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Ultraviolet (UV) transmittance characteristics of daily disposable and silicone hydrogel contact lenses

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Abstract

The ultraviolet (UV) transmittance spectra of daily wear hydrogel and disposable silicone hydrogel contact lenses were measured. Average transmittance percentages were calculated for each lens for the entire UV spectrum and individually for the UVC, UVB and UVA portions of the spectrum. The significance of the differences in transmittance spectra obtained for the lenses was analysed using a one-way ANOVA planned comparisons test ($\alpha = 0.05$). The transmittance data were then used to calculate a UV protection factor (PF) for each contact lens brand tested. The PFs for *1-DAY* ACUVUE® MOIST™ (6.22), ACUVUE® ADVANCE™ (10.02) and ACUVUE® OASYS™ (11.96) contact lenses show that these contact lenses have superior UV-blocking capabilities. The PFs for Focus® DAILIES® (1.79), SofLens™ 1-day disposables (1.72), NIGHT & DAY™ (1.84), O2 Optix™ (1.99) and Purevision™ (2.62) show that these contact lenses posses more modest UV-blocking characteristics. This paper reviews the importance of protection of the anterior ocular surface from UV damage and quantifies the protection afforded by selected commercially available disposable contact lenses.

Keywords: Ultraviolet; Disposable contact lenses; Hydrogel contact lenses; Silicone hydrogel contact lens; Protection factor

1. Introduction

Ocular tissue damage due to exposure to ultraviolet (UV) radiation has been demonstrated by the results of epidemiological [1–12] and experimental human and animal studies [13–25]. Soft contact lenses have been shown to reduce the amount of UV reaching the anterior ocular surface and have been recommended as a form of protection from these adverse ocular effects of UV [26–46]. Their large diameters and intimate placement on the surface of the eye ensures that the lens will absorb or transmit most ambient UV and UV bypassing sunglass lenses or reflected from their inner surfaces. The UV-attenuating property of soft contact lenses protects not only the cornea, but also the internal ocular structures. The amount of corneal UV protection depends on the unique UV transmittance characteristics of different lens materials. The amount of UV absorbed or transmitted by these contact lenses varies considerably between brands [26–46]. A new generation of silicone hydrogel contact lenses have entered the market. To date, little has been published on the UV-attenuating properties of both first- and second-generation silicone hydrogel contact lenses.

The International Commission on Non-Ionising Radiation Protection (I.C.N.I.R.P.) divides the UV spectrum into three wavebands: UVC (200–280 nm), UVB (280–315 nm) and UVA (315–400 nm), according to the photobiological effect initiated by each of these wavebands [47]. Wavelengths in the UVC waveband are absorbed by stratospheric ozone, resulting in negligible UVC wavelengths being incident at the earth's surface [48–52]. These are therefore of little clinical relevance when considering ocular exposure to UV in outdoors recreational environments. The UVB wavelengths have been associated with corneal damage. The UVA wavelengths are far less photobiologically active, with deeper penetration than UVB wavelengths. The UVA may pose more of a long-term hazard, since the levels of UVA present in solar radiation are higher than that of UVB and UVC. Photokeratitis, climatic keratopathy and pterygia

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are conditions associated with corneal UV exposure [53–61]. Ultraviolet exposure threshold values for corneal tissue have been published and are used as the basis of quantifying corneal damage associated with UV exposure [57–60,62].

The American National Standards Institute (A.N.S.I.) standard for sunglass UV transmittance has been applied to UV-blocking contact lenses. This is a voluntary standard referring to plano over-the-counter sunglasses. According to this standard, a sunglass lens is classified as UV-blocking if it absorbs a minimum of 95% of UVB (transmits a maximum of 5% UVB) and 70% of the UVA (transmits 30% UVA). It further dictates that the entire contact lens, not just particular regions, must block UV [63,64]. To ascertain whether all lenses of a particular brand meet the A.N.S.I. standard, the lens specification with the lowest average thickness is measured, and this is commonly taken to be a lens of power −3.00 D. The Center for Devices and Radiological Health (CDRH) of the US Food and Drug Administration (FDA) has published guidelines on the classification of 'UV-blocking' contact lenses. According to these guidelines, class 2 UV absorbers have the same requirements as the A.N.S.I. standard. Class 1 absorbers must absorb a minimum of 99% UVB and 90% of UVA, with the upper limit of UVB being defined as 380 nm [65].

The calculation of a protection factor (PF) has been proposed as a method to quantify the UV protection afforded by a hydrogel contact lens. This attempts to predict the minimum UV dose necessary in each UV waveband to cause clinically detectable photodamage. This is analogous to the sunscreen sun protection factor for skin [66,67]. Contact lens PF values provide the practitioner with a guideline as to the level of corneal protection afforded by a particular contact lens. A higher PF would indicate a superior level of protection afforded by the contact lens. The basic method for calculating the PF is to calculate it as the inverse of the transmittance of the lens material [30,33,35,66]. A more detailed method of calculating the PF, incorporating the wavelength features of the incident UV radiation and action spectrum of corneal tissue has also been proposed [53–55,58,59,68–70].

The purpose of this study was to measure the UV-attenuating properties of daily disposable hydrogel and disposable silicone hydrogel contact lenses and to assess and quantify these in terms of the UV transmittance characteristics for each portion of the UV spectrum. This is achieved using new methodology based on the design of a novel contact lens holder. This is shown in Fig. 1. The contact lens is mounted within the aperture shown. The aperture is then covered by two quartz plates and is filled with saline. A protection factor (PF) was calculated for the overall UV spectrum transmitted by each lens. This calculation was performed in order to provide a guideline to contact lens fitters as to the relative efficacy of UV protection afforded by established disposable contact lenses and second-generation silicone hydrogel contact lenses, which are relatively new to the market.

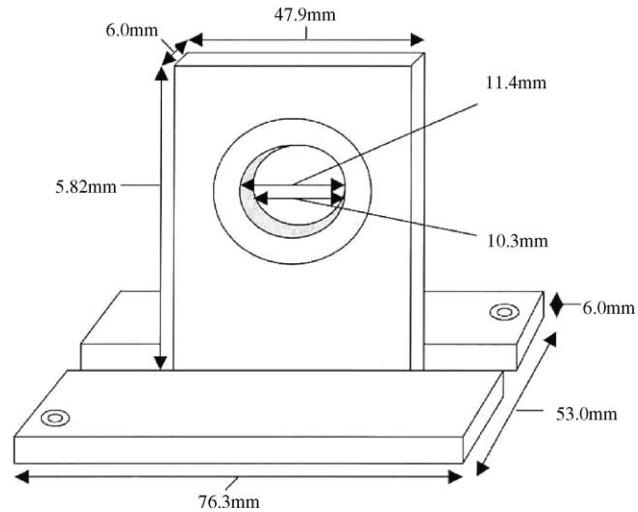

Fig. 1. Novel contact lens holder for contact lens spectrophotometry.

2. Materials and methods

2.1. Contact lenses

Contact lenses promoted as being UV-absorbing, as well as those not marketed as such were included in the study. The contact lenses selected were: *1-DAY* ACUVUE® MOIST™, ACUVUE® ADVANCE™, ACUVUE® OASYS™ (Johnson & Johnson Vision Care Inc.), Focus® DAILIES®, NIGHT & DAY™, O2 Optix™ (CIBA Vision), SofLens™ 1-day disposables, Purevision™ (Bausch & Lomb). An optical power of −3.00 D was selected for all lenses, as this is the power specified by the A.N.S.I. standard. Five lenses of each type were measured. The parameters of the lenses measured are specified in Table 1. Note that in this table, the central thickness values are those as supplied by the manufacturers and were not measured for the purposes of this study.

2.2. Instrumentation and experimental procedure

The Perkin-Elmer® Lambda900 dual beam spectrophotometer was used for the measurement of UV transmittance spectra. A novel contact lens holder was designed and constructed to ensure that the soft contact lens remained mounted in AMO® Lens Plus® OcuPure™ saline in a stable, upright, intact and hydrated state throughout the measurement process. Placement of the contact lens in a saline-filled cell during spectrometry results in a reduction in Fresnel reflections from the lens surfaces. The refractive indices of the lens and saline are similar. The effect of these reflections is negligible and therefore does not need to be taken into account in further calculations [43,45,57]. This 'wet-state' measurement of UV transmittance of a contact lens has been applied in previous studies [29,31,36,38,43,45,46,71,72]. The holder containing the contact lens and saline is referred to as the sample holder, while that containing