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Effect of Photochromic Senofilcon a Contact Lens on Total Aberrations of the Eye

Fotokromik Senofilcon A Kontakt Lensin Total Göz Aberasyonlarına Etkisi

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Abstract

Objective: To investigate the effect of newly designed photochromic Senofilcon-A lens (PCL) on optical aberrations of the eye (total (TA) and high-order-aberrations (HOA)) under ambient illumination conditions.

Materials and Methods: In this retrospective study, 40 eyes of 20 volunteers were fitted with a non-photochromic Senofilcon-A contact lens on the right eye, a PCL on left eye. Subjects were evaluated in terms of best-corrected visual-acuity. Aberrometric measurements were obtained at baseline(lens-free), with activated and deactivated PCL in 3 mm, 6 mm and maximum pupil size.

Results: In lens-free situation there was no difference in terms of TA and HOAs (for 3mm, 6mm and max-pupil-size, TA; p=0.456; p=0.687; p=0.899 and HOA; p=0.226; p=0.259; p=0.442 respectively).In all pupil diameters, in the PCL group compared to the standard lens group, there was a slight increase in total aberrations independent of lens activation, which was not statistically significant(for 3mm,6mm and max-pupil-size, activated lens situation; p=0.523; p=0.622; p=0.244 and deactivated lens situation; p=0.785; p=0.357; p=0.201, respectively). Contrary to total aberrations, higher order aberrations were non-significantly slightly decreased in the PCL group (for 3mm,6mm and max-pupil-size, activated lens situation; p=0.235; p=0.661; p=0.841 and deactivated lens situation; p=0.245; p=0.071; p=0.231, respectively).

Conclusion: The PCL produces similar TA and HOAs with the non-photochromic soft contact lens in both activated and deactivated situation. PCLs can be preferred for those who need uninterrupted vision in variable light conditions.

Keywords: Aberration, Contact Lens, Photochoromic, Ultraviolet

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Öz

Amaç: Fotokromik Senofilcon-A kontakt lensin (FKL) ortam aydınlatma koşullarında gözün optik aberasyonları (toplam (TA) ve yüksek sıralı aberasyonlar (YSA)) üzerindeki etkisini araştırmak.

Gereç ve Yöntemler: Bu geriye dönük çalışmada, sağ gözlerine fotokromik olmayan Senofilcon-A kontakt lens (KL), sol gözlerine FKL takılan 20 gönüllü ele alındı. FKL aktif ve inaktif fazlarında ölçümler yapıldı. FKL'nin aktif fazına ulaşabilmek ultraviyole cihazı kullanıldı. Aberrometrik ölçümler 3 aşamada; lens takılmadan önce, FKL inaktifken ve FKL aktifken yapıldı. Ayrıca pupil boyutlarının aberasyonları etkileyebileceğinden aberasyonlar pupil çapları 3 mm, 6 mm ve maksimum genişlikte alındı.

Bulgular: Her iki göz için başlangıçta TA ve YSA'lar açısından fark yoktu (3 mm, 6 mm ve maksimum pupil boyutu için, TA; p=0,456; p=0,687; p=0,899 ve YSA; p=0,226; p=0,259; p=0,442). Tüm pupil çaplarında, FKL grubunda KL grubuna göre toplam aberasyonlarda lens aktivasyonundan bağımsız olarak istatistiksel anlamlı olmayan artış bulundu (3 mm, 6 mm ve maksimum pupil boyutu için, aktif lens durumu; p=0,523; p=0,622; p=0,244 ve inaktif lens durumu; p=0,785; p=0,357; p=0,201, sırasıyla). FKL grubunda, YSA'larda istatistiksel anlamlı olmayan azalma bulundu (3mm, 6mm ve maksimum pupil boyutu için, aktif lens durumu; p=0,235; p=0,661; p=0,841 ve inaktif lens durumu; p=0,245; p=0,071; p=0,231, sırayla).

Sonuç: FKL, hem aktif hem de inaktif durumda fotokromik olmayan yumuşak kontakt lens ile benzer TA ve YSA'lara sahip olduğu bulundu. Değişken ışık koşullarında FKL tercih sebebi olabilirler.

Anahtar Kelimeler: Aberasyon, Kontakt Lens, Fotokoromik, Ultraviyole

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Introduction

Contact lenses are an indispensable part of visual rehabilitation. Although they provide a spectacle-free life, some patients were complaining from being uncomfortable. These comfort and mechanic problems have been largely resolved due to the improvements in lens material and technology. However, the glare disability and light disturbance that occur in ambient illumination still continues. For this purpose, fixed-tinted lenses were developed (1). However, they affect vision adversely, especially in scotopic conditions by absorbing near the peak of visible light. (1,2) On the other hand, newly designed photochromic contact lenses (PCL) reduce visual disturbances such as halo, glare, and light scatter and improve photostress recovery by adjusting the light entering the eye (3). PCLs are activated by ultraviolet (UV) and high energy visible light and change their color depending on the wavelength and intensity of ambient light in the environment. This color change is relatively rapid, reversible, and dose-dependent. Under indoor and/or nighttime conditions, PCLs are colorless and provide optimal vision (3).

Although visual acuity is the hallmark of optimal vision and visual function, image quality deteriorates from the optical aberrations (2). The eye, as any other optical system, is far from perfect and also suffers from optic aberrations that affect optical quality. In the eye, the majority of the wavefront aberrations are caused by low-order aberrations (LOA), including refractive errors such as myopia (positive defocus), hyperopia (negative defocus), regular astigmatism, and other non-visually significant aberrations. Most of these aberrations are tolerated well and corrected with spectacles or contact lenses (2,4). High-order aberrations (HOA) reduce retinal image quality and cannot be corrected using conventional optical corrections.

Corneal topography and wavefront technology have allowed ophthalmologists to evaluate these aberrations and thus optical quality objectively and quantitatively. They helped ophthalmologists in deeper understanding the effect of aberrations on vision. The iDesign Advanced Wavescan system is a Hartmann-Shack aberrometer, which uses a Fourier mathematic reconstruction of the wavefront profile. This system provides precise detection of not only LOA but also HOA with better resolution and more detection points (2).

The effect of PCL on visual performance has been widely investigated (4-6). The studies were focused on especially visual acuity and the patients' visual qualities on outdoor activities. However, the investigations about the effect of PCLs on ocular aberrations still lacks. Thus, the aim of this retrospective study was to evaluate the effect of photochromic Senofilcon A lens on optical aberrations of the eye under ambient illumination conditions.

Materials and Methods

This retrospective cross-sectional single center study was conducted in the Cornea and Refractive Surgery Department of Kayseri City Hospital and organized in accordance with the ethical standards. The study was approved by the Ethics Committee of Kayseri City Hospital (date: 21.07.2022 and approval number: 2022/670). All the study procedures were performed in accordance with the Declaration of Helsinki. Informed consent was obtained from patients or their legal guardians. Medical records of 40 eyes of 20 volunteers over the age of 18 years were included in this retrospective study. Subjects whose spherical equivalent is in the range of -0.75 to -3.50 D in each eye and whose best contact lens corrected visual acuity was 20/20 were included in the study. The exclusion criteria are as follows: presence of ocular surface diseases (dry eye, active ocular infection, allergic conjunctivitis, herpetic keratitis, corneal scar or opacities, corneal neovascularization), eyelid problems, such as ectropion and entropion, contact lens wearing in the past three weeks, history of cataract, uveitis, glaucoma and retinal disease, history of ocular trauma and ocular surgery, smoking, any systemic disease, pregnancy, use of systemic or ocular medication known to affect visual acuity and quality.

All cases were evaluated for manifest and subjective refraction, best corrected visual acuity, preliminary slit-lamp biomicroscopy and aberrometry scans before contact lens insertion. Refraction measurements were recorded as spherical equivalents (SE).

Contact Lenses

The lenses fitted were Acuvue Oasys (Johnson & Johnson Vision Care Inc., Jacksonville, Florida) in the right eyes and Acuvue Oasys with Transition (Johnson & Johnson Vision Care Inc., Jacksonville, Florida) in the left eyes. In both lenses the lens material was Senofilcon A, which has a Dk/t of 147 and 38% water content. The total diameter is 14.0 mm, the base curve is 8.4 mm and refractive power is available ranging -12.0 to +8.0 diopter (D) in 0.25 D steps.

Acuvue Oasys with Transition Light Intelligent Technology soft contact lens was approved by The U.S. Food and Drug Administration in 2018. (3)

This contact lens contains naphthopyran monomers, which can darken in 45 seconds when exposed to UV and high energy visible light and transmit 35%±5% of 380-780 nm visible light. When removed from direct sunlight, the lens rapidly fades in 90 seconds and transmits 85%±5% of visible light. (4)

In this study PCLs were activated by using a Light-Link CXL Crosslinking System (Lightmed, Taiwan) emitting 355±5 nm wavelength. After five minutes of exposure to the UV light of the machine, lenses were fitted to the patients and the activation of PCL was confirmed with a slit lamp biomicroscopic examination (Figure 1).

Figure 1. Subject has Senofilcon-A lens in the right eye and activated photochromic Senofilcon-A contact lens in the left eye.

Aberration Measurements

Before fitting a lens all patients were scanned with the iDesign Advanced Wavescan (Abbott Medical Optics, Santa Ana, CA) device to measure the total aberrations (TA) and HOA. Afterwards, subjects were asked to wear Senofilcon A soft contact lens (Group 1, Acuvue Oasys (Johnson & Johnson Vision Care Inc., Jacksonville, Florida)) in the right eye and the active photochromic Senofilcon A soft contact lens (Group 2, Acuvue Oasys with Transitions™ (Johnson & Johnson Vision Care Inc., Jacksonville, Florida)) in the left eye. Lens fit, vertical and horizontal alignment, and 0.5-1 mm movement with each blink were confirmed.

Total aberrations and HOA measurements were repeated. The subjects were kept in room light (200 Lux) for 15 minutes for the inactivation of the PCL and inactivation of the lens was confirmed with a slit lamp biomicroscopy. Measurements of aberrations were then repeated with the inactivated lens.

All aberrometric measurements were evaluated at least three times for each eye at baseline (lens-free), with activated PCL and deactivated PCL by an experienced ophthalmologist (DK). The image with best wavefront quality was selected for further statistical analysis. Root mean square (RMS) of the total and HOAs at 3 mm, 6 mm, and maximum pupil size were recorded. The maximum pupil size is the largest

measurable pupil diameter. Maximum wavefront diameter is 8.5 mm. Total and HOA measurements of both eyes in three examinations (lens-free, PCL activated and deactivated) were compared.

Statistical Analysis

Statistical analysis of the data was evaluated using the SPSS version 24.0 (IBM Corporation, Armonk, NY, USA) software program. The mean, standard deviation, minimum and maximum values of the numerical variables were calculated. Shapiro Wilk test was used to evaluate the normal distribution of variables. In addition, the variables with kurtosis and skewness values in the range of -2, +2 were considered to have a normal distribution. Paired T test was used if groups showed normal distribution in pairwise comparisons, and Wilcoxon test was used if groups did not provide normal distribution. A p value of < .05 was considered statistically significant.

Results

Forty eyes of 20 subjects with a mean age of 29.95±5.23 (range, 25-44) years were included in the study. The study group consisted of 13 (65%) males and 7 (35%) females. The mean SE in the standard contact lens group was -2.36±1.12 D, whereas that in the PCL group was 2.26±1.04 D, exhibiting no significant difference (p=0.777). The eyes were all asymmetrical in biometrical features. After fitted a contact lens, both groups were not different in mean SE (-0.25±0.12 in standard CL vs -0.22±0.20 in PCL, p=0.856). Groups were equal in best corrected visual acuity (BCVA) in Snellen tests (0.98±0.10 in standard CL and 0.97±0.13, p=0.899). Comparison of total and HOAs between the two groups with lens-free, PCL activated and deactivated was shown in Table 1. In lens-free situation there was no statistically significant difference in terms of total and HOAs in all pupil size. Total aberrations were slightly higher in Group 2 compared to Group 1 in all three lens situations, but the differences were not statistically significant. Contrary to total aberrations, there was a slight decrease in Group 2 compared to Group 1 in HOAs, which was not significant (except HOAs measured at maximum pupil size in PCL activated).

Table 1
Comparison of total and high order aberrations between the two groups with lens-free, PCL activated and deactivated.

	Total aberrations			HOAs		
	Group 1	**Group 2**	**P**	**Group 1**	**Group 2**	**P**
3 mm pupil size						
Lens-free	0.78±0.47	0.79±0.22	0.456	0.08±0.17	0.07±0.12	0.226
Activated	0.31±0.34	0.34±0.28	0.523	0.15±0.15	0.11±0.17	0.235
Deactivated	0.33±0.37	0.34±0.22	0.785	0.14±0.12	0.10±0.12	0.245
6 mm pupil size						
Lens-free	30.36±10.33	30.21±10.11	0.687	0.29±0.12	0.26±0.6	0.259
Activated	0.93±0.41	10.02±0.63	0.622	0.32±0.14	0.30±0.13	0.661
Deactivated	0.89±0.34	10.03±0.55	0.357	0.30±0.13	0.23±0.09	0.071
Maximum pupil size						
Lens-free	40.37±10.88	40.30±10.47	0.899	0.45±0.21	0.40±0.13	0.442
Activated	10.14±0.51	10.38±0.71	0.244	0.41±0.23	0.42±0.15	0.841
Deactivated	10.12±0.44	10.37±0.75	0.201	0.44±0.19	0.37±0.15	0.231

HOAs: High-order aberrations

Discussion

Acuvue® Oasys with Transitions™ is a relatively new PCL and there is no study in the literature investigating the effect of PCLs on wavefront aberrations. This comparative study has shown that there is no significant difference on total and HOAs between Oasys CL and Oasys with Transition PCLs.

Contact lenses are mostly transparent to visible light. In recent years, the contact lens industry has advanced remarkably with the design of PCL, which adapt to intensity and wavelength of light. PCLs may be useful for improving visual performance and reducing ocular fatigue, especially for drivers, artists, and athletes who are exposed to variable illumination conditions. Erickson et al. reported better contrast discrimination, visual performance, and better speed of visual recovery in bright sunlight with sport-tinted contact lenses. (5) Recently, it has been reported that greater than 95% of subjects composed of neophyte population were successfully fitted with the PCL based on comfort and vision and it provides advantages among a variety of both indoor and outdoor situations. (4) Photochromic additive contact lenses reduce the extent of positive dysphotopsia compared to non- PCL regardless of lens activation.

In a randomized controlled trial, all visual functions including glare disability, glare discomfort, and photostress recovery time were significantly improved with the activated PCL versus the clear lens. The authors reported that the photochromic feature improves individuals' abilities to cope with intense and short wavelength light and provides a rapid visual recovery after photo stress. (6) Studies have shown that PCL not only improved visual performance in the outdoors and in bright light conditions, but also improved visual functions including photostress recovery, glare disability, glare discomfort, and chromatic contrast in the indoors. (7) It has been shown that the effect of PCLs on nighttime and daytime driving visual performance is non-inferior to non-photochromic soft contact lens and plano photochromic spectacle lenses. (8)

The close relationship between ocular aberrations and visual performance has been investigated and well-known. The effect of soft contact lenses on visual acuity and contrast sensitivity was investigated and it was observed that visual performance was worse than rigid-gas permeable contact lenses. This situation may be associated with induced wavefront aberrations. (9,10) High-order aberrations were found to be significantly increased in the wavefront analysis in myopic soft contact lens wearers.(11) Decentration of soft contact lens from pupil center, ocular surface deformation and interaction between tear film and contact lens may induce wavefront aberrations. (12) In many studies tinted soft contact lenses have been shown to reduce contrast sensitivity, lead night vision disturbances and visual field problems. (13,14) Cosmetically, tinted soft contact lenses also increase HOAs and induce a reduction in optic quality under both photopic and mesopic conditions. (15,16) Besides, it is well known that BCVA is a prognostic factor for abberrations.(15) However, in this study it was found that both groups were similar in BCVA.

It is considered that structural deformations at the junctional zone between clear pupillary area and tinted area may cause an increase in HOAs. (17) In the present study, we found that total wavefront aberrations in all pupil size were not different in the PCL group compared to the non-photochromic soft contact lens group. PCLs ensure a slight reduction in HOAs that were not statistically significant regardless of lens activation. The inability of PCLs in both activated and deactivated situation to induce total and HOAs can provide continuous clear vision in varying lighting conditions.

In a recent study by Recep et al. (18) have assessed the change in ocular aberrations after fitting a FCL. They found that FCL did not influence ocular aberration in both phases (activated-inactivated.). This recent study is different than their study. The two lenses with the same material but a photochromic feature in one were compared. It is therefore valuable and is first to investigate the aberrations in the same material, but a photochromic lens and we believe that its contribution to the literature is important. As ophthalmologists know, there are great individual variations in ocular aberrations. The confounding effect of individual differences was eliminated by comparing the two eyes of subjects. The comparison with the non-photochromic soft contact lens with same material (Senofilcon A) enabled the study to better evaluate

the effect of the photochromic feature. This study also has some limitations, such as the relatively small sample size, and not evaluating the visual performance with objective or subjective methods.

Conclusions

In sum, in both the activated and deactivated situation, the PCL produces similar total and HOAs with the non-photochromic soft contact lens. Therefore, PCLes may be preferred by individuals such as athletes, artists, and drivers who work under bright lights or who need to maintain their visual performance uninterruptedly in ambient illumination. Future large-sampled clinical studies will be needed to better reveal the effect of PCL on ocular aberrations and visual performance.

Ethics Committee Approval: The study was approved by the Ethics Committee of Kayseri City Hospital (date: 21.07.2022 and approval number: 2022/670).

Informed Consent: Written consent was obtained from the participants or their legal guardians.

Conflict of Interest: Authors declared no conflict of interest.

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