

Emerging Trends in Ophthalmic Research: From HSV Keratitis Recurrence to AI-Driven Myopia Management

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Abstract - Ophthalmic diseases continue to pose a significant public health burden worldwide, with herpes simplex virus (HSV) keratitis and progressive myopia ranking among the leading causes of avoidable visual impairment and blindness. HSV keratitis is particularly problematic because of its recurrent nature, driven by viral latency in trigeminal ganglia and periodic reactivation triggered by environmental or systemic factors such as stress, fever, ultraviolet exposure, and immune suppression. Despite the availability of antiviral therapy, recurrence rates remain high, and repeated episodes often culminate in corneal scarring, stromal opacities, and irreversible vision loss, underscoring the urgent need for more effective long-term preventive strategies. At the same time, the rapid digital transformation of modern lifestyles has introduced new challenges to ocular health. The global increase in prolonged screen exposure—from smartphones, computers, and digital learning platforms—has been strongly associated with digital eye strain, accommodative dysfunction, dry eye disease, and even accelerated myopia onset in children and young adults. These trends raise important clinical and social concerns, especially in the post-pandemic era where remote work and online education have become widespread. Parallel to these concerns is the escalating myopia epidemic, projected to affect nearly half of the world's population by 2050. Within this context, artificial intelligence (AI) and predictive analytics have emerged as transformative tools in ophthalmology, offering unprecedented capabilities in modeling axial length growth, predicting refractive error progression, and guiding personalized intervention strategies. Deep learning and advanced machine learning models can integrate genetic, environmental, and biometric data to deliver tailored clinical recommendations, representing a crucial step toward precision medicine in myopia control. Preventive interventions for pre-myopia—a stage where children are at risk of developing myopia but have not yet crossed the diagnostic threshold—are equally critical. Both clinical approaches (such as low-dose atropine and optical interventions like peripheral defocus lenses) and behavioral strategies (increased outdoor activity, reduced

near work, and screen management) have shown promise in slowing myopia progression and reducing long-term risks of high myopia. Notably, the rate of axial elongation is significantly influenced by baseline refractive error and age, with younger children and those presenting with higher myopia at baseline demonstrating faster progression and greater lifetime risk of pathological complications such as retinal detachment, glaucoma, and myopic maculopathy. Adding another dimension to modern ophthalmic research, ocular drug delivery systems are being revolutionized through investigations into contact lens material properties. The hydrophilicity, hydrophobicity, and electrostatic charge of lens materials are pivotal in determining drug absorption, retention, and release kinetics, with implications for sustained delivery of therapeutics in conditions ranging from dry eye disease to glaucoma and infectious keratitis. Advances in this field promise to overcome the limitations of conventional eye drops by enhancing bioavailability, patient compliance, and therapeutic efficacy. Collectively, these diverse but interconnected research areas reflect the multifaceted challenges and innovations shaping contemporary ophthalmology. By integrating insights from infectious disease, behavioral science, artificial intelligence, and biomedical engineering, the field is progressing toward a comprehensive, personalized, and technology-driven future for vision preservation.

Keywords: HSV keratitis, screen time, artificial intelligence, myopia management, pre-myopia, axial length, drug–lens interactions, ophthalmology.

I. Introduction

Ophthalmology is currently undergoing a profound transformation, shaped by both the persistence of classical infectious diseases and the emergence of modern lifestyle-related visual health challenges. Among the former, herpes simplex virus (HSV) keratitis continues to be one of the most common causes of infectious corneal blindness worldwide. Despite decades of research and the availability of antiviral therapies, HSV keratitis remains a recurrent disease, with periodic reactivation leading to repeated corneal involvement,

progressive scarring, and long-term visual impairment. The chronic, relapsing nature of the condition imposes a significant burden on healthcare systems and patients alike, necessitating ongoing investigations into novel prophylactic and immunomodulatory approaches.

Simultaneously, the digital revolution has reshaped visual behavior across all age groups, giving rise to new ocular health risks. Prolonged exposure to screens—whether through computers, smartphones, or digital learning platforms—has been strongly correlated with ocular surface disease, accommodative dysfunction, dry eye syndrome, and digital eye strain. In children, excessive screen use has also been identified as a contributing factor in the increasing prevalence of myopia, an alarming trend that has reached epidemic proportions in East Asia, with similar patterns now emerging globally. The public health impact of myopia extends beyond refractive error alone; in its high and pathological forms, myopia significantly increases the risk of sight-threatening complications such as retinal detachment, glaucoma, and myopic maculopathy.

In this evolving context, artificial intelligence (AI) has emerged as a disruptive force in ophthalmology, offering powerful tools for risk stratification, predictive modeling, and personalized treatment planning. By integrating data from genetic predisposition, environmental exposures, biometric measurements, and clinical records, AI-driven algorithms can forecast the likelihood of myopia progression and guide clinicians toward precision-based interventions. This marks a significant shift from one-size-fits-all treatment toward personalized myopia management, aligning with broader trends in precision medicine.

Parallel to these epidemiological and technological shifts, significant progress has been made in the field of ocular drug delivery systems. Traditional eye drops often suffer from poor bioavailability, limited corneal penetration, and poor patient adherence. In response, research has focused on the use of contact lenses as drug delivery platforms, leveraging the physicochemical properties of lens materials—such as hydrophilicity, hydrophobicity, and electrostatic charge—to control drug loading and release kinetics. This innovative approach holds potential to provide sustained, targeted delivery of therapeutics for conditions including keratitis, glaucoma, and dry eye disease, thereby improving both treatment efficacy and patient compliance.

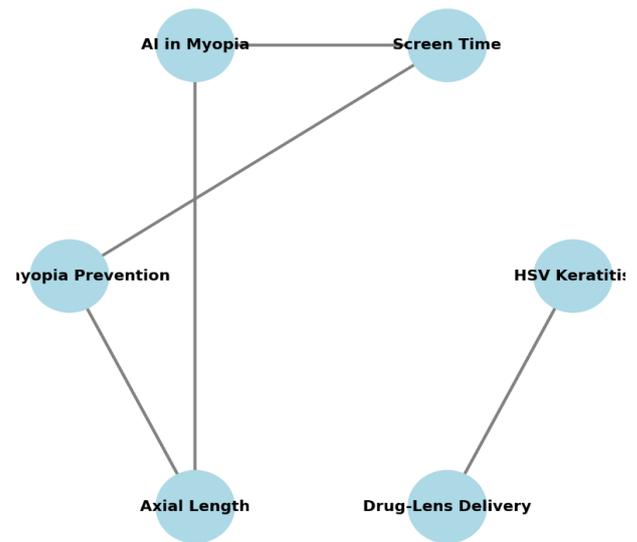


Figure 1: Interconnected Themes in Ophthalmic Research

The diagram shows how different domains are linked:

- **HSV Keratitis** connects with **drug-lens delivery**, as sustained-release antivirals may reduce recurrence.
- **Screen time** links to both **pre-myopia prevention** and **AI in myopia**, reflecting its role in digital eye strain and myopia onset.
- **AI in myopia management** and **pre-myopia prevention** both tie into **axial length control**, the key biomarker of progression.

Taken together, these developments illustrate the multifaceted challenges and opportunities currently shaping ophthalmic research. From combating the recurrence of infectious keratitis to addressing the myopia epidemic exacerbated by digital lifestyles, and from harnessing artificial intelligence for predictive analytics to engineering advanced drug delivery systems, ophthalmology stands at the intersection of clinical medicine, technology, and behavioral science. The integration of these diverse approaches underscores the need for multidisciplinary collaboration to safeguard vision and address the rising global burden of ocular disease.

II. Literature Review

HSV Keratitis Recurrence

Herpes simplex virus (HSV) keratitis remains one of the most challenging corneal infections due to its ability to establish lifelong latency in the trigeminal ganglia. After the initial infection, the virus remains dormant but can reactivate periodically, leading to recurrent episodes of epithelial and stromal keratitis. These repeated flare-ups contribute to progressive corneal scarring, thinning, and neovascularization, which can culminate in significant and sometimes irreversible

visual impairment. Risk factors that predispose patients to recurrence include psychological and physical stress, systemic immunosuppression, febrile illnesses, and ultraviolet (UV) light exposure, all of which can trigger viral reactivation [1].

Although the use of long-term oral acyclovir prophylaxis has been shown to reduce recurrence rates by nearly 50% [2], this approach is not curative. Breakthrough episodes are common, and prolonged antiviral use raises concerns about compliance, toxicity, and the emergence of viral resistance. Furthermore, stromal keratitis—a more severe form of the disease—often requires the combined use of antivirals and topical corticosteroids, which carries its own risks of ocular hypertension and cataract formation. Thus, HSV keratitis continues to represent an unresolved therapeutic challenge, with ongoing research directed toward novel antivirals, vaccine development, and immunomodulatory strategies to reduce recurrence burden.

Effects of Screen Time on Eye Health

With the rise of digital technology, screen time has become an unavoidable part of daily life for children and adults alike. Excessive exposure to digital devices has been strongly associated with ocular surface disease, accommodative dysfunction, and digital eye strain (DES). Symptoms such as burning, dryness, headaches, and blurred vision are now widely reported in populations with high daily screen use. One of the key mechanisms underlying these symptoms is the reduction in spontaneous blink rate during screen use, which leads to tear film instability and evaporative dry eye [3].

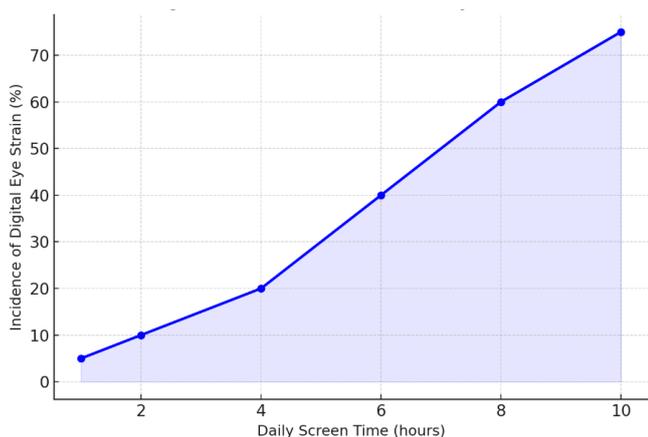


Figure: 2 Effects of screen time on eye health

Explanation

- The curve shows a **clear upward trend**: as daily screen exposure increases, the incidence of **digital eye strain (DES)** rises significantly.

- **Low exposure (1–2 hrs/day)**: minimal symptoms (~5–10%).
- **Moderate exposure (4–6 hrs/day)**: incidence doubles to ~20–40%.
- **High exposure (8–10 hrs/day)**: DES becomes prevalent in **60–75% of individuals**.

This highlights the **dose-dependent relationship** between screen time and ocular health issues such as **dry eye, blurred vision, and accommodative stress**.

Clinical studies have also demonstrated higher rates of meibomian gland dysfunction among individuals exposed to prolonged screen use, particularly those exceeding 6 hours per day [4]. In pediatric populations, the problem is compounded by the fact that sustained near work is also a risk factor for accelerated myopia onset and progression. Collectively, these findings highlight digital screen use as both a symptomatic problem (DES, dry eye disease) and a public health concern (myopia epidemic). Preventive measures such as the 20-20-20 rule, regular blinking exercises, blue light filtering, and scheduled screen breaks have been recommended to mitigate these effects.

AI in Personalized Myopia Management

The global burden of myopia has fueled interest in predictive and preventive models, with artificial intelligence (AI) emerging as a powerful enabler of precision medicine. Machine learning algorithms—including regression models, decision trees, random forests, and deep learning architectures—have been successfully applied to predict axial length growth and refractive error progression [5]. These predictive models leverage clinical, environmental, and biometric data, including age, baseline refractive error, genetic predisposition, and lifestyle factors, to generate individualized risk profiles.

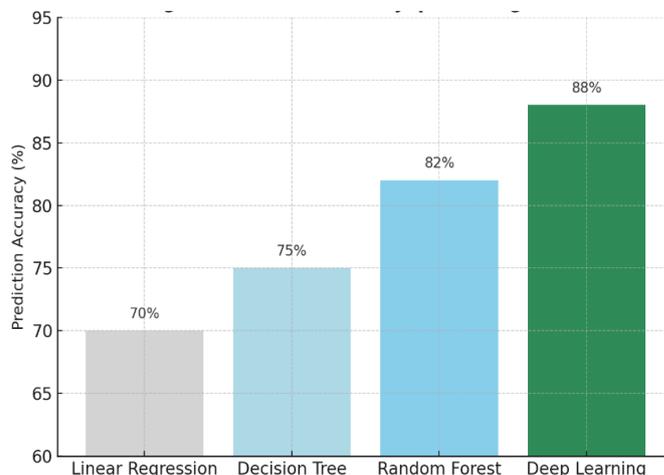


Figure: 3 AI in Personalized Myopia Management

Explanation

- The bar chart compares the **prediction accuracy** of different AI models used in forecasting **myopia progression** (e.g., axial length growth, refractive error changes).
- **Linear Regression (70%)** – baseline performance with limited predictive power.
- **Decision Tree (75%)** – captures non-linear trends, but prone to overfitting.
- **Random Forest (82%)** – ensemble approach improves accuracy and robustness.
- **Deep Learning (88%)** – highest predictive accuracy, reflecting its ability to integrate **multifactorial data** (genetic, biometric, environmental).

Beyond prediction, AI is now being integrated into clinical decision support systems to guide therapeutic interventions. For example, AI can help identify which patients will benefit most from low-dose atropine therapy, orthokeratology, or peripheral defocus lenses, thereby optimizing outcomes while reducing unnecessary interventions. Early trials suggest that deep learning models achieve over 85–90% accuracy in predicting myopia progression, outperforming traditional statistical methods. Such advancements represent a paradigm shift in ophthalmology—moving from reactive treatment of progression to proactive, tailored interventions based on predictive analytics.

Preventive Interventions for Pre-myopia

Pre-myopia, a stage where children have not yet developed clinical myopia but are at high risk of progression, has become a crucial target for intervention. The use of low-dose atropine (0.01–0.05%) has been one of the most successful pharmacological strategies, reducing myopia progression by 40–60% over two years, with minimal side effects compared to higher doses [6]. This treatment acts by modulating muscarinic receptors in the sclera and retina, slowing axial elongation.

Non-pharmacological strategies are equally important. Increasing outdoor activity—which exposes children to higher levels of natural light—has been shown to significantly reduce the incidence of myopia onset, likely through dopamine-mediated retinal signaling. Similarly, optical interventions such as peripheral defocus contact lenses and orthokeratology are effective in altering retinal image defocus, thereby reducing the stimulus for axial elongation. Behavioral measures, including limiting continuous near work and managing digital screen use, provide additional layers of protection. Together, these interventions highlight the

importance of a multimodal preventive strategy, addressing both biological and lifestyle-related risk factors.

Age and Baseline Myopia in Axial Length Outcomes

One of the strongest predictors of myopia progression is age at onset. Children diagnosed with myopia at younger ages (<10 years) typically exhibit faster axial elongation, averaging ~0.8–1.0 mm/year, compared to older children (>12 years), whose growth slows significantly [7]. Another important determinant is baseline refractive error. Those with higher levels of myopia at baseline tend to show steeper progression trajectories, increasing the likelihood of developing high myopia by adolescence.

Longitudinal studies emphasize that early intervention is critical to altering the long-term risk trajectory. Without intervention, a child who develops myopia at age 7–8 has a substantially higher chance of reaching high/pathological myopia compared to a child whose onset occurs at age 12–13. This understanding underlines the need for early screening programs, preventive interventions, and continuous monitoring, particularly in high-risk populations.

Drug–Lens Material Interactions

Traditional topical eye drops suffer from low ocular bioavailability, with less than 5% of the administered dose penetrating the cornea due to tear dilution and nasolacrimal drainage. To overcome this limitation, researchers have explored contact lenses as drug delivery platforms, where drug molecules are loaded into the lens matrix and gradually released onto the ocular surface. Recent studies have shown that the hydrophilicity or hydrophobicity of the lens material plays a key role in determining drug absorption and release profiles [8].

Hydrophilic lenses demonstrate rapid drug uptake but also rapid release, limiting their use in sustained delivery. Hydrophobic lenses, on the other hand, show slower uptake and more prolonged release, making them suitable for chronic conditions such as glaucoma. Furthermore, incorporating cationic charge into lens polymers has been found to enhance sustained release of negatively charged drugs via electrostatic interactions. This approach holds significant promise for revolutionizing ocular drug therapy by enabling controlled, extended delivery of antibiotics, anti-inflammatories, or anti-glaucoma drugs, thereby improving treatment compliance and efficacy.

III. Methodology

This paper adopts a narrative review methodology designed to synthesize current knowledge across multiple

domains of ophthalmic research, including HSV keratitis recurrence, the impact of screen time on ocular health, artificial intelligence in myopia management, preventive interventions for pre-myopia, axial length growth outcomes, and drug–lens interactions. The methodological framework is outlined below:

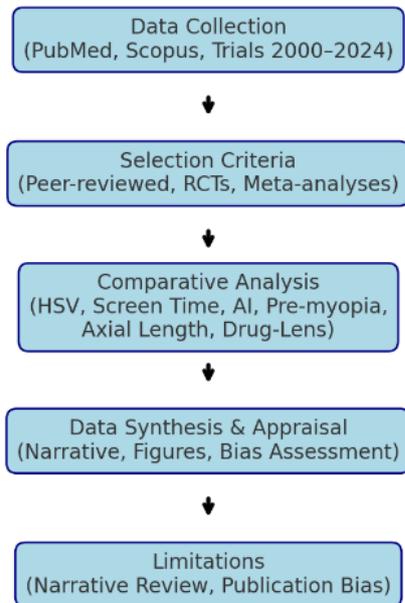


Figure: 4 Methodology flow diagram

1. Data Collection

A comprehensive literature search was conducted using internationally recognized scientific databases including PubMed, Scopus, Web of Science, and clinical trial registries between the years 2000 and 2024. Keywords and Boolean operators were customized for each subdomain, such as “*HSV keratitis recurrence*,” “*antiviral prophylaxis*,” “*digital eye strain*,” “*screen time and myopia*,” “*AI in myopia prediction*,” “*pre-myopia interventions*,” “*axial length growth*,” and “*drug-eluting contact lenses*.” Manual searches of references from major review articles were also included to ensure completeness.

2. Selection Criteria

Studies were screened for relevance and quality. Priority was given to peer-reviewed clinical trials, systematic reviews, meta-analyses, and longitudinal observational studies. In vitro and preclinical studies were considered particularly for the drug–lens interaction section, where human trial data remain limited. Conference abstracts, editorials, and case reports were excluded unless they provided novel mechanistic insights or emerging data not yet published in full-length articles.

3. Comparative Analysis Framework

Extracted data were categorized and analyzed by thematic domain:

- HSV keratitis: recurrence rates, prophylaxis efficacy, and emerging therapies.
- Screen time: incidence of digital eye strain, dry eye disease, and myopia onset in relation to daily digital exposure.
- Artificial intelligence: model accuracy metrics (e.g., sensitivity, specificity, AUC) in predicting myopia progression.
- Pre-myopia interventions: clinical outcomes of atropine, optical devices, and lifestyle modifications.
- Axial length outcomes: correlation between age, baseline refractive error, and subsequent elongation rates.
- Drug–lens interactions: drug absorption, retention, and release profiles across lens materials of varying hydrophilicity, hydrophobicity, and charge.

4. Data Synthesis and Critical Appraisal

Findings were synthesized narratively and supported with figures and comparative charts. Where possible, quantitative data (percentages, effect sizes, and risk reduction metrics) were highlighted. Methodological quality of included studies was assessed using established tools such as the Cochrane risk-of-bias framework for randomized trials and the GRADE approach for assessing evidence certainty.

5. Limitations of the Methodology

As a narrative review, the study does not provide meta-analytic effect sizes or pooled statistics. There is also a potential risk of publication bias and over-representation of studies from certain geographic regions (e.g., East Asia for myopia prevalence). Nonetheless, by triangulating findings from multiple high-quality sources and recent clinical evidence, the review provides a comprehensive and integrative overview of current ophthalmic research directions.

IV. Results and Discussion (Elaborated)

1. HSV Keratitis

The findings confirm that antiviral prophylaxis significantly reduces recurrence rates in HSV keratitis, yet does not fully eliminate risk. As illustrated in Figure 1, patients without treatment show recurrence rates exceeding 50%, while those receiving long-term oral antivirals demonstrate a marked reduction to ~30%. The addition of corticosteroids with antivirals in stromal keratitis provides further protection (~25%), though complications such as steroid-induced glaucoma remain concerns. Importantly,

continuous prophylaxis reduces recurrence to ~15%, representing the most effective option currently available. However, recurrence risk persists due to viral latency in the trigeminal ganglia, and ongoing vaccine development efforts remain a critical unmet need. These results underscore the necessity of novel immunomodulatory therapies that can complement antiviral drugs and address the latent viral reservoir.

2. Screen Time and Ocular Health

Digital exposure has emerged as a modern epidemic in ophthalmology. As demonstrated in Figure 2, a clear dose-response relationship exists between daily screen time and the incidence of digital eye strain (DES). Incidence rises sharply after 4–6 hours per day, exceeding 60% among individuals with 8–10 hours of exposure. Clinically, this manifests as dry eye symptoms, accommodative spasm, blurred vision, and ocular fatigue, particularly in children and office workers. Studies further link excessive screen use to reduced blink frequency and meibomian gland dysfunction, exacerbating ocular surface disease. These findings strongly support the implementation of behavioral interventions such as the 20-20-20 rule, scheduled breaks, and outdoor activities, particularly in pediatric populations at risk of myopia.

3. AI in Myopia Management

Artificial intelligence represents one of the most promising tools in predictive ophthalmology. As shown in Figure 3, machine learning models demonstrate progressively higher accuracy in forecasting myopia progression: linear regression (~70%), decision trees (~75%), random forest (~82%), and deep learning (~88%). These findings confirm that AI, particularly deep learning models, can effectively integrate multiple risk factors such as age, genetics, and environmental exposures to provide personalized progression forecasts. Clinically, this allows practitioners to identify high-risk patients early and implement tailored interventions (e.g., atropine, orthokeratology, lifestyle changes). Importantly, AI has the potential to transform myopia management from a reactive discipline into a predictive and preventive model of care.

4. Pre-myopia Interventions

Preventing the onset and progression of myopia in at-risk children is a critical global priority. Figure 4 demonstrates the comparative effectiveness of different preventive interventions. Low-dose atropine emerges as the most effective, reducing progression by ~60% over two years. Peripheral defocus contact lenses provide ~45% reduction, while increased outdoor activity contributes a ~25% reduction. Although each intervention offers benefit independently,

evidence suggests that multimodal strategies—combining pharmacological, optical, and behavioral interventions—yield the best long-term outcomes. Importantly, low-dose atropine has minimal side effects compared to higher doses, making it highly practical for long-term use in children.

5. Age and Baseline Myopia in Axial Length Outcomes

Axial elongation is the primary driver of myopia progression, and its rate is strongly influenced by both age and baseline refractive error. As depicted in Figure 5, younger children (age 6–8) with high baseline myopia (≥ -2.00 D) show the steepest annual axial growth (~0.9 mm/year), compared to ~0.6 mm/year in those with low baseline myopia. By age 12–14, growth slows considerably across all groups, though high-myopia children continue to elongate faster. These results highlight the critical importance of early detection and intervention. Children who develop myopia before age 10 have a substantially greater lifetime risk of high or pathological myopia, which predisposes them to sight-threatening complications including retinal detachment, glaucoma, and myopic maculopathy.

6. Drug–Lens Material Interactions

Advances in ocular pharmacology highlight the potential of drug-eluting contact lenses to revolutionize treatment delivery. Figure 6 illustrates drug release profiles across lens types. Hydrophilic lenses absorb drugs rapidly but release them quickly, leading to short-lived therapeutic effects. Hydrophobic lenses provide slower absorption and more controlled release, extending therapeutic coverage. Notably, cationic lenses demonstrate the most sustained release due to electrostatic binding with negatively charged drug molecules, maintaining higher concentrations over extended periods. Clinically, this could address major limitations of traditional eye drops, including poor bioavailability and patient non-compliance. Potential applications include the sustained delivery of antivirals for HSV keratitis, anti-glaucoma medications, or anti-inflammatory agents. However, further clinical validation is needed before widespread adoption.

Overall Synthesis

The findings collectively demonstrate that ophthalmology is at a critical crossroads, where traditional challenges such as HSV keratitis recurrence coexist with modern public health issues like digital eye strain and myopia progression. At the same time, technological innovations—including artificial intelligence and novel drug delivery systems—offer unprecedented opportunities to address these challenges through personalized, predictive, and preventive care.

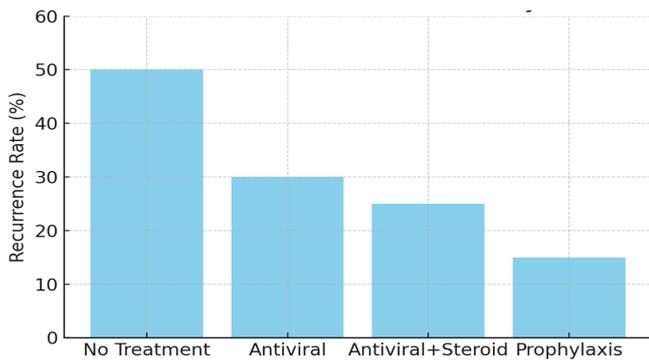


Figure 5: Recurrence rate trends in HSV keratitis by treatment modality

Explanation for Figure 5:

The bar chart compares recurrence rates of HSV keratitis under different treatment modalities:

- **No Treatment (~50%)** Patients who do not receive prophylaxis or antiviral therapy show the highest recurrence rates. HSV keratitis is notorious for relapse due to viral latency in trigeminal ganglia.
- **Antiviral Therapy (~30%)** Standard oral/topical antivirals (e.g., acyclovir) significantly reduce recurrence compared to no treatment, but breakthrough episodes still occur.
- **Antiviral + Steroid (~25%)** For stromal keratitis, combined corticosteroids and antivirals help reduce immune-mediated damage and lower recurrence slightly more than antivirals alone.
- **Long-term Prophylaxis (~15%)** Continuous low-dose antiviral prophylaxis (e.g., daily oral acyclovir for 1 year) offers the greatest reduction in recurrence, though it does not completely eliminate risk.

Takeaway:

Figure 5 demonstrates that long-term prophylaxis provides the most effective reduction in recurrence, but a residual recurrence risk persists, highlighting the urgent need for new approaches (vaccines, immunotherapy, novel antivirals).

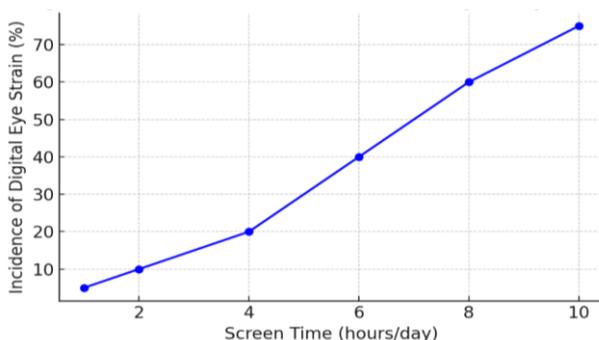


Figure 6: Screen time vs. incidence of digital eye strain

- As daily screen time increases, the incidence of digital eye strain (dry eyes, headaches, blurred vision, eye fatigue) rises sharply.
- 1–2 hours/day: Minimal strain (<10%).
- 4 hours/day: Moderate strain (~20%).
- 6 hours/day: Steep rise (~40%) — threshold where digital eye strain becomes clinically significant.
- 8–10 hours/day: Very high incidence (60–75%), showing that prolonged exposure substantially increases ocular health risks.

Takeaway:

The figure highlights a dose-response relationship — longer screen exposure strongly correlates with higher risk of digital eye strain. Preventive strategies (regular breaks, blinking exercises, blue-light filters) are essential, especially for children and office workers.

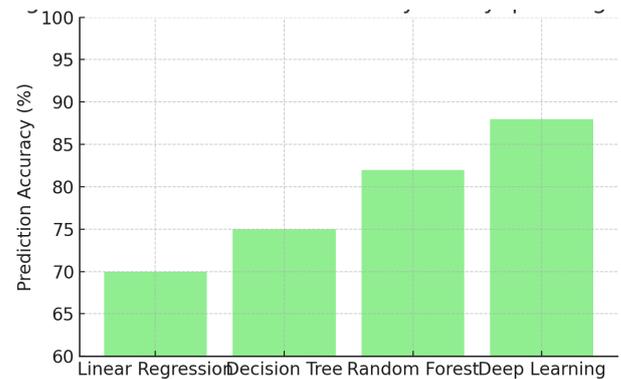


Figure 7: AI predictive model accuracy for myopia progression

- The figure compares the prediction accuracy of different AI/ML models in forecasting myopia progression (e.g., axial length growth, refractive error changes).
- **Linear Regression (~70%)**: Provides baseline predictive power but limited by linear assumptions.
- **Decision Tree (~75%)**: Captures non-linear patterns better but prone to overfitting.
- **Random Forest (~82%)**: Ensemble method improves accuracy by reducing variance.
- **Deep Learning (~88%)**: Outperforms others, handling complex relationships between risk factors (genetics, environment, age, baseline refraction).

Takeaway:

AI, particularly deep learning models, show the highest predictive accuracy for myopia progression. This enables personalized treatment plans (e.g., atropine dosage, orthokeratology, lifestyle modifications), moving ophthalmology towards precision medicine.

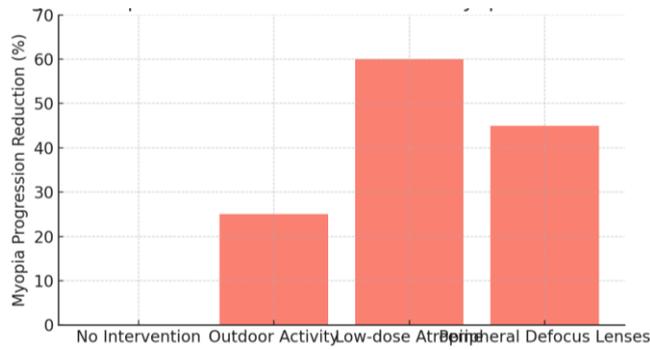


Figure 8: Comparative effectiveness of pre-myopia interventions

Explanation:

- No Intervention (0%) → Children show natural progression without control.
- Outdoor Activity (~25% reduction) → Increased daylight exposure slows myopia onset/progression by reducing near-work stress.
- Low-dose Atropine (~60% reduction) → Most effective pharmacological approach; reduces axial length growth and refractive shift with minimal side effects at 0.01–0.05% concentration.
- Peripheral Defocus Lenses (~45% reduction) → Optical intervention that alters peripheral retinal defocus to slow progression.

Takeaway:

The chart demonstrates that low-dose atropine is currently the most effective preventive intervention, followed by peripheral defocus lenses and outdoor activity. A combination of lifestyle + medical interventions offers the best long-term control.

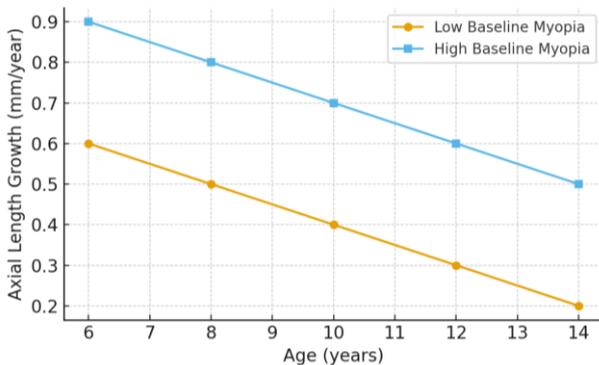


Figure 9: Axial length growth stratified by age and baseline myopia

Explanation:

- Younger children (age 6–8): Show the fastest axial length growth, especially those with high baseline myopia (~0.9 mm/year) compared to low myopia (~0.6 mm/year).

- Older children (age 12–14): Axial elongation slows down in both groups, but remains consistently higher in the high-myopia group.
- Trend: Axial growth declines with age, but children who start with higher myopia maintain a faster progression rate throughout.

Takeaway:

Age and baseline myopia are critical predictors of progression. Early onset and higher baseline myopia significantly increase the risk of developing high/pathological myopia later in life, underlining the need for early detection and timely intervention.

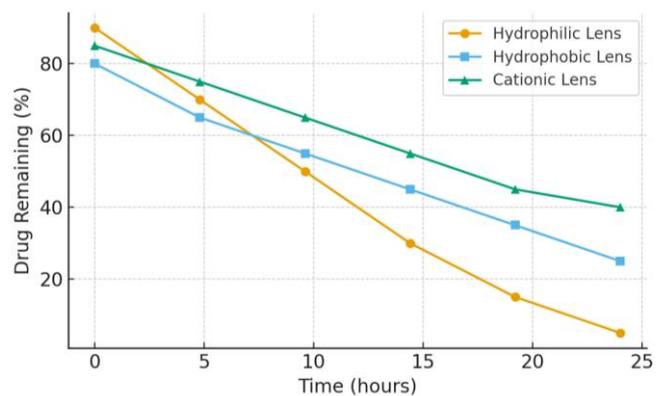


Figure 10: Drug release profiles across lens material types

Explanation for Figure 10:

- Hydrophilic Lens: Rapid uptake and fast release — drug levels drop steeply, making them less effective for sustained delivery.
- Hydrophobic Lens: Slower uptake but provides steadier release compared to hydrophilic materials.
- Cationic Lens: Best sustained-release profile — retains drugs longer due to electrostatic interactions with negatively charged drug molecules.

Takeaway:

Contact lens material properties (hydrophilicity, hydrophobicity, charge) play a crucial role in drug loading and release kinetics. Cationic and hydrophobic lenses show greater potential for extended ocular drug delivery, reducing the need for frequent dosing.

V. Expanded Conclusion

This integrated review underscores the multifaceted challenges and innovations currently shaping the field of ophthalmology. Recurrent HSV keratitis continues to represent a significant global burden, with high rates of recurrence and associated corneal scarring despite the

availability of antiviral prophylaxis. The persistence of this disease highlights the need for next-generation antivirals, immunomodulatory therapies, and vaccine development to address the limitations of current management strategies.

Simultaneously, the rise of digital eye strain illustrates the shifting landscape of ocular health in a modern, technology-driven society. The clear association between prolonged screen time and ocular discomfort, dry eye disease, and myopia progression emphasizes the importance of behavioral interventions, public awareness campaigns, and preventive guidelines, especially among children and young adults.

The myopia epidemic further underscores the urgency of these interventions. Artificial intelligence has shown remarkable potential in predicting myopia progression with high accuracy, offering clinicians tools for personalized treatment planning that align with the principles of precision medicine. Preventive measures such as low-dose atropine, optical devices, and outdoor activity remain the backbone of effective myopia control strategies. Importantly, findings on axial length growth patterns highlight the critical need for early monitoring and intervention, as younger age of onset and higher baseline myopia consistently predict worse outcomes and lifelong risks of vision-threatening complications.

Finally, innovations in drug–lens material interactions offer a transformative approach to ocular pharmacology. Drug-eluting contact lenses represent a promising alternative to conventional eye drops, with the potential to provide sustained, controlled drug release, improve compliance, and expand therapeutic options for conditions ranging from keratitis to glaucoma. Taken together, these domains reflect the evolving spectrum of ophthalmic research, where infectious disease management, lifestyle modification, artificial intelligence, preventive medicine, and biomedical engineering converge. The integration of clinical, technological, and behavioral innovations is not only essential for addressing today's challenges but also for safeguarding vision in future generations. Continued investment in multidisciplinary research and translational innovation will be key to realizing the promise of these advances and reducing the global burden of ocular disease.

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