CLINICAL SIGNIFICANCE OF ARTIFICIAL INTELLIGENCE AND OPTICAL COHERENCE TOMOGRAPHY IN THE EARLY DETECTION AND PREVENTION OF DIABETIC RETINOPATHY

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ABSTRACT

Background: Diabetic retinopathy (DR) is a major vision-threatening complication of diabetes, and early disease may remain asymptomatic. Objective: To critically examine how artificial intelligence (AI) applied to retinal photography and optical coherence tomography (OCT) contribute to earlier recognition, referral and prevention of DR-related vision loss. Methods: A focused narrative synthesis of peer-reviewed diagnostic studies, systematic reviews and major clinical guidance available through 2026 was undertaken; no new patient data were collected. Results: A 2025 meta-analysis of 18 studies reported pooled sensitivity of 87.7% and specificity of 90.6% for AI-based DR detection, while a 2026 real-world study reported 88.9% sensitivity and 98.7% specificity for referable disease in its analysed population. In clinical pathways, AI can accelerate retinal-image triage, whereas structural OCT improves identification and monitoring of diabetic macular edema (DME). OCT angiography provides complementary information on microvascular abnormalities but does not yet replace established screening. Conclusion: Validated AI screening integrated with targeted OCT, clear referral pathways and systemic risk-factor control may improve the prevention of avoidable visual impairment; local external validation and quality assurance remain essential. [1–9]

Keywords: diabetic retinopathy; artificial intelligence; deep learning; retinal photography; optical coherence tomography; OCT angiography; diabetic macular edema; screening.

INTRODUCTION

Diabetic retinopathy (DR) reflects progressive neurovascular damage associated with diabetes mellitus. Microaneurysms, retinal hemorrhages, capillary non-perfusion and, in advanced cases, neovascularization are manifestations of the disease. Diabetic macular edema (DME) can develop at different stages and is an important cause of reduced visual acuity. Because the earliest lesions are often clinically silent, the absence of visual symptoms cannot be used to exclude DR. Timely retinal evaluation is therefore a central element of diabetes care. [1]

The practical challenge is not merely identifying retinal changes but connecting those findings to a patient who can obtain ophthalmic assessment and treatment. Conventional dilated examination and photograph-based grading remain important, yet they may be difficult to deliver consistently where ophthalmologists, trained graders or imaging infrastructure are limited. AI-assisted retinal analysis can supply rapid categorization of fundus photographs, while OCT provides cross-sectional retinal information that is difficult to infer from colour imaging alone. The two modalities should be considered complementary rather than interchangeable. [1–3]

AIM OF THE ARTICLE

This article evaluates the clinical roles, diagnostic performance and implementation constraints of AI-assisted fundus photography, structural OCT and OCT angiography (OCTA) in the early detection of DR. Particular attention is paid to their implications for referral, monitoring and prevention of vision loss, rather than to an unsupported claim that imaging technologies prevent the metabolic onset of retinopathy.

MATERIALS AND METHODS

A targeted narrative review was prepared using major international guidance and selected peer-reviewed publications on diabetic eye screening, AI diagnostic accuracy, OCT/OCTA imaging and referral uptake. The evidence includes the American Diabetes Association (ADA) Standards of Care in Diabetes—2026, the National Institute for Health and Care Excellence (NICE) guideline on DR management, pivotal diagnostic validation studies, and systematic reviews and implementation studies published through 2026. Sources were interpreted in relation to their study design, clinical setting, disease threshold and reference standard. This is not a registered systematic review or a meta-analysis; no prospective recruitment, experimental intervention or original statistical dataset is claimed. [1–10]

RESULTS AND DISCUSSION

1. The preventive framework: early screening plus systemic risk management

The ADA recommends improving glycemic control and addressing blood pressure and lipid goals to reduce the risk or slow the progression of DR. In adults with type 1 diabetes, an initial comprehensive dilated examination is generally recommended within five years of onset; in type 2 diabetes, it is recommended at diagnosis. When repeated examinations show no retinopathy and glycemic indicators are within target, the interval may be extended to one to two years for selected patients. Once retinopathy is present, at least annual specialist assessment is generally indicated, with shorter intervals for progression or sight-threatening disease. These intervals must be personalized rather than automatically assigned by an AI result. [1]

AI-assisted screening can support secondary prevention by identifying people who require timely specialist evaluation, but it cannot substitute for glucose control, blood-pressure management or lipid optimization. The outcome that ultimately matters is prevented visual impairment, not just an improved classification score on a test dataset. A screening programme must therefore measure completed examinations, referral adherence and time to treatment as well as image-level sensitivity and specificity. [1,7]

2. Artificial intelligence in retinal-image assessment

Modern DR algorithms usually analyse colour fundus photographs using deep-learning models trained to detect retinal abnormalities or classify severity. In a landmark prospective primary-care validation study, Abràmoff and colleagues reported sensitivity of 87.2% (95% confidence interval [CI], 81.8–91.2%) and specificity of 90.7% (95% CI, 88.3–92.7%) for detecting more-than-mild DR, with a 96.1% imageability rate. These results described the performance of a particular regulated autonomous system in a defined setting; they should not be assumed for every commercial algorithm or camera. [3]

A systematic review published in 2025 synthesised 18 diagnostic studies and estimated pooled sensitivity of 87.7% and specificity of 90.6% for AI-supported DR screening. Another meta-analysis of 82 studies covering 887,244 examinations across 28 countries reported pooled per-patient sensitivity of 93% and specificity of 90% for regulator-approved systems. These estimates differ partly because eligibility criteria, reference standards, image quality and retinopathy thresholds vary. Consequently, higher pooled estimates do not prove that a given model will retain the same accuracy in an untested population. [4,5]

In a 2026 real-world evaluation at a Belgian endocrinology clinic, 405 adults were screened and 353 were included in the primary analysis; the system reported 88.9% sensitivity and 98.7% specificity for referable DR. The excluded or non-analysable proportion illustrates an operational issue: image gradability is integral to safety. A failed capture must trigger repeat photography, dilation when appropriate, or a conventional eye examination; it must never be counted as a negative finding. [6]

3. Structural OCT and OCT angiography: distinct diagnostic contributions

Structural OCT creates high-resolution cross-sectional retinal images, allowing characterization of retinal thickness, intraretinal fluid, subretinal fluid and other anatomical features relevant to DME. NICE recommends OCT when evaluating a patient for the presence of DME. In patients with reduced vision or suspicious macular findings, OCT can reveal anatomical alterations that colour fundus photography may not quantify

accurately and can provide reproducible information for subsequent specialist management. Nevertheless, a macula-centred OCT scan does not survey the peripheral retina sufficiently to replace full DR assessment. [2]

OCTA is a non-invasive imaging approach that visualizes flow-related signals in retinal capillary networks. Research has investigated vessel density, capillary non-perfusion and the foveal avascular zone as possible markers of early microvascular damage. Unlike structural OCT, which primarily details tissue morphology, OCTA adds layer-specific vascular information. Its interpretation remains sensitive to segmentation artefacts, signal strength, scan dimensions, device software and biological variability. OCTA should therefore be described as a potentially valuable adjunct for specialist evaluation and research, not as an independently proven replacement for validated population-screening approaches. [8,9]

Table 1. Complementary roles of imaging modalities in diabetic eye care

Approach	Main clinical purpose	Important advantage	Key limitation
Dilated examination / fundus photography	Baseline DR assessment and conventional screening	Established retinal grading and clinical context	Depends on trained personnel and image acquisition
AI analysis of fundus photographs	Automated triage for referable DR in validated settings	Rapid result and potential reach outside eye clinics	Algorithm-, population- and image-quality dependence
Structural OCT	Detection and follow-up of DME	Objective cross-sectional macular assessment	Does not replace comprehensive DR screening
OCT angiography	Adjunctive mapping of macular microvasculature	Non-invasive, layer-specific vascular information	Artefacts and incomplete standardization

Approach	Main clinical purpose	Important advantage	Key limitation
Integrated pathway	Screen → review → refer → monitor	Links diagnostic output with clinical action	Requires clear responsibility and follow-up tracking

Note: Roles summarized from guideline recommendations and published clinical evidence; not original comparative study results. [1–3,8,9]

4. From detection to action: a practical integrated pathway

A feasible model begins with a diabetes visit that confirms the timing of the most recent retinal examination and systemic risk profile. For an eligible patient, standardized fundus photography is obtained and assessed using an appropriately validated AI system or qualified human grading. An ungradable image prompts repeat capture or specialist evaluation; a negative result leads to a documented next screening date according to risk and guidelines. A positive or symptomatic presentation requires ophthalmology assessment, where dilated retinal examination and OCT are used when macular edema is suspected. Severe retinopathy or DME requires prompt referral to a clinician experienced in its management. [1,2]

This operational sequence is particularly relevant when ophthalmic resources are concentrated in tertiary hospitals and diabetes follow-up occurs closer to patients' homes. However, the model is a proposed care pathway, not a locally tested intervention. Before implementation, each clinic would need to define data security arrangements, camera quality standards, validation against specialist grading, referral deadlines, repeat imaging rules and audit measures such as the proportion of completed referrals within a specified period. A referral recommendation without accessible follow-up may have limited preventive value. [5,7]

5. Referral adherence, clinical outcomes and limitations

Technology may influence patient behavior because rapid results can enable immediate counseling and scheduling. A 2026 systematic review and meta-analysis

comparing AI-enabled and standard pathways found greater referral uptake with AI-supported care (pooled relative risk 1.89; 95% CI, 1.18–3.03), but the authors reported substantial heterogeneity (I^2 = 91.9%). This suggests that workflow redesign, access to appointments and communication practices may be as important as the algorithm itself. The result should not be interpreted as direct proof that AI alone prevents blindness. [7]

Major limitations of AI-assisted screening include spectrum bias, imperfect reference standards, reduced accuracy with poor-quality images, differences in camera hardware and imbalanced training populations. Autonomous systems also operate within specific cleared indications; they may not detect unrelated ocular disorders or reliably determine the management of advanced disease. OCT and OCTA have their own acquisition artefacts and interpretation requirements. Governance, patient consent, safe storage of retinal images and periodic external audits are therefore core elements of responsible clinical use. [3–9]

CONCLUSION

Artificial intelligence applied to standardized retinal photography can strengthen the early recognition of DR and improve the efficiency of screening and referral in appropriately validated care settings. Structural OCT is indispensable when DME is suspected and during specialist monitoring, while OCTA offers an additional, still-evolving window into diabetic retinal microcirculation. Their greatest clinical value emerges when imaging results are embedded in a coordinated pathway that includes systemic risk-factor control, timely ophthalmology referral and documented follow-up. Future multicentre implementation studies in local clinical populations should assess not only diagnostic accuracy but also image gradability, referral completion, cost, equity and patient-relevant visual outcomes. [1–9]

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