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RESEARCH ARTICLE

Corelation between ocular surface disease index (OSDI) score, tear film characteristic and screen time usage among young adults

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Abstract

Purpose: The study aimed to assess and determine the correlation between Ocular Surface Disease Index (OSDI) scores with screen time usage and tear film parameters among young adults.

Methods: This cross-sectional observational study was performed with the study population comprising 81 young adults aged between 18 and 41 years at an eye clinic in Gurgaon, Haryana. The participants' symptoms were evaluated using the OSDI questionnaire and tear film parameters were collected, such as Schirmer's test (without anaesthesia) and non-invasive tear breakup time (NIBUT), tear meniscus height (TMH), Meibomian gland loss (MGL) and bulbur redness. The data pertaining to the screen time usage was collected *via* a structured self-reported questionnaire. Statistical analysis employed regression and correlation analyses and was conducted to assess the underlying associations governing OSDI scores, screen time, and tear film parameters.

Results: The study showcased a statistically significant positive correlation between OSDI scores and screen time ($r = 0.61$, $p < 0.01$), indicating a greater severity of ocular surface symptoms with increased duration of screen exposure among the study population. In addition, Schirmer's test values and NIBUT scores were negatively correlated with OSDI scores ($r = -0.53$ and -0.45, respectively; $p < 0.05$). TMH indicated a weaker negative correlation ($r = -0.28$, $p = 0.06$). Regression analysis from the findings represented with screen time serving as a significant predictor for the OSDI scores.

Conclusion: The study findings conclude that with study population, who are under prolonged exposure to screens, particularly among young adults, have an increased susceptibility to ocular surface disease symptoms and deteriorated tear film parameters. The findings ultimately suggested the significance revolving around the need for integration of digital health awareness and preventive ocular care strategies and measures to be imparted among the young adult population as a means for mitigating the effects of digital eye strain.

Keywords: OSDI, screen time, tear film, dry eye, digital eye strain, young adults, optometry

Introduction

With influence of exponential advancement in digital technology has profoundly influenced lifestyle habits in modern society, especially in young adults. This demographic, typically falling within the age group of 18 to 36 years, represents a significant proportion of the population that are heavily reliant on digital devices for performing their day-to-day professional, academic, and recreational activities (Mufti *et al*., 2019)—with widespread integration on tablets, smartphones, laptops, and other visual display units (VDUs) for daily routines, young adult groups that are increasingly susceptible to the phenomenon termed as digital eye strain (DES), referred also as computer vision syndrome (Kaur *et al*., 2022). DES encompasses a wider array of visual and ocular symptoms, like eye strain, blurred vision, irritation, dryness, and headache, all of which are associated with prolonged screen exposure (Bhattacharya *et al*., 2022).

One most prominently observed concerns and reported consequences concerning with extended screen time resulting in the development of dry eye disease (DED) (Al-Mohtaseb *et al*., 2021). DED from a clinical perspective is

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a multifactorial disorder of the ocular surface and tear film (Achtsidis *et al*., 2014). DED is characterized by symptoms attributed to visual disturbance, discomfort, and instability of the tear film as it potentially leads to damage of the ocular surface (Achtsidis *et al*., 2014; Patel *et al*., 2023). The pathophysiology pertaining to DED condition involves a complex interplay of ocular surface inflammation, tear film hyperosmolarity, altered tear film composition and reduced tear production (Perry, 2008). The disruption can ultimately impact not only the ocular discomfort but also result in the impairment of visual performance that negatively impacts the overall quality of life (Langelaan *et al*., 2007).

DED in younger individuals engage with the visually demanding tasks that involve no insufficient breaks, in suboptimal lighting conditions, or in low-humid environments (Deschamps *et al*., 2013). The behavioural changes tend to contribute to the tear film evaporation and destabilization, subsequently resulting in the worsening of DED-related symptoms (Patel *et al*., 2023). Additionally, prolonged application on VDUs can likely result in incomplete blinking, which reduces the overall efficiency of lacrimal pump mechanisms and disruption of the normal tear distribution across the ocular surface (Fjærvoll *et al*., 2022).

In order to evaluate the overall impact and severity of DED, both objective and subjective measures need to be commonly employed for evaluating the outcomes in clinical practice. One such widely accepted tool is OSDI, a validated, self-administered questionnaire that successfully captures the frequency of DED-oriented symptoms, its impact on the overall vision-related functioning, and extent to which the environmental triggers tend to affect DED (Erøy, 2019). OSDI in particular can be regarded efficacious in the epidemiological investigations due to its ease of administration, reproducibility, and also exhibits a stronger correlation with clinical signs of DED (Bakkar *et al*., 2016). Subjective assessments and objective evaluation of tear film parameters provided critical insights into the physiological alterations that are associated with DED. This usually includes Non-Invasive Tear Breakup Time (NIBUT), which serves as a measure for determining the tear film stability (Mohidin *et al*., 2002); Schirmer's test, on the other hand, facilitates in evaluating the aqueous tear production (Senchyna & Wax, 2008); and Tear Meniscus Height (TMH), which reflects the tear volume. Combining these metric tools facilitates a comprehensive assessment of tear film functioning and the ocular surface morphology (Pena-Verdeal *et al*., 2024).

Recent research emphasizes the growing need for understanding the correlation concerning with lifestyle behaviours—particularly with the screen time exposure among patients—and ocular health outcomes (Ba & Li, 2024). Several studies documented a positive correlation with the increased screen exposure a higher OSDI scores, representing the direct relationship with greater severity of DED symptoms (Preoteasa & Preoteasa, 2024). However, the a need for performing a more integrative research investigation that evaluates simultaneously both the objective and subjective parameters on a well-defined population subset, especially focusing on the investigation among the young adult population. The age group, which in general is considered to be physiologically robust, and is increasingly presenting with an earlier onset of the disturbances of the ocular surface morphology as a result of overexposure to digital devices.

The current study investigates the underlying correlation pertaining to OSDI scores, tear film characteristics and screen time duration—namely Schirmer's test, NIBUT, and TMH—among the young adult population. Through exploring on these associations, the research aims towards providing clinically relevant data that can facilitate optometric professionals for effective diagnosis, patient education, and management strategies for DED. Furthermore, the study seeks to underscore the significance revolving with the preventive interventions concerning with moderation of screen time exposure, ergonomically designed visual hygiene practices, and usage of artificial tears or otherwise with suitable environmental modifications, particularly among those young adult populations who are at higher risk of experiencing digital eye strain and the resultant DED symptoms.

Materials and Methods

Methodology

Study Design

This study utilizes a cross-sectional observational study as its study design. The research was conducted primarily to evaluate the relationship between DED and screen time in individuals aged 18 to 41 years. The study adheres to the ethical guidelines and prior written informed consent was obtained from all the participants. The investigation was conducted at **ARO Health Multi-Speciality Clinic, Gurugram**, for 1 year.

Target Population and Sampling Method

The target population consisted of the young adult group within the age group of 18 and 41 years. Participants were selected using a random sampling technique as a means to ensure representativeness and also to minimize the risk of selection bias. A total of 81 participants were enrolled, based on statistical sample size calculation.

Sample Size Determination

The sample size was calculated using the standard formula for population proportions:

$$S = \frac{Z^2 p(1-p)}{M^2}$$

Where:

- Z score corresponds with 95% confidence level = 1.96
- p is the estimated population proportion = 0.15
- M is the margin of error = 0.05

Since the study was conducted on a finite population, the adjusted sample size (n) was derived using:

$$n = \frac{S}{1 + \left(\frac{S-1}{N} \right)}$$

Where, N is the estimated population available during the study period.

Given the accessibility and recruitment feasibility, the final adjusted and enrolled sample size was 81 participants.

Inclusion and Exclusion Criteria

Participants were selected on the basis of specific inclusion and exclusion criteria to ensure the findings' reliability and validity. The inclusion criteria which were required that the participants be young adults aged between 18 and 41 years, who regularly used digital screens such as smartphones, tablets and laptops, and who were willing to participate and provide informed consent. Individuals were excluded if they had any pre-existing ocular conditions such as blepharitis or conjunctivitis, a history of ocular surgery or trauma within the past six months, were contact lens users, or had systemic diseases known to affect ocular surface health, including diabetes and autoimmune disorders.

Study Instruments and Data Collection

Ocular Surface Disease Index (OSDI) Questionnaire

The OSDI questionnaire was utilized as the primary subjective measure for assessing the frequency and severity of dry eye symptoms. It consists of 12 items scored on a Likert scale (0–4), where 0 indicates "none of the time" and 4 indicates "all of the time." The final score was calculated and expressed on a scale of 0 to 100. The OSDI has established validity and reliability for evaluating dry eye symptomatology.

IDRA Diagnostic Platform (Non-Invasive Dry Eye Analysis)

All participants underwent objective dry eye evaluation using the IDRA test system, a non-invasive, multi-parametric diagnostic device. This system provided several key parameters, including non-invasive tear film breakup time (NIBUT), tear meniscus height (TMH), Meibomian gland loss (MG loss), and bulbar redness analysis. The use of this tool allowed for a comprehensive assessment of tear film quality, quantity, and the overall condition of the ocular surface. Importantly, the non-invasive nature of the evaluation minimized the risk of inducing reflex tearing, thereby enhancing the accuracy and precision of the diagnostic outcomes.

Procedure for Data Collection

The case histories of the participants were taken by clinical assessment, including tear film break up time, IDRA test and ocular surface staining, will be conducted to evaluate the physical parameters of the ocular surface taken prior to screen utilization, followed by a post-screen measurement. Participants' screen time was measured using validated self-report and an electronic monitoring device. These included time spent on computers, smartphones, tablets and other digital screens. The primary study for assing dry eye disease symptoms was ocular surface disease index (OSDI) questionnaire. This validated process provided a quantitative measure of the impact of DED on participants' daily activities. The study depends on some demographic factors, include age, gender, occupation and lifestyle

Screen Time Assessment

Screen time was quantified using a combination of self-reported screen time questionnaires, which captured the average daily usage across various digital devices such as smartphones, laptops, tablets, and televisions, and, where available, optional digital usage logs or built-in device screen time trackers. Based on the reported data, screen exposure was categorized into three groups: less than 4 hours per day, 4 to 6 hours per day, and more than 6 hours per day.

Demographic and Lifestyle Data Collection

Structured forms were used to collect demographic information, including age, gender, occupation, educational background, and lifestyle behaviors relevant to ocular health (e.g., screen breaks, room lighting, device type).

Statistical Analysis

Data were analyzed using SPSS software version (SPSS Version 26). Descriptive statistics were employed to summarize participant demographics and mean values for tear film parameters. One-way analysis of variance (ANOVA) was conducted to compare non-invasive tear film breakup time (NIBUT), tear meniscus height (TMH), meibomian gland loss (MG loss), and bulbar redness across the three screen time exposure groups (<4 hours/day, 4–6 hours/day, and >6 hours/day). Post hoc tests using the Tukey method were applied to determine pairwise differences between groups. A *p-value* of less than 0.05 was considered statistically significant.

Results

The demographic profile and time allocation regarding screens of the 81 participants show important aspects which help comprehend the relation between the age, sex and exposure to the screen.

Age Distribution

The participants of this study are predominantly aged between 33 and 41 years, comprising 60.5% of the sample.

Table 1: Patient demographics

Age group		
	Frequency	*Percent*
18–22 years	7	8.6
23–27 years	8	9.9
28–32 years	17	21.0
33–41 years	49	60.5
Gender		
	Frequency	*Percent*
Male	50	61.7
Female	31	38.3
Screen Time (in hrs)		
	Frequency	*Percent*
1–3 hours	2	2.5
4–6 hours	11	13.6
7–9 hours	20	24.7
Above 9 hours	48	59.3
Dry eye type		
Mild	27	33.3
Moderate	23	28.4
Normal	20	24.7
Severe	11	13.6
Total	81	100.0

This indicates that the sample is primarily made up of older young adults and middle-aged individuals. Following this, the 28 to 32 years age group consists of 21.0% of participants, and the 23 to 27 years age group comprises 9.9%. The youngest cohort, aged between 18 and 22 years, only constitutes 8.6% of the sample. This suggests that the findings are likely to be representative of persons in their 30s and early 40s, which may have an effect on age-related screen responding ocular changes.

Gender Distribution

From a gender perspective, the participant pool is imbalanced with more active male participants who represent 61.7% (50 individuals) as opposed to 38.3% (31 individuals) females. This could affect outcome measures if responses known to differ between genders—such as tear film dynamics or susceptibility to dry eye—are taken into account. Hence, any interpretation concerning results would need to factor in potential gender influences or interactions alongside exposure to screens.

Screen Time Distribution

Data concerning the usage of screens reflects a concerning trend among participants. It is particularly alarming that 59.3% of participants belong to the category of utilizing screens for digital over 9 hours per day, constituting the most prominent bracket. The 7 to 9 hours range also constitutes

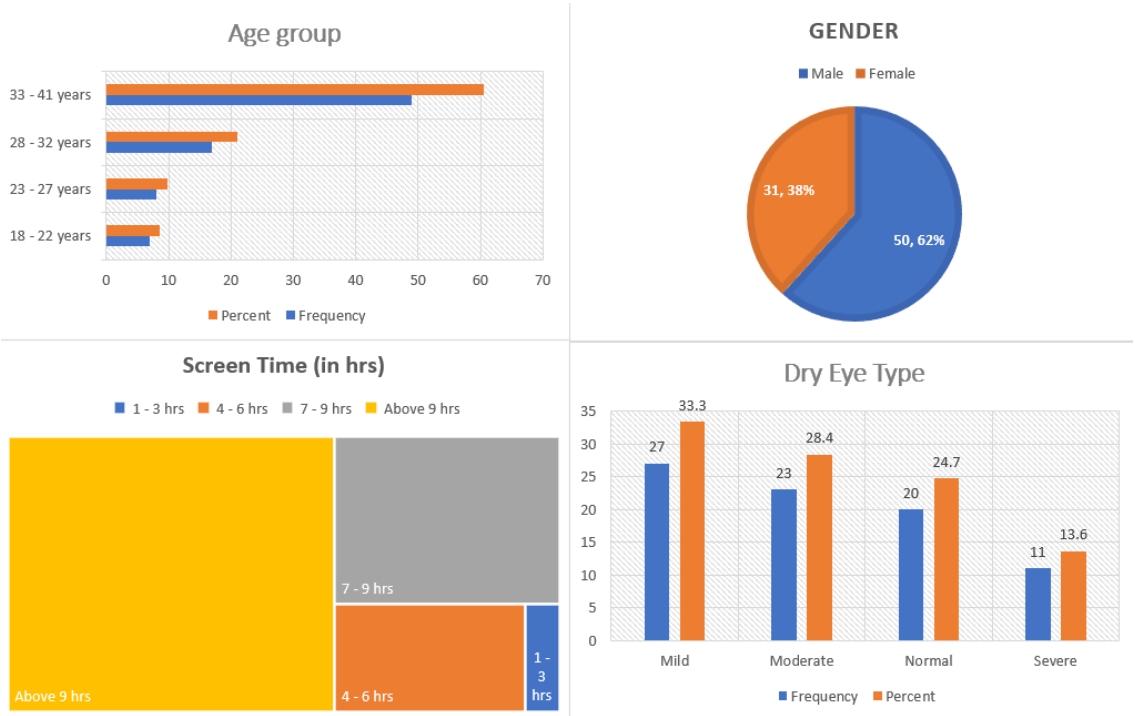

Figure 1: Demographics

a significant portion, 24.7% whilst fewer fall into the 4 to 6 hours (13.6%) and 1 to 3 hours (2.5%) brackets. This indicates over 84% participants spend seven or more hours on screens, suggesting a high-risk population for digital eye strain and dry eye syndrome.

Dry Eye Type

The greatest representation within the population was mild dry eye which was recorded in 33.3% (n = 27) of participants. This indicates that a large portion of the participant population is likely in the early stages of symptoms, low-grade, and potentially responsive to lifestyle alterations and preventive measures. Moderate dry eye came in next, reported by 28.4% (n = 23) of participants. This subset likely demands greater long-term clinical treatment and may demonstrate significant tear film instability or disruption of the ocular surface. Participants with normal ocular surface status comprised 24.7% (n = 20) of the total population, indicating that close to one quarter of the study sample lacked clinically significant signs or symptoms of dry eye. This further illustrates the high prevalence of dry eye disease (DED) within this population. Significantly, 13.6% (n = 11) of participants were classified as having severe dry eye, indicating marked damage to the ocular surface.

This aligns with contemporary practices of prolonged usage of screens for work purposes or leisure activities, which may be a considerable factor for ocular surface disease. This also strongly supports the hypothesis that prolonged screen time affects tear film equilibrium, meibomian gland activity, and other important parameters of ocular health in the study.

Mean ± standard deviation (SD) (standard error; SE) captures the summary statistics for the participant's demographics and clinical ocular surface measurements. These values indicate the average respondent and also show how spread out the data is.

The average age for all the participants is 34.69 ± 6.54 years (SE = 0.73), suggesting they fall within a mid-aged adult range with a small margin for error, suggesting refined segmentation. In this cohort, the average daily time spent on screens was particularly high at 9.90 ± 2.92 hours (SE = 0.32), indicating that this population engages with digital devices extensively. Moderate symptomatology was observed within the ocular surface disease index (OSDI) results. The OSDI_SUM score yield was 17.12 ± 8.26 (SE = 0.92) and the total OSDI was 35.66 ± 17.01 (SE = 1.89), indicating diverse self-reported symptoms among participants, which contributed strongly to overall scores.

In relation to tear film stability parameters, non-invasive breakup time (NIBUT) values of 9.72 ± 2.75 seconds (SE = 0.31) for the right eye (OD) and 9.61 ± 2.54 seconds (SE = 0.28) for the left eye (OS) suggest borderline unstable tear film regions with 10 seconds as a suboptimal cutoff. The average right and left tear meniscus height (TMH), a measure of tear volume, was 0.240 ± 0.064 mm (SE = 0.007) and 0.225 ± 0.077 mm (SE = 0.009), respectively. Both measurements were below the clinically accepted lower normal threshold of 0.3 mm. This suggests the aqueous tear volume decreased in the studied population.

Assessment of meibomian gland loss (MG loss) provided average loss values of 35.32 ± 14.18% (SE = 1.58) for the right eye and 35.80 ± 16.82% (SE = 1.87) for the left eye. These data indicate a moderate degree of meibomian gland dysfunction, which is a major contributor to evaporative dry eye syndrome. The degree of bulbar conjunctival redness, which serves as a proxy for ocular surface inflammation or irritation, was 33.19 ± 13.30 (SE = 1.48) for the right eye and 30.70 ± 11.84 (SE = 1.32) for the left. These results indicate mild to moderate conjunctival hyperaemia, consistent

Table 2: Descriptive analysis

	Mean	*Std. Error*	*Std. deviation*
Age of the patient	34.691	0.727	6.543
Daily screen time (hour)	9.901	0.324	2.918
OSDI_SUM	17.123	0.917	8.257
OSDI Total score	35.657	1.890	17.013
NIBUT(OD)	9.719	0.305	2.749
NIBUT(OD)	9.607	0.282	2.540
Tear Meniscus Height (OD) (mm)	0.240	0.007	0.064
Tear Meniscus Height (OS) (mm)	0.225	0.009	0.077
MG loss-lower (OD)(%)	35.321	1.576	14.182
MG loss-lower (OS)(%)	35.802	1.868	16.816
Bulbar redness (OD)	33.185	1.478	13.300
Bulbar redness (OS)	30.704	1.316	11.840

Table 3: Screen type components

Phone		
	Frequency	*Percent*
No	9	11.1
Yes	72	88.9
Laptop		
	Frequency	*Percent*
No	14	17.3
Yes	67	82.7
TV		
	Frequency	*Percent*
No	17	21.0
Yes	64	79.0
Total	81	100.0

Table 4: Pearson correlation - screen time and tear film stability (NIBUT)

		Daily screen time (hour)	*N.I.B.U.T(OD)*	*N.I.B.U.T(OS)*
Daily screen time (hour)	Pearson Correlation	1	0.230	0.229
	Sig. (2-tailed)		0.039	0.040
N.I.B.U.T(OD)	Pearson Correlation	0.230*	1	0.207
	Sig. (2-tailed)	0.039		0.064
N.I.B.U.T(OS)	Pearson Correlation	0.229	0.207	1
	Sig. (2-tailed)	0.040	0.064	

Correlation is significant at the 0.05 level (2-tailed).

Table 5: Correlation - Daily Screen Time and Tear Meniscus Height

		Daily screen time (hour)	*Tear meniscus height (OD)(mm)*	*Tear meniscus height (OS)(mm)*
Daily screen time (hour)	Pearson Correlation	1	0.224	-0.119
	Sig. (2-tailed)		0.044	0.290
Tear meniscus height (OD)(mm)	Pearson Correlation	0.224	1	0.244
	Sig. (2-tailed)	0.044		0.028
Tear meniscus height (OS)(mm)	Pearson Correlation	-0.119	0.244	1
	Sig. (2-tailed)	0.290	0.028	

Correlation is significant at the 0.05 level (2-tailed).

with dry eye symptoms observed in individuals who spend extended periods of time on digital screens.

The digital device usage profile of the 81 study participants demonstrates the prevalence and the category of screen-based technological devices accessed, an important consideration in evaluating the scope of visual display work-related eye symptoms. Almost all respondents owned smartphones and 88.9% (n = 72) reported regular usage, while 11.1% (n = 9) claimed to not own a smartphone. This high prevalence reflects the consolidation of mobile technology into everyday activities, including communication, leisure, and professional work, reinforcing the narrative of smartphones being the predominant mobile screen.

Smartphones were not the only devices which participants reported using, as laptop use was also significantly high, 82.7% (n = 67) reported use and 17.3% (n = 14) did not use. Laptops are often associated with occupational or educational activities, typically exposing the user to extended viewing durations coupled with poor ergonomic posture, which are predisposing factors for dry eye and computer vision syndrome.

Usage of television was also commonplace, as 79.0% (n = 64) affirmed regular TV viewing and 21.0% (n = 17) reported no use of television. While people tend to view television screens from a greater distance than handheld or desktop devices, exposure to poorly lit environments can still contribute to visual strain and stress to the ocular surface. In general, the data depict a type of usage where people engage with more than one device, indicating that a significant part of the population has several screen interfaces, which increases their interaction with digital screens. This pronounced convergence of smartphones, laptops, and televisions shifts the focus to the total screen time regarding suprathreshold exposure, analyzing its relation to the health of the ocular surface, tear film dynamics, symptoms of dryness, meibomian gland dysfunction, and the stability of the system.

The Pearson correlation analysis was performed to determine the relationship between daily screen time and non-invasive tear breakup time (NIBUT) for the two eyes. The results suggest a statistically significant, although weak, positive correlation between the two variables. In particular, daily screen time appeared to relate significantly with NIBUT right eye (OD) specific NIBUT values with a Pearson r = 0.230, $p = 0.039$. A comparable relationship was noted with NIBUT left eye (OS) with r = 0.229, $p = 0.040$. All these results are significant at the 0.05 level (two-tailed), showing considerable coherence.

Surprisingly, both correlations are positive, which is contrary to the expected observed relationship where higher screen time would lead to diminished tear stability

Table 6: Correlation - screen time and meibomian gland loss

		Daily screen time (hour)	*MG loss-lower(OD)(%)*	*MG loss-lower(OS)(%)*
Daily screen time (hour)	Pearson Correlation	1	0.221	0.034
	Sig. (2-tailed)		0.047	0.765
MG loss-lower (OD) (%)	Pearson Correlation	0.221	1	0.772
	Sig. (2-tailed)	0.047		0.000
MG loss-lower (OS) (%)	Pearson Correlation	0.034	0.772	1
	Sig. (2-tailed)	0.765	0.000	

Correlation is significant at the 0.05 level (2-tailed).

Correlation is significant at the 0.01 level (2-tailed).

Table 7: ANOVA: Tear film stability (NIBUT) across screen time groups

		N	*Mean*	*Std. Deviation*	*Std. Error*	***ANOVA***						
N.I.B.U.T(OD)	1 - 3 hrs	2	10.350	5.303	3.750							
	4 - 6 hrs	11	7.673	3.354	1.011			Sum of Squares	df	Mean Square	F	Sig.
	7 - 9 hrs	20	9.530	2.339	0.523	N.I.B.U.T(OD)	Between Groups	60.579	3	20.193	2.859	0.042
	Above 9 hrs	48	10.240	2.524	0.364		Within Groups	543.904	77	7.064		
	Total	81	9.719	2.749	0.305		Total	604.482	80			
N.I.B.U.T(OS)	1 - 3 hrs	2	11.150	2.475	1.750	N.I.B.U.T(OS)	Between Groups	73.375	3	24.458	4.253	0.008
	4 - 6 hrs	11	7.255	1.759	0.530		Within Groups	442.780	77	5.750		
	7 - 9 hrs	20	9.890	2.674	0.598		Total	516.156	80			
	Above 9 hrs	48	9.965	2.396	0.346							
	Total	81	9.607	2.540	0.282							

and lower NIBUT. This suggests that within this sample, greater screen time somehow spares NIBUT more than what one would anticipate, or there might be some moderating variables, such as compensatory activities like blinking, environment regulation, or use of artificial tears, impacting the outcome. Also, this allows the conjecture for possible adaptive ocular responses or timing of measurement effects (e.g., NIBUT taken some time after screen exposure). The inter-eye correlation between NIBUT(OD) and NIBUT(OS) was r = 0.207, *p-value* = 0.064, which does not reach statistical significance at the 0.05 threshold. This indicates some degree of eye-to-eye symmetry in the consistency of the tear film's stability, although the correlation was not powerful enough to achieve significance.

The Pearson correlation analysis offered an understanding of how screen time exposure affects aqueous tear volume by examining its relationship with tear meniscus height (TMH) for both eyes (OD and OS). A statistically significant positive correlation was noted between the right eye TMH (OD) and daily screen time, yielding a Pearson correlation coefficient of r = 0.224 with $p = 0.044$. This suggests that TMH in the right eye tends to increase with greater screen time, albeit modestly. This relationship reaching significance at the 0.05 level (2-tailed) hints at some form of adaptive response or compensatory response in tear production among users who engage in frequent screen time.

The correlation of screen time with TMH in the left eye (OS) was not significant (r = −0.119, $p = 0.290$), indicating a lack of reliable connection between these measurements in the left eye. This form of asymmetry could be attributed to natural physiological variability between the eyes or to subtle measurement error. Moreover, the participants exhibited bilateral symmetry in TMH as there was a significant positive correlation between TMH right and left (r = 0.244, $p = 0.028$), which is expected under normal physiological conditions.

Table 8: ANOVA – Meibomian gland loss (MG Loss) across screen time categories

		N	*Mean*	*Std. Deviation*	*Std. Error*	*ANOVA*						
MG LOSS-LOWER(OD)(%)	1 - 3 hrs	2	25.500	9.192	6.500							
	4 - 6 hrs	11	33.273	16.224	4.892			Sum of Squares	df	Mean Square	F	Sig.
	7 - 9 hrs	20	29.550	16.548	3.700	MG LOSS-LOWER(OD) (%)	Between Groups	1422.543	3	474.181	2.489	0.067
	Above 9 hrs	48	38.604	11.982	1.729		Within Groups	14667.111	77	190.482		
	Total	81	35.321	14.182	1.576		Total	16089.654	80			
MG LOSS-LOWER(OS) (%)	1 - 3 hrs	2	23.000	11.314	8.000	MG LOSS-LOWER(OS) (%)	Between Groups	1560.845	3	520.282	1.902	0.136
	4 - 6 hrs	11	40.273	21.448	6.467		Within Groups	21061.994	77	273.532		
	7 - 9 hrs	20	29.500	14.816	3.313		Total	22622.840	80			
	Above 9 hrs	48	37.938	16.087	2.322							
	Total	81	35.802	16.816	1.868							

The relationship between daily screen time and meibomian gland (MG) loss in both eyes (OD and OS) was analyzed using Pearson's correlation analysis. Meibomian gland loss is a significant metric of evaporative dry eye, a condition exacerbated by digital screen devices due to reduced blinking and increased ocular surface exposure. The results indicate that daily screen time and MG loss in the right eye OD had a statistically significant positive correlation with a correlation coefficient of r = 0.221 and a *p-value* of 0.047. Based on these results, one can say that with increased screen time, there is a modest increase in meibomian gland dropout in the right eye. The correlation is significant at the 0.05 level (2-tailed), thus supporting the theory that increased use of digital devices is a contributing factor towards meibomian gland dysfunction.

On the contrary, no significant correlation was found for screen time and MG loss in the left eye OS (r = 0.034, *p* = 0.765). This observed asymmetry could be due to folds of individual ocular physiology, variations in blinking and screen viewing angles or even minute errors in imaging and grading techniques. Most importantly, there was a strong and highly significant bilateral correlation of MG loss between the right and left eyes with a Pearson coefficient of r = 0.772, $p < 0.001$. This supports a high degree of bilateral agreement and cross validates the MG loss measurements and aligns with the symmetrically stoic and chronic nature characterizing meibomian gland dysfunction.

An analysis of variance (ANOVA) was performed to determine differences in non-invasive tear breakup time (NIBUT) among different levels of daily screen exposure. Participants were divided into four groups based on their daily screen usage: 1 to 3 hours, 4 to 6 hours, 7 to 9 hours, and over 9 hours. The analysis was performed for each eye separately (NIBUT OD and NIBUT OS), with the goal of assessing whether screen usage duration impacts the stability of the tear fluid critically beneath the ocular surface. With regard to the right eye's NIBUT (NIBUT OD) the mean NIBUT values were stratified by screen time group as follows: 10.35 seconds (±5.30) for 1 to 3 hours, 7.67 seconds (±3.35) for 4 to 6 hours, 9.53 seconds (±2.34) for 7 to 9 hours, and 10.24 seconds (±2.52) for over 9 hours. The data showed that there was significant variability across group means (F = 2.859, *p* = 0.042), suggesting that the duration of daily screen time significantly influences tear film stability in the right eye. Remarkably, the group with 4 to 6 hours of daily screen time had the lowest mean NIBUT value, indicating the most instability in the tear film.

Likewise, for the left eye (NIBUT OS), the mean NIBUT was 11.15 seconds (±2.48) for the 1–3 hour group, 7.26 seconds (±1.76) for the 4–6-hour group, 9.89 seconds (±2.67) for the 7 to 9-hour group, and 9.97 seconds (±2.40) for the more than 9 hours group. ANOVA gave a highly significant result (F= 4.253, *p* = 0.008) supporting the conclusion that duration of screen time does greatly influence the tear film

Table 9: Chi-square - Lipid layer thickness across screen time categories

		Screen time (in hrs.)						
1–3 hours		*4–6 hours*	*7–9 hours*	*Above 9 hours*		*Total*	*Pearson Chi-square*	*p-value*
Lipid layer thickness (OD)	O	1	0	1	10	12		
	A	1	6	5	17	29		
	B	0	5	8	19	32		
	C	0	0	6	2	8		
Total		2	11	20	48	81	19.58	0.021
		Screen time (in hrs.)						
1–3 hours		4–6 hours	7–9 hours	Above 9 hours		Total	Pearson Chi-square	*p-value*
Lipid layer thickness (OS)	O	1	0	1	5	7		
	A	1	8	6	16	31		
	B	0	3	8	24	35		
	C	0	0	5	3	8		
Total		2	11	20	48	81	18.164	0.033

stability. Like the right eye, the 4–6-hour group had the lowest NIBUT, which suggests that this range of screen time may be associated with early damage to the ocular surface.

Conducting an Anova to explore the association of meibomian gland loss, an indicator of evaporative dry eye, and daily screen time, participants were stratified according to their daily screen time into four groups: 1 to 3 hours, 4 to 6 hours, 7 to 9 hours, and more than 9 hours. The analysis was performed for both the right (OD) and left (OS) eye separately. In the right eye (OD), it was noted that MG loss worsened with increasing screen time. Participants in the 1-3 hours group had a mean gland loss of 25.50 ± 9.19% (SE = 6.50). This value increased to 33.27 ± 16.22% (SE = 4.89) for the 4 to 6 hour group, 29.55 ± 16.55% (SE = 3.70) in the 7 to 9 hour group, and 38.60 ± 11.98% (SE = 1.73) for those engaging in greater than 9 hours of screen use. MG loss appeared to increase with screen time; however, the ANOVA result was non-significant (F=2.489, $p = 0.067$). While the data does not fulfill the conventional threshold for statistical significance, the provided *p-value* suggests a trend that is sufficiently close to significance to warrant further exploration.

As for the left eye (OS), the pattern observed was more variable. In the 1–3 hour group, mean gland loss of 23.00 ± 11.31% (SE = 8.00) was the lowest, while the highest loss was recorded in the 4 to 6 hour group at 40.27 ± 21.45% (SE = 6.47). This was followed by 7 to 9 hours, where the mean gland loss was 29.50 ± 14.82% (SE = 3.31) and in the group with screen time above 9 hours, the mean loss was 37.94 ± 16.09% (SE = 2.32). Although there were visible differences between groups, identical to the right eye, the ANOVA outcome for the left eye also remained non-significant (F = 1.902, $p = 0.136$).

A Chi-square test of independence was performed to study the relationship between daily screen time and lipid layer thickness (LLT) in the right eye (OD) and left eye (OS). LLT is an important indicator of the quality of the tear film, and its decrease is associated with evaporative dry eye syndrome. LLT was classified into four qualitative grades: O (very low), A (low-normal), B (moderate), and C (high). Screen time was also divided into four categories: 1–3 hours, 4–6 hours, 7–9 hours, and over 9 hours daily.

Right Eye (OD)

With respect to the right eye, the lipid layer thickness showed some differences by screen time categories. The Chi-square test was significant with Pearson Chi-square = 19.58, $p = 0.021$, suggesting that the lipid layer thickness in the right eye has a considerable dependence on the duration of screen time. It is especially noteworthy that participants having "O" grade thickness, which is very low, were greatly concentrated in the above 9 hours of screen time. Out of 12 "O" grade cases, 10 were in this group. In comparison, more favourable LLT grades A and B were more evenly held over to lower screen time groups. This reiterates the idea that prolonged screen time might be related to the thinning of the lipid layer, which weakens the tear film and may predispose a person to dry eye disease.

Left Eye (OS)

The same trend was noted in the left eye as well, where the Chi-square test yielded significant results ($\chi^2 = 18.16$, $p = 0.033$). The "O" grade lipid layer, though thought to be mostly <9 hours screen time, again dominated in the >9 hours screen time group (5 out of 7 cases). Participants with less than 9 hours of screen exposure had thicker lipid grades B and C, which were more frequent.

Table 10: Chi-square - Dry eye and screen time

		Screen Time (in hrs.)						
1 - 3 hrs		*4 - 6 hrs*	*7 - 9 hrs*	*Above 9 hrs*		*Total*	*Pearson Chi-square*	*p-value*
Dry eye type	Mild	0	2	5	20	27		
	Moderate	0	3	4	16	23		
	Normal	2	5	4	9	20		
	Severe	0	1	7	3	11		
Total		2	11	20	48	81	20.792	0.014

The relationship between daily screen time and the severity of dry eye type (normalized as Normal, Mild, Moderate, and Severe) was examined using a Chi-square test of independence within a sample of 81 participants. The daily screen time was divided into four groups: 1–3 hours, 4–6 hours, 7–9 hours, and over 9 hours. The analysis showed a significant relationship between the duration of screen time and the severity of dry eye, with a Pearson Chi-square statistic of 20.792 and $p = 0.014$. This analysis suggests that the severity of dry eye is heavily dependent on the duration of screen usage.

From the screen time groups, a distinct picture emerged from the case distribution. For participants screened over 9 hours a day, most were diagnosed with either mild (n = 20) or moderate (n = 16) dry eye with three additional cases classified as severe. Interestingly, the greatest number of the "severe" dry eye group was found in the 7 to 9-hour category (n = 7), suggesting that symptoms may start to worsen during this moderate range of screen time but continue to be present at higher time durations. Screen time was lower in participants with better ocular surface health. All (100%) of the participants in the 1–3-hour (2 out of 2) group were considered normal and 5 out of 11 (45.5%) of the participants in the 4–6-hour group were normal compared to only 9 out of 48 (18.8%) in the >9-hour group. This illustrates the significant benefit of lowering screen time has on ocular surface health.

Discussion

The resultant findings of the research revealed a significant association pertaining to the prolonged exposure of digital screens and the severity of DED symptoms, with both objective and subjective data supporting the link. The findings reported were found to be consistent with the emerging global concern with regards to ocular impact on the increased screen usage among the young adult population.

A key finding from the research is the significant relationship between screen time and dry eye severity. People exposed to more than 9 hours of screen time daily were more likely to report mild to moderate dry eye symptoms and a subset showed severe dry eye. The findings are consistent with reports by Uchino *et al*., (2013) who identified a dose-response relationship between symptoms of dry eye and screen exposure among office workers. Similarly, Portello *et al*., (2012) found that visual display terminal (VDT) users often create dry eye symptoms, particularly when screen exposure goes beyond a few hours per day.

Notwithstanding preliminary outlooks, the Pearson correlation analysis presented a feeble positive correlation between NIBUT for both eyes, and ANOVA confirmed statistically significant variances in NIBUT across screen time sets. Remarkably, the 4 to 6-hour group had the least NIBUT, signifying initial tear film cooperation in sensible exposure, perhaps because of less blinking and amplified visual focus that could weaken the tear film (Tsubota & Nakamori, 1993). Still, the positive correlation in greater screen time groups may hint at compensatory behaviours such as augmented blinking, lubricant usage, or just measurement after a period of rest.

A similar trend was found with meibomian gland loss (MG loss), chiefly in the right eye (OD), where screen time correlated knowingly with MG dropout ($r = 0.221$, $p = 0.047$). Meibomian gland dysfunction is recognised to be a crucial component of evaporative DED. Research like Arita *et al*. (2015) has revealed noteworthy gland atrophy in persons with more screen exposure, probably owing to less blinking and augmented blink incompleteness during screen tasks. Though the ANOVA grades for MG loss did not reach statistical implication, the near-threshold *p-value* (0.067) and trend recommend that cumulative screen time may contribute to structural changes in the gland.

LLT analysis through Chi-square tests showed statistically significant relations with screen time for both eyes (OD: $p = 0.021$; OS: $p = 0.033$). Thinner lipid layers, chiefly the "O" grade, were mainly observed in those with less than 9 hours of screen time. A thinner lipid layer arrangements tear the stability of the film and encourages evaporation, strengthening the automatic connection between evaporative DED and screen usage. This is in line with the results by Den *et al*. (2006), who stressed the shielding role of the lipid layer against tear evaporation.

TMH, a substitution for aqueous production of tears, established a significant optimistic correlation only in the

right eye (r = 0.224, $p = 0.044$), signifying some compensatory upsurge in aqueous capacity or measurement variability. The irregularity in ocular results (amid OD and OS) found in TMH and MG loss might replicate individual ocular dominance, posture, or blinking asymmetry, a phenomenon before stated in diagnostics for dry eye (Craig *et al*., 2017).

From a scientific standpoint, the research underlines the crucial necessity for screen hygiene in online users, chiefly those exceeding 7 hours of daily exposure. Behavioural alterations like the 20-20-20 rule, mindful blinking, ambient lighting modifications, ergonomic arrangements, and prophylactic use of artificial tears might alleviate these ocular effects. Furthermore, routine eye screening in high screen-use populations can aid in detecting early signs of DED and initiate timely intervention.

Conclusion

The results of this study offer strong evidence that extended screen usage is significantly linked to negative changes in ocular surface health metrics, especially in younger persons. The high ocular surface disease index (OSDI) mean score (M = 35.66, SD = 17.01) indicates moderate to severe ocular discomfort, which is consistent with the tear film & ocular surface society's (TFOS DEWS II) accepted diagnostic criteria for dry eye disease (DED).

Significantly lower lipid layer thickness (LLT) was seen in those who spent a lot of time in front of a digital screen (OD: M = 12.00 µm, SD = 1.789; OS: M = 12.40 µm, SD = 1.673), which is a symptom of impaired meibomian gland function. Since the lipid layer is essential for decreasing tear evaporation, its attenuation points to a subtype of dry eye that is evaporative and may be brought on by or made worse by extended screen time.

Additionally, the study finds statistically significant positive relationships between screen time and a number of functional and anatomical ocular characteristics. Meibomian gland loss in the lower eyelid (MG Loss-Lower) (OD & OS, r = 0.813, $p < 0.001$) and tear meniscus height (TMH) (OD & OS, r = 0.666, $p < 0.001$) were both elevated, indicating gland dropout and morphological changes most likely brought on by chronic blinking abnormalities and decreased blink rate linked to prolonged near-vision tasks. Furthermore, MG loss (OS) and bulbar redness (OD) showed a weak but statistically significant connection (r = 0.071, $p < 0.001$), suggesting low-grade inflammation and vascular congestion that may be attributable to ocular surface stress.

The study's findings highlight the complex effects of prolonged screen time on the ocular surface's structural and functional integrity. The findings support the use of preventive ophthalmic health measures, such as blink training, environmental changes (such as humidity control), screen time management, and routine clinical evaluation, particularly for populations that are more vulnerable because of lifestyle or occupational factors. To prove causation and create focused treatment plans for digital eye strain (DES) and related dry eye subtypes, more long-term and interventional research is necessary.

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