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Measurement of Ultraviolet Light Transmittance of Different Contact Lens Types

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Abstract: Scientific evidence showing the harmful effects of ultraviolet radiation on different ocular tissues has led manufacturers to incorporate UV-blocking monomers into contact lenses. In this study, the spectral and optical properties of contact lenses were analyzed in the ultraviolet and visible light wavelength ranges using the JASCO V-730 UV/Vis spectrophotometer device. The results obtained showed that the light transmittance in the wavelength (550nm) range to which the human eye is most sensitive in the lens samples examined was over 70 % and that B contact lens had a maximum value of 72,98 %. The largest cutting-edge wavelength value was obtained in the A contact lens as 376 nm. At 550 nm, the absorption spectra were found to be below 0.12. In terms of visual quality, visible light transmittance is expected to be high and ultraviolet alight transmittance is expected to be minimal. The degree of damage caused by the amount of ultraviolet light absorption increases. Among the contact lenses with and without ultraviolet-protected monomers, lens A did not transmit the UV-B wavelength region, while lens B transmitted UV-A and UV-B wavelengths. This result showed that the protection of lens A was higher. It is seen that the UV transmittance taken with the phocometer is 45% UV in A lens and 91% UV in B lens. The results obtained by UV/Vis spectrophotometer and phocometer supported each other. The results will contribute to the literature by revealing the importance of UV-protected monomer-containing contact lenses in vision equipment, and by enabling the development and selection of full-protection contact lenses.

Key words: Contact lens, eye health, UV radiation, light transmission.

Farklı Türden Kontak Lenslerin Ultraviyole Işık Geçirgenliğinin Ölçülmesi

Öz: Ultraviyole radyasyonun farklı oküler dokular üzerinde zararlı etkilerini gösteren bilimsel kanıtlar üreticileri UV bloke edici monomerleri kontak lenslere dâhil etmeye yönlendirmiştir. Bu araştırmada, kontak lenslerin spektral ve optik özellikleri ultraviyole ve görünür ışık dalga boyu aralıklarında JASCO V-730 UV/Vis spektrofotometre cihazı kullanılarak analiz edildi Elde edilen sonuçlar incelenen kontak lens örneklerinde insan gözünün en duyarlı olduğu dalga boyu (550 nm) aralığında ışık geçirgenliğinin %70'nin üzerinde olduğunu ve maksimum değere %72,98 olarak B kontak lensin sahip olduğunu gösterdi. En büyük kesme kenarı dalga boyu değeri A kontak lensinde 376 nm olarak elde edildi.550 nm'de soğurma spektrumlarının ise 0.12 altında olduğu bulundu. Görme kalitesi açısından görünür ışık geçirgenliğinin yüksek olması, ultraviyole ışık geçirgenliğinin minimum olması beklenir. Ultraviyole korumalı monomer içeren ve içermeyen kontak lenslerden A lensinin UV-B dalga boyu bölgesini geçirmediği, B lensinin ise UV-A ve UV-B dalga boylarını geçirdiği görüldü. Bu sonuç A lensinin korumasının daha yüksek olduğunu gösterdi. Fokometre ile alınan UV geçirgenlikleri A lensinde %45, B lensinde %91 olarak görülmektedir. UV/Vis spektrofotometre ile fokometreden alınan sonuçlar birbirini destekledi. Sonuçlar, görme gereçlerinde UV korumalı monomer içerikli kontak lenslerin önemini ortaya çıkararak, tam korumalı kontak lenslerin geliştirilmesini ve seçilmesini sağlayarak literatüre katkı sağlayacaktır.

Anahtar kelimeler: Kontak lens, göz sağlığı, UV radyasyon, ışık geçirgenliği

1. Introductıon

According to TUIK 2021 [1] data, it is stated that the use of glasses or lenses has increased by 2.6% and the number of individuals blind increased by 0.3%. This situation has led manufacturers to increase the number of contact lenses. The development of contact lenses has been researched by scientists for centuries. Silicone hydrogel contact lenses, hard contact lenses, soft hydrogel contact lenses, and today, hydrogel lenses with high oxygen permeability have been used chronologically by adding silicon with high oxygen permeability, methacrylic acid for wettability, and methyl methacrylate for optical properties [2,3]. Contact lenses are basically divided into soft and hard. Soft contact lenses have high water content, high oxygen permeability and can remain stable in the cornea due to their diameter width, have a short adaptation time and do not cause blurred glasses, photophobia and glare. Soft contact lenses are used in the structure of HEMA (2-hydroxyethyl methacrylate), MMA (methacrylate acid), MMA (methyl methacrylate), GMA (glycerin methacrylate). Hard contact lenses, on the other hand, are

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lightweight, durable, transparent, but have a long adaptation time and low water content. It is not preferred because it causes hypoxia [4-6]. Contact lenses affect the structure of the cornea because they create a hypoxic environment. Therefore, it was tried to minimize the hypoxic effect by adding silicone with high oxygen permeability to soft lenses. Therefore, soft contact lenses are largely preferred as visual aids [3-4,7]. Contact lenses are expected to have good parameters such as light transmission and ultraviolet light protection and correction of eye defects. According to the American National Standards Institute, lenses with Ultraviolet (UV) blocking absorb 95% of UVB and 70% of UVA, while lenses without UV blocking transmit 90% of the UV spectrum [8]. Looking at the literature UV-blocking lenses obtained by adding UV-absorbing monomer to soft contact lenses [9] have been shown to reduce the amount of UV light coming into the eye and protect against damage caused by UV in ocular tissues [10-13]. Soft contact lenses provide more protection than hard contact lenses because they completely cover the cornea and conjunctiva [8].

In order to protect the eye against ultraviolet radiation, contact lenses are preferred as well as UV protection glasses. Although UV-blocking glasses provide good protection, UV light is reflected when the sun is overhead, as the eyebrow is blocked by the eyelid, but about 98% of the light is absorbed when the light comes parallel to the eye. Light cannot provide full protection to the eye due to reflection from the back of the lenses due to the temporal and upper parts [14]. UV blocking lenses effectively protect the eye when glasses are insufficient. The phenomenon of vision occurs when light falls on the photoreceptor cone and rod cells located in the macular region of the retina. The wavelength of visible light to which the human eye is sensitive is between 400-700 nm [15]. The light transmission of a good contact lens is expected to be very high in this range, and the maximum vision corresponds to a wavelength of 550 nm. Contact lenses must exhibit maximum light transmittance at these wavelengths [16].

Ultraviolet light makes up 5% of the electromagnetic radiation energy from the sun reaching the earth's surface. Ultraviolet (UV) is an electromagnetic radiation ranging in wavelengths of light (100-400 nm). The UV Radiation spectrum is divided into three bands according to the wavelength. UVA (320-400 nm), UVB (280-320 nm), UVC (100-280 nm) [17]. Although UVC is retained by the ozone layer, recently due to the thinning of the ozone layer, short-wavelength electromagnetic radiation reaching the earth has been increasing [18]. The eye is a complex dioptric system and the light coming into the eye is absorbed or transmitted in the refractive environment of the eye in the cornea, aqueous fluid, lens and vitreous fluid. The cornea is the transparent layer located in the anterior part of the eyeball and is the first barrier to absorb all wavelengths shorter than 295 nm. The second barrier is the crystalline lens, which absorbs all of the UVB and most of the UVA, but wavelengths of 400 nm and above are not absorbed by the cornea and lens. Although the effect of UV on the skin is known by 85% of the population, only 7% of the population is aware of its effect on the eye [19]. The damage caused by UV radiation to the lens of the eye, which is a radiosensitive tissue, determines the intensity of the light and the wavelength received by the ocular tissues [20,30]. Since UV light has more energy than visible light, it acts more on ocular tissues [21]. Long-term exposure to UV causes cataracts, pterygium, photokeratitis in the human eye [22,23] and has been expressed in experimental studies [8,14,24-25]. Our eyes are exposed to UV every day, causing damage to ocular tissues that can accumulate over a lifetime [16] UV blocking contact lenses have increased in importance as the treatment of ocular diseases increases health care costs.

In this study, UV/VIS spectrophotometer and phocometer devices were used to measure the UV absorption and transmittance of different types of contact lenses. Measurements were taken and data on the permeation and absorption spectra were plotted using OriginPro-8 software. The data were compared with the standards in the literature and a different perspective was brought to contact lenses for our eye health.

2. Material and Method

Due to its chemical structure, composition, light structure, high water content, short adaptation time and low hypoxic, many types of soft contact lenses widely used in the optical industry are available on the market. The soft contact lenses used in this study belong to different companies and the necessary information for the lenses is given in Table 1. In Table 1, the samples A, B represent two different firms. For the absorption and permeability measurements including the visible region of different soft contact lenses that the user may prefer, the JASCO V-730 UV/Vis Dual Beam Spectrophotometer device, shown in Figure 1 and located in Şırnak University Technology and Research Center Laboratory, was used. The number of photons transmitted from the contact lenses and the absorption of light according to the material properties are explained by the Beer-Lambert law [31]. After the contact lens was removed from the blister pack, it was placed in the lens holder compartment with the convex side facing the scan beam. The spectrum was chosen, which allowed absorption and transmission measurements to be made continuously as the wavelength changed. In this study, the permeability and absorption spectra of soft contact lenses used in visual aids were measured by UV/Vis spectroscopy. For all the results, relevant graphs were drawn using the OriginPro-8 software.

Table 1. Some parameters for contact lenses used.

Lenses	Materials	Diameter (mm)	UV Protection	Coating Type	Thickness (mm)	Power of Lens (D)
A	Senofilcon A	14.3	Yes	8.5	0.07	-5.00
B	Lotrafilcon B	14.2	No	8.5	0.08	-5.00

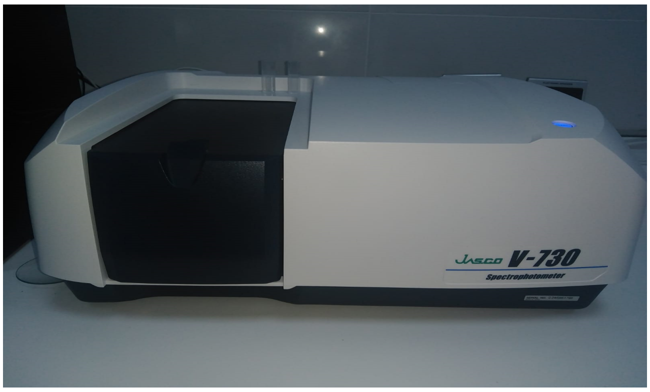

Figure 1. The JASCO V-730 UV/Vis dual beam spectrophotometer device.

The UV transmittance of contact lenses with Table 1 specifications from different companies was also measured with the TUSCONY brand digital phocometer in Şırnak University Optician Laboratory. The phocometer is an optical device used to determine the spherical and cylindrical diopters of spectacle lenses, the axes of cylindrical lenses, the diopters of contact lenses and UV transmittances. By selecting the UV measurement mode of the digital phocometer for the measurement, its display was switched to the UV measuring mode. The contact lens was placed on the meter. We based the measurement on two different environments because it was measured in light and dark environments, considering that the light from the surroundings could affect the UV transmittance of the lens. When we look at the values measured in the bright environment with the digital phocometer, the UV transmittance value of the A lens was as 45% and the UV transmittance value of the B lens as 91% in Figure 2. When the same process was measured in a dark environment, the transmittance values for both lenses decreased at %3.

(A) (B)

Figure 2. UV Transmittance of TUSCONY brand phocometer and A and B contact lenses.

3. Results and Dıscussıon

Many types of contact lenses offered by optical companies are available on the market. In this study, absorption and transmittance measurements were made using UV/Vis Dual Beam Spectrophotometer device to investigate the optical properties of contact lenses (A, B) whose properties are given in Table 1. When the measurements were made, the wavelength was taken in the range of 200-800 nm.

In a study conducted in 2000, Harris et al measured the transmittance of different types of contact lenses. As a result of the measurement, they found that the UV transmittance of lenses containing UV-protective monomers experimentally decreased [27]. In studies on the effect of other parameters on the UV transmittance of contact lenses, it has been shown that the diopter power and center thickness of the lenses affect the level of UV protection [34]. Faubl and Quinn at study in 2000, stated that contact lenses with thin center thickness absorb less UV radiation than thick contact lenses [35]. In addition, Ateş and Bilici (2022) and K. Mutlu and Ekem (2021) found in their studies on lenses that as the center thickness increases, the absorbance increases and the UV transmittance decreases [17,36]. In the study, when interpreting the UV transmittance of contact lenses, it was not included in the interpretation because the diopter was the same and the center thickness was approximately the same. In addition, the interpretation of the graphics is based on the American National Standards Institute (ANSI Z80.20-2016) [32]. UV transmittance values for ANSI sunglasses are attached to contact lenses. With standard values, it can block 95% of UV-B and 70% of UV-A [28, 29].

UV light and visible light are electromagnetic waves. For the UV protective A contact lens, the graph in Figure 3 shows that it has no transmittance in the UV-B range and has a peak at 260 nm, with 5.66% of it. We see that the amplitude consumed to deplete the UV-A range is low and the transmittance continues to increase from 370 nm. It seems to meet ANSI Z80.20-2016 version. From 370 nm the capture amplitude started to increase and again at 730 nm there was a decrease. The maximum visibility in a good contact lens corresponds to a wavelength of 550 nm, and light expectation is expected to be very high in this range. The light transmittance at 550 nm is 71.87%, with a maximum value of 75.75% in the visible wavelength range.

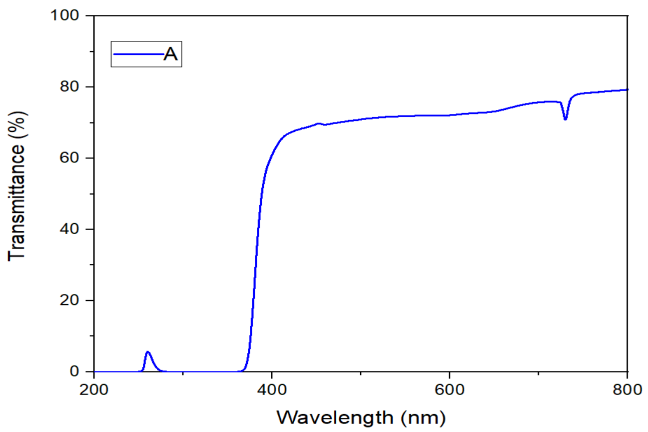

Figure 3. Wavelength versus transmittance plot for lens A.

When the graph in Figure 4 of the B contact lens without UV protection is examined, it is seen that the permeability increases from 241 nm and the permeability is present in the UV-B and UV-A ranges. We see that the UV-B range starts with 40% and ends with 55%, while the UV-A range ends with 62%. There seems to be a reduction of 730 nm, as in the A lens. The wavelength to which the human eye is most sensitive is 72.98% at 550 nm. It is seen that the permeability increases in the visible light region and the maximum transmittance value is 75.05%. B lens is more transparent to visible light.

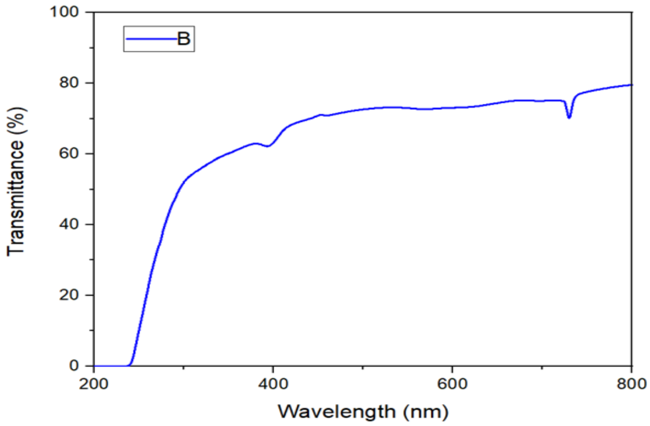

Figure 4. Wavelength versus transmittance plot for lens B.

Since UV light absorption affects the optical and mechanical properties of lens materials, the absorbance value graphs against the wavelength of different lenses A and B are given in Figure 5 and Figure 6. The absorbance of A lens in the UV region range absorbs more than the UV range of B lens than its region. It is seen that B lens passes through UV-A and UV-B wavelengths and the absorbance of both contact lenses in the visible region is very low.

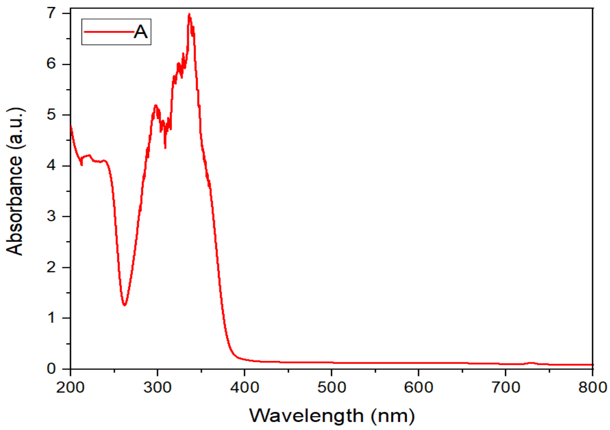

Figure 5. Wavelength versus absorbance plot for lens A.

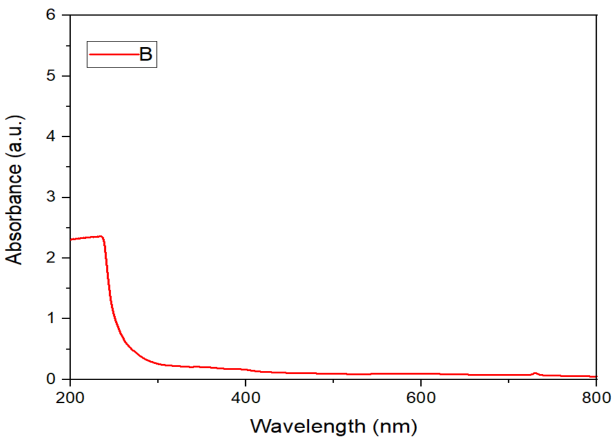

Figure 6. Wavelength versus absorbance plot for lens B.

4. Conclusion

In the electromagnetic spectrum, the wavelength range of UV (100-400 nm) corresponds to the wavelength range of visible light (400-700 nm). The cornea of the human eye shows transparency to light with high permeability and allows light to pass through the ocular tissues and reach the retina. The retina contains sensitive cells that are stimulated by sunlight, and in the retina the optical quality of the image depends on the incoming light. For eye health and quality vision, contact lenses should have low UV transmittance and high visible light transmittance. At the wavelength to which the human eye is most sensitive (550 nm), contact lenses should show maximum light transmission. When we look at the transmittance of two different contact lenses, we see that the A contact lens has no transmittance in the UV-B wavelength range, with a transmittance peak of 5.66% at 260 nm. In B contact lenses, the UV transmittance starts from 241 nm and increases to a maximum of 62% in the UV-A region and a maximum of 55% in the UV-B region. In the visible region (~550 nm), lens A is 71.87%, while lens B is 72.98%. When we look at the UV transmittance values with the phocometer device, the A contact lens passes 45% and the B contact lens passes 91%. Looking at the measurement results taken from different devices, the results supported each other. The absorbance graphs show that the UV wavelength range B contact lens has low absorbance, while A contact lens also has high absorbance. The low absorbance is interpreted as the beginning of light transmission, that is, the transition of the valence electrons of the incident photon to the conduction band [38]. Considering all these results, we can say that A contact lens has less UV transmittance and higher absorbance value than B contact lens, and A lens can provide better protection for our eye health. In addition, lens A had a transmittance of 5.66% in the UV region, and it was stated in the literature that UV transmittance could be seen even if lenses that completely block radiation were worn. Lens A fulfills the requirement for contact lenses specified by International ANSI Z80.20-2016, while lens B does not. The cut-off value in the absorbance plots represents the wavelength at which absorbance ends and transmission begins. The cut-off value of the A lens corresponds to 376 nm, and the cut-off value of the B lens corresponds to 252 nm. The higher the cut-off value, the higher the protection and we can say that the A contact lens provides better protection. Light and dark environments were selected while measuring in the phocometer. The aim was to determine whether the light coming from different angles had an effect on the UV transmittance. Since the lights coming from different angles are blocked in the dark environment, the UV transmittance value of both contact lenses decreased by 3% compared to the bright environment. The results show that the light intensity of the environment affects the UV transmittance. Considering all these data and comments, it is tried to express whether the contact lenses available in the market provide UV protection, and if so, how much they provide and to contribute to the literature.

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