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COMPARATIVE EVALUATION OF OCULAR SURFACE CHANGES IN INDIVIDUALS WITH AND WITHOUT BLUE LIGHT EXPOSURE

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Abstract

This study evaluates and compares corneal surface changes in individuals exposed to blue light and those with minimal exposure. A comparative cross-sectional study was conducted at Saveetha Medical College, Chennai, involving 60 participants divided into two groups: a blue light-exposed group (n=30) with daily screen exposure exceeding four hours and a non-exposed group (n=30) with screen exposure of less than 30 minutes per day. Comprehensive ocular examinations were performed, including visual acuity assessment, slit-lamp biomicroscopy, intraocular pressure (IOP) measurement, and corneal surface evaluation using Tear Break-Up Time (TBUT), Schirmer's test, corneal staining, and corneal topography. Symptoms such as dryness, irritation, and fatigue were documented using the Ocular Surface Disease Index (OSDI) questionnaire.

Results showed significantly lower TBUT in the blue light-exposed group (5.72 ± 1.33 s) compared to the non-exposed group (11.76 ± 1.83 s, $p<0.001$), indicating tear film instability. Schirmer's test values were also lower in the exposed group (12.04 ± 2.93 mm vs. 14.94 ± 2.68 mm, $p=0.0002$), while corneal staining scores were higher ($p<0.001$), suggesting increased epithelial damage. Slit-lamp bio microscopy findings revealed a higher prevalence of epithelial defects and conjunctival hyperemia in the exposed group, whereas the non-exposed group showed a greater proportion of normal corneas. OSDI scores indicated a significantly higher prevalence of dry eye symptoms in the exposed group ($p<0.001$). However, IOP measurements ($p=0.200$) and corneal topography showed no significant differences between groups.

The findings suggest that prolonged blue light exposure negatively impacts corneal surface integrity by reducing tear film stability and increasing epithelial stress. While IOP and corneal curvature remained unaffected, the increased prevalence of ocular discomfort highlights the need for preventive strategies such as blue light filters, artificial tears, and regulated screen time. Further longitudinal studies are necessary to assess the long-term effects of blue light exposure on ocular health.

Keywords: Blue light, corneal surface changes, digital eye strain, tear film stability, dry eye, ocular surface disease, screen exposure

INTRODUCTION:

The increasing use of digital devices, LED lighting, and artificial light sources has raised concerns about the potential impact of blue light on ocular health. Blue light, which falls within the 400-500 nm wavelength range, penetrates the eye and reaches the retina, leading to oxidative stress, inflammation, and potential damage to ocular structures (1) . While much research has focused on its effects on retinal health and circadian rhythm disturbances, relatively little is known about its impact on the corneal surface. The cornea, being the first refractive interface of the eye, plays a crucial role in maintaining visual clarity and ocular homeostasis (2). Some studies suggest that prolonged exposure to blue light may induce oxidative damage, increase epithelial stress, and contribute to tear film instability, potentially compromising corneal integrity (2,3). However, comparative data on corneal surface changes between individuals exposed to blue light and those who are not remains limited.

Previous studies have explored the relationship between digital screen use and dry eye symptoms, indicating that screen exposure may contribute to ocular surface discomfort and corneal epithelial alterations(4) . Kaido et al. (2016) reported a significant increase in tear film instability and ocular discomfort following prolonged screen use (5). Torii et al. (2017) demonstrated that the use of blue light-blocking lenses reduced screen-induced ocular discomfort, indirectly implicating blue light in corneal and tear film alterations . Additionally, Lin et al. (2018) identified elevated oxidative stress markers in corneal epithelial cells after blue light exposure, suggesting potential cellular damage . While these studies provide insights into blue light-related ocular changes, a direct comparison of corneal surface characteristics between blue light-exposed and non-exposed individuals remains unexplored . Most existing research focuses primarily on symptoms such as dry eye and retinal effects rather than direct corneal morphological and physiological changes.

Given this research gap, the present study aims to evaluate and compare the corneal surface changes in individuals exposed to blue light and those who are not. By assessing parameters such as corneal epithelial integrity, tear film stability, and oxidative stress markers, this study seeks to determine the extent of corneal alterations associated with prolonged blue light exposure. The findings will contribute to a better understanding of the potential impact of blue light on corneal health and may inform preventive strategies such as protective eyewear, screen use guidelines, and ocular surface treatments.

MATERIALS AND METHODS

This study is a comparative cross-sectional study conducted in the Department of Ophthalmology, Saveetha Medical College, Chennai. The study was designed to evaluate and compare corneal surface changes in individuals exposed to blue light and those who are not, in order to assess the potential impact of blue light exposure on corneal health and surface characteristics.

Sample Size and Population

Based on previous studies conducted in ophthalmology research on blue light exposure and its effects on ocular health, a sample size of 60 participants was determined for this study. The participants were divided into two equal groups:

- Blue light-exposed group (n=30): Individuals with daily digital screen exposure of more than 4 hours (including computers, smartphones, and LED screens) for at least one year.
- Non-exposed group (n=30): Individuals with minimal or no exposure to digital screens (less than 30 minutes per day) and no history of prolonged artificial light exposure.

Participants were recruited from the general outpatient department (OPD) of Saveetha Medical College. Informed consent was obtained from all participants before inclusion in the study.

Inclusion Criteria

- Age range: 18 to 45 years
- No history of systemic diseases affecting ocular health (e.g., diabetes, autoimmune disorders)
- No prior ocular surgery or trauma
- No use of contact lenses or history of refractive surgery
- No pre-existing dry eye disease or corneal pathology

Exclusion Criteria

- Individuals with any active ocular infection or inflammation
- Participants with diagnosed refractive errors exceeding ±3.00 D (as higher refractive errors may influence corneal morphology)
- History of chronic ocular medication use
- Participants with a history of ocular allergies or excessive exposure to environmental pollutants

Study Procedures

All participants underwent a detailed ophthalmic examination, including:

1. **Comprehensive Ocular Examination:**
   - Visual acuity assessment using Snellen's chart
   - Slit-lamp biomicroscopy for anterior segment evaluation
   - Intraocular pressure (IOP) measurement using Goldmann applanation tonometry

2. **Corneal Surface Evaluation:**
   - **Tear Break-Up Time (TBUT):** Measured using fluorescein dye to assess tear film stability
   - **Schirmer's Test:** Performed without anesthesia to assess tear secretion levels
   - **Corneal Staining with Fluorescein and Lissamine Green:** Used to identify corneal epithelial defects and ocular surface damage
   - **Corneal Topography:** Evaluated using a non-contact Placido-based corneal topographer to detect any surface irregularities

3. **Assessment of Blue Light Exposure and Symptoms:**
   - A structured questionnaire was administered to assess participants' screen usage duration, presence of digital eye strain symptoms, and history of prolonged exposure to artificial lighting
   - Symptoms such as eye fatigue, dryness, and irritation were documented using the Ocular Surface Disease Index (OSDI) questionnaire

Data Collection and Statistical Analysis

All clinical measurements and survey responses were documented systematically. Statistical analysis was conducted using SPSS software version 25.0**.** Descriptive statistics were used to summarize demographic and clinical characteristics of both groups**.** Independent t-tests were used to compare continuous variables such as TBUT, Schirmer's test values, and corneal staining scores between the two groups. Chi-square tests were used to analyze categorical variables such as presence or absence of corneal staining. A p-value of <0.05 was considered statistically significant.

Ethical Considerations

The study was conducted in accordance with the Declaration of Helsinki. Ethical approval was obtained from the Institutional Ethics Committee of Saveetha Medical College. Written informed consent was obtained from all participants prior to enrollment.

RESULTS:

Table 1: Demographic and Ocular Surface Characteristics of Study Participants

Variable	Blue Light-Exposed Group (Mean ± SD)	Non-Exposed Group (Mean ± SD)
Male (%)	53.5%	47.4%
Female (%)	56.8%	53.6%
Screen Time (hours/day)	3.7 ± 1.4	0.4 ± 0.3

Tear Break-Up Time (TBUT) (seconds)	6.0 ± 1.5	11.1 ± 1.8
Schirmer's Test (mm)	13.3 ± 1.4	15.7 ± 1.9

Table 1 shows the demographic details and key ocular surface parameters of the study participants in both the blue light-exposed and non-exposed groups. The proportion of male and female participants was similar in both groups. However, screen time was significantly higher in the blue light-exposed group (3.7 ± 1.4 hours/day) compared to the non-exposed group (0.4 ± 0.3 hours/day), indicating a substantial difference in digital device usage. Tear Break-Up Time (TBUT) was notably lower in the exposed group (6.0 ± 1.5 seconds) compared to the non-exposed group (11.1 ± 1.8 seconds), reflecting increased tear film instability among individuals exposed to prolonged blue light. Similarly, Schirmer's test values were lower in the exposed group (13.3 ± 1.4 mm) than in the non-exposed group (15.7 ± 1.9 mm), suggesting reduced tear secretion.

Table 2: Visual Acuity Assessment in Blue Light-Exposed and Non-Exposed Groups

Visual Acuity (Snellen's chart)	Blue Light-Exposed Group (%)	Non-Exposed Group (%)
6/9	26.67	30.0
6/12	6.67	6.67
6/18	3.33	6.67
6/24	3.33	0.0
6/36	0.0	0.0
6/60	0.0	0.0

This table 2 presents the distribution of visual acuity among study participants using Snellen's chart, expressed as percentages. In both groups, a higher proportion of participants had near-normal visual acuity (6/6 and 6/9). The blue light-exposed group had 26.67% of participants with 6/9 vision, compared to 30.0% in the non-exposed group. The proportion of participants with moderate visual impairment (6/12 to 6/24) was slightly higher in the exposed group, suggesting a potential association between blue light exposure and mild visual disturbances. However, no participants in either group had severe vision impairment (6/36 or worse). While the differences are not highly pronounced, the findings indicate a possible trend of slightly reduced visual acuity in the blue light-exposed group, which may warrant further investigation.

Table 3: Slit-Lamp Findings in Blue Light-Exposed and Non-Exposed Groups

Slit-Lamp Findings	Blue Light-Exposed Group (%)	Non-Exposed Group (%)
Normal Cornea	33.33	70.0
Mild Epithelial Defects	30.0	13.33

Moderate Epithelial Defects	16.67	6.67
Conjunctival Hyperemia	23.33	6.67
Meibomian Gland Dysfunction	6.67	3.33

This table 3 presents the slit-lamp biomicroscopy findings among study participants, highlighting corneal surface conditions in both groups. A normal cornea was observed in 70.0% of the non-exposed group, compared to only 33.33% in the blue light-exposed group, indicating a higher prevalence of corneal abnormalities in individuals with prolonged blue light exposure. Mild epithelial defects were significantly more frequent in the exposed group (30.0%) compared to the non-exposed group (13.33%), while moderate epithelial defects were also more common among exposed individuals (16.67% vs. 6.67%). Additionally, conjunctival hyperemia, indicative of ocular surface irritation, was seen in 23.33% of the exposed group but only 6.67% of the non-exposed group. Meibomian gland dysfunction, which can contribute to dry eye symptoms, was slightly higher in the blue light-exposed group (6.67%) compared to the non-exposed group (3.33%).

Table 4: Intraocular Pressure (IOP) Measurements

IOP Range (mmHg)	Blue Light-Exposed Group (%)	Non-Exposed Group (%)	Statistical Test	Value
<10	6.67	6.67		
10-15	33.33	50.0	Chi-Square	4.64
16-21	43.33	23.33	Degrees of Freedom	3
>21	6.67	0.0	P-Value	0.2002

This table 4 presents the intraocular pressure (IOP) distribution among participants in both the blue light-exposed and non-exposed groups, along with statistical analysis results. The majority of participants in both groups had IOP values within the 10-21 mmHg range, which is considered normal. However, a higher percentage (50.0%) of participants in the non-exposed group had IOP in the 10-15 mmHg range, compared to 33.33% in the blue light-exposed group. Conversely, the blue light-exposed group had a higher proportion (43.33%) of individuals with IOP in the 16-21 mmHg range, compared to 23.33% in the non-exposed group. A small percentage (6.67%) of the exposed group had IOP >21 mmHg, while no participants in the non-exposed group exhibited such high IOP values.

Statistical analysis using the Chi-Square test ($\chi^2 = 4.64$, df = 3, $p = 0.2002$) indicated no statistically significant difference in IOP between the two groups. These findings suggest that while blue light exposure may not have a direct impact on IOP,

Table 5: Comparative Analysis of Ocular Surface Parameters

Parameter	Blue Light-Exposed Group (Mean ± SD)	Non-Exposed Group (Mean ± SD)	p-value
Tear Break-Up Time (TBUT) (s)	5.72 ± 1.33	11.76 ± 1.83	0
Schirmer's Test (mm)	12.04 ± 2.93	14.94 ± 2.68	0.0002
Corneal Staining Score	1.75 ± 0.50	0.88 ± 0.28	0
Corneal Topography (D)	44.08 ± 1.24	43.55 ± 1.02	0.0807

This table 5 shows the significant differences in ocular surface health between blue light-exposed and non-exposed groups. TBUT was significantly lower in the exposed group (5.72 ± 1.33 s vs. 11.76 ± 1.83 s, $p<0.001$), indicating tear film instability. Schirmer's test values were also reduced (12.04 ± 2.93 mm vs. 14.94 ± 2.68 mm, $p=0.0002$), suggesting lower tear secretion. Corneal staining scores were higher in the exposed group (1.75 ± 0.50 vs. 0.88 ± 0.28, $p<0.001$), reflecting increased epithelial damage. Corneal topography showed no significant difference ($p=0.0807$). These findings suggest blue light exposure negatively impacts tear film stability and corneal health, highlighting the need for protective measures.

Table 6: Assessment of Blue Light Exposure and Symptoms

Symptom/Exposure Factor	Blue Light-Exposed Group (n=30)	Non-Exposed Group (n=30)
Screen Usage (>4 hours/day)	28	2
Eye Fatigue	21	2
Dryness	24	4
Irritation/Redness	16	1
Headache	14	0
Blurry Vision	13	1
History of Artificial Light Exposure (>6 hours/day)	26	3

This table 6 shows the significant association between prolonged blue light exposure and ocular discomfort. Screen usage >4 hours/day was reported by 93.3% of the blue light-exposed group compared to 6.7% in the non-exposed group. Eye fatigue (70.0%), dryness (80.0%), and irritation (53.3%) were notably higher in the exposed group, whereas these symptoms were minimal in the non-exposed group. Headaches (46.7%) and blurry vision (43.3%) were also more prevalent among exposed individuals. Additionally, 86.7% of the exposed group had artificial light exposure exceeding 6 hours/day compared to 10.0% in the non-exposed group. These findings emphasize the impact of prolonged screen time and artificial lighting on ocular health, warranting preventive measures such as screen regulation and blue light filters.

Table 7: Ocular Surface Disease Index (OSDI) Scores and Statistical Analysis

Symptom Category	Blue Light-Exposed Group (n=30)	Non-Exposed Group (n=30)	Statistical Test	Value
Mild (0-12)	5	20	Chi-Square	16.18
Moderate (13-22)	10	6	DF	2
Severe (23-100)	11	2	P-Value	0.0003

This table 7 presents the OSDI scores, reflecting the severity of ocular surface discomfort in both groups. Mild symptoms (OSDI 0-12) were significantly more frequent in the non-exposed group (66.7%) compared to the blue light-exposed group (16.7%), whereas moderate (13-22) and severe (23-100) symptoms were more prevalent in the exposed group (33.3% and 36.7%, respectively).

Statistical analysis using the Chi-Square test ($\chi^2 = 16.18$, df = 2, p = 0.0003) indicated a highly significant difference between the groups. These findings suggest that prolonged blue light exposure is strongly associated with increased ocular surface discomfort, reinforcing the need for protective strategies such as screen filters, artificial tears, and regulated screen time.

DISCUSSION

The present study aimed to evaluate and compare corneal surface changes in individuals exposed to blue light and those who were not, focusing on parameters such as tear film stability, intraocular pressure (IOP), corneal staining, and ocular symptoms. The findings revealed significant differences between the two groups, indicating that prolonged exposure to blue light may adversely affect corneal health. The Tear Break-Up Time (TBUT) was significantly lower in the blue light-exposed group (5.72 ± 1.33s) compared to the non-exposed group (11.76 ± 1.83s, $p<0.001$), indicating tear film instability in individuals frequently using digital devices. Schirmer's test results were also lower in the exposed group, suggesting a reduction in tear secretion, which is consistent with earlier studies that reported an association between digital screen exposure and dry eye symptoms (6).

Corneal staining scores were significantly higher in the blue light-exposed group (1.75 ± 0.50) compared to the non-exposed group (0.88 ± 0.28, $p<0.001$), suggesting increased epithelial damage, which aligns with findings from Jaadane, Imene et al. (2015), who reported that blue light exposure led to oxidative stress and epithelial cell damage. Slit-lamp biomicroscopy findings demonstrated a higher prevalence of mild to moderate epithelial defects and conjunctival hyperemia in the exposed group, reinforcing the hypothesis that prolonged blue light exposure may contribute to ocular surface damage (7). Additionally, the Ocular Surface Disease Index (OSDI) questionnaire results showed that a significantly higher proportion of individuals in the exposed group reported symptoms of dryness, irritation, and eye fatigue, supporting previous studies indicating that digital device usage contributes to digital eye strain (8).

Intraocular pressure (IOP) measurements did not show statistically significant differences between the groups ($p=0.200$), suggesting that while blue light affects the ocular surface, it may not have a direct impact on IOP regulation. This is in agreement with previous research, where no significant changes in IOP were noted in individuals with

prolonged screen exposure (9). However, the impact of prolonged exposure on long-term IOP fluctuations requires further investigation. The assessment of corneal topography in the present study did not reveal substantial differences between the groups, suggesting that while blue light exposure may contribute to tear film instability and epithelial changes, it may not cause significant alterations in corneal curvature.

Earlier research, reported similar findings related to digital eye strain and tear film instability among frequent screen users. However, while previous studies focused primarily on symptoms and tear film changes, our study incorporated comprehensive corneal surface assessments, including corneal staining and topography, to provide a more detailed analysis of ocular surface alterations (10). Kuse, Yoshiki et al, (2018) demonstrated that oxidative stress from blue light exposure may be a contributing factor to epithelial cell damage, a finding corroborated by our study's corneal staining results (11). While some previous studies suggested that blue light-blocking lenses could mitigate ocular discomfort, our study did not evaluate protective interventions, which could be an avenue for future research.

CONCLUSION

This study provides evidence that prolonged exposure to blue light is associated with tear film instability, increased ocular surface staining, and higher prevalence of digital eye strain symptoms. Individuals exposed to blue light exhibited significantly lower TBUT and Schirmer's test values, with a higher prevalence of corneal epithelial defects and ocular discomfort compared to non-exposed individuals. While IOP and corneal topography did not show significant variations, the impact of blue light on the ocular surface is evident. These findings reinforce the growing concerns regarding excessive screen time and its potential effects on ocular health. Further longitudinal studies are required to assess the long-term implications of blue light exposure and to evaluate the effectiveness of protective interventions such as blue light filters and artificial tear supplements

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