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ARTICLE

Ultraviolet Transmittance of Daily and Monthly Disposable Contact Lenses with UV Filters and Compliances with American National Standard Institute (ANSI) Classification

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Abstract: Significance: Ultraviolet (UV)-blocking contact lenses (CLs) may limit the exposure to UV radiation and prevent UV-associated adverse effects. However, the effectiveness of daily disposable CLs (DDCLs) and monthly disposable CLs (MDCLs) in blocking UV radiation and how well they conform to the American National Standard Institute (ANSI) Z80.20 standard are not fully understood. **Aim:** This study aimed to determine the UV-blocking effectiveness of DDCLs and MDCLs available in Jordan and examine their compliance with the criteria specified by the ANSI. **Approach:** Visible and UV light transmittances of the CLs (DDCLs: 1-DAY ACUVUE® MOIST™, Bausch + Lomb Biotrue®ONEday, ACUVUE® OASYS™; MDCLs: Avaira Vitality™, CooperVision® Biomedics® 55 sphere, Clear 58™) were evaluated using a spectrophotometer. The data were analyzed using a one-way analysis of variance ANOVA followed by Tukey's pairwise comparison test. **Results:** One-way ANOVA showed a significant difference between UV transmission from three DDCLs of different brands in the UVA, UVB, and UVC regions ($P < 0.001$). In the case of MDCLs, a significant difference was also observed in the UV transmission characteristics. Most importantly, all three DDCLs met the class 2 criteria of ANSI for UV-blocking CLs. Among the MDCLs, however, only one met these criteria. **Conclusion:** These findings suggest that the Acuvue OASYS is the best daily contact lens for blocking UV radiation. Among MDCLs, Avaira and Biomedics Sphere 55 are recommended for UV protection. All DDCLs met ANSI class 2 criteria for UV blockage.

Keywords: Ultraviolet, Radiation, Protection, CLs, Spectrophotometry.

Table of Abbreviations:

ANOVA:	Analysis of variance
ANSI:	American National Standard Institute
CL:	Contact lenses
DDCL:	Daily disposable contact lenses
MDCL:	Monthly disposable contact lenses
UV:	Ultraviolet

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Introduction

Exposure to ultraviolet (UV) radiation can damage the eye layers and/or skin surrounding the eyes [1-5]. Therefore, precautionary measures should be taken to protect the eyes from UV exposure [6-12]. UV radiation from the Sun ranges from 100 to approximately 400 nm and can be divided into three regions: UVC (100–280 nm), UVB (280–315 nm), and UVA (315–400 nm) [13]. However, only UVB and UVA pass through the atmosphere of the Earth because UVC is absorbed primarily in the stratosphere before reaching the surface of the planet.

UV-blocking contact lenses (CLs) can protect the eye from UV exposure. However, due to the many differences between CLs in terms of quality and specifications, users rarely have a sufficient understanding of CLs' UV-blocking properties [14]. The UV transmittance parameter, or the quantity of UV light that passes through lenses to the eyes, is a crucial consideration when selecting appropriate CLs [14, 15]. Individuals seeking UV protection/blocking can choose between daily disposable CLs (DDCLs), which are used for one day, and monthly disposable CLs (MDCLs), which can last up to a month [15]. The material, design, functionality, and ease of use of DDCLs and MDCLs are expected to vary between DDCLs and MDCLs [16-22]. Although several CLs have been examined for their spectrum transmission and UV radiation protection properties, these studies did not include DDCLs and MDCLs [23-25]. Furthermore, prior investigations have rarely used the American National Standard Institute (ANSI) Z80.20 standards for UV-blocking CL [24, 26].

The UV and visible-light transmittances of CLs are important optical properties. CL users who spend a lot of time outdoors, patients with aphakic or pseudophakic syndrome, and those taking photosensitizing medications should be particularly concerned about this property of CLs [27, 28]. This concern is especially relevant in the Middle East, where UV radiation levels are high [29, 30]. For instance, according to World Health Organization (WHO) data, the ultraviolet index (UVI) in Jordan often exceeds eight, indicating intense solar UV exposure [31]. Such high levels of UV radiation have been linked to increased light sensitivity in the general population and among patients with ocular surface diseases [32, 33]. Despite the growing popularity of CLs in Jordan, no studies have assessed their UV-blocking properties, making it essential to evaluate their compliance with ANSI standards [34].

This study aimed to determine the UV transmittance of commonly available DDCLs and MDCLs in Jordan. The transmittance properties in the UVA, UVB, UVC, and visible regions were analyzed, and the lenses were categorized based on ANSI guidelines.

Materials and Methods

CLs

The CLs used in this study were purchased from local optical stores in Jordan and were marketed as UV-blocking lenses. The CLs selected were as follows: 1. DDCLs: 1-DAY ACUVUE® MOIST™, Bausch + Lomb Biotrue® ONEday, ACUVUE® OASYS™. 2. The MDCLs were Avaira Vitality™, CooperVision® Biomedics® 55 sphere, and Clear 58™. An optical power of – 3.00 D was selected for all lenses used in this study, as this power is specified by ANSI standards [13, 24]. The parameters of the DDCLs and MDCLs, as provided by the manufacturers, are summarized in Tables 1 and 2, respectively.

TABLE 1. Characteristics of the DDCLs used in this study.

Type	Content H_2O [%]	Diameter (mm)	Base curve (mm)	Power (D)	UV-blocking
Moist (1-Day Acuvue)	58	14.2	8.5	-3.00	Yes
Biotrue (Bausch+Lomb)	78	14.2	8.6	-3.00	Yes
Acuvue Oasys	38	14.3	8.5	-3.00	Yes

TABLE 2. Characteristics of MDCLs used in this study

Type	Content H_2O[%]	Diameter (mm)	Base curve (mm)	Power (D)	UV-blocking
Cooper Vision (Avaira Vitality)	55	14.2	8.4	-3.00	Yes
Cooper Vision (Biomedics sphere 55)	55	14.2	8.6	-3.00	Yes
Clear 58	58	14.0	8.7	-3.00	Yes

Instrumentation and Experimental Procedure

A Shimadzu UV-Vis 2450 dual-beam spectrophotometer was used to obtain the UV and visible transmittance spectra. This device uses a combination of two lamps with a wide range of wavelengths: a deuterium lamp for the UV region and a tungsten/halogen lamp for the visible region of the electromagnetic spectrum. The spectrophotometer was adjusted by installing an internal integrating sphere. The measured sample was placed in the transmittance/reflectance parts of the sphere, and the transmittance (T) was recorded as a function of the wavelength. The transmittance values were scaled and averaged based on a single measurement of transmittance in the visible spectrum (250–800 nm).

An ad hoc contact lens holder was designed to fit the device into a specific dimension/shape. The contact lens was then located (and stabilized) at the center of the holder to obtain the spectra. The holder was moved to a total internal integrating sphere to measure transmittance. Measurements were conducted on three brands of lenses, with five lenses from each brand tested. Each lens underwent five individual measurements.

Statistical Analysis

The ultraviolet and visible (UV-Vis) transmittance data of the CLs were statistically analyzed by one-way analysis of variance (ANOVA) followed by the Tukey pairwise comparison test at a significance level of ($P < 0.05$), using SPSS v25 to compare the mean values of transmittance of the different DDCLs and MDCLs in the UV (C, B, A) and visible-light regions.

Results

DDCLs

The average spectral transmittances of the UV and visible light regions of the DDCLs are shown in Fig. 1. Although all three lenses had considerably reduced transmission in the UV region (thus, all blocked UV light), there was a noticeable variation in their relative blocking efficacy in the UVA, UVB, and UVC regions. All DDCLs had minimal transmittance in the UVB region; however, in the UVC region, Moist and Biotrue lenses had a transmittance of approximately 20%, whereas Acuvue Oasys had a transmittance of less than 10 %. Acuvue Oasys CLs transmitted the lowest amount of UV light within the transmission window, starting at 240 nm and closing at 300 nm. The mean values of the UV (C, B, A) and visible light transmittances for the three lenses are presented in Table 3. Compared to Biotrue and Moist lenses, the Acuvue Oasys lens had lower transmittance values, which were more noticeable in the UVC and UVB regions and less noticeable in the UVA and visible regions.

Statistical analysis using one-way ANOVA revealed significant differences in UV transmittance among the three lenses in the UVA, UVB, and UVC regions ($P < 0.001$). Post-hoc analysis using Tukey's test showed that in the UVC region, the mean transmittance of Acuvue Oasys lenses was significantly lower than that of Biotrue and Moist lenses, while the difference between Biotrue and Moist lenses was not statistically significant ($P = 0.15$). Significant differences in transmittance were also observed among the three lenses in the UVB and UVA regions.

In the visible light region, ANOVA indicated a significant difference in transmittance among the three lenses ($P = 0.049$), although the differences were smaller than those observed in the UV region. Further comparisons revealed a statistically significant difference between Acuvue Oasys and Moist lenses but not between Acuvue Oasys and Biotrue lenses or between Biotrue and Moist lenses ($P > 0.15$). For wavelengths longer than 400 nm, all lenses maintained relatively uniform light transmittance of approximately 80%, as shown in Fig. 1.

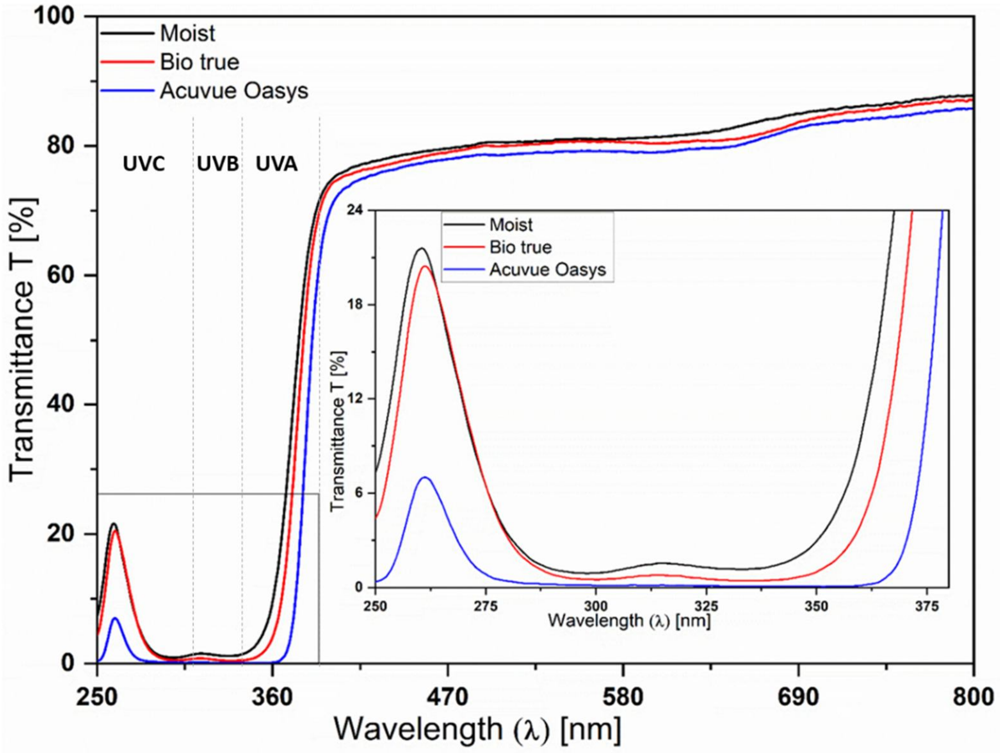

FIG. 1. Transmittance spectra of UV-vis regions for DDCLs.

TABLE 3. UV-vis transmittance of DDCLs (mean ± SD).

Lenses	Ultraviolet transmittance			Visible transmittance
	UVC (250-280 nm)	UVB (280-315 nm)	UVA (315-400 nm)	(400-720nm)
Acuvue Oasys	2.88 ± 0.386 [a]	0.18 ± 0.01 [a]	16.06 ± 0.26 [a]	79.22 ± 0.54 [a]
Biotrue	11.77 ± 0.92 [b]	0.95 ± 0.12 [b]	21.94 ± 0.69 [b]	80.60 ± 1.39 [a b]
Moist	12.82 ± 1.29 [b]	1.38 ± 0.24 [c]	25.37 ± 0.98 [c]	81.07 ± 1.14 [b]

Means that do not share a letter within the same column are significantly different ($P \leq 0.05$).

MDCLs

The average spectral transmittances of the UV and visible light regions of the MDCLs are shown in Fig. 2. Although all three CLs have noticeably reduced transmission in the UV region, it can be inferred from the observations for the DDCLs that they differ in relative attenuation. In the UVC region, Avaira had a transmittance of approximately 20%, whereas Biomedics and Clear had a transmittance of less than 10 %. Interestingly, Avaira transmitted less UV light in the UVB and UVA regions, with a sharp increase in transmission beginning only at 360 nm. Biomedics and Clear had a hump in the UVB region and a higher transmittance in the UVA region. The mean values of the UV (C, B, A) and visible light transmittances of the three MDCLs used and investigated are presented in Table 4. Variations were observed among the three lenses in each UV transmittance region (C, B, and A). In the UVC region, the Biomedics Sphere 55 lenses had the lowest mean transmittance, while the Avaira lenses had the highest. One-way ANOVA revealed a significant difference between the three lenses ($P < 0.004$). Tukey's pairwise comparison showed a significant difference between the Avaira and Biomedics Sphere 55 lenses. However, the differences between these two lenses and the Clear lens were not statistically significant ($P = 0.25$).

For the UVB and UVA regions, the Avaira lens exhibited the lowest mean transmittance, while the Clear lens had the highest. One-way ANOVA indicated highly significant differences among the three lenses in the UVB and UVA regions (P < 0.001). The follow-up pair comparison for each (UVB and UVA) revealed that for the UVB, the difference between the Avaira and Biomedics sphere 55 lenses was not statistically significant (P = 0.15), but both were significantly different from the Clear lens. However, at the UVA level, the difference between the Biomedics sphere 55 and the Clear lenses was not significant (P = 0.15), but both were significantly different from the Avaira lens.

For visible light transmittance, the Avaira lens had the highest mean value (95.06), whereas the Biomedics Sphere 55 and Clear lenses had lower mean values and were very similar (88.72 and 88.77, respectively). One-way ANOVA showed a significant difference between the lenses (P < 0.001), and the follow-up pair comparison revealed that the difference between the Biomedics sphere 55 and the Clear lenses was not significant (P = 0.10), but both were significantly different from the Avaira lens.

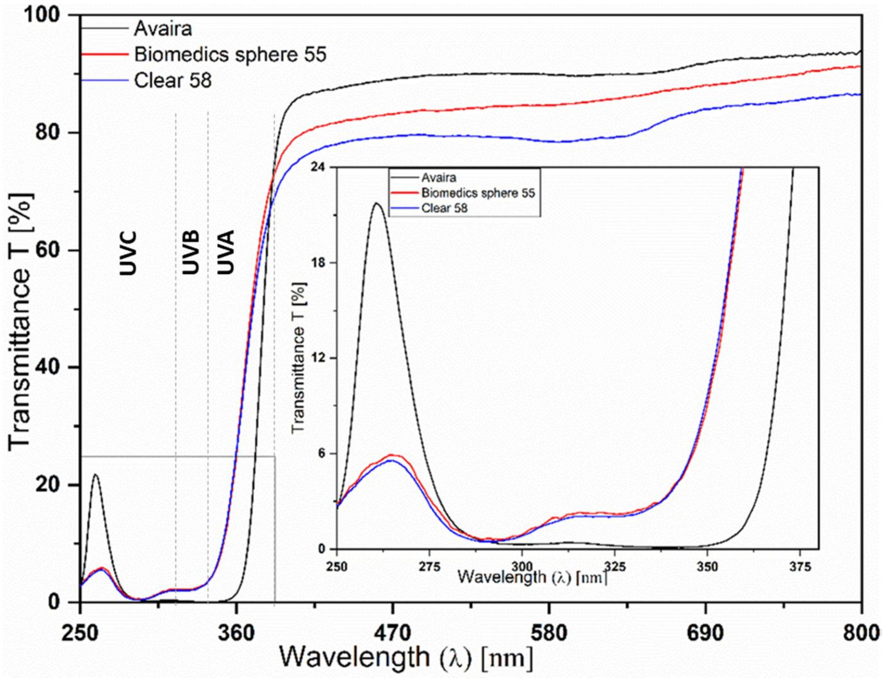

FIG. 2. Transmittance spectra of UV-vis regions for MDCLs.

TABLE 4. UV-Vis transmittance of MDCLs (mean±SD).

Lenses	Ultraviolet Transmittance			Visible Transmittance
	UVC (250-280 nm)	UVB (280-315 nm)	UVA (315-400 nm)	(400-720nm)
Avaira	6.49 ± 2.17 [a]	0.26 ± 0.07 [a]	21.89 ± 1.23 [a]	95.05 ± 0.97 [a]
Biomedics Sphere 55	2.53 ± 1.16 [b]	0.49 ± 0.32 [a]	32.69 ± 2.14 [b]	88.72 ± 1.47 [b]
Clear 58	4.85 ± 0.65 [a b]	1.28 ± 0.22 [b]	34.61 ± 0.96 [b]	88.76 ± 0.45 [b]

Means that do not share a letter are significantly different (P <0.05) in each column separately.

Discussion

The long-term and short-term adverse effects of UV radiation on the eyes have been well documented [35]. Therefore, protection from UV radiation is a desirable feature of CLs. UV protection has been researched from various perspectives, including comparisons between tinted and non-tinted CLs, CLs that include UV blockers and regular CLs, and according to the type of radiation [13, 23-25]. This study assessed the UV transmittance properties of six different UV-blocking CLs available in Jordan to determine how well they meet the ANSI standards for UV-blocking CLs. Different brands of CLs that have not been previously studied were included, namely, Avaira Vitality, CooperVision Biomedics 55 sphere, and Clear 58. Most importantly, this study expanded this topic by conducting studies on DDCLs and MDCLs and reported discernible differences between light transmittance in the UVA, UAB, UAC, and visible spectrum regions.

UVA transmittance ranged from 16.06 ± 0.26 (Acuvue Oasys, DDCL) to 34.61 ± 0.96 (Clear 58, MDCL). The mean UVB transmittance ranged between 0.18 ± 0.01 (Acuvue Oasys, DDCL) and 1.38 ± 0.24 (Moist, DDCL), while the mean UVC transmittance ranged between 2.53 ± 1.15 (Biomedics Sphere 55, MDCL) and 12.82 ± 1.29 (Moist, DDCL). The ANSI Z80.20 standard is a common standard for UV transmittance. This standard classifies UV-blocking CLs into two classes. First-class blocks attenuate 90% of UVA and 99% of UVB and are recommended for high-exposure environments, such as mountains and beaches, whereas second-class blocks attenuate 70% of UVA and 95% of UVB and are recommended for general environments [26, 36]. Based on these parameters, all DDCLs met the standards for second-class blocks; however, two MDCLs had a blockage slightly lower than 70% UVA and thus failed to meet the ANSI criteria for second-class UV blocks.

These differences can be attributed to lens formulation, thickness, and design [37]. Artigasa *et al*. examined the transmission curves of nine soft CLs, five of which incorporated UV filters [23]. In their investigation, two CLs met the criteria for the first-class blocks with 100% UVB blockage and greater than 90% UVA blockage, while three CLs matched the criteria for second-class blocks. These authors did not specify the usage of DDCLs or MDCLs; therefore, a direct comparison with this work is not possible. Furthermore, the CL powers in their study ranged from -0.5 to -4.0.

Another noteworthy study evaluated the influence of UV-blocker-tinted CLs on UV transmission and found that Freshlook CLs transmitted between 45% and 56% more visible light than Acuvue CLs in the visible light spectrum, but not in the UV spectrum [25]. A recent study, employing the ANSI standard, assessed the spectral transmittance of 20 varieties of soft DDCLs available in Australia and concluded that the UV protection provided by class 1 or class 2, as indicated by the manufacturers, was adequate [24]. In contrast, Rahamni *et al*., using four CLs with a power of -3 and all marked as UV-blocking, found that three of the CLs transmitted more than 30% of UVA, failing to meet the ANSI UV-blocker Class 1 or 2 standards [38]. This failure was attributed to differences in the UV-absorbing materials used in the fabrication of the CLs. Prior research from Iran reached similar conclusions, noting that while CLs filter UV light, their performance is often insufficient to provide the desired protection [39].

The transmission within the visible light spectrum was greater than 80% for all CLs. All the MDCLs included in this study had a water content of approximately 55%, while the water content of the DDCLs ranged from 38% to 78%. Differences in the chemical composition of the UV absorbers appear to be the primary factor influencing UV transmission in the area of interest, given that the water content itself does not seem to alter UV transmission. The CLs included in this study also showed minor variations in their UV cutoff threshold. In all cases, transmission increased rapidly once the wavelength crossed 360 nm into the visible region. Since the UV filters incorporated in different CLs are not identical, although they all block the most dangerous radiation, their cutoff wavelengths vary. Consistent with Artigas et al., we also observed a narrow transmission window centered around 260 nm, transmitting slightly more than 20%, which can be attributed to the composition of the CLs [23]. It should be noted that this window is not included in the ANSI criteria, primarily because solar radiation below 300 nm does not reach the Earth's surface [23].

It is well known that exposure to UV radiation has both long- and short-term effects on the eye. We believe that UV-blocker-containing CLs can help prevent various visual pathologies influenced by UV radiation [40, 41]. As identified in previous studies, not all CLs incorporate UV filters, and even those that do may offer suboptimal protection. According to our study, at least three brands of DDCLs in Jordan provide class 2 UV protection, one MDCL meets the class 2 criterion, and two others are very close to it. Overall, our findings, along with available data, support the effectiveness of UV-filtering CLs. However, further research is needed to rule out any potentially harmful effects due to the complex biochemical interactions between UV-filter-containing CLs and ocular dynamics [42].

Conclusion

DDCLs and MDCLs are available to users and each has its advantages and disadvantages. This study, the first to use the ANSI criteria for UV-blocking CLs in Jordan, found that all three DDCLs met the criteria for class 2 UV blockers; however, only one of the three MDCLs met the class 2 criteria. In particular, all CLs exhibited transmittance of more than 80% in the visible region. A significant difference in the UVC region, which is not included in the ANSI classification, was observed across the various CLs, attributed to the basic chemical properties of the UV blockers used in the lenses. These findings support the UV protection efficiency of both MDCLs and DDCLs available in Jordan. The results may encourage the use of UV-blocking CLs, potentially reducing the risk of UV-induced ocular disorders.

Disclosures

The authors declare no conflict of interest related to this article.

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