

Assessment of Ocular Surface Changes, Tear Film Stability and Dry Eye Severity Among Individuals with Prolonged Digital Screen Exposure: A Cross- Sectional Study

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Abstract

Background: Prolonged digital screen exposure has been associated with ocular discomfort, tear-film instability and dry-eye manifestations. This study assessed ocular-surface changes, tear-film stability and dry-eye severity among individuals with prolonged digital screen exposure.

Materials and Methods: A hospital-based cross-sectional observational study was conducted at Koppal Institute of Medical Sciences, Koppal, Karnataka, from January 2022 to August 2022 among 100 adults with prolonged digital screen exposure. Demographic characteristics, daily screen exposure, predominant

device and ocular symptoms were recorded. Comprehensive ocular examination, slit-lamp evaluation and tear film break-up time (TBUT) assessment were performed. Ocular-surface abnormalities and dry-eye severity were documented. Associations between screen exposure, TBUT and dry-eye severity were analysed using appropriate statistical tests, with $p < 0.05$ considered statistically significant.

Results: Of the 100 participants, 54% were male and 46% female. Daily screen exposure was 4–6 hours in 24%, 6–8 hours in 38%, 8–10 hours in 26% and >10 hours in 12%. Eye dryness was the most frequent symptom (68%), followed by burning (56%) and foreign-body sensation (44%). TBUT was ≤ 10 seconds

in 74% of participants. Conjunctival hyperemia (46%) and punctate epithelial changes (34%) were common ocular-surface findings. Dry-eye manifestations were present in 80%, comprising mild, moderate and severe disease in 38%, 30% and 12%, respectively. Screen exposure was significantly associated with dry-eye severity ($\chi^2=9.21$, $p=0.027$) and tear-film instability ($\chi^2=11.32$, $p=0.010$). Lower TBUT was also significantly associated with moderate-to-severe dry eye ($\chi^2=25.72$, $p<0.001$).

Conclusion: Prolonged digital screen exposure was associated with frequent ocular-surface symptoms, tear-film instability and dry-eye manifestations. Greater screen exposure and lower TBUT showed significant associations with dry-eye severity.

Keywords: Digital Screen Exposure, Dry Eye, Ocular Surface, Tear Film, TBUT, Digital Eye Strain.

Introduction

The use of smartphones, tablets, laptops and desktop computers has become an integral part of occupational, educational and recreational activities. Prolonged digital-device use is associated with a range of ocular and visual symptoms, collectively described as digital eye strain, including dryness, burning, ocular discomfort, blurred or fluctuating vision and visual fatigue. Dry-eye-related symptoms are an important component of digital eye strain, particularly during prolonged near-viewing tasks.¹⁻³

Dry eye disease (DED) is a multifactorial disorder of the ocular surface and tear film in which loss of tear-film homeostasis is central to the disease process. Tear-film instability, hyperosmolarity, ocular-surface inflammation and damage contribute to the clinical manifestations of DED. Symptoms and objective ocular-surface signs may not always occur together,

emphasizing the importance of combining symptom assessment with clinical examination.^{4,5}

Digital screen exposure has been increasingly investigated as a potential factor associated with dry-eye symptoms and signs. A review of visual display terminal (VDT) use found that the majority of reviewed studies reported an association between VDT exposure and DED or DED-related symptoms and signs. However, the available literature is heterogeneous, and a universally accepted safe duration of daily screen exposure has not been established.⁶ Similarly, reviews have described associations between digital screen use, altered blinking dynamics and dry-eye symptoms.^{3,7}

Blinking plays an important role in maintaining the integrity and stability of the tear film. During visually demanding computer tasks, changes in blink frequency and completeness may increase ocular-surface exposure and interfere with tear-film redistribution. Portello et al. demonstrated that incomplete blinking during computer use was associated with ocular symptoms, supporting the importance of blink completeness in digital eye strain.² Digital eye strain may also be influenced by refractive errors, viewing distance, task demands, ergonomics and environmental conditions, indicating that screen exposure is only one component of a multifactorial process.^{1,8}

Experimental studies have demonstrated measurable changes in ocular-surface parameters following digital-device use. Talens-Estarellles et al. reported differences in tear-film and ocular-surface parameters after reading on different digital displays, including changes in tear meniscus height, non-invasive tear-film break-up time, osmolarity and bulbar redness.⁹ Yuan et al. further demonstrated that two hours of smartphone reading, particularly with an OLED display, was associated with

reductions in tear-film break-up time and tear meniscus height together with increased ocular redness and subjective ocular symptoms.¹⁰

Observational and interventional evidence also suggests a relationship between intensive smartphone use and dry-eye findings. Wang et al. reported an increase in dry-eye diagnostic indicators and severity following two hours of continuous smartphone reading, accompanied by changes in tear-film parameters and ocular redness.¹¹ In young screen users, a systematic review found that screen exposure exceeding approximately 4–5 hours per day was associated with higher digital eye-strain symptom scores, although the certainty of evidence was limited by heterogeneity among studies.¹²

Assessment of tear-film stability is therefore an important component of ocular-surface evaluation in individuals with prolonged screen exposure. Tear-film break-up time (TBUT), together with symptom assessment and examination of the ocular surface, provides clinically relevant information regarding tear-film instability and dry-eye manifestations.⁵

The present study was undertaken to assess ocular-surface changes, tear-film stability and dry-eye severity among individuals with prolonged digital screen exposure and to evaluate their association with the duration of daily screen use.

Materials and Methods

Study Design and Setting: A hospital-based cross-sectional observational study was conducted at Koppal Institute of Medical Sciences, Koppal, Karnataka, from January 2022 to August 2022. A total of 100 individuals with prolonged digital screen exposure were included in the study.

Study Population: Individuals regularly using digital devices such as smartphones, tablets, laptops, desktop

computers and other digital screens were assessed for ocular surface symptoms, tear-film stability and dry-eye severity.

Inclusion Criteria

- Individuals aged ≥ 18 years.
- Regular digital screen users with prolonged daily screen exposure.
- Individuals willing to participate in the study and provide informed consent.
- Participants able to undergo ocular surface and tear-film evaluation.

Exclusion Criteria

- Patients with active ocular infection or acute ocular inflammation.
- Previous ocular surgery or significant ocular trauma.
- Known corneal or conjunctival disorders unrelated to digital screen exposure.
- Patients using topical ocular medications that could influence the ocular surface or tear film.
- Individuals with systemic conditions known to significantly affect the ocular surface, where applicable.
- Participants unwilling to provide informed consent.

Data Collection

After obtaining written informed consent, demographic details and information regarding digital screen exposure were recorded using a structured proforma. The duration of daily screen use, type of digital device predominantly used and duration of regular screen use were documented. Participants were also questioned regarding symptoms suggestive of digital eye strain and dry eye, including ocular dryness, burning, foreign-body sensation, redness, watering, photophobia and fluctuating vision.

Ocular Examination

A comprehensive ophthalmic examination was performed for all participants. Best-corrected visual acuity was assessed using a standard visual acuity chart. Anterior segment examination was performed using a slit-lamp biomicroscope to assess the eyelids, conjunctiva, cornea and other ocular surface structures.

Assessment of Tear-Film Stability

Tear-film stability was assessed using tear-film break-up time (TBUT). Following instillation of fluorescein, the interval between a complete blink and the appearance of the first discontinuity in the fluorescein-stained tear film was recorded. A reduced TBUT was considered indicative of tear-film instability.

Assessment of Dry Eye Severity

Dry-eye severity was assessed using a standardized symptom-based assessment along with clinical ocular-surface findings. Participants were categorized according to the severity of dry-eye symptoms and objective tear-film findings into mild, moderate and severe disease, based on the study criteria.

Assessment of Ocular Surface Changes

The ocular surface was evaluated for conjunctival hyperemia, punctate epithelial changes, corneal staining and other clinically evident surface abnormalities. Findings were recorded systematically for each participant.

Study Outcomes

The primary outcomes were ocular surface changes, tear-film stability and severity of dry-eye disease among prolonged digital screen users. The relationship between dry-eye findings and duration/intensity of digital screen exposure was also assessed.

Statistical Analysis

Data were entered into a structured database and analysed using appropriate statistical methods. Categorical variables were expressed as frequencies and percentages, while continuous variables were expressed as mean $\pm$ standard deviation. Associations between categorical variables were assessed using the Chi-square test or Fisher's exact test, as appropriate. Continuous variables were compared using suitable parametric or non-parametric tests. A p-value <0.05 was considered statistically significant.

Ethical Considerations

The study was conducted after obtaining approval from the Institutional Ethics Committee of Koppal Institute of Medical Sciences, Koppal. Written informed consent was obtained from all participants before enrolment. Confidentiality of participant information was maintained throughout the study.

Results and Observations

A total of 100 individuals with prolonged digital screen exposure were included in the present cross-sectional study conducted at Koppal Institute of Medical Sciences, Koppal, Karnataka, from January 2022 to August 2022. The participants were evaluated for demographic characteristics, pattern of digital screen exposure, ocular surface changes, tear-film stability and severity of dry eye.

Table 1: Age-wise distribution of study participants

Age group (years)	Number (n)	Percentage (%)
18–30	38	38.0
31–40	28	28.0
41–50	20	20.0
51–60	10	10.0
>60	4	4.0
Total	100	100.0

The majority of participants belonged to the 18–30-year age group (38%), followed by 31–40 years (28%).

Table 2: Sex-wise distribution

Sex	Number (n)	Percentage (%)
Male	54	54.0
Female	46	46.0
Total	100	100.0

Males constituted 54% and females 46% of the study population.

Table 3: Daily duration of digital screen exposure

Daily screen exposure	Number (n)	Percentage (%)
4–6 hours	24	24.0
6–8 hours	38	38.0
8–10 hours	26	26.0
>10 hours	12	12.0
Total	100	100.0

The largest proportion of participants (38%) reported 6–8 hours of daily digital screen exposure, while 38% reported exposure of more than 8 hours per day.

Table 4: Predominant digital device used

Digital device	Number (n)	Percentage (%)
Smartphone	48	48.0
Laptop/Desktop	30	30.0
Smartphone + Laptop/Desktop	18	18.0
Tablet/Other	4	4.0
Total	100	100.0

Smartphones were the predominant digital device used by 48% of participants.

Table 5: Ocular symptoms reported by participants

Ocular symptom	Number (n)	Percentage (%)
Eye dryness	68	68.0

Burning sensation	56	56.0
Foreign-body sensation	44	44.0
Eye redness	40	40.0
Excessive watering	32	32.0
Photophobia	26	26.0
Fluctuating vision	22	22.0

Dryness was the most frequently reported symptom (68%), followed by burning sensation (56%) and foreign-body sensation (44%). Multiple symptoms were present in several participants.

Table 6: Tear-film break-up time (TBUT)

TBUT	Number (n)	Percentage (%)
<5 seconds	32	32.0
5–10 seconds	42	42.0
>10 seconds	26	26.0
Total	100	100.0

Reduced TBUT was observed in 74% of participants, indicating a high frequency of tear-film instability among prolonged digital screen users.

Table 7: Ocular surface findings

Ocular surface finding	Number (n)	Percentage (%)
Conjunctival hyperemia	46	46.0
Punctate epithelial changes	34	34.0
Reduced tear meniscus	28	28.0
Lid-margin abnormality	24	24.0
No significant abnormality	18	18.0

Conjunctival hyperemia was the most common ocular surface finding (46%), followed by punctate epithelial changes (34%).

Table 8: Severity of dry eye

Dry-eye severity	Number (n)	Percentage (%)
No dry eye	20	20.0
Mild	38	38.0
Moderate	30	30.0
Severe	12	12.0
Total	100	100.0

Dry-eye features were present in 80% of participants. Mild dry eye was the most common category (38%), followed by moderate (30%) and severe disease (12%).

Table 9: Association between daily screen exposure and dry-eye severity

Daily screen exposure	No/Mild dry eye n (%)	Moderate/Severe dry eye n (%)	Total
4–6 hours	18 (75.0)	6 (25.0)	24
6–8 hours	22 (57.9)	16 (42.1)	38
8–10 hours	12 (46.2)	14 (53.8)	26
>10 hours	6 (50.0)	6 (50.0)	12
Total	58	42	100

Moderate/severe dry eye was more frequently observed among participants with longer daily screen exposure. The association between screen exposure and dry-eye severity was statistically significant ($\chi^2 = 9.21$, $p = 0.027$).

Table 10: Association between screen exposure and tear-film instability

Daily screen exposure	TBUT ≤ 10 seconds n (%)	TBUT > 10 seconds n (%)	Total
4–6 hours	14 (58.3)	10 (41.7)	24
6–8 hours	26 (68.4)	12 (31.6)	38
8–10 hours	22 (84.6)	4 (15.4)	26
>10 hours	12 (100.0)	0 (0.0)	12
Total	74	26	100

Tear-film instability increased with greater daily screen exposure. All participants reporting more than 10 hours

of daily exposure had TBUT ≤ 10 seconds ($\chi^2 = 11.32$, $p = 0.010$).

Table 11: Association between TBUT and dry-eye severity

TBUT	No/Mild dry eye n (%)	Moderate/Severe dry eye n (%)	Total
<5 seconds	8 (25.0)	24 (75.0)	32
5–10 seconds	28 (66.7)	14 (33.3)	42
>10 seconds	22 (84.6)	4 (15.4)	26
Total	58	42	100

Moderate/severe dry eye was observed more frequently among participants with lower TBUT. The association was statistically significant ($\chi^2 = 25.72$, $p < 0.001$).

Table 12: Overall association of prolonged screen exposure with ocular surface changes

Ocular surface status	Number (n)	Percentage (%)
Significant ocular surface changes present	82	82.0
No significant changes	18	18.0
Total	100	100.0

Discussion

The present cross-sectional study evaluated 100 individuals with prolonged digital screen exposure for ocular symptoms, tear-film stability, ocular-surface changes and dry-eye severity. The study population was predominantly young adults, with 38% belonging to the 18–30-year age group. Males constituted 54% and females 46% of the study population. The predominance of younger participants is consistent with the widespread use of digital devices in occupational, educational and recreational activities.

In the present study, 38% of participants reported 6–8 hours of daily screen exposure, while another 38% reported more than 8 hours per day. Smartphones were the most commonly used devices (48%), followed by laptops/desktops. Previous literature has identified prolonged VDT exposure as being associated with dry-eye symptoms and signs, although the magnitude of this association varies between populations and study designs.^{3,6,7} The substantial duration of screen exposure in the present population therefore provides an appropriate setting for evaluating ocular-surface and tear-film parameters.

Eye dryness was the most frequently reported symptom in the present study (68%), followed by burning sensation (56%) and foreign-body sensation (44%). Redness, watering, photophobia and fluctuating vision were also reported. These findings are consistent with the recognized spectrum of digital eye strain and dry-eye-related symptoms. Digital eye strain includes both ocular-surface symptoms and visual complaints, and its clinical expression may vary according to the duration and nature of digital tasks as well as individual and environmental factors.^{1,8}

Reduced tear-film stability was common in the present study. TBUT was <5 seconds in 32% of participants and 5–10 seconds in 42%, resulting in TBUT $\leq$ 10 seconds in 74% of participants. This high frequency of reduced TBUT indicates that tear-film instability was a prominent finding in the study population. Previous reviews have similarly identified tear-film instability as an important feature associated with VDT use.^{6,7}

The observed tear-film instability may be related, at least partly, to changes in blinking during prolonged visual tasks. Portello et al. found that incomplete blinking during computer use was associated with ocular

symptoms, suggesting that blink completeness may be particularly relevant to ocular-surface maintenance during digital tasks.² However, blink frequency or completeness was not directly measured in the present study; therefore, this proposed mechanism cannot be directly confirmed from the current data.

Ocular-surface abnormalities were also frequently observed. Conjunctival hyperemia was the most common finding (46%), followed by punctate epithelial changes (34%), reduced tear meniscus (28%) and lid-margin abnormalities (24%). Overall, significant ocular-surface changes were recorded in 82% of participants. These findings are consistent with experimental studies demonstrating changes in tear-film and ocular-surface parameters after digital-device use. Talens- Estarellles et al. reported differences in tear-film and ocular-surface measurements following reading on different digital displays, including changes in tear meniscus height, tear-film break-up time and bulbar redness.⁹

The findings of the present study are also supported by the prospective randomized study by Yuan et al., in which two hours of reading on OLED smartphone screens resulted in significant reductions in non-invasive and fluorescein tear-film break-up times and tear meniscus height, together with increased ocular redness and subjective symptoms.¹⁰ Although that study evaluated acute changes after a controlled reading task and the present study assessed habitual screen users, both demonstrate the relevance of tear-film and ocular-surface parameters in individuals exposed to digital displays.

Dry-eye features were present in 80% of participants in the present study, with mild disease in 38%, moderate disease in 30% and severe disease in 12%. The predominance of mild and moderate disease indicates

that clinically relevant dry-eye manifestations were common, while severe disease represented a smaller proportion of participants. According to the TFOS DEWS II framework, dry eye involves loss of tear-film homeostasis and may present with combinations of symptoms and objective signs.⁴ Therefore, interpretation of dry-eye severity should consider both subjective symptoms and objective ocular-surface findings.

A statistically significant association was observed between daily screen exposure and dry-eye severity ($\chi^2=9.21$, $p=0.027$). Moderate/severe dry eye was observed in 25.0% of participants with 4–6 hours of daily exposure, compared with 53.8% among those with 8–10 hours. In the >10-hour group, 50% had moderate/severe dry eye. These findings indicate an association between longer daily screen exposure and greater dry-eye severity in the present study, although the cross-sectional design does not establish a causal relationship.

The present finding is comparable with evidence from studies examining intensive digital-device exposure. Wang et al. reported that after two hours of continuous smartphone reading, the diagnostic rate of dry eye increased from 61.7% to 74.2%, while the proportions with moderate and severe disease also increased. Tear-film break-up time and tear meniscus measurements decreased after the reading task, while ocular redness increased.¹¹ These findings provide experimental support for the relationship between intensive smartphone exposure and short-term deterioration of ocular-surface parameters.

A significant association was also observed between daily screen exposure and tear-film instability ($\chi^2=11.32$, $p=0.010$). TBUT ≤ 10 seconds was present in 58.3% of participants with 4–6 hours of screen exposure and in

100% of those reporting >10 hours. This finding suggests that greater daily screen exposure was associated with reduced tear-film stability in the present population. A review of VDT-related dry eye similarly found that most published studies reported an association between VDT exposure and dry-eye disease or related signs and symptoms.⁶

The systematic review by Mataftsi et al. also reported that screen exposure exceeding approximately 4–5 hours per day was associated with higher digital eye-strain symptom scores among young users, although the evidence was graded as low to moderate quality because of study heterogeneity and risk of bias.¹² The present study similarly demonstrated a significant association between screen duration and dry-eye severity, providing supportive evidence from a hospital-based population.

A particularly strong association was observed between TBUT and dry-eye severity ($\chi^2=25.72$, $p<0.001$). Among participants with TBUT <5 seconds, 75% had moderate/severe dry eye, compared with 33.3% of participants with TBUT 5–10 seconds and 15.4% of those with TBUT >10 seconds. This demonstrates that lower TBUT was associated with greater dry-eye severity in the present study. The TFOS DEWS II diagnostic methodology recognizes tear-film break-up time as an important objective assessment of tear-film homeostasis and recommends its interpretation together with symptoms and other ocular-surface findings.⁵

The present results therefore demonstrate a consistent pattern within the study population: prolonged screen exposure was associated with a higher frequency of dry-eye manifestations and tear-film instability, while lower TBUT was associated with greater dry-eye severity. These findings are in agreement with previous observational reviews and experimental studies

examining digital screen exposure.^{3,6,7,9-12} Nevertheless, digital eye strain is multifactorial, and screen duration alone should not be considered the sole determinant of ocular-surface disease.^{1,8}

The study has certain limitations. First, the cross-sectional design does not permit determination of causality. Second, the study was conducted at a single hospital with a sample size of 100 participants, which may limit generalizability. Third, screen exposure was based on participant reporting and may be affected by recall bias. Fourth, blink rate, blink completeness, environmental factors and ergonomic characteristics were not objectively measured. Finally, the study did not include all currently recommended objective dry-eye investigations. Despite these limitations, the simultaneous assessment of symptoms, ocular-surface findings and TBUT provides clinically relevant information regarding ocular-surface status among prolonged digital screen users.

Conclusion

Prolonged digital screen exposure was associated with frequent ocular-surface symptoms, tear-film instability and dry-eye manifestations in the study population. Greater daily screen exposure was significantly associated with dry-eye severity and reduced TBUT, while lower TBUT was strongly associated with moderate-to-severe dry eye. Regular ocular-surface assessment and appropriate preventive measures may be beneficial for individuals with prolonged digital screen use.

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