Review Article

Visual impact of smartphones: A narrative review of ocular changes and management approaches

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The rapid rise in smartphone use has raised growing concern about its impact on ocular health. This narrative review explores current evidence on the visual consequences of prolonged smartphone exposure focusing on tear film instability, blink pattern alterations, accommodative stress, and intraocular pressure changes. Digital eye strain, increasingly prevalent across all age groups, presents with symptoms including dryness, visual fatigue, burning, and blurred vision. Reduced blink rate and incomplete blinking during screen use contribute to tear film instability and evaporative dry eye. Studies have documented decreased tear breakup time and increased ocular discomfort following even brief periods of smartphone use. In pediatric populations, prolonged screen exposure correlates with myopic progression. Diagnostic challenges arise due to temporary symptom amplification following recent device use warranting standardized preassessment protocols. Evidence-based interventions include blink training, screen time limitation, ergonomic modifications, and use of preservative-free lubricants. Blue light filters and nutritional supplements offer variable benefit with limited clinical validation. This review highlights the need for increased awareness and well-designed longitudinal studies to inform the diagnosis and management of smartphone-related ocular changes.

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The widespread use of digital devices, especially smartphones, has become an essential part of daily life across all age groups. These devices are now used extensively for communication, education, work, and recreation. However, prolonged screen exposure is increasingly linked to a cluster of ocular and visual symptoms collectively known as digital eye strain (DES). Symptoms include eye fatigue, dryness, blurred vision, burning, and headache and are often accompanied by musculoskeletal discomfort.[1]

The global prevalence of DES ranges from 50% to 70% with some student populations reporting rates as high as 97%.[2,3] A study from Saudi Arabia reported that over 66% of university students experienced at least one ocular symptom after regular smartphone use.[4] In children, just 1 hour of smartphone gaming significantly reduced the blink rate and worsened dry eye symptoms, suggesting early-onset vulnerability.[5] Working on smart phones is different from other digital devices like computer screens with regard to proximity of work. The visual discomfort associated with smartphones is attributed to factors such as reduced blink frequency, tear film instability, accommodative stress, and poor ergonomics. Despite the high usage of smartphones, their specific effects on the ocular surface and blinking behavior are still not fully understood.

Given the growing use of smartphones from a young age and their necessity in everyday life, this review presents current literature on the impact of smartphone use on ocular health, particularly addressing tear film parameters, blinking patterns, and visual comfort, and also outlines evidence-based strategies for prevention and clinical management.

Methodology of literature search

A comprehensive literature search was conducted on January 10, 2025 across three major biomedical databases—PubMed, Scopus, and EMBASE—to identify peer-reviewed publications addressing DES and its impact on ocular function. The search strategy employed a combination of predefined keywords including "digital eye strain, computer vision syndrome, screen time, Ocular fatigue, visual discomfort." Boolean operators AND and OR were systematically applied to optimize and refine search outcomes. The inclusion criteria comprised original observational and interventional studies as

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well as systematic reviews and meta-analyses specifically focusing on DES. Articles were excluded if they lacked accessible full texts or were unrelated to the primary topic of digital eye strain.

Upon initial screening, a total of 238 studies were retrieved. After evaluating titles and abstracts for relevance and accessibility, 144 studies were included for full-text review and qualitative synthesis.

Common digital technologies and their characteristics

Modern digital devices like smartphones emit blue light and require prolonged near-vision focus, both of which contribute significantly to visual strain. A key characteristic of these devices is their emission of high-energy visible (HEV) blue light which has been linked to DES and potential retinal damage.[6] Continuous screen usage also imposes prolonged near-work demands, necessitating sustained accommodation and convergence, leading to eye fatigue.[7] Additionally, screen refresh rates and flicker, although often imperceptible, can contribute to visual discomfort and fatigue.[8] Glare and contrast issues, particularly in low-light environments, further exacerbate discomfort due to variable brightness and contrast settings.[9] Extended screen time is also associated with a reduced blinking rate, resulting in tear film instability and dry eye symptoms. Ergonomic constraints such as poor posture and improper screen positioning are common during digital device use and can cause both ocular and musculoskeletal discomfort.[7] Table 1 summarizes the characteristics of digital technologies and their associated ocular effects.

Effect of smart phone on visual functions

Increased accommodative and convergence load: When an individual focuses on near objects, the triad of near reflex comes into play. This triad consists of accommodation, miosis, and convergence. Working on smart phones increases demands on the accommodative status and the vergence of eyes as these devices have smaller fonts and closer viewing distances. Pre-existing problems with any of the components of near reflex like convergence insufficiency, poor vergence facility, and decompensated heterophoria cause asthenopia in near work and may aggravate the computer vision syndrome.

Visual fatigue: Even subjects with normal visual acuity without any prior accommodative dysfunction or disorders of binocular vision had symptoms of eye fatigue with prolonged use of smart phones as reported by Long *et al*.[8] in participants as young as 8 years with high accommodative reserve with prolonged use, person starts holding the screen closer to make the small fonts larger.[10] Close viewing distance while using smartphones has been attributed as the main reason leading to increased visual demands and increased near point stress in some individuals.[11]

Impact on circadian rhythm: Light emitted from the visual display unit of smartphones has spectral distribution and influences the pupil causing miosis, which further aggravates convergence difficulties while reading.[12] In addition, the blue spectrum of the light restrains the production of melatonin, the hormone that controls our sleep–wake cycles and adversely affects our natural circadian rhythm.[13] Chronic sleep disturbance in long run can negatively affect the psychosomatic wellbeing of an individual. Exposure to the light radiating from the smartphone screen for a longer period drives human eyes into recognizable mental and visual fatigue, resulting into sleep disturbances, mood fluctuations, insomnia, dry eyes, computer vision syndrome, misconceptions, and tactile hallucinations.

Cognitive and neurological effects: Status of critical flicker fusion frequency (CFF), an indicator of physical human fatigue, mental workload, and cognitive function, has also been studied in smartphone users. It is the highest frequency at which subjects are unable to perceive flickering of light and is reportedly around 35 to 40 Hertz in normal adults. It was found that prolonged screen time on smartphones may decrease the CFF rate in both eyes of the respondents that indicated marked visual and mental

Table 1: Summary of digital technology characteristics, associated ocular impacts, clinical manifestations, and recommended management strategies

Technology characteristic	Ocular impact	Clinical manifestations	Management strategies
High-energy visible (HEV) light emission	Blue-light emission linked to digital eye strain and potential retinal damage	Eye strain, photophobia, potential macular changes	Use blue-light filters, reduce screen brightness, and limit evening exposure to HEV light
Prolonged near-work demand	Excessive accommodation and convergence leading to eye fatigue	Asthenopia, headache, difficulty focusing	Incorporate regular visual breaks, practice the 20-20-20 rule, and use accommodative exercises
Screen refresh rates and flicker	Imperceptible screen flicker contributing to visual discomfort and fatigue	Visual fatigue, transient blurred vision	Adjust refresh rate settings if available, take visual breaks to reduce fatigue
Glare and contrast issues	Brightness and contrast variations causing discomfort in low-light settings	Ocular discomfort, difficulty reading in dim light	Optimize screen contrast and brightness settings, use antiglare screens, and maintain adequate ambient lighting
Reduced blinking rate	Reduced blink frequency associated with dry eye symptoms	Dry eye symptoms, foreign body sensation, burning	Blink exercises, use of lubricating eye drops, ensure conscious blinking during screen use
Ergonomic constraints	Improper posture and screen positioning leading to ocular and musculoskeletal strain	Neck/shoulder pain, eye ache, visual inefficiency	Ergonomic adjustments: correct screen height, posture correction, use of supportive seating
Augmented and virtual reality effects	Vergence-accommodation conflict causing eye strain and discomfort	Double vision, visual disorientation, nausea	Limit VR/AR use duration, ensure appropriate headset calibration, and alternate with real-world focus tasks

fatigue.[14] However, being a subjective test, CFF should not be used as surrogate for subjective questionnaires of visual fatigue.[15]

Effect of smart phone on refractive status

Myopia has become a major health issue around the world. Prevalence of myopia has been on rise for decades with a rapid surge after the COVID era, and presently, it has acquired the status of global epidemic.[16] The World Health Organization estimates that half of the population of the world may be myopic by 2050.[17] Insufficient time spent in outdoor activities is a well-established risk factor for the development of myopia, whereas the role of prolonged near work remains debatable, though several studies have reported a positive association.[18] Recently, researchers have speculated that smartphone use is an additional risk factor for myopia since it adds considerably to the total hours spent on near work.[19] School-going children are the most susceptible age group to develop myopia with prevalence up to 90% due to introduction of new forms of learning using smart devices as well as changing lifestyle.[20] A study evaluating association between time spent on smart device and change in refractive error in children and adolescents aged 8–14 recommends a screen time not more than 2 h per day to avoid any negative shift in refractive error.[21] A study in 525 teenagers, 12 to 16 years of age, has reported that children with episodes of 20 minutes of continuous screen time were associated with more myopic refractive errors, particularly in those with low outdoor exposure.[22] Sleep patterns among adolescents using smart devices also get adversely affected, and certain studies indicate that refractive error in an individual can be altered by his sleep pattern as well.[23]

Effect of smart phone on intraocular pressure

Ocular adjustments made for using hand-held digital devices like smart phones pertain basically to the near vision reflex with increased demand for accommodation and vergence. Transient fluctuations in IOP in progressing myopia reported by Yan *et al*.[24] have been attributed to the mechanism of accommodation, although the exact mechanism is not yet clear. Another possibility for IOP fluctuation is the disturbance in the circadian rhythm by using smartphones especially at night. Qudsiya *et al*.[25] have reported significant IOP elevation after 4 hours of computer work among healthy young individuals. Ha *et al*.[26] investigated the effect of reading and writing on smart phone on the IOP and concluded that reading or writing on smartphone significantly increases IOP. The effect was faster and greater under the low-light condition (100 lux). A prospective interventional study suggests a time-dependent increase in IOP during the smartphone fixation task that was faster in eyes with a smaller anterior chamber depth less than 2.32 mm or with better VF mean deviation (MD≥−0.22dB) and those who were more than 48 years of age.[27]

Effects of smartphone use on ocular surface

Ocular surface parameters

Tear meniscus parameters: The tear meniscus height, which reflects tear volume, is significantly reduced following intense smartphone use. Wang *et al*.[28] reported that the noninvasive keratograph tear meniscus height (NIKTMH) decreased notably after 2 hours of continuous reading on a smartphone. The proportion of eyes with NIKTMH < 0.20 mm increased significantly post exposure, indicating compromised aqueous tear production.[29] In the Indian pediatric study by Jadeja *et al*.,[30] Schirmer's values were significantly lower in children with moderate-to-severe dry eye correlating with longer screen exposure times (>3.5 hours/day). In contrast, Wang *et al*.[28] found that Schirmer's test values remained relatively unchanged after 2 hours of smartphone use, suggesting that evaporative mechanisms rather than aqueous deficiency predominate in acute digital eye strain. Inomata *et al*.[29] analyzed over 4400 smartphone users and found that ocular surface disease index (OSDI) scores >33 were common among high screen users (>8 hours/day) with statistically significant associations between screen time and symptomatic DED.

Tear osmolarity: Although not consistently measured in all studies, increased tear osmolarity is suggested as a consequence of prolonged screen exposure. Smartphone-associated tear instability, exacerbated by reduced blinking and tear evaporation, likely contributes to hyperosmolarity—a core mechanism in DED pathogenesis as described by Al-Marri *et al*.[31]

Tear evaporation rate and stability: Smartphone use accelerates tear film evaporation due to infrequent and incomplete blinking. Golebiowski *et al*.[32] observed that tear breakup time (TBUT), both fluorescein-based and noninvasive (NIBUT), significantly decreased after smartphone tasks with over 40% of eyes showing TBUT ≤5 seconds following a 60-minute task. These findings suggest a rapid destabilization of the tear film even after short durations of screen exposure.

In a pediatric study, Moon *et al*.[33] reported that children with dry eye had significantly shorter TBUT values than controls correlating strongly with smartphone use duration. Among urban school children, those who used smartphones for more than 3 hours/day showed TBUT values <5 seconds meeting diagnostic thresholds for DED.

Blinking characteristics: Smartphone tasks lead to a substantial decline in blink rate and an increase in incomplete blinks. Chidi-Egboka *et al*.[5] documented a reduction in blink rate from a baseline of 20.8 blinks/min during conversation to 8.9 blinks/min during smartphone gaming in children aged 6–15 years with interblink intervals increasing from 2.9 to 8.7 seconds. Golebiowski *et al*.[32] further observed a progressive increase in incomplete blinks over a 60-minute task which correlated with increased symptom severity.

Meibomian gland function: Smartphone use impairs meibomian gland expressibility and morphology. Wang *et al*.[28] noted that subjects with post-task worsening of DED symptoms had significantly poorer gland function and more evident conjunctival hyperemia. These changes contribute to evaporative dry eye by destabilizing the lipid layer of the tear film.

Symptoms and diagnosis

Ocular symptoms: Prolonged smartphone use is commonly associated with ocular symptoms such as dryness, burning, stinging, foreign body sensation, blurred vision, eye strain, headache, and difficulty refocusing. These symptoms can be broadly categorized into two groups: those related to accommodative stress such as blurred near vision, transient distance blur after screen use, and difficulty shifting focus between distances; and those linked to ocular surface disturbance and dry eye, including irritation, burning, dryness, eye fatigue, headaches, and sensitivity to bright light.

In a large-scale population-based study, Inomata *et al*.[29] investigated 4454 users of smartphone and found a significant link between longer screen exposure and symptomatic dry eye with OSDI scores >33 more common in high screen users (adjusted OR: 1.55; 95% CI: 1.25–1.91). Similarly, Jaiswal *et al*.[34] reported that adolescents using smartphones for over 2 hours/day had nearly twice the risk of experiencing visual discomfort including eye fatigue and blurred vision independent of other contributing factors.

Subjective symptom assessment tools: The OSDI remains the most widely used questionnaire for assessing dry eye symptoms. Multiple studies have documented significant increases in OSDI scores following smartphone or screen-based tasks. Other tools such as the Symptom Assessment in Dry Eye (SANDE) and Instant Ocular Surface Score (IOSS) have also been validated in smartphone-related studies. These instruments effectively capture transient symptom exacerbation following visual display terminal (VDT) exposure and may be useful in screening high-risk individuals.[32]

Diagnostic challenges and risk of overestimation: Accurate diagnosis of DED in the context of recent smartphone use presents a unique clinical challenge. Short-term digital screen exposure can transiently intensify both the symptoms and signs of DED leading to false-positive diagnosis in otherwise healthy individuals. Wang *et al*.[28] demonstrated that the diagnostic rate of DED increased from 61.7% to 74.2% in a cohort of young adults just after 2 hours of continuous smartphone reading without any change in baseline ocular pathology. This acute symptom flare-up may mislead clinicians into diagnosing chronic dry eye when the condition may be temporary and induced by recent digital exposure.

To improve diagnostic accuracy and avoid misclassification, ophthalmologists are advised to adopt standardized preassessment protocols which may include a minimum rest period away from screens prior to clinical examination, documentation of recent screen exposure including duration and type of device used, and consideration of environmental influences such as room lighting, humidity, and posture during device use.

Prevention and management of ocular side effects from smartphone use

The increasing reliance on smartphones and digital devices has been consistently associated with a wide range of ocular disturbances, collectively termed DES. According to Kaur *et al*.,[1] the prevalence of DES in the general population ranges from 50% to 65% with a noticeable rise among school-age children following the COVID-19 pandemic due to increased digital learning. Reported symptoms include eye fatigue, dryness, blurry vision, photophobia, and neck or back pain. Management approaches for DES must therefore be multidimensional [Fig. 1].

Behavioral and ergonomic interventions: These are first-line strategies. The American Academy of Ophthalmology and several DES reviews recommend the 20-20-20 rule—taking a 20-second break to look at an object 20 feet away every 20 minutes of screen use. Maintaining a screen distance of 30–40 cm and positioning the device slightly below eye level reduces ocular surface exposure and supports normal blinking.[2] Kaur *et al*.[1] noted that restricting screen time to less than 4 hours per day can reduce the severity of DES symptoms, particularly among school-aged children. The night shift modes on the apple ipads showed that melatonin levels were still suppressed even when the color gradient was shifted to warmer tones. In order to avoid the decrease of melatonin production, it is suggested to turn down the brightness setting on device in addition to turning on "night shift." These technologies are being studied further in order to create new screens that emit the minimum amount of blue light, but researchers have found that software-controlled blue light reduction has a minimal effect on reducing blue light exposure and melatonin suppression.[2]

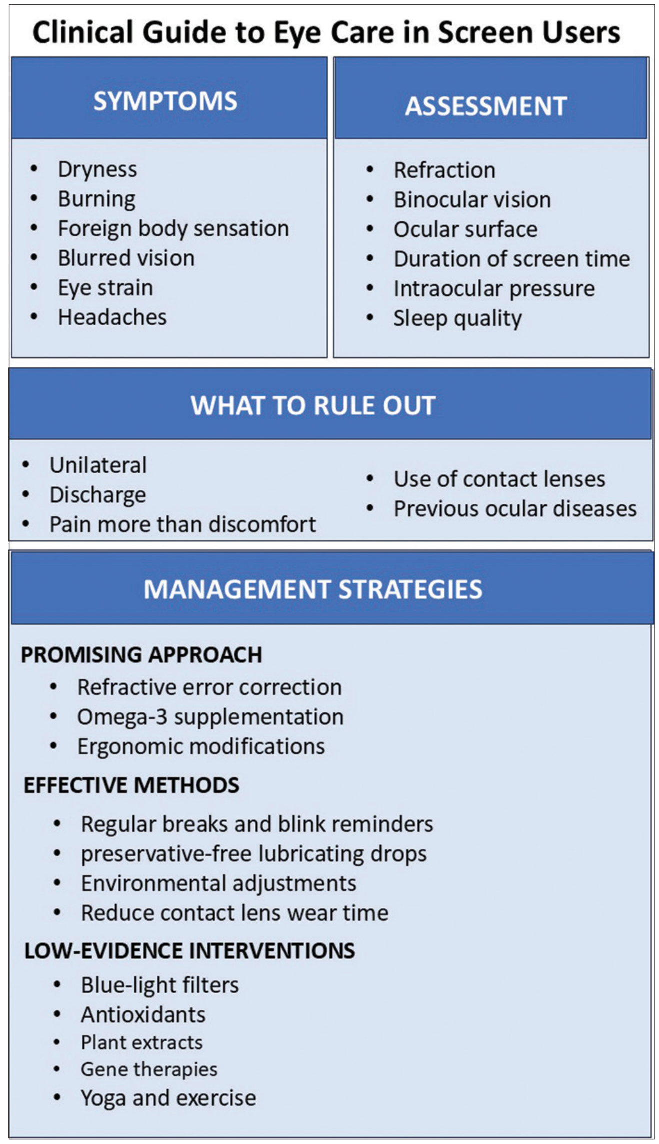

Figure 1: Schematic summary of clinical assessment and evidence-based management strategies for ocular symptoms associated with digital screen exposure

Optical interventions: Blue-light filtering spectacles and screen filters have gained popularity. Standard spectacle lenses typically protect against ultraviolet light (UV) up to a wavelength of 380 nm. To further reduce the potential harm from blue light (wavelengths between 415 and 455 nm), a yellow chromophore coating on anterior and posterior surfaces of spectacle lenses was done. This coating is designed to filter out the hazardous portions of blue light entering the eye. A Cochrane review, which included 17 studies involving 619 subjects, investigated the potential effects and safety of blue-light filtering glasses compared to non-blue filtering lenses.[35] However, randomized trials have shown no significant difference in fatigue or muscle activation in users of blue-blocking lenses compared to control lenses.[6] Subjective improvements in visual comfort and sleep have also been noted in some smaller studies.[36] Blue-light filtering intraocular lenses (IOLs), such as Acrysof Natural, aim to protect the retina from high-energy visible light. Though promising, long-term comparative studies, such as those by Lavric and Pompe, have reported no significant macular differences between blue-filtering and standard UV-filtering IOLs.[37]

To improve tear film integrity: Preservative-free lubricating eye drops are recommended alongside warm compresses to manage meibomian gland dysfunction. Nutritional supplementation with antioxidants such as lutein, zeaxanthin, and omega-3 fatty acids has been shown to improve macular health and absorb high-energy light. The AREDS-2 trial demonstrated that a formulation containing vitamins C and E, zinc, copper, and beta-carotene reduced progression of ARMD by 25%. Plant extracts such as Prunella vulgaris, blueberry, and curcumin have shown retinal protective effects against oxidative stress in experimental models.[38]

Emerging treatments: It includes gene therapies targeting oxidative stress and photoreceptor apoptosis. Xu *et al*.[39] demonstrated that REG1A gene activation preserved mitochondrial function and prevented retinal cell death. Ouyang *et al*.[40] used RNA-seq in murine models to identify 737 differentially expressed genes related to blue light exposure including miR-34a-5p. Nanoparticle-based agents like alpha-mangostin and flavonoids such as kaempferol have also been studied for neuroprotection in light-exposed retinal models.

Strengths and limitations: This review presents a broad and clinically relevant overview of the ocular effects of smartphone use drawing from diverse populations and multiple aspects of visual health. Its strengths include practical insights, clear visual aids, and a strong focus on preventive strategies. However, as a narrative review, it does not include systematic bias assessment or pooled data analysis. The included studies vary in their design, duration, and outcome measures, which limits direct comparison of results. Additionally, many studies rely on subjective symptoms reporting, which may introduce bias. There are also insufficient long-term data, particularly regarding chronic effects in young users.

Conclusion and recommendations: Smartphone-associated DES is a rising concern, primarily driven by prolonged screen use, reduced blinking, and tear film instability. Evidence supports limiting daily screen exposure to under 4 hours, adopting the 20-20-20 rule, and maintaining optimal ergonomics to reduce visual stress. Conscious blinking and regular use of preservative-free lubricating drops are effective in relieving symptoms. Omega-3 supplementation may offer additional support. However, blue-light filters and alternative therapies lack consistent scientific validation. Routine screening using tools like the OSDI is recommended for early detection, especially in high-risk groups such as students, contact lens users, and digital workers.

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