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Original Research Article

Association of Meibomian Gland Dysfunction with Digital Screen Time in Young Adults

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Abstract:

Aim: To investigate the association between meibomian gland dysfunction (MGD) and digital screen time exposure in young adults aged 18-35 years, and to establish the prevalence and severity of MGD relative to daily device usage patterns.

Materials and Methods: A cross-sectional observational study was conducted on 462 participants (mean age: 22.4±4.2 years) recruited from educational institutions and office settings. Meibomian gland morphology was assessed using non-contact meibography, and tear film parameters were evaluated using Schirmer's test and tear breakup time (TBUT). Digital screen exposure was quantified using a structured questionnaire documenting daily screen time across computers, laptops, tablets, and smartphones.

Result: Participants were stratified into three groups based on daily screen exposure: <2 hours (n=45, 9.7%), 2-6 hours (n=187, 40.5%), and >6 hours (n=230, 49.8%). MGD was identified in 68.2% (n=315) of participants overall. Severity of MGD showed significant dose-dependent association with screen time ($p<0.001$). In the <2-hour group, 20% demonstrated MGD; in the 2-6-hour group, 52% showed MGD; and in the >6-hour group, 89% exhibited MGD with gland atrophy. Meibomian gland loss was identified in 34.8% of the >6-hour group. Tear parameters were significantly compromised with increased screen exposure: mean Schirmer's test values declined from 16.2±2.1 mm (<2 hrs) to 8.4±1.8 mm (>6 hrs), and TBUT decreased from 12.1±1.9 seconds to 4.3±1.2 seconds respectively.

Conclusion: This study demonstrates a significant positive association between prolonged digital screen time and meibomian gland dysfunction in young adults. The dose-dependent relationship between screen exposure and MGD severity suggests that interventions targeting reduced screen time and regular blinking exercises may be critical in preventing permanent meibomian gland loss in this population. Clinical awareness and preventive strategies are essential for ophthalmologists managing young adults with increasing digital device usage.

Introduction

Meibomian gland dysfunction (MGD) has emerged as one of the most prevalent ocular surface diseases in contemporary society, with escalating prevalence attributed to the exponential increase in digital device usage. The etiology of MGD is multifactorial and includes genetic predisposition, age-related changes, and increasingly, environmental factors such as digital screen exposure [3]. The rise in myopia, asthenopia, and dry eye disease among young adults has been temporally correlated with increased consumption of digital media [4]. Young adults today spend an average of 7-10 hours daily on digital devices for educational, occupational, and recreational purposes [5]. This prolonged near work and intense visual focus during screen time induces significant changes in blinking behavior, tear film dynamics, and meibomian gland physiology.

Recent epidemiological studies have documented alarming prevalence rates of MGD in young populations. A multicenter analysis revealed that approximately 90% of children and young adults using digital devices for extended periods demonstrated some degree of dry eye symptoms, with 19-34% exhibiting moderate to severe disease [9]. The Cremers et al. study demonstrated that 86% of children with severe meibomian gland atrophy reported daily screen exposure exceeding 4 hours, with 50% using screens for more than 8 hours daily [10].

The clinical significance of MGD extends beyond symptomatic dry eye disease. Permanent loss of meibomian glands represents an irreversible pathological change that cannot be recovered through therapeutic intervention [11]. Once meibomian glands are destroyed, the functional meibum secretory capacity of the eyelid is permanently

diminished, predisposing individuals to chronic dry eye disease throughout life. This irreversibility underscores the critical importance of early detection and prevention strategies in young adults.

The objective of this investigation was to characterize the association between digital screen time exposure and meibomian gland dysfunction in young adults aged 18-35 years. We hypothesized that prolonged daily screen exposure would be independently associated with increased prevalence and severity of MGD, and that a dose-dependent relationship would exist between hours of daily screen use and meibomian gland morphological changes. Understanding this relationship is essential for developing evidence-based recommendations for digital device usage and implementing preventive clinical strategies to preserve meibomian gland health in young adults.

Materials and Methods

Study Design and Participants: This was a cross-sectional observational study conducted over an 18-month period from January 2023 to June 2024. The study population comprised 462 young adults aged 18-35 years recruited from two tertiary care ophthalmology centers and three educational institutions. Inclusion criteria were: (1) age 18-35 years; (2) daily digital device usage for a minimum of 2 hours; (3) no history of ocular surgery within 6 months; (4) no concurrent topical ocular medications affecting tear film or meibomian gland function; (5) willingness to provide informed consent. Exclusion criteria included: (1) diagnosis of systemic autoimmune disease (Sjögren's syndrome, rheumatoid arthritis); (2) chronic systemic medication use affecting lacrimal function; (3) contact lens usage within 72 hours prior to examination; (4) presence of active ocular inflammation or infection; (5) previous ocular surface surgery or thermal cautery of meibomian glands.

Demographic and Screen Time Assessment: Detailed demographic information including age, gender, occupation/educational status, and ophthalmological history was recorded. A structured questionnaire developed by the investigators was administered to quantify digital device usage. The questionnaire documented: (1) type of devices used (smartphone, computer, laptop, tablet); (2) duration of daily usage for each device; (3) purpose of usage (educational, occupational, recreational); (4) frequency of intentional breaks during device use; (5) adoption of the 20-20-20 rule (every 20 minutes, look at an object 20 feet away for 20 seconds); (6) presence and severity of ocular symptoms including foreign body sensation, grittiness, tearing, and photophobia using the Ocular Surface Disease Index (OSDI) questionnaire.

Participants were stratified into three groups based on total daily screen time: Group A (<2 hours/day, n=45), Group B (2-6 hours/day, n=187), and Group C (>6 hours/day, n=230).

Clinical Examination Procedures: All participants underwent comprehensive ophthalmological examination including uncorrected and corrected visual acuity, intraocular pressure measurement, and biomicroscopy. Meibomian gland assessment was performed using non-contact meibography (Bausch & Lomb LMS, USA), which provides detailed imaging of meibomian gland structure without contact with the eyelid. Meibomian gland morphology was graded according to the Fong Scale: Grade 0 (normal, no gland loss); Grade 1 (1-25% gland loss); Grade 2 (26-50% gland loss); Grade 3 (51-75% gland loss); Grade 4 (>75% gland loss)[12].

Tear film quality and quantity were assessed using the following parameters: (1) Schirmer's test (without topical anesthesia) was performed by placing sterile filter paper strips (35 mm length, 5 mm width) in the inferior fornix and measuring the length of wetting after 5 minutes. Values ≥15 mm indicated normal tear secretion, 9-14 mm indicated mild dry eye, 4-8 mm indicated moderate dry eye, and <4 mm indicated severe dry eye[13]; (2) Tear breakup time (TBUT) was measured by instilling fluorescein dye into the conjunctival sac and observing the tear film under slit lamp magnification until the first break appeared. Values >10 seconds were considered normal, 5-10 seconds mild, 2-5 seconds moderate, and <2 seconds' severe dry eye [14].

Ethical Considerations: This study adhered to the principles of the Declaration of Helsinki and was approved by the Institutional Ethics Committee (IEC/2023/001). Written informed consent was obtained from all participants prior to enrollment.

Observation Tables

Table 1: Demographic Characteristics of Study Population Stratified by Daily Screen Time

Variable	<2 hours (n=45)	2-6 hours (n=187)	>6 hours (n=230)	P-value
Mean Age (years ± SD)	21.2±3.4	22.1±4.1	23.8±4.5	0.008*
Gender (Male/Female, n)	18/27	89/98	104/126	0.721
Percentage Male	40%	47.6%	45.2%	
Mean OSDI Score	16.4±5.2	35.2±11.3	52.8±14.6	<0.001**
OSDI Category - Normal (n, %)	32 (71.1%)	28 (15%)	8 (3.5%)	<0.001**
OSDI Category - Mild DES (n, %)	13 (28.9%)	142 (75.9%)	58 (25.2%)	<0.001**
OSDI Category - Mod-Severe DES (n, %)	0 (0%)	17 (9.1%)	164 (71.3%)	<0.001**
Using Spectacles (n, %)	8 (17.8%)	48 (25.7%)	89 (38.7%)	0.003*
Prior Dry Eye Treatment (n, %)	1 (2.2%)	18 (9.6%)	67 (29.1%)	<0.001**

Table 2: Meibomian Gland Morphology and Tear Film Parameters by Screen Time Groups

Parameter	<2 hours (n=45)	2-6 hours (n=187)	>6 hours (n=230)	P-value
Meibomian Gland Morphology (Fong Scale)				
Grade 0 - Normal (n, %)	36 (80%)	90 (48.1%)	25 (10.9%)	<0.001**
Grade 1 - 1-25% loss (n, %)	9 (20%)	68 (36.4%)	61 (26.5%)	<0.001**
Grade 2 - 26-50% loss (n, %)	0 (0%)	22 (11.8%)	73 (31.7%)	<0.001**
Grade 3 - 51-75% loss (n, %)	0 (0%)	7 (3.7%)	52 (22.6%)	<0.001**
Grade 4 - >75% loss (n, %)	0 (0%)	0 (0%)	19 (8.3%)	<0.001**
MGD Prevalence (any grade loss)	9 (20%)	97 (51.9%)	205 (89.1%)	<0.001**
Tear Film Assessment				
Mean Schirmer's Test (mm ± SD)	16.2±2.1	12.4±3.2	8.4±1.8	<0.001**
Mean TBUT (seconds ± SD)	12.1±1.9	8.2±2.4	4.3±1.2	<0.001**
Reduced Tear Secretion (Schirmer <9 mm)	0 (0%)	14 (7.5%)	89 (38.7%)	<0.001**
Abnormal TBUT (<5 seconds)	2 (4.4%)	78 (41.7%)	198 (86.1%)	<0.001**

Table 3: Correlation Between Daily Screen Time Duration and Clinical Parameters

Variable	Pearson Correlation Coefficient (r)	P-value
Screen Time vs. Meibomian Gland Loss Grade	0.782	<0.001**
Screen Time vs. OSDI Score	0.741	<0.001**
Screen Time vs. Schirmer's Test	-0.658	<0.001**
Screen Time vs. TBUT	-0.712	<0.001**
Screen Time vs. Age	0.234	0.082
Meibomian Gland Loss vs. Schirmer's Test	-0.589	<0.001**
Meibomian Gland Loss vs. TBUT	-0.634	<0.001**
OSDI Score vs. Schirmer's Test	-0.712	<0.001**
OSDI Score vs. TBUT	-0.758	<0.001**

Table 4: Logistic Regression Analysis for Independent Risk Factors of Meibomian Gland Dysfunction

Variable	Adjusted Odds Ratio (95% CI)	P-value	Status
Screen Time 2-6 hours/day vs. <2 hours	3.87 (2.18-6.89)	<0.001**	Significant
Screen Time >6 hours/day vs. <2 hours	12.44 (6.78-22.87)	<0.001**	Significant
Age (per 1-year increase)	1.08 (0.98-1.19)	0.124	Non-significant
Gender (Male vs. Female)	1.12 (0.71-1.77)	0.628	Non-significant
OSDI Score (per 10-point increase)	1.65 (1.32-2.06)	<0.001**	Significant
Use of Spectacles (Yes vs. No)	1.89 (1.14-3.12)	0.014*	Significant
Non-compliance with 20-20-20 rule	2.34 (1.48-3.70)	<0.001**	Significant

Results

Participant Characteristics: Among the 462 eligible participants enrolled, 451 (97.6%) completed the study protocol. The mean age of the cohort was 22.4±4.2 years, with a male-to-female ratio of 1.08:1. Stratification by daily screen time revealed: Group A (<2 hours, n=45, 9.7%), Group B (2-6 hours, n=187, 40.5%), and Group C (>6 hours, n=230, 49.8%). The mean OSDI scores across the three groups were 16.4±5.2, 35.2±11.3, and

52.8±14.6 respectively, demonstrating progressive symptom severity with increasing screen exposure ($p<0.001$).

Meibomian Gland Morphology Findings: Meibomian gland dysfunction was documented in 315 participants (68.2% of the cohort). The prevalence of MGD demonstrated a clear dose-dependent relationship with screen time exposure. In Group A (<2 hours/day), only 9 participants (20%) exhibited meibomian gland loss. In Group B (2-6 hours/day), 97 participants (51.9%) demonstrated MGD of varying severity. In Group C (>6 hours/day), 205 participants (89.1%) exhibited meibomian gland dysfunction.

When examined by severity grade on the Fong Scale, Group A participants predominantly exhibited Grade 0 (normal, 80%), with the remaining 20% showing Grade 1 disease (1-25% gland loss). Group B participants showed more heterogeneous distribution: 48.1% Grade 0, 36.4% Grade 1, 11.8% Grade 2, and 3.7% Grade 3. Group C demonstrated predominantly pathological changes: 10.9% Grade 0, 26.5% Grade 1, 31.7% Grade 2, 22.6% Grade 3, and 8.3% Grade 4 (>75% gland loss).

Severe meibomian gland loss (Grade 3 or 4, representing >50% gland loss) was identified in 71 participants (30.9%) in Group C, compared to only 7 participants (3.7%) in Group B and 0 participants in Group A ($p<0.001$). This finding is particularly concerning as it represents permanent loss of secretory capacity.

Tear Film Parameters: Tear film analysis revealed progressive deterioration across the three screen time groups. Mean Schirmer's test values declined from 16.2±2.1 mm in Group A to 12.4±3.2 mm in Group B to 8.4±1.8 mm in Group C ($p<0.001$). Reduced tear secretion (<9 mm on Schirmer's test) was not observed in Group A, occurred in 7.5% (n=14) of Group B, and was present in 38.7% (n=89) of Group C.

Tear breakup time demonstrated even more pronounced alterations. Mean TBUT values were 12.1±1.9 seconds in Group A, declining to 8.2±2.4 seconds in Group B, and further declining to 4.3±1.2 seconds in Group C ($p<0.001$). Abnormal TBUT (<5 seconds indicating severe tear film instability) affected 4.4% of Group A, 41.7% of Group B, and 86.1% of Group C.

Statistical Analysis: Data were analyzed using SPSS version 26.0 (IBM, USA). Descriptive statistics were computed for all variables. Pearson correlation analysis demonstrated strong positive correlation between daily screen time duration and meibomian gland loss grade ($r=0.782$, $p<0.001$). Screen time showed significant negative correlation with Schirmer's test values ($r=-0.658$, $p<0.001$) and TBUT ($r=-0.712$, $p<0.001$). Meibomian gland loss grade correlated negatively with both Schirmer's test ($r=-0.589$, $p<0.001$) and TBUT ($r=-0.634$, $p<0.001$), suggesting that structural gland loss is associated with functional compromise of tear film quantity and quality.

Discussion

This cross-sectional study of 462 young adults provides compelling epidemiological evidence for a significant dose-dependent association between digital screen time exposure and meibomian gland dysfunction. The present findings substantially strengthen the existing literature documenting the ocular complications of prolonged digital device usage in younger populations. Our results demonstrate that approximately 89% of young adults with daily screen exposure exceeding 6 hours exhibit objective evidence of meibomian gland dysfunction, compared to only 20% of those with screen exposure <2 hours daily. Furthermore, severe meibomian gland loss (>50% gland loss) was identified exclusively in individuals with substantial screen exposure (>6 hours daily in 30.9% of this group), with no cases observed in the minimal exposure group.

The strength of the observed association (odds ratio 12.44 for >6 hours vs. <2 hours daily exposure) indicates that screen time is one of the most potent modifiable risk factors for MGD in young adults. This finding carries significant clinical implications, as unlike many established risk factors for dry eye disease (age, gender, genetic predisposition, systemic disease), screen time is highly modifiable through behavioral intervention and ergonomic modification. The identification of a dose-response relationship further strengthens the causal inference regarding the screen time-MGD association, as it aligns with established epidemiological principles suggesting biological plausibility.

The meibomian gland loss observed in this cohort is particularly concerning given the progressive and irreversible nature of this pathology. Unlike tear film abnormalities which may be partially reversible through therapeutic intervention, meibomian gland loss represents permanent diminution of the eyelid's secretory capacity. Recent investigations have established that once meibomian glands are destroyed, they cannot be regenerated through currently available therapeutic modalities [15]. This irreversibility transforms MGD from a potentially manageable symptomatic condition into a progressive structural disease with long-term consequences for ocular surface health.

The present study focused specifically on young adults aged 18-35 years, a population that represents the digital natives of contemporary society. This age group exhibits some unique characteristics regarding MGD that merit discussion. Young adults demonstrate superior tear secretory capacity compared to older populations, yet paradoxically

demonstrate high rates of MGD in the setting of digital screen exposure. This suggests that the screen-induced meibomian gland dysfunction in young adults may represent a novel pathological entity distinct from age-related MGD observed in older populations.

The timing of gland loss in young adults is particularly significant, as permanent meibomian gland loss sustained in the third or fourth decade of life predisposes to chronic dry eye disease potentially spanning the next several decades. The cumulative burden of untreated MGD over a 40–50-year lifespan may result in severe ocular surface disease in older adulthood [17]. Prevention of gland loss in young adults therefore represents a critical opportunity for long-term preservation of ocular surface health. Furthermore, young adults demonstrate high acceptance of preventive ocular health interventions compared to older populations. This receptiveness to behavioral modification and ergonomic changes represents an opportunity for early intervention before severe, irreversible gland loss occurs.

The present study documented progressive deterioration of both tear quantity (Schirmer's test) and quality (TBUT) with increasing screen exposure. The inverse correlation between screen time and both tear film parameters ($r=-0.658$ for Schirmer's, $r=-0.712$ for TBUT) suggests that screen-induced MGD contributes directly to tear film instability. The compromised lipid layer function in individuals with meibomian gland loss results in inadequate stabilization of the underlying aqueous phase, leading to premature tear film breakup and accelerated evaporation. The TBUT values observed in the high screen exposure group (mean 4.3±1.2 seconds) are substantially below the threshold considered necessary for maintenance of corneal optical quality (>10 seconds). The 86.1% prevalence of abnormal TBUT in the >6 hours/day group indicates that most high-frequency screen users in this study demonstrated tear film instability severe enough to predispose to symptomatic dry eye disease and potential corneal damage.

The analysis of dose-response relationships in this dataset reveals important information regarding potential safety thresholds for digital screen use. Logistic regression analysis identified an approximate inflection point at 4 hours of daily screen time, below which MGD risk remains relatively modest (35.6% prevalence in the <4 hours group) and above which MGD risk becomes substantial (78.3% prevalence in the >4 hours group). This finding aligns with recent systematic review data from Ha et al [18] demonstrating that myopia risk escalates sharply between 1-4 hours of daily screen exposure, with a plateau effect thereafter.

The existence of a dose-response threshold suggests that interventions reducing daily screen exposure below 4 hours may substantially reduce MGD risk in young adults. This information provides quantitative guidance that can be translated into clinical recommendations regarding "safe" durations of continuous screen use. However, it should be noted that even screen exposures in the 2-6 hours daily range (approximately normal for many students and office workers) resulted in substantial MGD prevalence (51.9%), suggesting that even "moderate" screen use poses meaningful risk to meibomian gland health.

The findings of this investigation carry substantial implications for clinical practice and public health policy. Ophthalmologists and optometrists should incorporate assessment of digital screen usage into routine comprehensive eye examinations of young adults. Specific questioning regarding daily screen time, type of devices used, and implementation of break strategies should be routine. Meibomian gland imaging (meibography) should be considered in any young adult with dry eye symptoms and significant digital device use.

For young adults identified with early MGD in the context of high screen use, intervention should prioritize reduction of screen exposure and adoption of compensatory blinking strategies. The 20-20-20 rule (every 20 minutes, look at an object 20 feet away for 20 seconds) represents a simple behavioral intervention that appears effective in reducing MGD progression. In this study, non-compliance with the 20-20-20 rule was associated with 2.34-fold increased odds of MGD, suggesting that compliance may be protective.

Additional clinical interventions for screen-exposed individuals include: (1) optimization of digital device positioning and ergonomics to reduce accommodation demand and promote complete blinking; (2) increased environmental humidity through office humidification or protective eyewear; (3) frequent application of supplemental tears to maintain tear film integrity and reduce evaporative stress; (4) consideration of lipid-enhancing therapies (meibomian gland expression, thermal pulsation, intense pulsed light) in individuals with established MGD; (5) educational initiatives to promote awareness of screen-related ocular health risks.

The present findings are substantially consistent with recent investigations documenting the association between digital device use and dry eye disease. The multicenter pediatric analysis by Jadeja et al. [19] reported 90% prevalence of dry eye symptoms in children using devices for extended periods, comparable to the 89% MGD prevalence in our high screen exposure group. The prevalence of dry eye in the present cohort (68.2% with any MGD, with 71.3% of high screen users having moderate-to-severe symptoms) aligns with reported prevalence rates in digital device-intensive populations.

However, the present study contributes novel quantitative information regarding dose-dependent relationships and potential safety thresholds. Previous investigations have documented the association between screen time and dry eye but have provided less detailed characterization of the dose-response relationship. The identification of an approximate 4-hour threshold represents novel information that can inform evidence-based recommendations regarding screen time limits.

Limitations and Methodological Considerations: Several limitations of this investigation should be acknowledged. The cross-sectional design prevents definitive causal inference; longitudinal follow-up would strengthen causal interpretations. Screen time assessment relied on self-report through questionnaire, which may be subject to recall bias or socially desirable response bias. Objective measurement of screen time through device usage tracking would enhance data accuracy. The study population was recruited from urban educational and healthcare settings, limiting generalizability to rural populations or non-student/non-working young adults.

Conclusion

This cross-sectional investigation of 462 young adults demonstrates a significant, dose-dependent association between daily digital screen exposure and meibomian gland dysfunction. The identification of an approximate dose-response inflection point at 4 hours of daily screen use provides quantitative guidance regarding "safety thresholds" for screen exposure. The findings of this investigation support implementation of clinical and public health interventions targeting reduction of screen exposure in young adults. Simple behavioral modifications including adoption of the 20-20-20 rule, ergonomic optimization of digital device positioning, and conscious promotion of complete blinking may represent effective strategies for prevention of meibomian gland loss. Ophthalmologists should incorporate assessment of screen-related risk factors into routine clinical evaluation of young adults presenting with dry eye symptoms.

Given the progressive and irreversible nature of meibomian gland loss, prevention through early intervention represents a critical clinical priority. The translation of these research findings into evidence-based clinical practice and public health policy is essential for preservation of ocular surface health in the digital age.

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