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Comparison of Photochromic Vs Non-Photochromic Contact Lenses in Indoor and Outdoor Conditions

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Abstract

Purpose: Photochromic contact lenses darken when exposed to sunlight protecting intraocular structures from UV damage. This study investigated the impact of PCL on visual functions in both indoor and outdoor conditions.

Methods: Subjects aged 18-35 years of existing contact lens users with refractive errors of ≤-5.00DS and ≤-1.00DC. In the randomly chosen eye, baseline measurements were obtained with CCL followed by PCL measurements. High and low contrast visual acuities, vernier acuity, and contrast sensitivity were measured using FrACT software in indoor illumination of 250-300 lux and outdoor illumination of 5000-10000 lux. Color discrimination was assessed digitally using FM 100 hue test and photo stress recovery time was also measured. The jigsaw puzzle game was done and evaluated subjective comfort by using a survey questionnaire.

Results: The median difference of HCVA and LCVA between indoor and outdoor conditions with CCL was 0.01 [p=0.26] and -0.15 [p=0.02]. However, with PCL, the median difference of HCVA and LCVA between indoor and outdoor conditions was -0.295 [p=0.86] and -0.2 [p=0.01]. The median difference of contrast sensitivity of different spatial frequencies with CCL and PCL between indoor and outdoor conditions were -0.72, -0.64 [12 cpd], -0.94, -0.87 [15 cpd], and -0.62, 1.3 [18 cpd]. Among the different spatial frequencies, the 18 cpd in CCL [p= 0.02] and 12 cpd [p=0.05] in PCL between indoor and outdoor conditions were statistically significant. The median difference in color vision between indoor and outdoor conditions with CCL and PCL was -13 [p=0.27] and -3.5 [p=0.50]. The PSRT was improved by 2s with PCL than CCL [p 0.08]. The glare discomfort and glare disability were better in PCL [0.9 ± 0.96, 1.4 ± 0.50] than in CCL [-0.05 ±0.68, 1.95 ± 0.88] in outdoor conditions.

Conclusion: Photochromic contact lenses enhanced visual functions in both indoor and outdoor conditions, alleviated glare discomfort, and improved glare disability, proving its effectiveness in various environments.

Keywords: Ultraviolet Radiation; Ocular Diseases; Visual Functions; Photochromic Contact Lens; Non-Photochromic Contact Lens, and Clear Contact Lens

Abbreviations

UVR: Ultraviolet Radiation; CCL: Clear Contact Lens; PCL: Photochromic Contact Lens; HCVA: High Contrast Visual Acuity; LCVA: Low Contrast Visual Acuity; CSF: Contrast Sensitivity Function; VA: Vernier Acuity; PSRT: Photostress Recovery Time; GDC: Glare Discomfort; GD: Glare Disability.

Introduction

The human eye is exhibited directly by ultraviolet radiation [UVR]. The sun is the primary source of UVR, which emits electromagnetic radiation in the range of 100-400nm. It is classified into UVA [320-400nm], UVB [290-320nm], and UVC [100-290nm], which causes cataracts, pterygium, pinguecula, photokeratitis, and macular degeneration [1,2]. In modern life, our visual system is constantly challenged by the need to respond to a wide range of light conditions. People experience visual discomfort and disability, especially in brightly illuminated environments [3]. Tinted and photochromic lenses of both spectacles and contact lenses are reported to prevent damage from UVR and reduce the glare effect. Photochromic lenses have light-sensitive additives that gradually become darker when exposed to sunlight and become clear when removed from UVR [4]. Contact lenses have become more popular to correct refractive errors in the eyes. Adding a photochromic molecule to soft contact lenses is a relatively innovation. The first photochromic contact lenses [Transition Opticals Inc] approved by the U.S. Food and Drug Administration were available for commercial use from the year 2018 [5]. The ACUVUE OASYS Contact Lens with Transitions Light Intelligent Technology [Johnson & Johnson Vision Care, Inc., Jacksonville, FL] is a first-in-class photochromic contact lens [PCL] and it is recommended for daily use to correct vision and alleviate the impact of bright light [6].In previous studies, visual functions such as photo stress recovery time [PSRT], Glare discomfort [GDC], Glare disability [GD], and Chromatic contrast [CC] were improved in both indoor and outdoor conditions with PCL[7-9]. However, there is a lack of knowledge about visual functions with PCL in the Indian population. There is considering the variations in macular pigmentation and light-dark adaptation between Indian and other populations, it is important to investigate how these differences influence visual functions and the perceived benefits of using these contact lenses. Hence this study investigated visual functions among the Indian population [10].

Methods

Ethics Approval

The study was approved by the institutional ethical committee [IEC: 8400] followed by the principle of tenets of the Declaration of Helsinki. All the procedures were explained clearly to the participants and obtained sign from an informed consent form.

Study Design and Subjects

This is a Prospective, experimental, and comparative study. The existing contact lens users between 18-35 years with a refractive power of -0.50 to -5.00DS and ≤-1.00DC were included. The contraindications for contact lenses such as current pregnancy, corneal trauma, and any ocular surgeries or trauma were excluded. The refractive power of >-5.00 DS, >-1.00 Dc, and Hyperopes were also excluded.

Standardization of Photochromic Contact Lens

The ACUVUE OASYS of both PCL and CCL were used in this study, allowing a one-hour adaptation time. The activation of PCL was done by using a xenon light source in previous studies. Here xenon light was not available so the standardization of photochromic was done by using a mercury vapor lamp. Photochromic contact lens activation takes 25s (Figure 1A) and a reversible process took around 4.92s. The mercury vapor lamp emits more heat and it was hazardous to human health. So, we decided to do it in direct sunlight at an illumination level of 5000-10000 lux, and the standardization was done (Figure 1B). The visual functions were measured after the activation of the Photochromic contact lens.

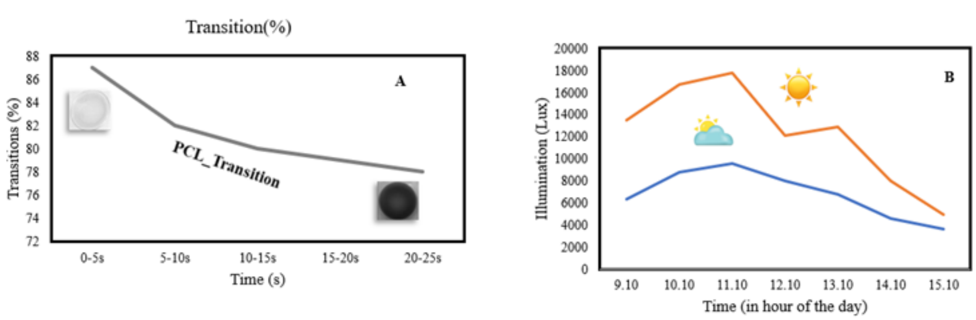

Figure 1: A: Shows the activation of photochromic contact lens; B: Shows the lux level of activation of photochromic contact lens in sunny conditions [red line] and cloudy conditions (blue line).

Study Setup

The setup in both indoor [250-300 lux] and outdoor [5000-10000 lux] conditions includes a calibrated LCD monitor with a 60 Hz display resolution of 1920×1020 pixels that was used to project the stimulus in the center of the monitor. The participants were seated at a viewing distance. The response keypad was used to respond to the stimulus for every measurement (Figure 2).

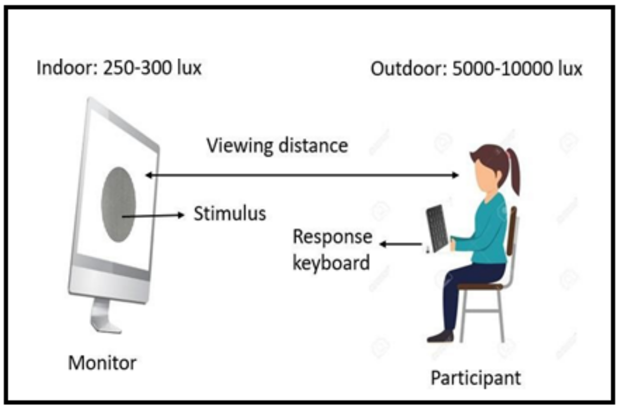

Figure 2: Shows the study setup.

Visual Functions Measurement

The visual functions such as HCVA, LCVA, VA, and Contrast sensitivity were measured using FrACT software. The blue line in the FrACT software was calibrated to measure the viewing distance between the target and the participants with a screen resolution of 1920*1020 pixels [60 Hz]. The viewing distance of 117 cm was used. The 100% optotype contrast was used in HCVA and VA, the 2.75% optotype contrast was used in LCVA, and the 50% optotype contrast was used in contrast sensitivity. The color vision was measured using digital FM 100 at a viewing distance of 50 cm. The jigsaw puzzle game was given to examine subjective comfort. Following that questionnaire was given to assess the comfort of lighting conditions. The PSRT was done at a distance of 3m to bleach the eye by using a direct ophthalmoscope.

Statistical Analysis

The data were entered in Excel and the statistical analysis was done using IBM Statistical Package for the Social Sciences [SPSS] version 22. All the parameters were not normally distributed. As a result, we reported the descriptive statistics using the median and quartile range. The non-parametric Wilcoxon signed-rank test was used to compare the medians of clear and photochromic contact lenses in indoor and outdoor conditions and Mann-Whitney U test was used in between the indoor and outdoor conditions with PCL and CCL.

Results

Participant Demographics

Twenty young adults with a mean age of 21 ± 1.5 [19 to 26 years]. Out of twenty participants, 40% [n=8] were male and 60% [n=12] were female. The mean value of refractive error for the right eye was -2.15 ± 1.31 and the left eye was -2.67 ± 1.37. The eye was tested as per randomization.

HCVA/LCVA

In Indoor conditions, the median logMAR HCVA was improved with CCL [-0.11±0.14] than PCL [-0.14±0.08] and it was not statistically significant [p=0.15]. The median logMAR LCVA was improved with PCL [0.28±0.14] than with CCL [0.36±0.10] and it was statistically significant [p=0.01]. However outdoor conditions, the median log MAR HCVA was improved with CCL [-0.12±0.07] than PCL [-0.15±0.03] and it was not statistically significant [p=0.50]. The median logMAR LCVA was improved with PCL [0.48±0.19] than with CCL [0.51±0.12] and it was not statistically significant [p=0.41] (Table 1).

The median difference of HCVA with CCL and PCL between indoors and outdoors was 0.01 and it was not statistically significant [p=0.26]. However, in LCVA, the median difference between indoor and outdoor was -0.15 and it was statistically significant [p=0.02]. However, with PCL, the median difference of HCVA between indoors and outdoors was -0.295 and it was not statistically significant [p=0.86]. However, in LCVA, the median difference between indoor and outdoor was -0.2 and it was statistically significant [p=0.01].

Vernier Acuity

In indoor conditions, the median arc seconds in vernier acuity was similar with both CCL [7.26±6.14] and PCL [7.96±6.23] and it was not statistically significant [p=0.37]. However, in outdoor conditions, the median arc seconds in vernier acuity was similar with both CCL [7.24±4.9] and PCL [7.80±4.42] and it was not statistically significant [p=0.39] (Table 1)

The median difference in vernier acuity with CCL between indoor and outdoor was 0.02 and it was not statistically significant [p=0.55]. However, with PCL, the median difference in vernier acuity between indoor and outdoor was 0.155 and it was not statistically significant [p=0.77].

Color Vision

In indoor conditions, the median TES in color vision was better with PCL [35.5±24.5] than CCL [43.5±44.75] and it was not statistically significant [p=0.08]. However, in outdoor conditions, the median TES in color vision was better with PCL [39±19.75] than CCL [56.5±13.75] and it was statistically significant [p=0.006] (Table 1). The median difference in color vision with CCL between indoor and outdoor was -13 and it was not statistically significant [p=0.27]. However, with PCL, the median difference in color vision between indoor and outdoor was -3.5 and it was not statistically significant [p=0.50].

Visual Functions	Indoor Conditions		P Value	Outdoor Conditions		P Value
	CCL	PCL		CCL	PCL	
HCVA (logMAR)	-0.11±0.14	-0.14±0.08	0.15	-0.12±0.07	-0.15±0.03	0.5
LCVA (logMAR)	0.36±0.10	0.28±0.14	0.01	0.51±0.12	0.48±0.19	0.41
Vernier acuity (Arcseconds)	7.26±6.14	7.96±6.23	0.37	7.24±4.9	7.80±4.42	0.39
Color vision (TES)	43.5±44.75	35.5±24.5	0.08	56.5±13.75	39±19.75	0.006

CCL: Clear Contact Lens; PCL: Photochromic Contact Lens; HCVA: High Contrast Visual Acuity; LCVA: Low Contrast Visual Acuity; TES: Total Error Score.

Table 1: Shows the visual functions in both indoor and outdoor conditions with CCL &PCL.

Contrast Sensitivity

The contrast sensitivity percentage of different spatial frequencies of 1,3,9,12,15 and 18 were measured in both indoor and outdoor conditions with PCL and CCL. As shown in the line graph, the spatial frequencies of 12 [0.83%], 15 [1.32%], and 18 [2.5%] cpd were improved with PCL than the CCL of 12 [1.18%], 15 [1.77%] and 18 [3.5%] in indoor conditions (Figure 3A). However, in outdoor conditions (Figure 3B), the spatial frequencies of 9 [1.04%], 12 [1.47%], 15 [2.19%], and 18 [3.77%] cpd were `improved with PCL than the CCL of 9 [1.2%], 12 [1.9%], 15 [2.71%] and 18 [4.12%]. Among the different spatial frequencies, the 18 cpd in CCL [p= 0.02] and 12 cpd [p=0.05] in PCL between indoor and outdoor conditions were statistically significant.

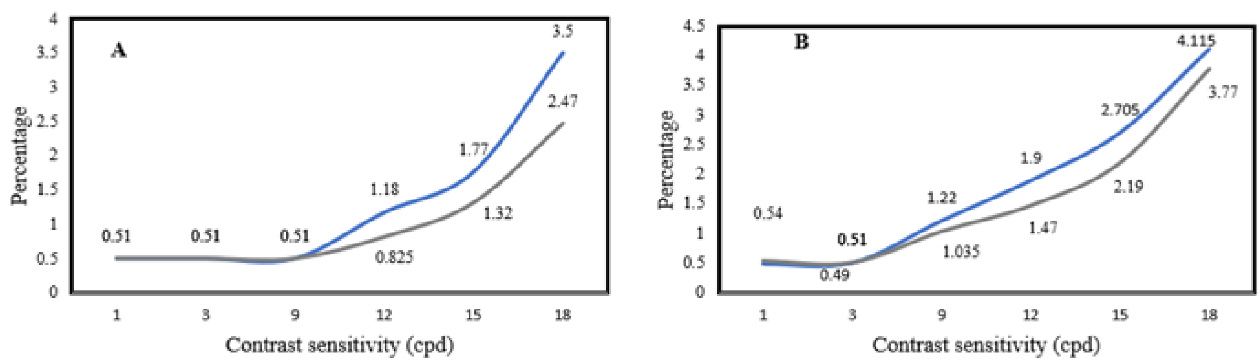

Figure 3: Line graph of PCL (Grey line) and CCL (Blue line) shows the improvement of spatial frequencies of (A) indoor and (B) outdoor conditions.

The area under a curve, the contrast sensitivity function [CSF] is an index of visual performance or sensitivity. The higher the areal measure, the better the visual performance. The area under the curve Figure 4 shows that the contrast sensitivity was higher in PCL [20.13] than in CCL [17.71] in indoor conditions. However, in outdoor conditions, the area under the curve was higher in PCL [203.8] than in CCL [68.52].

Subjective Comfort

The median baseline [CCL] values of the glare discomfort, glare disability, and comfort level were 1 ± 1.02, 1.4 ± 0.59, and 0.25 ± 0.85 in indoor conditions. The glare discomfort was not better with PCL [0.7 ± 0.97] and it was not statistically significant [p=0.17] whereas glare disability was similar with PCL [1.4±0.68] and it was not statistically significant [p=1.00] and comfort level was not better with PCL [0.25 ± 0.85] and it was not statistically significant [p=0.27] (Figure 5A). In outdoor conditions, the median values of the baseline measurement of glare discomfort, glare disability, and comfort level were -0.05 ± 0.68, 1.95 ± 0.88, and -0.25± 1.37. The glare discomfort was reduced with PCL [0.9 ± 0.96] and it was statistically significant [p=0.002] and glare disability was improved with PCL [1.4 ± 0.50] and it was also statistically significant [p=0.01] and comfort level was improved with PCL [0.95 ± 1.3] and statistically significant [p= 0.007] (Figure 5B).

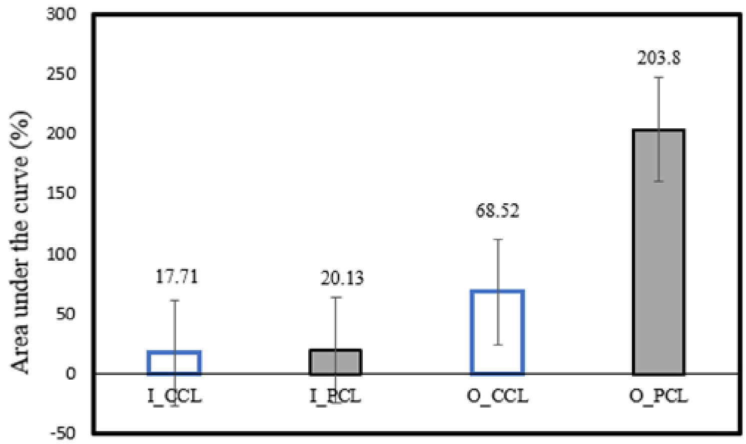

Figure 4: Shows the area under the curve of CCL (Blue Bar) and PCL (Grey Bar).

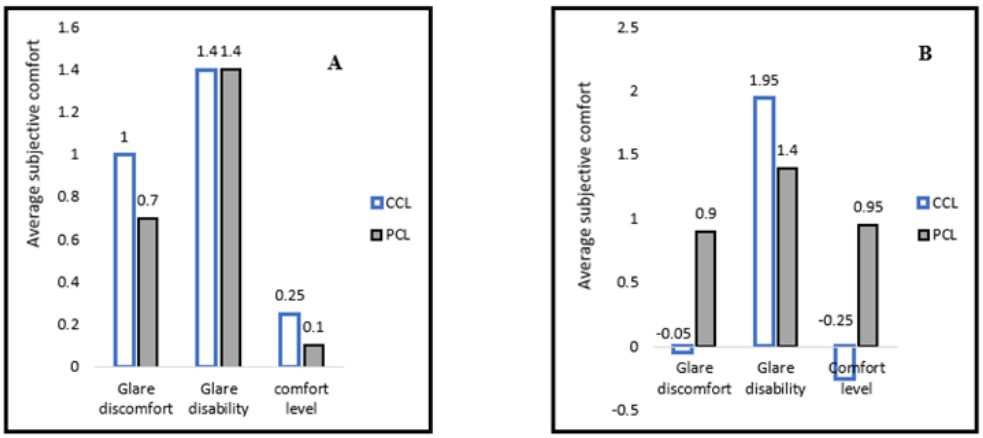

Figure 5: Shows the subjective comfort with CCL (Blue Bar) and PCL (Grey Bar) in indoor [A] and outdoor [B] conditions.

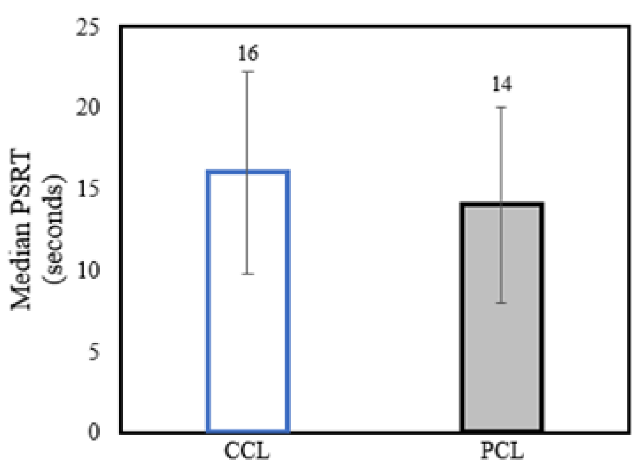

Figure 6: Shows the photo stress recovery time of CCL (Blue Bar) and PCL (Grey Bar).

PSRT

The baseline [CCL] median value of photo stress recovery time in seconds was 16 ± 6.25. However, the photo stress recovery time [14 ± 6.25] was improved with PCL and it was not statistically significant [p=0.089] (Figure 6).

Discussion

Ultraviolet radiation (UVR), due to its higher energy content compared to visible or infrared light, poses a significant risk to eye health. Photochromic contact lenses (PCL) have been developed to safeguard the eyes against UVR and blue light emitted by various technologies. These lenses contain light-sensitive additives that darken progressively under sunlight and return to a clear state when UVR exposure ceases. In this prospective, experimental, and comparative study, visual functions were evaluated using photochromic and non-photochromic contact lenses under controlled indoor and outdoor lighting conditions [11]. Illumination levels were standardized between 250–300 lux for indoor settings and 5,000–10,000 lux for outdoor settings to ensure activation of the photochromic contact lenses. There is a scarcity of literature on detailed visual function assessments in the Indian population across indoor and outdoor settings. Our study aimed to investigate the visual functions among Indian populations in both indoor and outdoor environments. Kamiya K, et al. [6] and Buch J, et al. [8] reported improved visual acuity with PCL under indoor conditions, similar to our study, but with variations in lighting conditions and macular pigmentation among participants. This suggests that PCL may also enhance visual acuity in the Indian population. Renzi H, et al. [11] demonstrated a statistically significant enhancement in photo stress recovery time with PCL. While we also observed an improvement, it was not statistically significant, likely due to methodological differences: they used xenon white flash exposure, whereas we utilized a direct ophthalmoscope to flash the eye. Under outdoor conditions, glare discomfort was significantly reduced with PCL, consistent with our statistically significant findings. Similarly, studies by Renzi H, et al. [11] and Renzi-Hammond L, et al. [12] demonstrated a statistically significant improvement in glare disability with photochromic contact lenses, which aligns with our results showing better glare disability in PCL. In our study, we also found that Color vision showed improvement with photochromic contact lenses, similar to the findings reported by Renzi H, et al. [11] and Renzi-Hammond L, et al. [12,13] in both indoor and outdoor conditions. However, in indoor conditions, the improvement was not statistically significant in their studies, as they used a green-yellow grating superimposed on blue, whereas we utilized the digital FM 100 test. Vernier acuity measures the eye's ability to detect small misalignments between two lines, making it a form of hyperacuity. It is much more precise than standard visual acuity, relying on the brain's spatial processing rather than retinal resolution. We also evaluated vernier acuity and found no difference between PCL and CCL. However, contrast sensitivity was significantly better with PCL compared to CCL [14-16]. This study focused on younger adults who were existing contact lens users and experienced shorter adaptation periods between PCL and CCL. Future research will explore the performance of contact lenses with longer adaptation times and assess their impact on visual functions in broader demographic groups.

Conclusion

A contact lens equipped with innovative light-adaptive photochromic technology addresses an important unmet need. It seamlessly integrates vision correction with a responsive photochromic filter, efficiently controlling light exposure by reducing high-energy visible light and shielding against ultraviolet rays. Our study revealed that PCL enhanced visual functions in indoor and outdoor conditions. Moreover, PCL effectively reduced glare discomfort and improved glare disability in outdoor conditions. These findings indicate that PCL improves visual functions in various environments.

Acknowledgments

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