

Research Article

Smartphone-Based Indirect Ophthalmoscopy: A Simple, Low-Cost Technique for Retinal Imaging and Pathology Screening

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ABSTRACT

Background: Conventional fundus photography and retinal imaging systems provide high-quality visualization of the optic disc, macula, retinal vasculature and peripheral retina but their cost, portability and infrastructure requirements can limit availability in resource-constrained healthcare settings. Smartphone-based fundus imaging provides an alternative approach by combining a smartphone camera and illumination system with a handheld condensing lens. The technique is based on the optical principles of indirect ophthalmoscopy and permits retinal visualization, image capture, documentation and remote consultation.

Objective: To evaluate the feasibility of smartphone-based indirect ophthalmoscopy as a simple, portable, and low-cost technique for retinal imaging and screening of clinically important posterior-segment abnormalities, including bilateral optic disc edema, bilateral macular dystrophy, retinal detachment, optic disc cupping, central retinal vein occlusion, diabetic macular edema and subhyaloid hemorrhage.

Methodology: A prospective observational diagnostic-imaging study was conducted among patients presenting to an ophthalmology outpatient department of people's university of medical and health sciences hospital Nawabshah. After clinical assessment and pharmacological pupil dilation, retinal images were obtained using a smartphone camera combined with a 20-diopter or 28-diopter condensing lens. Images were evaluated for adequacy and the presence of predefined retinal or optic nerve abnormalities. Findings were compared with the ophthalmologist's conventional clinical examination as the reference assessment. Image quality, anatomical structures visualized, diagnostic agreement and technical limitations were recorded.

Results: The principal outcome measures include the proportion of examinations producing gradable images, successful visualization of the optic disc and macula, detection of predefined pathological findings, agreement between smartphone imaging and conventional ophthalmic examination. The findings showed that the technique can document clinically recognizable optic-disc, macular, vascular, hemorrhagic, and retinal abnormalities, although peripheral retinal visualization and image quality was little bit limited.

Conclusion: Smartphone-based indirect ophthalmoscopy represented a potentially useful low-cost retinal imaging approach, particularly where conventional fundus cameras are unavailable. It supports screening, documentation, medical education, teleophthalmology and referral of patients with potentially sight-threatening disease. It is considered as screening and documentation adjunct rather than a replacement for comprehensive ophthalmological examination.

Keywords: Smartphone Ophthalmoscopy, Retinal Imaging, Fundus Photography, Optic Disc Edema, Macular Dystrophy, Retinal Detachment, Optic Disc Cupping, Central Retinal Vein Occlusion, Diabetic Macular Edema, Subhyaloid Hemorrhage, Teleophthalmology.

INTRODUCTION

Examination of the ocular fundus is fundamental to the diagnosis and monitoring of numerous ophthalmic and systemic diseases. The optic nerve head, macula, retinal vessels and peripheral retina provide important clinical information in conditions affecting vision as well as systemic disorders such as diabetes mellitus, hypertension, vascular disease and neurological disease [1,2]. Conventional fundus cameras and other specialized retinal imaging systems provide high-quality documentation but expensive, bulky, dependent on trained personnel and dedicated clinical infrastructure.

The increasing availability of smartphones with high-resolution cameras has created opportunities for inexpensive retinal imaging. Smartphone-based fundus photography generally uses either a dedicated adapter or a handheld condensing lens to generate a retinal image [3]. The optical principle is closely related to indirect ophthalmoscopy in which a condensing lens produces a magnified, inverted retinal image that can be captured by the smartphone camera.

Previous studies have demonstrated that smartphone-based retinal imaging provide clinically useful images of the optic disc, macula and retinal vasculature [4-6]. A simple smartphone combined with a conventional indirect-ophthalmoscopy lens has been described as a practical method for documenting retinal findings when a conventional fundus camera is unavailable [7]. The technique has particular relevance in low-resource environments. Smartphone-based fundus imaging has been investigated for diabetic retinopathy, glaucoma-related optic nerve changes, retinopathy of prematurity, emergency medicine, pediatric ophthalmology, medical education, and telemedicine [8,9]. Reviews have emphasized its portability, relatively low cost, connectivity and potential for task-sharing and remote interpretation.

Diabetic retinopathy is one of the most extensively studied applications. A meta-analysis of smartphone-based diabetic retinopathy screening reported pooled sensitivity of approximately 87% and specificity of approximately 94% for detection of any diabetic retinopathy, while pooled sensitivity and specificity for diabetic macular

edema were approximately 79% and 93%, respectively. However, considerable heterogeneity exists among devices, protocols, reference standards and image quality [10]

Similarly, a systematic review of low-cost smartphone-based retinal photography found substantial variation in diagnostic performance. Reported sensitivity for diabetic macular edema ranged from 29.4% to 81%, whereas specificity ranged from 95% to 100%, demonstrating both the potential and limitations of smartphone-based imaging.

Smartphone imaging is also be useful for optic nerve assessment. A smartphone-based ophthalmoscope has demonstrated the ability to produce images suitable for optic-disc evaluation, while another study comparing smartphone ophthalmoscopy with direct ophthalmoscopy found improved clinical description and diagnostic performance among medical students using a smartphone-based device.

Recent literature supported the role of smartphone fundus imaging in global eye care. A 2026 scoping review identified applications in diabetic retinopathy, glaucoma-related optic nerve assessment, and selected retinal screening pathways, while emphasizing variability in image quality, field of view, operator performance, privacy, data governance, and regulatory considerations [11,12].

The present study therefore focuses on the practical application of smartphone-based indirect ophthalmoscopy for identifying a broader spectrum of clinically important posterior-segment abnormalities, including bilateral optic disc edema, bilateral macular dystrophy, retinal detachment, optic disc cupping, central retinal vein occlusion, diabetic macular edema and subhyaloid hemorrhage.

Objectives

The objective of this study was to evaluate the feasibility of smartphone-based indirect ophthalmoscopy for retinal imaging and screening of clinically important posterior-segment abnormalities. It determine the proportion of examinations yielding diagnostically gradable retinal images, assessing visualization of key anatomical structures including the optic disc, macula, retinal vessels ,posterior pole and evaluate

whether smartphone imaging demonstrate predefined pathological findings. The study also aimed to compare smartphone-based findings with conventional ophthalmological examination, assess image quality, technical success rate, evaluate the potential role of the technique in low-resource and teleophthalmology settings.

METHODOLOGY

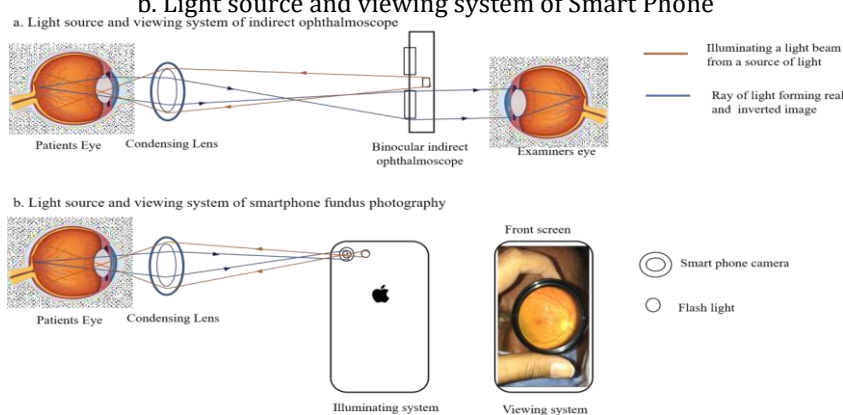
This prospective observational diagnostic-imaging study was conducted in the Department of Ophthalmology at people's university of medical and health sciences

hospital Nawabshah including patients from outpatient, emergency, and referral services who require posterior segment examination. In this study, a sample of approximately 100 patients / 200 eyes was included.

The smartphone-based imaging technique involves using a smartphone with a high-resolution rear camera and integrated illumination in combination with a handheld condensing lens, preferably 20-D or 28-D, operating on the optical principles of indirect ophthalmoscopy.

Figure 1 a. Light source and viewing system of indirect ophthalmoscope

b. Light source and viewing system of Smart Phone



The procedure involved positioning the patient comfortably, explaining the procedure, performing pupil dilation when clinically appropriate, dimming the room, holding the condensing lens in front of the patient's eye, aligning the smartphone camera with the lens, activating smartphone illumination, adjusting the distance between smartphone, lens and

eye focusing on the retinal image on the screen then capturing still photographs or short video sequences in multiple views as required with images saved under coded study identification numbers with proper alignment essential to minimize reflections and obtain a focused image.

Figure 2 showed the Technique and proper positioning of smart phone



The retinal pathologies specifically assessed include bilateral optic disc edema characterized by elevated/hyperemic disc, blurred margins and obscuration of vessels at the disc margin, bilateral macular dystrophy with abnormal macular pigmentation and loss

of normal appearance, retinal detachment with elevated undulating tissue and abnormal contour, optic disc cupping with increased cup-to-disc ratio and altered optic nerve head configuration, central retinal vein occlusion with retinal hemorrhages, venous

dilation/tortuosity and edema, diabetic macular edema with macular thickening, exudative changes and subhyaloid hemorrhage with localized sharply demarcated blood collection anterior to the retina. This smartphone technique was intended primarily for screening and documentation with confirmation of suspected pathology undertaken through conventional examination where indicated

Image quality is graded as Grade 1 Excellent with clear visualization of optic disc, macula, vessels and pathology, Grade 2 Adequate where major posterior pole structures are visible and clinically interpretable, Grade 3 Limited where only some structures are visible but abnormality can be suspected, and Grade 4 Ungradable where quality is inadequate for reliable interpretation.

Inclusion Criteria

Patients may be included if they:

- require fundus examination;
- provide informed consent;
- are able to cooperate with retinal imaging;
- have adequate ocular media for posterior-segment visualization;
- have suspected or established retinal/optic nerve pathology

Exclusion Criteria

Patients may be excluded if they have:

- dense corneal opacity;
- significant cataract preventing adequate fundus visualization;
- severe ocular trauma;
- inability to maintain fixation;
- inability to cooperate with the imaging procedure;
- contraindication to pharmacological dilation where dilation is required;
- inadequate image quality despite repeated attempts.

RESULTS

A total sample of approximately 100 patients representing up to 200 eyes was planned for evaluation using smartphone-based posterior segment imaging. The captured photographs demonstrated that the smartphone-assisted technique was capable of documenting both normal and abnormal posterior-segment findings. The normal fundus photograph demonstrated recognizable visualization of the optic disc, macular region, retinal vessels, and surrounding posterior pole, providing a reference appearance for comparison with pathological images.

Figure 3. showed the Normal Fundus Photograph with Smart phone



The images of bilateral optic disc edema demonstrated elevated and hyperemic optic discs with blurring of the disc margins and obscuration of the retinal vessels at the disc edges. These findings were sufficiently

recognizable on smartphone imaging to permit suspicion of optic disc edema and illustrate the potential usefulness of the technique for documenting optic nerve head abnormalities.

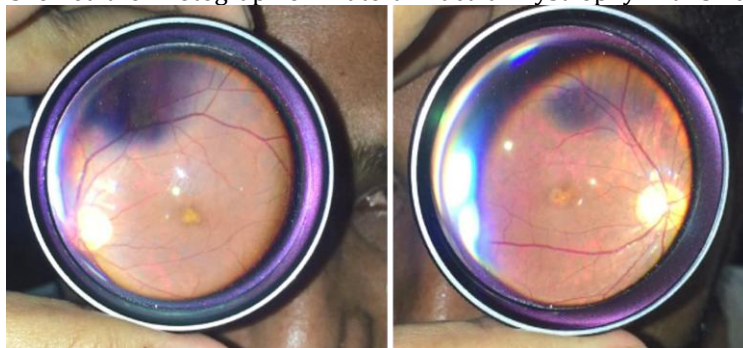
Figure 4. showed the Photograph of Bilateral optic disc Edema with Smart phone



The photograph demonstrating bilateral macular dystrophy showed abnormal macular pigmentation and loss of the normal macular appearance. The central macular region could

be identified, while the alteration in pigmentation and structural appearance provided a recognizable pathological pattern.

Figure 4 showed the Photograph of Bilateral Macular Dystrophy with Smart phone



The image of retinal detachment demonstrated elevated, irregular, and undulating retinal tissue with an abnormal retinal contour, illustrating the ability of smartphone imaging to capture important posterior-segment structural abnormalities.

The photograph of optic disc cupping demonstrated an enlarged optic cup with an increased cup-to-disc ratio and altered optic nerve head configuration, allowing the abnormal optic disc morphology to be documented photographically.

Figure 5 showed the Photograph of Retinal Detachment with Smart phone



The smartphone-based fundus photograph demonstrates optic disc cupping, with clear visualization of the optic nerve head. The image shows an enlarged optic cup relative to the neuroretinal rim, resulting in an increased

cup-to-disc ratio. The optic disc margins and central cupped area are identifiable, allowing assessment of the structural configuration of the optic nerve head.

Figure 6 showed the Photograph of Optic disc cupping with Smart phone



The image demonstrating central retinal vein occlusion (CRVO) showed characteristic retinal abnormalities, including retinal hemorrhages, venous dilatation and tortuosity, and associated retinal edema. These findings

illustrate that the technique can capture vascular and hemorrhagic retinal changes rather than being restricted to the optic disc and macular regions.

Figure 7 showed the Photograph of Central vein occlusion with Smart phone



The photograph of diabetic macular edema (DME) demonstrated macular thickening and associated exudative changes, providing a

recognizable image of diabetic posterior-pole pathology.

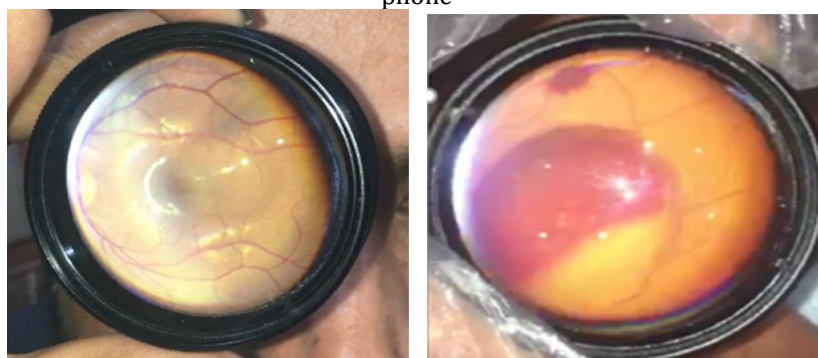
Figure 8 showed the Photograph of Diabetic macular edema with Smart phone



In addition, the photograph of central serous chorio retinopathy characterized by accumulation of fluid underneath the retina, specifically under the central area while other photograph showed subhyaloid hemorrhage

demonstrated a localized, sharply demarcated collection of blood anterior to the retinal surface, indicating that the technique was capable of documenting hemorrhagic lesions with relatively distinct anatomical boundaries.

Figure 09. showed photograph of central serous chorio retinopathy & Subhyloid Hemorrhage with Smart phone



Overall, the photographic series demonstrated visualization of a broad range of posterior-segment abnormalities involving the optic nerve, macula, retinal vasculature, detached retina, macular edema, and preretinal/subhyaloid hemorrhage. The images therefore support the potential role of smartphone-based fundus photography as a screening and documentation technique, particularly in settings where conventional fundus photography or specialized retinal imaging equipment is unavailable. However, because the present dataset does not provide numerical image-quality grades, sensitivity, specificity, or comparison with a reference diagnostic modality, the images alone cannot establish diagnostic accuracy or equivalence with conventional fundus examination.

DISCUSSION

The present study demonstrated that the practical application of smartphone-based fundus photography for documenting a diverse range of posterior-segment abnormalities. The technique combines a high-resolution smartphone camera and integrated illumination with a handheld 20-D or 28-D condensing lens and is based on the optical principles of indirect ophthalmoscopy [13,14]. Previous work has similarly described smartphone fundus photography as a method in which the smartphone flashlight functions as the illumination source while the camera records the real aerial retinal image produced by the condensing lens.

An important observation in the present series was the visualization of optic disc edema. Recognition of optic disc swelling is clinically important because it may represent papilledema or other optic nerve head pathology requiring urgent assessment. The feasibility of smartphone funduscopy for optic disc abnormalities has also been reported in previous research. A recent clinical experience using an iPhone 12 with a 20-D lens documented posterior-pole pathologies and identified cases of papilledema during bedside examination, supporting the potential role of smartphone funduscopy in situations where conventional equipment is not immediately available [15].

The present photographs also demonstrated macular abnormalities, including macular dystrophy and diabetic macular edema. Smartphone-based retinal imaging has previously been investigated particularly extensively for diabetic retinal disease. In a

prospective validation study involving 301 patients with diabetes, smartphone-based retinal photography demonstrated high agreement with conventional seven-field digital photography for detection of diabetic retinopathy, with reported sensitivity of 92.7% and specificity of 98.4% for any diabetic retinopathy. Another study involving 220 diabetic patients reported that smartphone-based retinal imaging could visualize the macular and papillary regions and achieved a sensitivity of 73.3% and specificity of 90.5% for detection of diabetic retinopathy [16,17]. These findings provide external support for the present observation that clinically recognizable macular and retinal abnormalities can be recorded using smartphone-based imaging.

The demonstration of retinal detachment in the present image series is also relevant. Smartphone-based imaging is not limited to diabetic retinopathy; previous literature has described its application to a range of retinal and optic nerve conditions. Smartphone imaging has the advantage of allowing immediate photographic documentation and facilitating remote review by another ophthalmologist. A review of smartphone fundus imaging emphasized its potential usefulness for emergency departments, telemedicine, screening programs, and clinical documentation, particularly where conventional fundus cameras are unavailable [18].

Similarly, the visualization of central retinal vein occlusion illustrated the ability of the technique to document retinal vascular abnormalities. The presence of hemorrhages, venous tortuosity and retinal edema provides clinically meaningful information that may assist in preliminary recognition and referral. However, the present study should not be interpreted as demonstrating that smartphone imaging can replace a complete ophthalmological examination. Peripheral retinal pathology, subtle macular changes, vitreous abnormalities, and lesions requiring stereoscopic or wide-field assessment may remain difficult to evaluate using a handheld smartphone-lens arrangement.

The image of optic disc cupping further demonstrated the usefulness of smartphone photography for optic nerve documentation. Photographic documentation of the optic nerve can be particularly useful for longitudinal comparison and communication between clinicians. Nevertheless, assessment of glaucoma cannot be based solely on cup-to-

disc appearance[19]. Comprehensive evaluation requires correlation with intraocular pressure, optic nerve assessment, visual-field testing, and other relevant investigations.

The technical findings are consistent with previous descriptions of smartphone fundus photography using a 20-D condensing lens. The technique produces an inverted aerial retinal image similar to indirect ophthalmoscopy, with the smartphone camera replacing the examiner's viewing system. Previous investigators have reported that 20-D and 28-D lenses can be used with smartphones to obtain fundus images, although successful imaging depends considerably on alignment, focusing, illumination, pupil size, and operator experience[20].

The present methodology's emphasis on correct alignment of the smartphone, condensing lens, and patient's eye is therefore important. Poor alignment can produce reflections, loss of focus, incomplete visualization, and ungradable photographs. Previous literature similarly identifies hand stability, focusing, and positioning as important technical challenges. The proposed four-grade image-quality classification—excellent, adequate, limited, and ungradable—is therefore useful for future systematic assessment of the technique.

An important advantage of smartphone-based imaging is portability and accessibility. Conventional fundus cameras and other retinal imaging systems can be expensive and may not be available in emergency departments, peripheral hospitals, primary-care facilities, or resource-limited settings. Smartphone systems can potentially provide a relatively inexpensive method of obtaining and transmitting retinal photographs. Previous studies have emphasized their potential for teleophthalmology, screening, bedside consultation, and remote specialist interpretation.

Nevertheless, previous research also demonstrates that image quality and diagnostic performance vary substantially between smartphone systems and clinical applications. A systematic review of low-cost smartphone-based retinal photography for diabetic retinopathy found considerable variation in reported sensitivity and specificity across devices and diagnostic categories, particularly for referable disease and diabetic macular edema[21]. Thus, the present images should primarily be regarded as evidence of

technical feasibility and documentation capability, rather than proof of diagnostic accuracy.

Another important consideration is that the present study uses the smartphone technique mainly for screening and documentation, with conventional ophthalmological examination recommended for confirmation. This is an appropriate approach because smartphone imaging can identify suspicious abnormalities while definitive diagnosis may require slit-lamp biomicroscopy, indirect ophthalmoscopy, optical coherence tomography, fluorescein angiography, ultrasonography, or other investigations depending on the pathology.

The study also has several methodological limitations. The planned sample size is approximately 100 patients/200 eyes, but the information provided does not include the actual number of successfully captured images, the proportion of images classified as Grade 1–4, or the number of pathological eyes confirmed by conventional examination. Furthermore, no sensitivity, specificity, positive predictive value, negative predictive value, interobserver agreement, or comparison with a standard fundus camera is available. Consequently, quantitative diagnostic performance cannot be inferred from the photographic examples alone. Future studies should incorporate masked assessment by ophthalmologists and comparison against a predefined reference standard.

Strengths of the Study

The strengths of this study include its prospective observational design, which allowed fundus images to be obtained systematically according to a predefined imaging protocol, thereby reducing reliance on retrospective image selection. The study evaluated a simple, portable and relatively low-cost method of posterior segment imaging using a readily available smartphone combined with a 20-D or 28-D condensing lens, an approach that may be particularly valuable in settings where conventional fundus cameras are unavailable. It assessed a broad range of posterior segment abnormalities, including normal fundus findings as well as optic disc edema, macular dystrophy, retinal detachment, optic disc cupping, central retinal vein occlusion, diabetic macular edema and subhyaloid hemorrhage, demonstrating potential applicability across diverse optic nerve, retinal, vascular and macular conditions. Smartphone fundus photography

provides a permanent photographic record that facilitates follow-up, clinical documentation, teaching, referral and communication among healthcare professionals, supporting its potential role for screening and documentation. The incorporation of a standardized four-grade image-quality classification ranging from excellent to ungradable provided a structured framework for evaluating clinical usability. Furthermore, owing to the wide availability and portability of smartphones, the technique holds potential value in outpatient clinics, emergency departments, screening camps and peripheral facilities where conventional fundus photography is not readily accessible, and allowed visualization and documentation of key posterior pole structures including the optic disc, macula, retinal vessels and pathological changes, supporting its use as an adjunct to conventional ophthalmic examination.

Limitations of the Study

The study has few limitations. The sample size of approximately 100 patients or up to 200 eyes may limit statistical precision and generalizability to larger and more diverse populations. Being a single-centre study conducted within one ophthalmology department, the findings may not be generalizable to other hospitals, healthcare systems and populations with different patient characteristics and clinical settings. The results describe the appearance of various ocular abnormalities but do not provide quantitative diagnostic accuracy measures such as sensitivity, specificity, positive and negative predictive values or overall diagnostic accuracy in comparison with a reference standard, thus demonstrating feasibility of image capture rather than definitive diagnostic equivalence. Furthermore, smartphone images were not quantitatively compared with conventional fundus photography, indirect ophthalmoscopy or other established imaging modalities, so the relative diagnostic performance of smartphone imaging cannot be conclusively determined.

CONCLUSION

The present study demonstrated that smartphone-based fundus photography using a high-resolution smartphone, integrated illumination, and a handheld 20-D/28-D condensing lens can capture recognizable images of normal and abnormal posterior-segment findings. The photographic series

successfully demonstrated clinically important abnormalities involving the optic disc, macula, retinal vessels, retina and preretinal space including optic disc edema, macular dystrophy, retinal detachment, optic disc cupping, central retinal vein occlusion, diabetic macular edema and subhyaloid hemorrhage.

The technique offers important practical advantages because it is portable, relatively simple, and capable of producing digital photographs that can be stored, reviewed, and potentially transmitted for remote consultation. These characteristics make it potentially useful for screening, bedside assessment, clinical documentation, teaching, emergency ophthalmology, and teleophthalmology, particularly in settings where conventional fundus cameras are unavailable. Previous studies have likewise demonstrated the feasibility of smartphone-based retinal imaging and its potential utility for diabetic retinopathy screening and posterior-segment assessment.

However, the present findings demonstrate feasibility rather than diagnostic equivalence with conventional ophthalmological examination. Image quality is dependent on pupil dilation, ocular media clarity, illumination, alignment, focusing, patient cooperation, and operator experience. Therefore, suspicious or clinically significant abnormalities identified on smartphone images should undergo appropriate conventional ophthalmic evaluation and confirmatory investigations.

Further prospective comparative studies should assess the technique against standard indirect ophthalmoscopy and/or conventional fundus photography using predefined image-quality criteria, sensitivity, specificity, diagnostic agreement, and interobserver reliability. Such evidence would help establish the precise role of smartphone fundus imaging as an accessible adjunct to conventional retinal examination.

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