STM JOURNALS

Research & Reviews: A Journal of
Medical Science and Technology

https://journals.stmjournals.com/rrjomst/

ISSN: 2319-3417 (Online)
ISSN: 2349-1272 (Print)
Volume 14, Issue 1, 2025
January–April
DOI (Journal): 10.37591/RRJoMST

Review RRJoMST

Diurnal Variation of Tear Film Dynamics During Digital Device Use

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Abstract

With a primary focus on their effects on tear dynamics and ocular health, this research effort addresses the hyperlink between pre and post digital screen usage, time of day, and tear dynamics. The desired outcomes of the eye health metrics divulge that post-digital screen exposure significantly reduces mean tear production values across all conditions ($p < 0.05$), with this impact intensifying as the day progresses. These observations show the interplay between digital stress and circadian alteration in tear dynamics, bringing attention to the relevance it has become for eye care professionals to contemplate temporal variations while preventing dry eye syndrome. Reduction in Schirmer value, tear breakup time and tear meniscus height suggest decreased tear production or lack of distribution across the eye possibly due to prolonged screen time causing reduced blink rate and increased evaporation. Individualized approaches that address these variables may enhance the effectiveness of treatment for people who suffer from dry eye disorders and ocular discomfort brought on by screen use.

Keywords: Tear film, Schirmer test, tear breakup time, tear meniscus height, diurnal variation

INTRODUCTION

Prolonged exposure to screens eventually disrupts the harmony of visual health. Since tear film discrepancies become increasingly frequent in our technologically sophisticated era, its essential to comprehend the assumption of digital devices and tear film behavior. Three layers comprise the tear film that sustains on the cornea: a substratum aqueous layer, extending with a deep mucous layer in the middle and a lipid layer at the crest. The hydrophobic nature of the cornea is adapted into a wet-able facet, owing to the acquisition of a mucous layer, laminated with an aqueous layer, and after a lipid layer, which inhibits dissipating the tear from the surface [1]. Lacrimal acinar cells, corneal and conjunctival epithelial cells, and goblet cells of the conjunctival epithelium emit mucin that fabricates the innermost layer of tear film. Proteins, urea, salts, glucose, and immunoglobulins are the vital components of the mucin layer that lubricates the corneal surface [2]. As to remain wet and safeguarded, the aqueous layer is predominant. It combines oxygen, metabolites, proteins, inorganic salts, glucose, and electrolytes, which are beneficial for exfoliating irritants and harmful substances. The primary lacrimal gland produces an aqueous layer, with a minor contribution from the conjunctival goblet cells [2]. The meibomian gland expels tear lipid at the air-tear interface, ensuring the tear film integrity and slowing down the tear evaporation [2, 3]. By minimizing surface tension and permitting the tear to outspread uniformly over the corneal surface while blinking, hydrophilic mucous and lipid (which contains phospholipids, wax, and fatty acids) function in tandem in preserving tear film buoyancy [1, 3]. The tear film physiology is profoundly resistant to nerve stimulation and

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Received Date: December 02, 2024
Accepted Date: December 18, 2024
Published Date: February 05, 2025

Citation: Sankhajyoti Saha, Abanti Sen, Pratyay Ranjan Dutta. Diurnal Variation of Tear Film Dynamics During Digital Device Use. Research & Reviews: A Journal of Medical Science and Technology. 2025; 14(1): 22–29p.

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environmental stressors. Restorative sympathetic and para-sympathetic neural innervation from the cornel and conjunctival regions restrains the equilibrium state between electrolytes, water, and proteins [2, 4]. Blinking not only enhances the processing of visual data accentuating low resolution but is also advantageous in detouring motor innervation into the retina. Considering each blink spanning 100–300 ms, humans frequently blink, accounting for 10% of their active time [5]. Digital screen use is prominent exogenous trigger, which is surmised to influence blinking dynamics, which in turn may guide dry eye [6–8]. The assumption that most literature supports is the concept that digital devices negatively impact blinking harmony. In addition, certain evidence suggests an altered tear breakup time, tear volume, tear film lipid layer status, and aqueous constituent linked to prolonged digital exposure [6]. Literature supports the impediment of digital device usage that intensifies the oxidative stress and tear film fragility, alongside environmental aggravation and deteriorative symptomatic indexes [9]. Blinking preserves the anterior eye terrain and/or tear lens. Changes in tear film dynamics may result in refractive limitation linked to the dry eye condition, as considerable ocular aberration has been reported, which may be the catalyst for such visual limitations [10, 11].

The Schirmer test assesses tear production based on capillary action, allowing tears' watery component to travel along a paper strip, which corresponds to tear formation. The non-anesthetized Schirmer test quantifies basal and reflex tear secretion simultaneously. On the other hand, by suppressing the stimulant of reflex tear, the anesthetic Schirmer test separately estimates basal tear activity [12]. To gauge the resilience and stability of tears, the tear film break-up time, which obtains the global criterion of dry eye, tend to be advantageous [13]. The volume and quality of the tear film can be assessed through tear meniscus height. Up-to 90% of the total tear volume constitutes the tear meniscus positioned at the edge of both upper eyelids and lower eyelids. The diagnosis of dry eye fundamentally works with the bottom tear meniscus, due to its stable orientation [14].

In accordance with stringent neurological regulation, the lacrimal gland secretes tear facilitating a rapid response to parasympathetic and sympathetic nerves, unveiling neurotransmitters, and activating sensory nerves in the cornea and conjunctiva [15]. Significant changes in ocular surface physiology and visual function are observed in participants with longer reading times and shorter blink times in the evening, as compared in the morning, indicating poorer visual performance [16]. The afternoon hour shows worsening ocular dryness in most people. Although the triggering part is deceitful. Owing to the usage of self-luminous devices right through the day and the intrusion of blue light-rich lighting in workplaces, blue light could harm the ocular surface in the evening, often associated with a deteriorating standard of living [17]. Environmental variables, the timing of the day, and both healthy individuals and patients with ocular surface complications affect tear film osmolarity. Results may differ in the middle of the day, across the start and/or finish of the day, or the other way around [18]. Several literatures investigate the way "residual light pollution" impacts human visual health. It seems that emission is affected by the spectrum features of lights and makes recommendations for future lighting controls [19]. A diurnal decline in tear volume may serve as the factor of the customary spike in end-of-day ocular dryness critiques in clinical practice [20, 21].

MATERIALS AND METHODS

Methodology

This research employed the diurnal variation of tear film dynamics on digital exposure using clinical testing, and patient-evaluated parameters to measure the severity, which were carried out at various times of the day. The setup evaluated how digital screens affected tear film activity by measuring tear production rate, quality, volume, and the tear film stability.

Study Design and Population

Participants who use digital devices were selected for cross-sectional, observational research at Probal Eye Institute, Kolkata. The institute granted approval for the study, along with a No Objection Certificate (NOC), and all subjects provided their informed consent. Prior to exposure to the digital screen, each participant, aged between 18 years and 40 years [22], without any anterior and/or posterior

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pathology, had not been using contact lenses for 18 days [23] and any ophthalmic medications executed diagnostic procedures. Tests were then subsequently repeated, following a predetermined protocol of controlled exposure to digital devices. The device utilized in this study offers 15.6 inches (39.63 cm) display size with 1920 x1080 pixel display resolution. 250 nits' brightness unit with a 500:1 contrast ratio, ensuring consistency across all tests. Additionally, its digital interface facilitates full HD with anti-glare nature. The participants were captivated by 30 minutes of combined video and text tasks. This session incorporated peering at video content and interacting with text materials. The content was outlined to occupy the participant on both cognitive level and active reading level. We, thereafter, assessed and equated the preceding and post-exposure data from the procedures. All the experiments were conducted from 6:00 to 11:30 in the morning and from 16:00 to 21:00 in the evening. Every investigation was carried out in the same setting, in the same room, in the same conditions [24].

CLINICAL EVALUATION AND GRADING

Non-Anesthetic and Anesthetic Schirmer test

Schirmer strips (Whatman filter paper #41) are positioned beneath the restalpebral conjunctiva and the eye's bulbar conjunctiva. The patient needs to stay with their gently closed eye for 5 minutes. The length of the tear-soaked section of the strips is proportional to the fluid movement and will quantify the Schirmer value. Since not existence of any "gold standard" diagnostic criteria for dry eye, we will assay the quantity of preceding and post-exposure measurement. By administrating topical anesthetic eye drops, Schirmer strips can be utilized for the anesthetic Schirmer test. The test continues for 5 minutes [12].

Tear Breakup Time (TBUT)

All participants underwent TBUT measurement, using slit lamp cobalt blue filter, while illuminating the widest corneal diameter. As the participants were instructed to blink once, a stopwatch began counting after the complete blink. The stopwatch was stopped and the time documented at the first evidence of surface fluorescence pattern disruptions.

Tear Meniscus Height (TMH)

The tear film's volume and quality can be evaluated using tear meniscus height, primarily focusing on the inferior tear meniscus due to its stable orientation. The inferior region obtains direct focal illumination with high magnification, along with a revolving beam to overlap the tear meniscus adjusting the illumination-slit thickness, while the participant to be blinking normally in primary gaze. The TMH height was measure between 4–7 minutes after fluorescence installation [25].

Data Analysis

Data from selected respondents was congregated using a systematic approach that secured obedience with institutional policies. The t-test statistical method was used to evaluate the data that was assembled. The t-test is well known for being authentic when comparing meaning and assessing how significant group differences are. The statistical significance and practical consequences of the results were revealed by the application of Minitab 19 statistical software, and SPSS version.28.0.

RESULTS

For the right eye, the mean values of the four eye health metrics are lower in the post-digital screen use condition compared to the pre-digital screen use use condition. For non-anesthetics Schirmer test, the difference is statistically significant ($p < 0.05$), with a mean of 26.8 in the pre-digital screen use condition and 21.01 in the post-digital screen use condition. For anesthetic Schirmer test, the difference is statistically significant ($p < 0.05$), with a mean of 21.7 in the pre-digital screen use condition and 17.34 in the post-digital screen use condition. For tear breakup time, the difference is statistically significant ($p < 0.05$), with a mean of 6.63 in the pre-digital screen use condition and 6.01 in the post-digital screen use condition. For tear meniscus height, the difference is statistically significant ($p < 0.05$), with a mean of 0.55 in the pre-digital screen use condition and 0.47 in the post-digital screen use condition (Table 1).

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For the left eye the mean values of the four eye health metrics are lower in the post-digital screen use condition compared to the pre-digital screen use use condition. For non-anesthetic Schirmer test, the difference is statistically significant ($p < 0.05$), with a mean of 26.94 in the pre-digital screen use condition and 21.87 in the post-digital screen use condition. For anesthetic Schirmer test, the difference is statistically significant ($p < 0.05$), with a mean of 22 in the pre-digital screen use condition and 18.14 in the post-digital screen use condition. For tear breakup time, the difference is statistically significant ($p < 0.05$), with a mean of 6.96 in the pre-digital screen use condition and 6.14 in the post-digital screen use condition. For tear meniscus height, the difference is statistically not significant ($p > 0.05$), with a mean of 0.59 in the pre-digital screen use condition and 0.5 in the post-digital screen use condition (Table 2).

For the right eye, the mean values of the four eye health metrics are lower in the post-digital screen use condition compared to the pre-digital screen use use condition. For non-anesthetic Schirmer test, the difference is statistically significant ($p < 0.05$), with a mean of 24.22 in the pre-digital screen use condition and 17.42 in the post-digital screen use condition. For anesthetic Schirmer test, the difference is statistically significant ($p < 0.05$), with a mean of 20.49 in the pre-digital screen use condition and 12.59 in the post-digital screen use condition. For tear breakup time, the difference is statistically significant ($p < 0.05$), with a mean of 7.1 in the pre-digital screen use condition and 5.79 in the post-digital screen use condition. For tear meniscus height, the difference is statistically significant ($p < 0.05$), with a mean of 0.64 in the pre-digital screen use condition and 0.33 in the post-digital screen use condition (Table 3).

Table 1. Comparative analysis of eye (Right Eye) health metrics of Pre- and Post-Digital Device uses in the morning.

Procedure	Mean (Pre)	Mean (Post)	T-Statistic	P-Value
Non-anesthetic Schirmer test	26.8	21.01	6.55	0
Anesthetic Schirmer test	21.7	17.34	5.66	0
Tear Breakup Time	6.63	6.01	2	0.0483
Tear Meniscus Height	0.55	0.47	2.26	0.0259

Source: Researcher's compilation.

Table 2. Comparative analysis of eye (Left Eye) health metrics of Pre- and Post-Digital Device uses in the morning.

Procedure	Mean (Pre)	Mean (Post)	T-Statistic	P-Value
Non-anesthetic Schirmer test	26.94	21.87	6.36	0
Anesthetic Schirmer test	22	18.14	4.47	0
Tear Breakup Time	6.96	6.14	2.76	0.0068
Tear Meniscus Height	0.59	0.5	1.57	0.12

Source: Researcher's compilation.

Table 3. Comparative analysis of eye (Right Eye) health metrics of Pre- and Post-Digital Device is used in the evening.

Procedure	Mean (Pre)	Mean (Post)	T-Statistic	P-Value
Non-anesthetic Schirmer test	24.22	17.42	10.3517	0
Anesthetic Schirmer test	20.49	12.59	7.61	0
Tear Breakup Time	7.1	5.79	9.81	0
Tear Meniscus Height	0.64	0.33	8.81	0

Source: Researcher's compilation.

For the left eye, the mean values of the four eye health metrics are lower in the post-digital screen use condition compared to the pre-digital screen use use condition. For non-anesthetic Schirmer test,

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the difference is statistically significant ($p < 0.05$), with a mean of 24.49 in the pre-digital screen use condition and 17.44 in the post-digital screen use condition. For anesthetic Schirmer test, the difference is statistically significant ($p < 0.05$), with a mean of 20.82 in the pre-digital screen use condition and 13.85 in the post-digital screen use condition. For tear breakup time, the difference is statistically significant ($p < 0.05$), with a mean of 7.49 in the pre-digital screen use condition and 6.13 in the post-digital screen use condition. For tear meniscus height, the difference is statistically significant ($p < 0.05$), with a mean of 0.68 in the pre-digital screen use condition and 0.39 in the post-digital screen use condition (Table 4).

For the right eye, two mean values are lower in the pre-digital screen used in the evening compared to the pre-digital screen used in the morning, while the other two are higher in the pre-digital screen used in the evening compared to the pre-digital screen used in the morning. For non-anesthetic Schirmer tests, the difference is statistically significant ($p < 0.05$), with a mean of 26.8 in the pre-digital screen used in the morning and 24.22 in the pre-digital screen used in the evening. For anesthetic Schirmer test, the difference is statistically not significant ($p > 0.05$), with a mean of 21.7 in the pre-digital screen use condition and 20.05 in the pre-digital screen used in the evening. For tear breakup time, the difference is statistically significant ($p < 0.05$), with a mean of 6.63 on the pre-digital screen used in the morning and 7.17 in the pre-digital screen used in the evening. For tear meniscus height, the difference is statistically significant ($p < 0.05$), with a mean of 0.55 in the pre-digital screen used in the morning and 0.64 in the pre-digital screen used in the evening (Table 5).

Table 4. Comparative analysis of eye (Left Eye) health metrics of Pre- and Post-Digital Device is used in the evening.

Procedure	Mean (Pre)	Mean (Post)	T-statistic	P-value
Non-anesthetic Schirmer test	24.49	17.44	11.8658	0
Anesthetic Schirmer test	20.82	13.85	5.95	0
Tear Breakup Time	7.49	6.13	9.72	0
Tear Meniscus Height	0.68	0.39	9.54	0

Source: Researcher's compilation.

Table 5. Comparative analysis of eye (Right Eye) health metrics based on Diurnal Variation.

Procedure	Mean Pre (Morning)	Mean Pre (Evening)	T-Statistic (Pre)	P-Value (Pre)
Non-anesthetic Schirmer test	26.8	24.22	2.54	0.0126
Anesthetic Schirmer test	21.7	20.05	1.78	0.0789
Tear Breakup Time	6.63	7.17	-2.61	0.0106
Tear Meniscus Height	0.55	0.64	-2.55	0.0123

Source: Researcher's compilation.

Table 6. Comparative analysis of eye (Left Eye) health metrics based on Diurnal Variation.

Procedure	Mean Pre (Morning)	Mean Pre (Evening)	T-Statistic (Pre)	P-Value (Pre)
Non-anesthetic Schirmer test	26.94	24.49	2.63	0.0099
Anesthetic Schirmer test	22	20.21	1.92	0.0576
Tear Breakup Time	6.96	7.34	–1.64	0.1036
Tear Meniscus Height	0.59	0.69	–1.74	0.0842

Source: Researcher's compilation.

For the left eye, two mean values are lower in the pre-digital screen used in the evening compared to the pre-digital screen used in the morning, while the other two are higher in the pre-digital screen used in the evening compared to the pre-digital screen used in the morning. For non-anesthetic Schirmer test, the difference is statistically significant ($p < 0.05$), with a mean of 26.94 in the pre-digital screen used

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in the morning and 24.49 in the pre-digital screen used in the evening. For anesthetic Schirmer test, the difference is statistically not significant ($p > 0.05$), with a mean of 22 in the pre-digital screen use condition and 20.21 in the pre-digital screen used in the evening. For tear breakup time, the difference is statistically not significant ($p > 0.05$), with a mean of 6.96 in the pre-digital screen used in the morning and 7.34 in the pre-digital screen used in the evening. For tear meniscus height, the difference is statistically not significant ($p > 0.05$), with a mean of 0.59 in the pre-digital screen used in the morning and 0.69 in the pre-digital screen used in the evening (Table 6).

For the right eye, the mean values of the four eye health metrics are lower in the post-digital screen used in the evening compared to the post-digital screen used in the morning. For non-anesthetic Schirmer tests, the difference is statistically significant ($p < 0.05$), with a mean of 21.01 in the post-digital screen used in the morning and 17.42 in the post-digital screen used in the evening. For anesthetic Schirmer test, the difference is statistically significant ($p < 0.05$), with a mean of 17.34 in the post-digital screen used in the morning and 13.4 in the post-digital screen used in the evening. For tear breakup time, the difference is statistically not significant ($p > 0.05$), with a mean of 6.01 in the post-digital screen used in the morning and 5.74 in the post-digital screen used in the evening. For tear meniscus height, the difference is statistically significant ($p < 0.05$), with a mean of 0.47 in the post-digital screen used in the morning and 0.33 in the post-digital screen used in the evening (Table 7).

For the left eye, the mean values of the four eye health metrics are lower in the post-digital screen used in the evening compared to the post-digital screen used in the morning. For non-anesthetic Schirmer test, the difference is statistically significant ($p < 0.05$), with a mean of 21.87 in the post-digital screen used in the morning and 17.44 in the post-digital screen used in the evening. For anesthetic Schirmer test, the difference is statistically significant ($p < 0.05$), with a mean of 18.14 in the post-digital screen used in the morning and 14.11 in the post-digital screen used in the evening. For tear breakup time, the difference is statistically not significant ($p > 0.05$), with a mean of 6.14 in the post-digital screen used in the morning and 5.96 in the post-digital screen used in the evening. For tear meniscus height, the difference is statistically significant ($p < 0.05$), with a mean of 0.5 in the post-digital screen used in the morning and 0.38 in the post-digital screen used in the evening (Table 8).

Table 7. Comparative analysis of eye (Right Eye) health metrics based on Diurnal Variation.

Procedure	Mean Post (Morning)	Mean Post (Evening)	T-statistic (Post)	P-value (Post)
Non-anesthetic Schirmer test	21.01	17.42	3.48	0
Anesthetic Schirmer test	17.34	13.4	4.5	0
Tear Breakup Time	6.01	5.74	1.08	0.2847
Tear Meniscus Height	0.47	0.33	5.73	0

Source: Researcher's compilation.

Table 8. Comparative analysis of eye (Left Eye) health metrics based on Diurnal Variation.

Procedure	Mean Post (Morning)	Mean Post (Evening)	T-Statistic (Post)	P-Value (Post)
Non-anesthetic Schirmer test	21.87	17.44	4.49	0
Anesthetic Schirmer test	18.14	14.11	4.25	0
Tear Breakup Time	6.14	5.96	0.73	0.4682
Tear Meniscus Height	0.5	0.38	4.64	0

Source: Researcher's compilation.

DISCUSSION

Chronic reliance on digital curtains has been acquired to be an essential contributor of ocular surface stress and tear film instability, which subsequently raises the possibility of dry eye disease. According to our statistics, the quality of tears decreases steadily amid the day, with noticeable repercussions by

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the evening. Evidently, there is a diurnal reduction in both pre-mobile use and post-mobile use, with lower tear quality in the evening than in the morning. These cumulative strains of screen use, blinking patterns, near-work fatigue, and their reinforced effects over time are emphasized by the similar drop in post-mobile use tear quality from morning to evening. Additionally, a gradual diminution in tear film integrity during the day is indicated by the significant decrease in Schirmer values, tear breakup time, and tear meniscus height.

CONCLUSIONS

Clinicians may need to consider the circadian variations in tear dynamics when evaluating patients, particularly those with complaints of dryness, irritation, or discomfort later in the day. Understanding the natural fluctuations in tear dynamics across different times of the day can help in developing more personalized treatment strategies for individuals suffering from dry eye symptoms and related conditions.

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