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Original Article

The Effect of Photochromic Contact Lenses on Pupil Size

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Abstract

Objectives: Photochromic contact lenses (PCL) are designed to increase the comfort of patients, in bright light conditions. The aim of the study was to evaluate the effect of PCL on pupil size.

Methods: The study was conducted with 30 patients who were admitted to the contact lens department. Automated pupilography images of the right eyes of patients were obtained without contact lenses (group 1) in scotopic (S: 0.4 lux), mesopic (M: 4.0 lux), and photopic (p=40 lux) conditions. The procedures were repeated with silicone hydrogel contact lenses (Group 2) and with silicon hydrogel PCL (group 3).

Results: Mean age was 23.87±3.27 (17–30) years and male/female ratio was 10/20. The mean spheric equivalent of their right eyes was −3.60±1.73 (−0.50–−7.50). Pupil diameters of Group 3, under scotopic conditions, were larger than Group 1 and 2 (p=0.001, p=0.044). There was no difference between groups under mesotopic and photopic conditions. Pupil diameters at the different illumination levels were similar regarding gender.

Conclusion: Similarity in mesotopic and photopic pupil sizes compared to all groups may be a result of insignificant pupil changes of photochromic lenses in indoor conditions or insufficient time for lens activation.

Keywords: Automated pupillography, contact lens, luminance, photochromic contact lens pupil size

Introduction

Photochromic contact lenses (PCL) have photochromic additives in their material. They change their color, become darker (activation) in bright light (containing ultraviolet or violet light), and blench (deactivation) in dim light (1). As they are cosmetically acceptable, with full coverage of pupil and without fogging regarding the photochromic spectacle lenses, they have a promising preference capacity (2).

There are studies demonstrating that PCLs are helpful to get rid of unpleasant feelings of brightness discomfort under intense light. They have favorable features such as increased photostress recovery, increased chromatic contrast, decreased glare disability, and decreased positive dysphotopsia which all are important for the patients (2,3).

However, it is known that light is the driving force for changes in pupil size. Pupil is a dynamic structure; changes in pupil size primarily depend on the exposed light, accommodation, and secondarily to autonomic impulses (4,5). It is reported that, in dilated pupils, high-order aberrations lead to decreased image quality and problems in near vision (6). In this study, the hypothesis was that if the pupil diameters were affected by the use of PCL in indoor conditions. To the best of our knowledge, the effect of PCLs on pupil size has not been studied yet. It is aimed to assess whether PCLs result in pupil size change in scotopic, mesopic, and photopic levels of illumination.

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Methods

This prospective case–control study was performed at a tertiary referral center in Türkiye. It is approved by the Institutional Ethics Committee (University of Health Sciences, Dışkapı Yıldırım Bayezit Training and Research Hospital Ethics Committee, April 06, 2020, 85/11) and followed the tenets of the Declaration of Helsinki.

The study population was composed of patients those were referred to the contact lens department who were willing to wear contact lenses for the 1st time. Volunteer participants who gave written consents were included in the study. All of them underwent ophthalmologic examination including corneal topography (Sirius; Costruzione Strumenti Oftalmici, Florence, Italy). Patients who had previous ocular surgery, ocular disease other than refraction errors, systemic disease, and any history of ocular or systemic medications were excluded from the study.

After routine ophthalmologic evaluation, their automated pupillography images were taken by corneal topography device.

Pupillography is the software that is embedded in the corneal topography device. It takes 3–5 s to gather scotopic, mesopic, and photopic pupil images. The lighting conditions in the scotopic measure are the only visible light source of LED (0.4 lux); in the mesopic condition, the disc is illuminated with 4 lux, and in the photopic condition, pupil is exposed to a bright ambient light with the intensity of 40 lux. It was performed in a dark room with pupillography as the only light source.

At first, their right eyes' pupillography without contact lens (Group 1) was obtained followed by pupillography of the same eye with clear silicone hydrogel contact lenses (Group 2, Acuvue Oasys [Johnson and Johnson Vision Care Inc., Jacksonville, Florida]) and then with the photochromic silicone hydrogel contact lenses (Group 3, Acuvue Oasys with Transitions (Johnson and Johnson Vision Care Inc., Jacksonville, Florida) (Figures 1a-c). In each procedure, they were told to look straight ahead to avoid accommodation.

Before all three processes, patients were requested to stay in a room brightly illuminated by daylight for 10 min, then immediately, introduced to the room of topography device. Measurements at different illumination levels within each group were compared.

Statistical Analysis

The sample size was chosen by taking alpha: 0.05, beta: 0.20, and standard effect size: 0.70 in a t-test table. The data were recorded in a standard sheet, and statistical analysis was performed by the Statistical Package for the Social Sciences version 20.0 (SPSS Inc., Chicago, Illinois, USA). $P<0.05$ was considered statistically significant.

Results

Thirty patients were included in the study. The male/female ratio was 10/20. The mean age was 23.87±3.27 (17–30). The mean spheric equivalent of their right eyes was −3.60±1.73 (−0.50–−7.50).

Pupil diameter was decreased with increased luminance ([Table 1]; S1>M1>P1, S2>M2>P2, S3>M3>P3, paired sample t-test, $p<0.001$). The only significant difference was the larger pupil diameters under scotopic conditions of Group 3 rather than Groups 1 and 2 (Table 2).

Pupil diameters at different illumination levels were similar regarding gender (Table 3).

Discussion

Photochromic lenses are preferred primarily, to reduce glare, improve vision in bright light conditions and protection from ultraviolet radiation (7). As the photochromic spectacle lenses have some disadvantages such as inability to use in some sports activities, fogging, being affected from temperature changes, not covering total eye, and cosmetic issues.

Table 1. Lens properties of acuvue oasys (Group 2) and acuvue oasys with transitions (group 3)

	Acuvue oasys	Acuvue oasys with transitions
Lens material	Silicone hydrogel (senofilcon A)	Silicone hydrogel (senofilcon A)
Water content (%)	38	38
Oxygen transmissibility ($\times 10^{-9}$)	147	121
Modulus (MPa)	0.7	0.7
UV blocking	96% UVA, 99% UVB	99% UVA, 100% UVB
Centre thickness (mm) (-3.00 D)	0.07	0.085
Dynamic light absorption	No	Yes

Table 2. Comparison of pupil diameter measurements of right eyes in scotopic, mesopic, and photopic conditions without CL (Group 1), with silicon hydrogel contact lens (Group 2), and with photochromic silicon hydrogel contact lens (group 3)

	Without contact lens (Group 1)	Silicone hydrogel contact lenses (Group 2)	Photochromic silicone hydrogel contact lenses (Group 3)	p*
Scotopic pupil size (mm)	6.13±0.77	6.22±0.74	*6.37±0.78***	0.015
Mesopic pupil size (mm)	4.72±0.78	4.66±0.77	4.82±0.63	0.23
Photopic pupil size (mm)	3.90±0.74	3.80±0.67	3.94±0.54	0.64

*P-value was calculated by ANOVA test. **Comparisons between groups were further explored using Bonferroni correction. *The group that differs is shown in italics.*

Table 3. Pupil diameter measurements of the right eyes in S: scotopic, M: mesopic, P: photopic conditions and without CL (Group 1), with silicon hydrogel contact lens (Group 2), and with photochromic silicon hydrogel contact lens (Group 3) on gender bases

	S1	S2	S3	M1	M2	M3	P1	P2	P3
Female	6.24 (5.00–7.60)	6.25 (4.63–7.85)	6.30 (5.17–7.82)	4.97 (3.85–6.37)	4.87 (3.42–5.95)	5.02 (3.73–5.72)	3.99 (2.70, 5.40)	3.92 (2.71–5.22)	4.06 (3.20–4.69)
Male	5.94 (4.60–6.80)	6.06 (5.19–7.34)	6.03 (5.00–7.72)	4.36 (3.09–5.60)	4.53 (2.72–5.88)	4.75 (3.49–5.52)	3.89 (2.75–4.64)	3.68 (2.34–4.52)	4.05 (2.55–4.56)
p[a]	0.328	0.475	0.422	0.091	0.169	0.350	0.307	0.328	0.559

[a]Mann–Withney U-test. S1: Scotopic pupil size in Group 1, S2: Scotopic pupil size in Group 2, S3: Scotopic pupil size in Group 3, M1: Mesopic pupil size in Group 1, M2: Mesopic pupil size in Group 2, M3: mesopic pupil size in Group 3, P1: Photopic pupil size in Group 1, P2: Photopic pupil size in Group 2, P3, Photopic pupil size in Group 3.

Hence, investigation for PCLs, even photochromic intraocular lenses have evolved (8,9).

Photochromic lenses have been available since 2018 following the FDA approval. Photochromic material is embedded to Senofilcon A material lens, which has specific physicochemical properties such as 84–94% light transmittance in inactivated and 31–53% in an activated form that dynamically absorbs visible light (10).

It is thought that the contact lens, when stimulated, will reach its 50% of its maximum activated state in 45 s, and as the stimulus has been eliminated, it will reach to its 50% of inactivated state in 90 s (11). Even in the inactive state, they absorb light (12). Buch et al. reported that PCLs have better daytime and nighttime driving performance (13). Our results approved that, in scotopic conditions, theoretically without light conditions, the PCL group revealed increased pupil diameter, compared to other groups. However, photopic and mesopic pupil diameters did not show a statistical difference in indoor conditions.

It is also known that temperature can have an effect on the reaction time of the molecules. In cold weather conditions, photochromic spectacles inactivate slowly (2). We performed the study at room temperature, sudden temperature changes were not existent and the contact lenses, as they are on the corneal surface, they have a stable temperature of about 35°C and are unaffected from this unwanted situation.

Pupil diameter is different depending on individual variance. Some formulas have been conducted to predict the size, including the effects of luminance (14). It is known that luminance is the most influencing factor on pupil size (15). To avoid the accommodation effect, the patients were allowed to look straight ahead. In our study, the pupil size significantly decreased with increased illumination as expected in all groups.

Pupil diameter decreases linearly with age (16). In our study group, participants were young adults, ages were in a narrow range between 17 and 30 years, that avoided age-related pupil sizes and reflex variations. Although we were not able to make an analysis on the effect of age on pupil size, we found that gender had no significant effect on pupil size even in the different illumination levels in all groups.

Pupil size is important as small pupils with increased discrimination have polarity advantage, increased image quality, and reading. On the other hand, large pupils increase detection acuity but also increase light scatter, high order aberrations, and decrease perceived image contrast (6). In the case of photochromic lens wear, the concern may arise about the possibility of relatively decreased light transmittance that could affect indoor reading or visual acuity. Our results showed that the pupil size is indifferent in mesopic and photopic light levels and those are closest to indoor conditions.

Hammond et al. previously demonstrated that photostress recovery, glare, and chromatic contrast do not differ from the controls in indoor conditions (17). Our study was conducted in the darkroom but with light conditions of pupillography. We used the young age group to minimize the effect of age on pupil reactions, that is why the effect of PCL in different ages could not be compared.

The present study had some limitations. The study group was small and had a narrow age range. Furthermore, we did not evaluate the effect of PCL on contrast sensitivity. Despite these factors, this study was important as being the first one investigating the suggested effects of PCL on pupils with a different approach.

Conclusion

PCL did not change mesopic and photopic pupil diameters that may be explained as there is no effect of PCL on pupil diameter in indoor conditions or did not have enough time to activate. In scotopic conditions, pupil diameters were larger statistically. This may be a result of light absorption in the inactive state. The clinical significance of the scotopic pupil size requires further investigation.

Disclosures

Ethics Committee Approval: This prospective case–control study was performed at a tertiary referral center in Türkiye. It is approved by the Institutional Ethics Committee (University of Health Sciences, Dışkapı Yıldırım Bayezit Training and Research Hospital Ethics Committee, April 06, 2020, 85/11) and followed the tenets of the Declaration of Helsinki.

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