELIMINATE BACKSIDE UVR REFLECTION**

To address the significant hazard of backside UVR reflection, Essilor has developed new Broad Spectrum Technology that extends the superior Crizal® antireflective lens efficacy from the visible light spectrum to the ultraviolet spectrum (Figure 3). Essilor's new Crizal Forte® UV and Optifog™ with Crizal® UV lenses are the first to feature this new technology for clear, everyday lenses, in which UVA and UVB reflections from the backside of the lens are reduced — without loss of the other benefits of Crizal® AR lenses. This means that Crizal® UV lenses not only maximize visible light transmission for enhanced visual clarity, they also provide protection from reflected UVR — in addition to resisting and repelling scratches, smudges, dust, and water (Table 3).

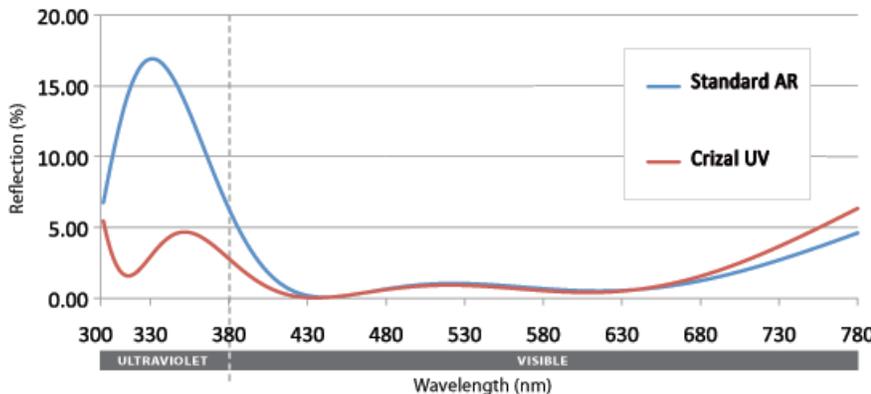


Figure 3 Crizal® UV extends effective blocking of UVR reflections deep into the UVR spectrum, while within the visible light spectrum Standard AR and Crizal UV provide virtually identical reflection blocking.

**PUTTING UVR IN PERSPECTIVE**

Long-term exposure to solar UVR causes cumulative damage to ocular tissues that can harm eye health. Environmental factors like depletion of the ozone layer will increase levels of UVR on the surface of the earth for decades to come, and prevention of UVR-associated eye diseases will become correspondingly more important.

Recent studies show that reflection of UVR from the backside of spectacle lenses represents a significant source of ocular UVR exposure. Other investigations have found that peak times of ocular UVR exposure are mid-morning and mid-afternoon — times when indi-

TABLE 3 Benefits of new Crizal® UV and Crizal Sun™ UV (designed specially for sunwear)

Superior visual clarity	Glare reduction
	Improved contrast sensitivity and visual acuity
	Resists scratches and smudges
	Repels dust and water
Maximum UV protection	Easy cleanability
	Blocks transmission of UVR (100%) through the lens*
	Reduces backside UVR reflection

\*when paired with a photochromic or higher-quality lens material.

## THE EYE-SUN PROTECTION FACTOR

People purchasing sunscreens know exactly how much UVR protection they are getting because sunscreens all carry a number on the label. This provides a precise indication of the sun-blocking strength of a given sunscreen and makes it easy to compare one sunscreen with another. Although UVR protection is as critically important to eyes as it is to skin, until now nothing like that has existed to indicate the UVR protection offered by specific spectacle lenses.

With this in mind, Essilor has worked with independent experts to develop the Eye-Sun Protection Factor (E-SPF). Defined as the ratio of UVR at the cornea with and without lenses in place, E-SPF measures the amount of protection provided by a lens as compared to no protection at all. (The ratio is weighted to take in consideration the impact of UVR at different wavelengths on the cornea.)

Calculation of E-SPF takes into account both transmission of UVR through the lens and backside UVR reflection. By integrating these two aspects of UVR protection, E-SPF provides a readily understandable measure of the UVR protection offered by a given lens. As with the reference index of the skincare industry, higher values of E-SPF indicate better UVR protection. For example, new Crizal® UV lenses, with minimal backside UVR reflectance, have higher E-SPF values than competitive antireflective lenses (see Table).

Perhaps the most important aspect of the E-SPF is that it gives eyecare professionals a simple way to tell patients how they can maximize protection—without lengthy, complex explanations or recommending specific products. Now telling patients how to protect their eyes is as straightforward as telling them how to protect their skin. Pick the highest number for the best protection. It's that simple.



E-SPF of different AR Lenses

Main AR Lenses	E-SPF
Crizal Sun UV Optifog Sun with Crizal UV	50+
Crizal Forte UV Optifog with Crizal UV	25
Competitor A	3
Competitor B	5
Competitor C	5

viduals are not likely to wear sunglasses. Hence, to achieve the goal of minimizing ocular UVR exposure, spectacle-wearing patients should be well protected in every pair of glasses they have, whether the lenses are clear, photochromic, or tinted/polarized.

Today's higher quality lens materials provide 100% blocking of UVR transmission, but the AR technology on the back surface of a lens can reflect unexpectedly high levels of UVR and significantly increase the eyes' dose of UVR. The most complete solution for everyday UVR protection, thus, is lenses that protect against both UVR transmission and reflection.

This is now possible for clear, everyday lenses with the patented Broad Spectrum Technology in Essilor's Crizal Forte® UV and Optifog™ with Crizal® UV lenses; and for sunwear with Crizal Sun® UV and Optifog Sun™ with Crizal UV. These lenses reduce backside UVR reflection to offer the most complete protection possible against ocular UVR exposure.

One of the reasons that eye protection from UVR has lagged behind skin protection has been the lack of an easy way for eyecare professionals to talk about it. The new Eye-Sun Protection Factor (E-SPF) takes care of this problem. Now, ECPs can explain that pa-

tients receive the most protection with the highest E-SPF (see box). Choosing the most complete eye protection becomes as simple as choosing a sunscreen: just look at the numbers.

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