Artificial Intelligence in Microbial Keratitis

Esther Leong
Ophthalmology Resident
Royal Melbourne Hospital/Save Sight Institute

The Royal Melbourne Hospital

THE UNIVERSITY OF SYDNEY

Acknowledgement of Country

Background

- Microbial keratitis (MK) is the fifth leading cause of blindness worldwide
- Estimated 1.5-2 million cases of monocular blindness each year [1]
- Incidence higher in LMICs ranging from 113 to 799 cases per 100,000 people, compared to 2.5 to 40.3 cases per 100,000 in HICs
- Driven by factors such as increased exposure to ocular trauma, agricultural injuries, poor ocular hygiene and limited access to timely and specialised eye care

Introduction

- MK is a rapidly progressive, sight-threatening corneal infection requiring urgent and accurate diagnosis
- Encompasess infections caused by bacteria, fungi, viruses and protozoa (Acanthamoeba)
- Clinical differentiation can be challenging
- Diagnostic delay can lead to corneal perforation, endophthalmitis and blindness [2]

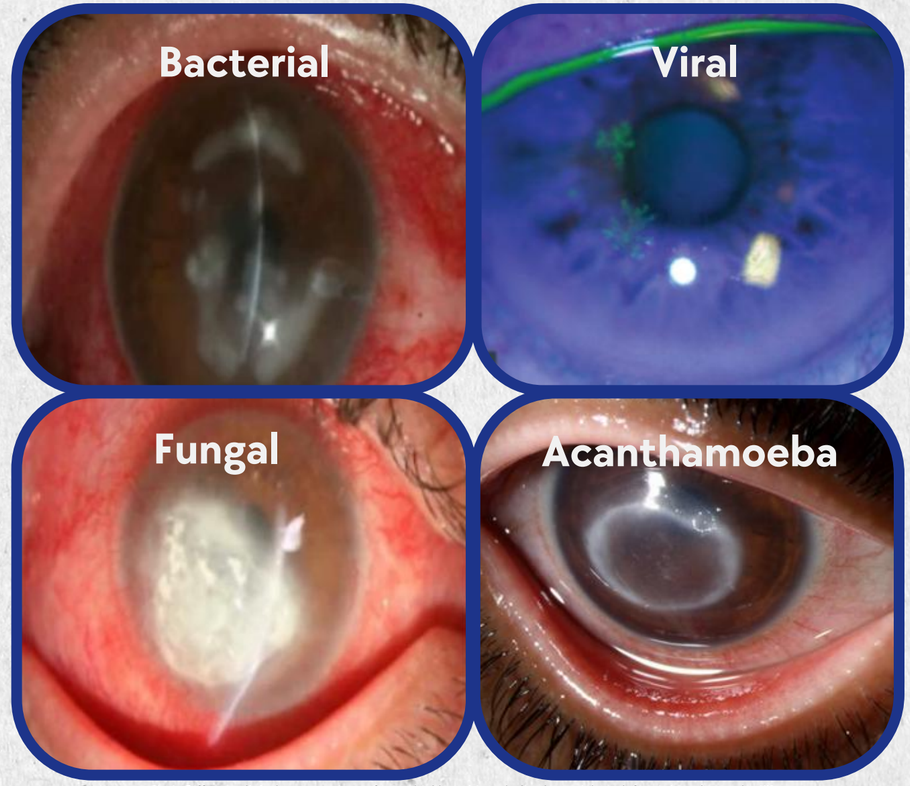
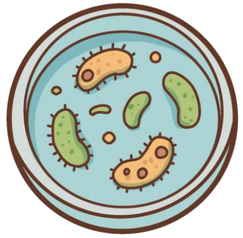


Fig 1. Different clinical presentations of microbial keratitis including bacterial, viral, fungi, Acanthamoeba [3]

Current Challlenges

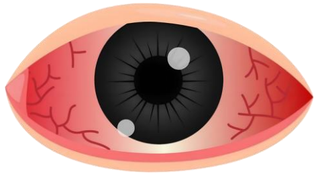
1 DIAGNOSTIC DELAYS

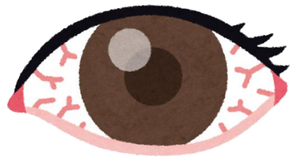
Microbiological confirmation may be delayed or unavailable (culture-negative), delaying diagnosis and treatment [4]



2 VARIABILITY IN CLINICAL PRESENTATION

Clinical differentiation is often difficult in early disease with significant phenotypic overlap between pathogens [5]





3 LIMITED ACCESS TO EYE SPECIALISTS

Subspecialist expertise may not be universally accessible, leading to delays in diagnosis and treatment

Understanding these challenges is essential to appreciate the role of AI in improving diagnostic accuracy

Why consider AI?

- Diagnosis of MK relies heavily on visual assessment
- Imaging modalities such as slit-lamp, in vivo confocal microscopy (IVCM) generate structured visual data [6]
- AI excels at pattern recognition in complex image datasets
- To better understand the current evidence, a systematic review of studies evaluating AI-based diagnostic models for MK was conducted

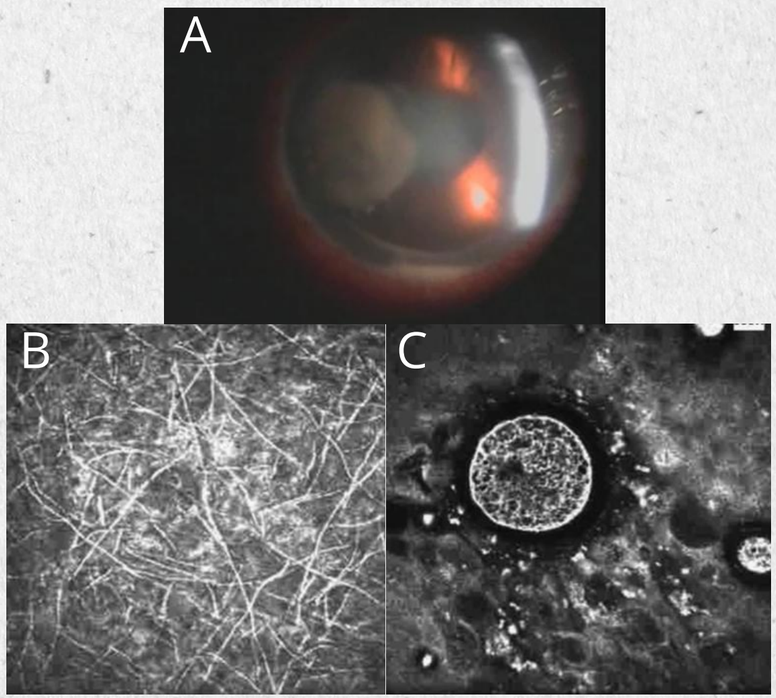


FIG 2. A: SLIT-LAMP PHOTOGRAPHY OF A PATIENT WITH SUSPECTED MICROBIAL KERATITIS;
B: In vivo confocal microscopy showing linear fungal filaments; C: double-walled acanthamoeba cysts (× 800) [7]

KEY QUESTION: Can AI improve early, accuarate and scalable diagnosis of microbial keratitis?

Methods

- This systematic review was conducted following PRISMA 2020 guidelines
- Study design: Primary research studies from 2020-2025 reporting original AI model development & validation
- Risk of bias tool using QUADAS-2

INCLUSION CRITERIA

- P: Patients with suspected or confirmed microbial keratitis (bacterial, fungal, viral, or parasitic)
- I: Artificial intelligence or machine learning algorithms for diagnosing or classifying microbial keratitis
- C: Reference standard diagnosis (microbiological culture, PCR, clinical diagnosis by experts) and/or comparison with human expert performance
- O: Diagnostic performance metrics including accuracy, sensitivity, specificity, area under the receiver operating characteristic curve (AUC)

EXCLUSION CRITERIA

- Excluded review articles, editorials, conference abstracts without full performance data, and studies that did not report quantitative diagnostic outcomes.

Study Characteristics

Characteristics of included studies:

- Total of 27 studies were included in this review between 2020–2025
- Majority published 2021–2024, reflecting rapid growth of AI in ophthalmology
- Predominantly retrospective, single-centre studies
- Only one multicentre validation study identified [8]

Imaging modalities:

- Slit-lamp photography is the most widely used modality (most common)
- In vivo confocal microscopy (IVCM) enables cellular-level pathogen visualization, particularly effective for fungal and Acanthamoeba keratitis
- Emerging use of smartphone imaging for point-of-care diagnostics [9]

AI methodologies:

- Predominantly deep learning (CNNs)
- Common architectures: EfficientNet, ResNet, VGGNet

Diagnostic Performance

- Liang et al. [10] reported accuracy of 97.73%, sensitivity of 97.02%, and specificity of 98.54% for fungal keratitis diagnosis using IVCM images with GoogLeNet and VGGNet.
- Li et al. [11] achieved sensitivity of 97.57% and specificity of 96.65% for fungal keratitis diagnosis using a two-stage deep neural network on 96,632 IVCM images, with performance comparable to experienced clinicians
- Zhongwen et al. [12] reported all AUC values exceeding 0.96 for keratitis detection using 6,567 slit-lamp images, with comparable sensitivity and specificity to experienced cornea specialists.

AI models demonstrated high diagnostic accuracy:	• Accuracy: 73–97.7% • Sensitivity: up to ~97% • Specificity: up to ~90-98.5% • AUC: commonly >0.85
Performance appeared highest for:	• Fungal keratitis diagnosis using IVCM imaging • Normal cornea vs. keratitis differentiation • Viral keratitis classification
Performance appeared more challenging for:	• Bacterial keratitis classification, particularly differentiation from other types

Discussion

Limitations:

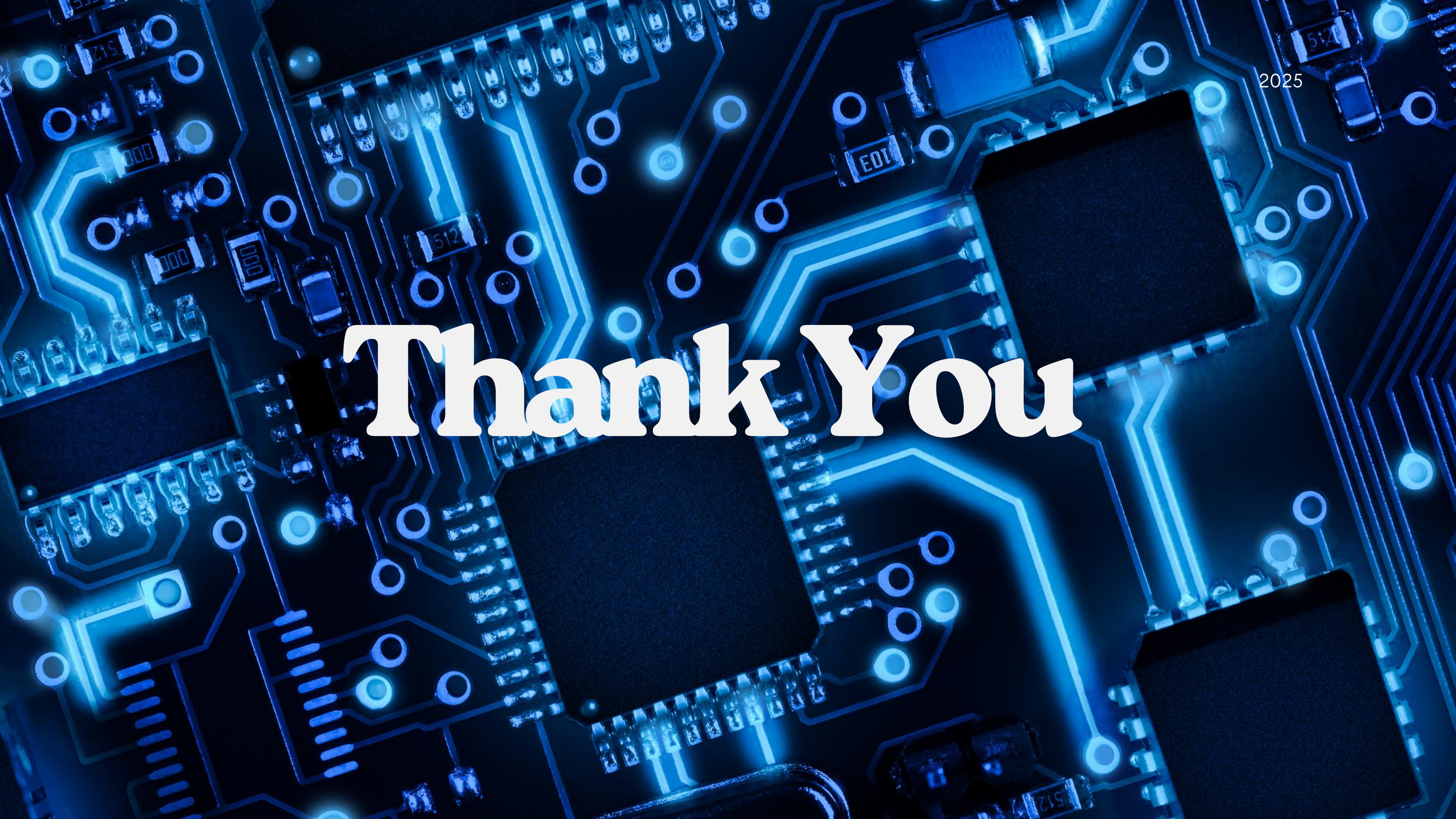
- Predominantly retrospective designs with single-centre datasets
- Limited external validation
- Unclear diagnostic reference standards

Key Takeaways:

- AI shows strong potential for diagnosing microbial keratitis
- Helps to improve diagnostic accuracy, time to diagnosis and assist clinicians in primary care settings
- AI should be not be viewed as a replacement for clinical expertise but as a tool that can support and enhance clinical decision-making
- Multicentre prospective studies is needed before clinical implementation

References

1. Flaxman, S. R., Bourne, R. R. A., Resnikoff, S., Ackland, P., Braithwaite, T., Cicinelli, M. V., Das, A., Jonas, J. B., Keeffe, J., Kempen, J. H., Leasher, J., Limburg, H., Naidoo, K., Pesudovs, K., Silvester, A., Stevens, G. A., Tahhan, N., Wong, T. Y., Taylor, H. R., & Vision Loss Expert Group of the Global Burden of Disease Study (2017). Global causes of blindness and distance vision impairment 1990-2020: a systematic review and meta-analysis. The Lancet. Global health, 5(12), e1221–e1234. https://doi.org/10.1016/S2214-109X(17)30393-5Soleimani, M., Esmaili, K., Rahdar, A. et al. From the diagnosis of infectious keratitis to discriminating fungal subtypes; a deep learning-based study. Sci Rep 13, 22200 (2023). https://doi.org/10.1038/s41598-023-49635-8
2. Ung, L., Bispo, P. J. M., Shanbhag, S. S., Gilmore, M. S., & Chodosh, J. (2019). The persistent dilemma of microbial keratitis: Global burden, diagnosis, and antimicrobial resistance. Survey of ophthalmology, 64(3), 255–271. https://doi.org/10.1016/j.survophthal.2018.12.003
3. Soleimani, M., Esmaili, K., Rahdar, A., Aminizadeh, M., Cheraqpour, K., Tabatabaei, S. A., Mirshahi, R., Bibak-Bejandi, Z., Mohammadi, S. F., Koganti, R., Yousefi, S., & Djalilian, A. R. (2023). From the diagnosis of infectious keratitis to discriminating fungal subtypes; a deep learning-based study. Scientific reports, 13(1), 22200. https://doi.org/10.1038/s41598-023-49635-8
4. McLeod, S. D., Kolahdouz-Isfahani, A., Rostamian, K., Flowers, C. W., Lee, P. P., & McDonnell, P. J. (1996). The role of smears, cultures, and antibiotic sensitivity testing in the management of suspected infectious keratitis. Ophthalmology, 103(1), 23–28. https://doi.org/10.1016/s0161-6420(96)30738-0
5. Redd, T. K., Prajna, N. V., Srinivasan, M., Lalitha, P., Krishnan, T., Rajaraman, R., Venugopal, A., Lujan, B., Acharya, N., Seitzman, G. D., Rose-Nussbaumer, J., Lietman, T. M., Campbell, J. P., Keenan, J. D., & Corneal Ulcer Image Interpretation Study Group (2022). Expert Performance in Visual Differentiation of Bacterial and Fungal Keratitis. Ophthalmology, 129(2), 227–230. https://doi.org/10.1016/j.ophtha.2021.09.019
6. Ramirez-Miranda, A., Guerrero-Becerril, J., Ramirez, M., Vera-Duarte, G. R., Mangwani-Mordani, S., Ortiz-Morales, G., Navas, A., Graue-Hernandez, E. O., & Alio, J. L. (2025). In vivo Confocal Microscopy for Corneal and Ocular Surface Pathologies: A Comprehensive Review. Clinical ophthalmology (Auckland, N.Z.), 19, 1817–1834. https://doi.org/10.2147/OPTH.S519705
7. Babu, K., & Murthy, K. R. (2007). Combined fungal and acanthamoeba keratitis: diagnosis by in vivo confocal microscopy. Eye (London, England), 21(2), 271–272. https://doi.org/10.1038/sj.eye.6702510
8. Li, Z., Xie, H., Wang, Z., Li, D., Chen, K., Zong, X., Qiang, W., Wen, F., Deng, Z., Chen, L., Li, H., Dong, H., Wu, P., Sun, T., Cheng, Y., Yang, Y., Xue, J., Zheng, Q., Jiang, J., & Chen, W. (2024). Deep learning for multi-type infectious keratitis diagnosis: A nationwide, cross-sectional, multicenter study. NPJ digital medicine, 7(1), 181. https://doi.org/10.1038/s41746-024-01174-w
9. Soleimani M, Cheung AY, Rahdar A, Kirakosyan A, Tomaras N, Lee I, De Alba M, Aminizade M, Esmaili K, Quiroz-Casian N, Ahmadi MJ, Yousefi S, Cheraqpour K. Diagnosis of microbial keratitis using smartphone-captured images; a deep-learning model. J Ophthalmic Inflamm Infect. 2025 Feb 13;15(1):8. doi: 10.1186/s12348-025-00465-x. PMID: 39946047; PMCID: PMC11825435.
10. Ramirez-Miranda A, Guerrero-Becerril J, Ramirez M, Vera-Duarte GR, Mangwani-Mordani S, Ortiz-Morales G, Navas A, Graue-Hernandez EO, Alio JL. In vivo Confocal Microscopy for Corneal and Ocular Surface Pathologies: A Comprehensive Review. Clin Ophthalmol. 2025 Jun 7;19:1817-1834. doi: 10.2147/OPTH.S519705. PMID: 40501480; PMCID: PMC12153954.
11. Li, C. P., Dai, W., Xiao, Y. P., Qi, M., Zhang, L. X., Gao, L., Zhang, F. L., Lai, Y. K., Liu, C., Lu, J., Chen, F., Chen, D., Shi, S., Li, S., Zeng, Q., & Chen, Y. (2024). Two-stage deep neural network for diagnosing fungal keratitis via in vivo confocal microscopy images. Scientific reports, 14(1), 18432. https://doi.org/10.1038/s41598-024-68768-y
12. Li, Z., Jiang, J., Chen, K., Chen, Q., Zheng, Q., Liu, X., Weng, H., Wu, S., & Chen, W. (2021). Preventing corneal blindness caused by keratitis using artificial intelligence. Nature communications, 12(1), 3738. https://doi.org/10.1038/s41467-021-24116-6


Thank You
2025