ORİJİNAL ARAŞTIRMA ORIGINAL RESEARCH

DOI: 10.5336/ophthal.2021-87854

Evaluation of the Effects of Photochromic Contact Lens on Visual Quality and Pupillary Diameter: Cross-Sectional Study

Fotokromik Kontakt Lensin Görme Kalitesi ve Pupilla Çapı Üzerine Etkilerinin Değerlendirilmesi: Kesitsel Çalışma

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This study was presented as an oral presentation at the 5th live surgery symposium of the Turkish Ophthalmological Association, September 3-5, 2021, Virtual.

ABSTRACT Objective: To evaluate the effects of photochromic contact lenses (CL) on contrast sensitivity, aberrations and pupillary diameter in indoor environments. **Material and Methods:** Contrast sensitivity of the participants was measured and their pupillography under scotopic, mesopic and photopic illumination and topography were taken. Transparent senofilcon A (Acuvue Oasys hydraLuxe) CL was inserted to one eye of the subjects and photochromic senofilcon A (Acuvue Oasys with transitions) CL was inserted to the other eye. Subsequently, contrast sensitivity of subjects was measured, pupillography and topography were taken again over the CL. Aberration values were obtained from the topography. In terms of occurred changes, the eye with photochromic CL was compared with the other eye. **Results:** Before CL insertion, there was no significant difference between the photochromic side and the other side in terms of all parameters examined (for all; p>0.05). After CL insertion, there was no significant change in scotopic, mesopic and photopic pupil diameters on both the photochromic and transparent sides compared to the pre-CL condition (for all; p>0.05), high order aberrations increased (p<0.05), and contrast sensitivity at high frequencies (12 and 18 cpd) decreased (for both; p<0.05). When the photochromic side was compared with the transparent side after CL insertion, no significant difference was observed in terms of all parameters (for all; p>0.05). **Conclusion:** Using the photochromic CL in indoors does not lead to different results than the transparent CL in terms of visual quality and pupil diameters. Both lenses cause a decrease in contrast sensitivity at high frequencies.

Keywords: Photochromic contact lens; contrast sensitivity; pupillary diameter; high-order aberrations

ÖZET Amaç: Fotokromik kontakt lenslerin (KL) iç ortamlarda kontrast duyarlılık, aberasyonlar ve pupilla çapı üzerine etkilerini değerlendirmektir. **Gereç ve Yöntemler:** Katılımcıların kontrast duyarlılıkları ölçülüp topografileri ve skotopik, mezopik ve fotopik aydınlatmada pupillografileri çekildi. Bireylerin rastgele bir gözlerine şeffaf senofilcon A KL (Acuvue Oasys hydraLuxe) diğer gözlerine ise fotokromik senofilcon A (Acuvue Oasys with transitions) KL takıldı. Daha sonra bireylerin tekrar kontrast duyarlılığı ölçülüp KL üzerinden topografi ve pupillografileri çekildi. Topografiden aberasyon değerleri elde edildi. Meydana gelen değişiklikler açısından fotokromik KL takılan göz ile diğer göz karşılaştırıldı. **Bulgular:** KL takılmadan önce fotokromik taraf ile diğer taraf arasında incelenen bütün parametreler açısından anlamlı bir fark yok idi (hepsi için; p>0,05). KL takıldıktan sonra hem fotokromik hem de şeffaf tarafta KL öncesi duruma göre skotopik, mezopik ve fotopik pupil çaplarında anlamlı bir değişiklik olmadı (hepsi için; p>0,05), yüksek sıralı aberasyonlar arttı (p<0,05) ve yüksek frekanslardaki (12 ve 18 cpd) kontrast duyarlılık düştü (her ikisi için; p<0,05). KL takıldıktan sonra fotokromik taraf şeffaf taraf ile karşılaştırıldığında bütün parametreler açısından aralarında anlamlı bir farkın olmadığı görüldü (hepsi için; p>0,05). **Sonuç:** İç mekânlarda çalışmamızda değerlendirilen fotokromik veya şeffaf KL'nin kullanılması görme kalitesi ve pupil çapları açısından farklı sonuçlara yol açmamaktadır. Her iki KL de yüksek frekanslarda kontrast duyarlılıkta düşüşe yol açmaktadır.

Anahtar Kelimeler: Fotokromik kontakt lens; kontrast duyarlılık; pupilla çapı; yüksek sıralı aberasyonlar

Light with a short wavelength damages tissues such as the retina because of its high energy. Sunglasses and yellow intraocular lenses were able to reduce this damage by filtering out high-energy light in the visible spectrum. However, since these devices have a constant filtering, they may have undesirable effects on visual function in mesopic or scotopic environments, although they are beneficial in high light.

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Peer review under responsibility of Turkiye Klinikleri Journal of Ophthalmology.

Received: 30 Dec 2021 ***Received in revised form:*** 05 Jun 2022 ***Accepted:*** 06 Jun 2022 ***Available online*:** 14 Jun 2022

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This dilemma prompted researchers to look for ways of filtering based on light intensity.[1,2]

Light sensitivity refers to the discomfort that occurs when individuals are exposed to light that exceeds their adaptive state.[3] Although the foundations of contact lenses (CL) date back to the 1500s and a wide range of CLs are produced today, innovations regarding CLs continue even in recent years.[4] One of the latest developments in CLs is the production of photochromic CLs in order to reduce glare and sensitivity to light.[5] In accordance with the design idea, the photolabile molecules inside the CL are activated in ultraviolet or high-energy visible light, and the lens darkens, while in dim light it is minimally active, and the CL is usually transparent. Thus, it adjusts the amount of light entering the eye according to the light intensity in the environment. It is fully activated in outdoor environments due to the ultraviolet in sunlight. Eyes can be exposed to a certain amount of high-energy visible light indoors, due to the ability of light sources used both from windows and indoors to emit ultraviolet light.[6] Thus, photochromic CL can be expected to be activated to some extent in the indoor environment.[7] Individuals using this CL have to continue to use this lens in indoor environments, as they cannot change their lenses during each indoor-outdoor environment changes. Therefore, it is important to examine the effect of this CL on visual quality in indoor environments. Accordingly, in this study, it was aimed to evaluate the effect of photochromic CL on visual quality and pupillary functions in indoor environments.

MATERIAL AND METHODS

This cross-sectional study was conducted with 40 volunteers without any eye disorder other than refractive error and who wanted to use CL. Before starting the study, approval was obtained from the Kafkas University local ethics committee (date: November 11, 2020, no: 80576354-050-99/265) and the study was conducted in accordance with the rules of the Declaration of Helsinki. Informed consent obtained from the participants. Individuals with astigmatism 0.75 D or higher in any eye, corneal haze or vascularity, corneal dystrophy or degeneration, and individuals who had any previous ocular surface or intraocular surgery were not included in the study. Subjects using topical drugs were not included in the study. Subjects who could not achieve CL compliance were excluded from the study. Those with distance best visual acuity less than 10/10 were not included in the study. Those who had a previous diagnosis of dry eye or had complaints about dry eye were excluded from the study.

Within the scope of the study, the visual acuity and contrast sensitivity of the participants were measured and routine ophthalmological examinations were performed before wearing CL. Contrast sensitivity was measured using the CSV-1000E (Vector Vision, Dayton, OH, USA) contrast sensitivity device in a lightened room. The instrument has a backlit translucent table of 85 cd/m^2 that calibrates automatically. In the 4 rows of the table are sinusoidal wave grids at spatial frequencies of 3, 6, 12 and 18 cycles per degree (cpd). Each line has 8 pairs of circular patches, and the lines become thinner as the frequency increases.[8] The test was performed in bright conditions from 2.5 m away after refractive correction, where the participant's best visual acuity was achieved. For each eye the participants were asked whether there was a test grid in the patch pairs and, if so, in which patch the grid was located. The last correctly known number for each line was considered as the contrast threshold for the corresponding spatial frequency.

Pupillography under different lighting conditions (scotopic, mesopic and photopic lighting) and topography (Sirius, CSO, Florence, Italy) were taken to individuals. With pupillography integrated into the Sirius topography device, most of the visual field is exposed to controlled illumination, allowing the pupil diameter to be measured objectively. According to the lighting conditions set in the device, the pupil diameter at 0.4 Lux illumination is recorded as scotopic, at 4 Lux illumination as mesopic, and at 40 Lux illumination as photopic pupil diameter.[9] Pupillography was taken in a windowless dark room. Thus, standardization was achieved only with the controlled lighting obtained from the device. During the shooting, each eye was evaluated individually and fellow eye patched. The participant was told not to focus on any point and to look straight ahead. Thus, accommodation was tried to be prevented. Then, transparent senofilcon A CL (Acuvue Oasys hydraLuxe, Johnson & Johnson Vision Care, Inc., Jacksonville, FL, USA) is inserted on the one eye of the participants and photochromic senofilcon A CL (Acuvue Oasys with transitions, Johnson & Johnson Vision Care, Inc., Jacksonville, FL, USA) is inserted on the other eye. Participants were not aware of which CL was placed on which eye. The suitability of CL was evaluated by considering the participant's visual acuity, CL centralization and movement. Then, contrast sensitivity was measured while wearing the CL, and pupillography under different lighting conditions and topography were taken over the CL. In our study, no additional attempts were made to fully activate the photochromic lenses. The reason for this was the idea to evaluate the level of activation seen indoors.

Almost all properties (material, water content, diameter, and base curve) except photochromia were the same in both lenses. Unlike the transparent CL, the photochromic CL is a relatively newly produced silicon hydrogel CL with photolabile molecules over its entire surface. These photolabile molecules become active when exposed to short wavelength light or ultraviolet, darkening the lens. Photocromic CL transmits approximately 35% +/- 5% of visible light at 380-780 nm when fully active and approximately 85% +/- 5% when inactive in the same range.[10] The transparent CL, on the other hand, had similar structural monomers with the photochromic lens, except for the photochromic monomer. The characteristics of the CLs used in our study are summarized in Table 1.

Changes in low and high frequency contrast sensitivity, high order aberrations in topography (anterior 3 mm), and pupil diameters in scotopic, mesopic, and photopic lighting conditions were evaluated after wearing CL in each eye. In addition, the photochromic side and the transparent side were compared with each other.

Statistical analysis was performed using SPSS (Statistical Package for Scientific Studies, SPSS Inc., Chicago, USA) version 24.0 statistical package program with 95% confidence. While evaluating the study data, descriptive statistics; mean and standard deviation were used. Both sides (photochromic and the fellow side) were compared with each other using paired samples t test. Changes occurring in each eye after CL insertion were evaluated with the paired samples t-test for the analysis of the quantitative data. A p value of <0.05 was considered statistically significant.

TABLE 1: Properties of the contact lenses.

Contact lens	Acuvue oasys with transitions	Acuvue oasys hydraLuxe
Monomer	Senofilcon A	Senofilcon A
Water content	38%	38%
Base curve	8.40	8.40 or 8.80
Diameter	14.00	14.00
Thickness (at -3.00D)	0.085 mm	0.07 mm
Dk/t (at -3.00D)	121	147
Lens design	Aspheric	Aspheric

RESULTS

The mean age of the participants in our study (13 men and 27 women) was 24.42±6.65 years. The mean refractive errors of the photochromic and transparent sides were -1.16±1.25 D and -1.07±1.19 D, respectively. There was no significant difference between the 2 sides in terms of refractive error (p=0.73). When the photochromic eye was compared with the other eye before CL insertion for baseline evaluation, it was found that there was no significant difference between the 2 eyes in terms of all parameters investigated in the study (for all; p>0.05).

It was observed that there was no significant change in scotopic, mesopic and photopic pupil diameters on both the photochromic and transparent sides after CL insertion compared to the pre-CL situation (for all; p>0.05). The changes in pupil diameters after CL insertion compared to the situation before CL insertion under different lighting conditions are summarized in Table 2. On the both sides, although there was no significant change in contrast sensitivity at low frequencies (3 cpd ve 6 cpd) after CL insertion (for both; p>0.05), it was observed that contrast sensitivity at high frequencies (12 cpd ve 18 cpd) decreased (for both; p <0.05). Figure 1 shows the changes in contrast sensitivity after CL insertion on the photochromic and transparent side.

TABLE 2: Changes in the pupil diameter after contact lens insertion.

	Lightening condition	Pupil diameter before CL insertion	Pupil diameter after CL insertion	p value*
Acuvue oasys with transitions	Scotopic	6.39±0.94	6.38±0.94	0.84
	Mesopic	5.33±1.11	5.35±1.07	0.83
	Photopic	3.92±0.91	4.01±0.76	0.30
Acuvue oasys hydraLuxe	Scotopic	6.39±1.10	6.41±0.90	0.84
	Mesopic	5.35±1.15	5.47±1.03	0.10
	Photopic	3.92±0.87	4.02±0.80	0.28

*:Paired samples t test.

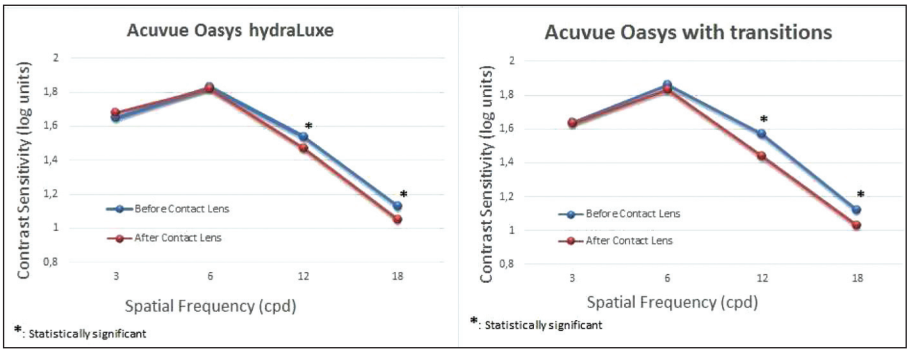

FIGURE 1: Changes in the contrast sensitivity after contact lens insertion.

Before CL insertion root mean square of high order aberrations, [root mean square (RMS) of higher-order aberrations (HOA)] was 0.08±0.05 µm on the photochromic side and 0.07±0.03 µm on the transparent side, while these values were 0.31±0.33 µm on the photochromic side and 0.36±0.33 µm on the transparent side after CL insertion. After CL insertion, RMS of HOA increased significantly on both the photochromic and transparent sides ($p<0.01$ for both). While the total RMS was 0.24±0.08 µm on the photochromic side and 0.22±0.09 µm on the transparent side before CL insertion, these values were 0.42±0.33 µm on the photochromic side and 0.51±0.38 µm on the transparent side after CL insertion. After CL insertion, total RMS increased significantly on both the photochromic and transparent sides ($p<0.01$ for both).

When the photochromic side and the transparent side were compared with each other after CL insertion, it was observed that there was no significant difference between them in terms of pupil diameters under different lighting conditions, aberrations and contrast sensitivity (for all; $p>0.05$).

DISCUSSION

Bright light is a common cause of visual disturbance, and many patients seek a solution to this problem. It has been stated that preventing or reducing the discomfort caused by bright light is the main reason why people need tinted glass. In a study conducted with patients using glasses or CL, 69% of the participants reported that the main reason for wearing tinted glasses was reduced glare, followed by fashion (18%) and ultraviolet protection (14%).[11]

In this study, the effect of photochromia, a relatively new development in soft CLs, on visual quality and pupillary functions in indoor environments was investigated. It was found that photochromic CL did not have a significant effect on pupil size under different lighting conditions, as in transparent CL. In a study investigating the relationship between the filters to be added on the multifocal CL and the pupil size, 3 different fixed filters that transmit 48.3%, 27.1% and 14.5% of the light were used, and it was found that the pupil sizes were significantly enlarged with all 3 filters.[12] Considering the results of this study, we think that the photochromic CL used in our study transmits more than 48.3% of the light in indoor environments. While the lens used in our study is inactive, approximately 85% of the light is transmitted while it is fully activated, 35%. This shows that CL used in our study is minimally activated indoors. In order to determine how much CL is activated in indoor environments, studies that measure the activation of the lens with a spectrophotometer are needed.

In a survey study, 50.5% of the patients reported that the indoor vision quality with photochromic lenses was similar to their habitual glasses. With the photochromic CL, 40% of the patients achieved visual benefit in indoor environments, while this rate was found to be 60% in outdoor environments. Therefore, the researchers stated that photochromic CL could not provide as much benefit indoors as outdoors.[10] In a study in which photochromic CL was partially activated (62% transmission), it was shown in the photostress test using a bright light that photochromic CL significantly shortened the photostress recovery time compared to the control CL.[5] This result shows that the effect of photochromic CL comes to the fore especially in bright light conditions.

In our study, although there was no significant change in low-frequency contrast sensitivity on both the photochromic and transparent sides after CL insertion, it was determined that there was a decrease in high-frequency contrast sensitivity. In a study evaluating the effect of CL insertion on visual quality and aberrations, it was found that transparent CL did not change low contrast sensitivity.[13] We think that the multiple light reflections formed by the pre-lens tear film and the anterior and posterior surface of the CL are effective in reducing the contrast sensitivity at high frequencies in our study. In the literature, it has been stated that the reason for the decrease in contrast sensitivity with CL insertion is induced aberrations.[14] In order to compare the photochromic side and the transparent side, when the contrast sensitivity measured over the CL is evaluated, it was seen that there was no significant difference between the 2 sides. Similarly, Buch et al. determined that there was no statistically significant difference between photochromic soft CL and control lenses in terms of low brightness (Mesotest II) or high brightness (Pelli-Robson) binocular contrast threshold.[15]

In a study in which the effect of the photochromic CL on personal driving performance during the day and night was questioned with a 6-question questionnaire, although the participants reported the superiority of the photochromic CL in some cases in daytime driving, they stated that there was no difference between the photochromic and the non-photochromic CL in night driving. For this reason, it was stated that the use of photochromic CL at night may be equivalent to the use of transparent CL.[15] These results suggest that the photochromic CL may be more beneficial, especially in conditions of bright sunlight containing ultraviolet. In a study conducted with multifocal CLs, it was determined that contrast sensitivity decreased when a filter with 48.3% transmittance was added to the CL.[12] The similarity of contrast sensitivity measured on photochromic and transparent CL in our study may be due to the lower activation rate (transmit higher than 48.3% of light) of photochromic CL in our study indoors.

In our study, it was found that aberrations increased with both lenses after CL insertion. No significant difference was detected between the transparent side and the photochromic side when the CL was on the eye. In a study conducted with 7 different transparent soft CLs in the literature, it was found that all CLs examined increased the RMS of wavefront aberrations.[16] Roberts et al. found that soft CLs worn for myopia increased HOAs.[17] In the literature, the increase in aberrations in the CL plus eye system has been attributed to various factors. The first of these is the position of the center of CL relative to the axis of vision. It has been stated that the movement of CL may cause it to move away from the center and increase HOAs.[18,19] It has been emphasized that the interaction between the cornea and CL can change the thickness and the homogeneity of precorneal tear film and cause irregularity. It has been stated that the prelens tear film can potentially cause deformations on the anterior surface of CL.[20,21] It has been reported that the optical quality, material, water content, design, manufacturing process, power, thickness and modulus of CL affect the triggered aberrations.[16,22-24] In our study, we think that the effects of the 2 lenses on aberrations are similar, since these properties are the same except for the addition of photochromic molecules. The lack of difference between the aberrations of the photochromic and transparent sides indicates that the photochromic molecules are minimally activated indoors.

In our study, 2 different groups were formed with 2 eyes of the same patient, considering that accommodation, patient compliance, ocular surface and tear film health, horizontal visible iris diameter and baseline pupil parameters (color, thickness, diameter, contraction-dilatation speed) would be similar, which could affect pupillography and visual quality. Although each eye was evaluated separately, comparison of the fellow eye may limit the statistically generalization of the results for different individuals. This is one of the important limitations of our study. For this reason, our study needs to be supported by studies in which different groups are formed with the eyes of different individuals and all the parameters affecting the pupillography and visual quality mentioned above are evaluated in detail.

CONCLUSION

Using the photochromic CL in indoors does not lead to different results than the transparent CL in terms of visual quality and pupil diameters. Both lenses cause a decrease in contrast sensitivity at high frequencies. This may be due to aberrations induced by CL insertion.

Source of Finance

During this study, no financial or spiritual support was received neither from any pharmaceutical company that has a direct connection with the research subject, nor from a company that provides or produces medical instruments and materials which may negatively affect the evaluation process of this study.

Conflict of Interest

No conflicts of interest between the authors and / or family members of the scientific and medical committee members or members of the potential conflicts of interest, counseling, expertise, working conditions, share holding and similar situations in any firm.

Authorship Contributions

***Idea/Concept:** Ersin Muhafiz, Şerif Nizamoğulları; **Design:** Ersin Muhafiz, Şerif Nizamoğulları; **Control/Supervision:** Ersin Muhafiz, Şerif Nizamoğulları; **Data Collection and/or Processing:** Ersin Muhafiz, Şerif Nizamoğulları; **Analysis and/or Interpretation:** Ersin Muhafiz, Şerif Nizamoğulları; **Literature Review:** Ersin Muhafiz, Şerif Nizamoğulları; **Writing the Article:** Ersin Muhafiz, Şerif Nizamoğulları; **Critical Review:** Ersin Muhafiz.*

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