· Review Article ·

Application of smartphone ophthalmoscope in ophthalmic clinical practice and teaching

Jia-Ning Qiu[1,2], Jing Luo[1,2], Man-Yun Xie[1,2]

[1]Department of Ophthalmology, the Second Xiangya Hospital, Central South University, Changsha 410011, Hunan Province, China
[2]Hunan Clinical Research Center of Ophthalmic Disease, Changsha 410011, Hunan Province, China
Correspondence to: Man-Yun Xie. Department of Ophthalmology, the Second Xiangya Hospital, Central South University, No.139, Renmin Middle Road, Furong District, Changsha 410011, Hunan Province, China. xiemanyun@csu.edu.cn
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Abstract
● The rapid development and increasing popularity of smartphones have led to their gradual integration as essential aids in medical examinations and teaching tools. The smartphone ophthalmoscope (SO) is one of them. Specifically, SO is comprised of a smartphone and an attachment. The smartphone serves as a versatile device for recording and transmitting information, while the attachment functions as a tool for phone fixation as well as focus adjustment and providing light resources, albeit with slight variations across different devices. Presently, the convenience, universality, and transferability of SO have greatly expanded its potential in fields of clinical practice and ocular teaching. The review provides a concise overview of the contemporary SO devices, elucidates the diseases amenable to assessment *via* SO, and outlines the various applications of SO in clinical practice and teaching.
● **KEYWORDS:** smartphone; ophthalmoscope; ocular consultation; medical education
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INTRODUCTION
In recent years, smartphones have demonstrated remarkable advancements in photography, enabling effortless editing, labeling, and uploading of images into medical record systems. Moreover, smartphones facilitate the sharing of images with multidisciplinary teams and higher-level medical institutions. Additionally, the unparalleled portability and popularity of smartphones have significantly impacted various specialty medical practices, including early diagnosis[1-2], patient education[3], and information collection and sharing[4]. The prevalence of smartphones among doctors and medical students is significantly high[5], thereby facilitating the advancement of medical education and consultation. One notable application of smartphones in medical practice is the smartphone ophthalmoscope (SO)[6], which involves the assembly of smartphones, adapters, and lenses. This technology allows for dynamic fundus observation through video capture[7] or direct fundus imaging resembling the portable fundus camera[8]. SO can be used with or without pupil dilation[9]. Currently, SO is predominantly employed in clinical practice, yet it also serves a purpose in various other contexts, including ocular consultation[8,10] and teaching[11]. This review primarily consolidates the existing devices of SO, while also examining the significance of SO in the realms of ocular application and ophthalmoscopy teaching.

DEVICE OF SMARTPHONE OPHTHALMOSCOPE
Since its introduction of SO in 2010[6], numerous commercial devices of SO have been developed. These commercial SOs are primarily utilized in clinical settings. Additionally, several custom-made SOs have been employed primarily to investigate teaching methodologies. Certain studies have exclusively utilized smartphones equipped with lenses (primarily from Volk Optical) with varying diopter values, following the principle of indirect ophthalmoscope. Commercial and team-made SOs offer adapters and brackets that facilitate the adjustment of lens-to-smartphone distance and axial illumination. This enhancement alleviates the challenges faced by doctors. When selecting an SO, factors such as device cost, field of view, and safety approval are crucial considerations. Table 1 provides a concise overview of these aspects for currently available commercial SOs[12-16]. The primary distinctions among various SO devices pertain to how the fixed smartphone is affixed to the lens, the accompanying software for data storage, and the diverse lens options available.

Table 1 Commercial SO devices

Device (company)	FOV	Relevant approvals	Supported phone models	Clinical applications	Teaching applications
oDocs Nun (oDocs Eye Care, New Zealand)[a]	30° at pupil size 4 mm	A CE sign registered with TGA and Medsafe	Androids and iPhones	Yes	No
oDocs Nun IR (oDocs Eye Care, New Zealand)[a,c]	45°-55° without pupil dilation	A CE sign registered with TGA and Medsafe	Androids	No	No
MII Ret Cam (MIIRetCam, India)[b [12]]	46°, 53°, and 90° after pupil dilation given by 20 D, 28 D, and 40 D lenses	Not mentioned	iPhone 5s	Yes	No
iNview® (VOLK Optical, United States of America)[a]	50° at pupil size 5 mm at least	An FDA approval	iPhone 6 and 6s, iPod Touch	Yes	No
C3 Funduscam (Colpen Products, India)[b [13]]	50°-65° with pupil dilation	No FDA approval	iPhone 6s	Yes	No
iC2 funduscope (HEINE Optotechnik, Germany)[b [14-15]]	34°	A CE sign	iPhone 6 and 7	No	Yes
D-EYE (D-EYE, Italy)[b [16]]	20° with pupil dilation and 5°-8° without pupil dilation	An FDA approval	iPhones	Yes	Yes
PanOptin™ Ophthalmoscope+iExaminer (Welch Allyn, USA)[a]	25° without pupil dilation	Not mentioned	Androids and iPhones	Yes	Yes

Information on products for which complete information is not available directly from the official website for various reasons is derived from previous researches, with references labeled in the upper corner label after the product name. [a]Details supplied by distributors, [b]Details supplied by previous study, [c]New product introduced by the developer, no research applications detected at this time. SO: Smartphone ophthalmoscope; FOV: Field of view; CE: Conformité Européen; TGA: Therapeutic Goods Administration; FDA: Food and Drug Administration.

The utilization of the light-emitting diode (LED) flashlight of smartphones as the light source for these SO devices raises concerns regarding its safety[17-20]. The spectral profile, weighted irradiance, and thermal exposure rates of LED flashlight of five versions of Android-operated smartphones and four versions of iPhone for indirect ophthalmoscope are tested to be safe[21-23]. However, the presence of a significant amount of blue light at short wavelengths emitted by LED flashlights used in SO has been found to have phototoxic effects on the retina[23], particularly when inspections are prolonged and repeated. To summarize, a short period of ophthalmoscopy via smartphone is permissible.

The advancement of SO devices is primarily directed towards the virtual reality and artificial intelligence (AI). Virtual reality aims to provide an authentic representation of the fundus, emphasizing its structural details, whereas AI focuses on image analysis for diagnostic assistance. The integration of a virtual reality headset with a smartphone enables the visualization of three-dimensional ocular fundoscopy images[24]. Additionally, a computer-aided diagnosis system has been developed to effectively execute algorithms for fundus localization and optic head nerve detection, yielding satisfactory results in the D-EYE and iExaminer databases[25].

SMARTPHONE OPHTHALMOSCOPE IN CLINICAL APPLICATIONS

With the progressive investigation of SO in various fundus diseases, diverse application scenarios, and varied user groups, it appears that SO has the potential to optimize the service range of a robust ophthalmic center. This includes extending the scope of services beyond ocular diagnosis to encompass in-hospital consultation, community outreach, and even telemedicine in remote regions.

The emergence of SO has facilitated the acquisition of fundus photographs by non-ophthalmologists, enabling them to independently assess the advancement and regression of fundus diseases without constant reliance on ophthalmologists for consultation. Additionally, the availability of stored fundus photos captured at various time points by SO can furnish a more comprehensive medical history for ophthalmic consultations, when necessary. The movable SO can also be employed for patients who are unable to alter their posture and collaborate with medical professionals, thereby rendering it more appropriate for the emergency department, intensive care unit, and similar settings.

The utilization of the SO is marginally less specialized compared to the conventional direct ophthalmoscope and indirect ophthalmoscope, thereby facilitating primary care practitioners in swiftly acquiring proficiency and generating high-quality fundus photographs following a brief learning period[7,26]. Both patients and local SO users were positive of SO in under-resourced settings[27-28]. In certain regions, local ophthalmic technicians may lack the expertise of professional ophthalmologists in discerning retina/optic nerve pathology[4]. Consequently, primary care providers or ophthalmologists situated in remote areas can employ the SO to capture fundus images and transmit them wirelessly to a secure web platform for teleconsultation purposes[29-32]. Furthermore, the photographs captured by SO can be uploaded to the AI database for the purpose of comparison, thereby facilitating a broader spectrum of assistance[33].

Glaucoma Glaucoma is a group of diseases characterized by progressive degeneration of the optic nerve. Accurate diagnosis often necessitates the assessment of the optic nerve head through fundoscopy and the determination of the vertical cup-to-disc ratio (vCDR)[34]. The diagnostic accuracy of normal vCDR by SO is deemed satisfactory, yet the consistency of vCDR diagnosis when compared to slit lamp examination remains a subject of controversy[35-36]. This discrepancy may be attributed to the absence of pupil dilation during the use of SO in some researches, which leads to imprecise fundus images and vCDR measurements[9,35]. Furthermore, the vCDR derived from dilated images of SO exhibited a high level of concordance with the vCDR determined through optical coherence tomography[37].

The present utilization of SO has the potential to expand the diagnostic capabilities for glaucoma beyond the confines of the ophthalmology office. SO has demonstrated its ability to accurately diagnose moderate to severe optic nerve head elevation in emergency department, enabling prompt prioritization of these patients to prevent significant ocular damage[38]. Additionally, successful investigations have been conducted utilizing SO for glaucoma monitoring in resource-limited regions[26,37]. It has been demonstrated that nonclinical photographers can effectively acquire optic nerve images for remote grading purposes[39]. However, the recognition of SO fundus images in glaucoma may necessitate further training or the accrual of experience[40]. The development of an automated analysis algorithm utilizing D-EYE images could potentially offer a novel approach to address this issue[41].

Diabetic Retinopathy Diabetic retinopathy (DR) is a prevalent cause of blindness and visual impairment in the adult population globally, and its prevalence and impact are projected to rise significantly in the future[42]. The implementation of graded diagnosis and treatment approaches for DR has proven effective in preventing unfavorable visual outcomes. In this regard, the use of SO has demonstrated superior performance in obtaining gradable fundus images when compared to conventional tabletop fundus cameras and slit lamp biomicroscopes[43-44]. Consequently, primary care practitioners can consider utilizing SO as a valuable tool for acquiring DR screening images. Moreover, SO had fairly high accuracy for the detection of DR with or without dilation[44-46]. Furthermore, it is noteworthy that the sensitivity of SO demonstrates a higher efficacy in identifying stages of DR that require a specific therapeutic intervention[45]. Additionally, the diagnostic accuracy for proliferative DR is observed to be the most superior among all stages[47]. This could be attributed to the fact that the proliferative DR phase exhibits more prominent alterations in the fundus, making them easier to discern from fundus images. In addition, AI programs based on SO images can prove beneficial in the identification and grading of DR images[41-42].

Epidemiological projections suggest a transition in the disease burden of DR from high-income nations to low- and middle-income regions[42]. However, due to limited resources for nationwide screening initiatives, the screening of DR has been inadequate[48]. To address this issue, the use of SO has been implemented in certain regions for early detection of fundus lesions in remote environments. The findings from the application of SO have generally aligned with clinical diagnoses, supporting its efficacy in early screening for DR[8,49-50].

Pediatric Retinal Diseases The process of fundus imaging in children presents distinct differences compared to adults, primarily due to the relatively uncooperative nature of children. To facilitate the examination and reduce the time required to reassure the child, ophthalmologists can effectively utilize the versatile appearance of the SO to attract the child's attention[51]. The use of SO enables the identification of the normal optic nerve[52], retinoblastoma, Coats' disease, commotio retinae, optic nerve hypoplasia, and retinopathy of prematurity[53] in pediatric patients, with a notable level of consistency observed between SO image-based diagnoses and clinical evaluations[51]. Furthermore, the video capability of the SO proves to be advantageous in such cases when examining pediatric patients with nystagmus or poor compliance[54]. The portability and cost-effectiveness of SO also facilitate the widespread implementation of bedside diagnosis for fundus diseases in infants. Ophthalmologists have successfully employed SO in neonatal intensive care units and regions with limited medical resources for documenting retinopathy of prematurity at the bedside[12,55] and estimating the gestational age of preterm infants[56]. However, in cases where additional identification of the specific zone and stage of retinopathy of prematurity is necessary, it may be imperative to employ pupil dilation to achieve a broader field of view and employ the rotation of the eye with a scleral indenter[13].

Other Ocular Diseases Several systemic diseases, including neoplasms, infectious diseases, neurological disorders, and circulatory disorders, have the potential to induce alterations in the fundus. The fundus image obtained through SO in retinoblastoma patients exhibited clear macular details, along with a distinct superior tumor mass and a tumor mass located in the far peripheral nasal region[57]. Additionally, SO has demonstrated its capability to diagnose abnormal ocular fundus manifestations associated with acute hypertension in emergency department settings[58].

The initial exploration of screening for human immunodeficiency virus (HIV)[59], malaria[60] and toxoplasmosis[61-62] associated fundus disease through direct observation of fundus lesions using SO has been undertaken in developing countries. Furthermore, SO serves as a valuable tool in the multidisciplinary diagnosis and treatment of newborns with congenital toxoplasmosis, facilitating the acquisition, storage, and sharing of consultation data[61]. Moreover, in the context of controlling nosocomial infections, the utilization of SO in managing fundus disease in patients with infectious diseases can effectively mitigate the risk of infection among additional healthcare workers. Particularly during the ongoing COVID-19 pandemic, the practice of capturing fundus images by a nurse or junior residents stationed in COVID-19 wards, and subsequently transmitting them to an ophthalmologist for diagnosis *via* SO, has demonstrated significant utility and a reduction in unnecessary exposure[10,63].

Neurologists conducted fundus screening using SO[64], which can offer objective and recordable evidence of central vestibular pathology[65]. However, the glare artifact and steep learning curves associated with SO limit its effectiveness[66], although these issues could potentially be addressed through enhanced training and improved equipment. Furthermore, it is crucial to acknowledge the rapid indicative function of the pupil in monitoring changes in the neurology of critically ill patients, which may be compromised if the pupil becomes dilated[66]. While pupil expansion is not obligatory when employing SO, it is commonly advised by the majority of equipment manufacturers. Consequently, the using of portable non-mydriatic fundus photography screening may be more suitable for neurology, which demonstrates greater accuracy compared to SO in the context of neurology inpatients[67].

SMARTPHONE OPHTHALMOSCOPE IN OCULAR TEACHING

As previously stated, proficiency in basic ophthalmoscopic examination techniques is essential for physicians across all subspecialties[68]. The conventional ophthalmoscope presents challenges for medical students to master, potentially related to the lack of confidence and regular practice[69]. To tackle these concerns, various teaching methods have been innovated to enhance ophthalmoscopic instruction, including SO, fundus photograph matching exercise[70], the Eye Retinopathy Trainer®[71], Eyesi® Binocular Indirect Ophthalmoscope Simulator[72], and so on. Among these innovative teaching methods, it appears that SO holds an indispensable position.

First, incorporating familiar teaching aids, such as smartphones, may facilitate a more efficient onboarding process and foster greater acceptance among students. Comparative research conducted by SO and direct ophthalmoscope[11,16,73-77], indicates that SO is generally regarded as more user-friendly and enables a more precise identification of structural elements, thereby bolstering confidence in ophthalmoscopy. Furthermore, medical students exhibit a preference for employing SO in comprehending fundus structure and evaluating the patient's fundus condition[78]. SO which deviates from conventional teaching aids has the potential to bring freshness to students and thus stimulate their interest in ophthalmoscopy. Second, SO enables students to share their vision with professors thereby facilitating the acquisition of more precise guidance[79]. Additionally, the recorded nature of SO allows students to revisit the material repeatedly, reinforcing their learning through practice exercises after class, while also enabling professors to create instructional videos for broader dissemination[80]. However, it is worth noting that certain undergraduate optometry students, who possess prior experience with direct ophthalmoscope, may exhibit a preference for its usage due to their limited exposure to SO[79], a preconception that can be comprehended. In summary, SO is believed to be beneficial as an educational tool for students lacking fundamental knowledge of ophthalmoscopy to fully utilize its universality, enjoyment and shareability. However, the key point to note is that using the combination of a lens and a smartphone presents greater challenges compared to other commercial SOs, and students may encounter difficulties in aligning the imaging axes manually[19].

The question of whether to include teaching of SO after pupil dilation is a matter of significance. The practice of observing patients after dilation aligns more closely with clinical protocols, and the manufacturer of D-EYE advises its use after dilation. However, the administration of dilation to students[19,78], may potentially extend instructional time, necessitate additional medication to reduce pupil dilation, or compromise visual clarity to meet instructional deadlines. Alternatively, the involvement of volunteers who have undergone dilation, utilization of eye models, or examination of animal fundus could potentially offer viable solutions to this issue[74,81-83]. Nevertheless, if the purpose of teaching is only to become familiar with the operation of ophthalmoscope and the anatomy of the fundus, conducting precise screenings, the author contends that conducting undilated ophthalmoscopy is deemed acceptable.

If the purpose of using SO is solely to acquire fundus images rather than to observe fundus structure or diagnose fundus diseases, the scope of teaching can also be expanded to include non-ophthalmic personnel and the families of patients[84]. Previous research has demonstrated that individuals without medical expertise, such as patients' families, can successfully capture adequate fundus images after trains for subsequent clinical examination[18,20,85]. Furthermore, the quality of fundus images obtained by trained assistants was not significantly different from those captured by ophthalmologists but assistants took longer to examine[83]. This way enables early detection and timely intervention of fundus diseases, as well as the preservation of follow-up data and facilitation of telemedicine.

CONCLUSION

In conclusion, the use of SO has the potential to contribute significantly to the field of portable ocular diagnosis and in-hospital consultations. Consequently, SO will likely improve access to specialist ophthalmic care in underprivileged communities worldwide. Furthermore, the ability to store photos acquired through SO in the cloud allows for long-term analysis of examination results, facilitating patient follow-up and referral. Additionally, it is worth noting that SO has been positively received and effectively utilized as an educational resource for both educators and students. In forthcoming times, substantial efforts will be required to develop a retina-friendly LED light source, attachments that facilitate peripheral retina visibility without necessitating pupil dilation, technology that guarantees the delivery of information with high quality and safety and promotes greater acceptance among physicians, patients, and medical students. As smartphones continue to advance in capabilities and become increasingly prevalent, it is anticipated that they will offer enhanced functionalities in the field of ophthalmology.

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REFERENCES

1 Jabir AR, Zaheer HA, Zaheer MA, *et al*. Detection and diagnosis of retinoblastoma: can mobile devices be the next step toward early intervention? *Cureus* 2022;14(10):e30074.

2 Hogarty DT, Hogarty JP, Hewitt AW. Smartphone use in ophthalmology: What is their place in clinical practice? *Surv Ophthalmol* 2020;65(2): 250-262.

3 AlHilali SM, AlMuammar AM, AlKahtani E, *et al*. Preferred method of education among patients in ophthalmic care in Saudi Arabia. *Middle East Afr J Ophthalmol* 2016;23(2):168-171.

4 Collon S, Chang D, Tabin G, *et al*. Utility and feasibility of teleophthalmology using a smartphone-based ophthalmic camera in screening camps in Nepal. *Asia Pac J Ophthalmol* (*Phila*) 2020;9(1):54-58.

5 Ozdalga E, Ozdalga A, Ahuja N. The smartphone in medicine: a review of current and potential use among physicians and students. *J Med Internet Res* 2012;14(5):e128.

6 Lord RK, Shah VA, San Filippo AN, *et al*. Novel uses of smartphones in ophthalmology. *Ophthalmology* 2010;117(6):1274-1274.e3.

7 Singh A, Cheyne K, Wilson G, *et al*. On the use of a new monocular-indirect ophthalmoscope for retinal photography in a primary care setting. *N Z Med J* 2020;133(1512):31-38.

8 Shah D, Dewan L, Singh A, *et al*. Utility of a smartphone assisted direct ophthalmoscope camera for a general practitioner in screening of diabetic retinopathy at a primary health care center. *Indian J Ophthalmol* 2021;69(11):3144-3148.

9 Wintergerst MWM, Brinkmann CK, Holz FG, *et al*. Undilated versus dilated monoscopic smartphone-based fundus photography for optic nerve head evaluation. *Sci Rep* 2018;8(1):10228.

10 González-Márquez F, Luque-Romero L, Ruiz-Romero MV, *et al*. Remote ophthalmology with a smartphone adapter handled by nurses for the diagnosis of eye posterior pole pathologies during the COVID-19 pandemic. *J Telemed Telecare* 2023;29(6): 474-483.

11 Wang HX, Liao XL, Zhang MZ, *et al*. Smartphone ophthalmoscope as a tool in teaching direct ophthalmoscopy: a crossover randomized controlled trial. *Med Educ Online* 2023;28(1):2176201.

12 Goyal A, Gopalakrishnan M, Anantharaman G, *et al*. Smartphone guided wide-field imaging for retinopathy of prematurity in neonatal intensive care unit-a Smart ROP (SROP) initiative. *Indian J Ophthalmol* 2019;67(6):840-845.

13 Lin JY, Kang EY, Banker AS, *et al*. Comparison of RetCam and smartphone-based photography for retinopathy of prematurity screening. *Diagnostics* (*Basel*) 2022;12(4):945.

14 Wintergerst MWM, Jansen LG, Holz FG, *et al*. A novel device for smartphone-based fundus imaging and documentation in clinical practice: comparative image analysis study. *JMIR Mhealth Uhealth* 2020;8(7):e17480.

15 Krieger B, Hallik R, Kala K, *et al*. Validation of mobile-based funduscope for diabetic retinopathy screening in Estonia. *Eur J Ophthalmol* 2022;32(1):508-513.

16 Wu AR, Fouzdar-Jain S, Suh DW. Comparison study of funduscopic examination using a smartphone-based digital ophthalmoscope and the direct ophthalmoscope. *J Pediatr Ophthalmol Strabismus* 2018;55(3):201-206.

17 Adam MK, Brady CJ, Flowers AM, *et al*. Quality and diagnostic utility of mydriatic smartphone photography: the smartphone ophthalmoscopy reliability trial. *Ophthalmic Surg Lasers Imaging Retina* 2015;46(6):631-637.

18 Willett K, Barkmeier A. Layperson minimal-resource smartphone retinal photography. *Ophthalmol Retina* 2022;6(10):885.

19 Kohler J, Tran TM, Sun SS, *et al*. Teaching smartphone funduscopy with 20 diopter lens in undergraduate medical education. *Clin Ophthalmol* 2021;15:2013-2023.

20 Gobbi JD, Braga JPR, Lucena MM, *et al*. Efficacy of smartphone-based retinal photography by undergraduate students in screening and early diagnosing diabetic retinopathy. *Int J Retina Vitreous* 2022;8(1):35.

21 Kim DY, Delori F, Mukai S. Smartphone photography safety. *Ophthalmology* 2012;119(10):2200-2201.

22 Hong SC, Wynn-Williams G, Wilson G. Safety of iPhone retinal photography. *J Med Eng Technol* 2017;41(3):165-169.

23 Solyman OM, Hamdy O, Abdelkawi SA, *et al*. Investigating the light emitting diode (LED) flashlight characteristics of a sample of smartphones for its safety in indirect retinal photography. *Pan Afr Med J* 2022;43:15.

24 Solyman O, Aref A, Abo Obaia AS, *et al*. An all-digital, binocular, indirect virtual video ophthalmoscope: a novel approach to retinal examination and photography. *Clin Ophthalmol* 2022;16:3905-3909.

25 Elloumi Y, Akil M, Kehtarnavaz N. A mobile computer aided system for optic nerve head detection. *Comput Meth Programs Biomed* 2018;162:139-148.

26 Bilong Y, Domngang CN, Nwanlih Gimma G, *et al*. Smartphone-assisted glaucoma screening in patients with type 2 diabetes: a pilot study. *Med Hypothesis Discov Innov Ophthalmol* 2020;9(1):61-65.

27 Mercado C, Welling J, Oliva M, *et al*. Clinical application of a smartphone-based ophthalmic camera adapter in under-resourced settings in Nepal. *J Mob Technol Med* 2017;6(3):34-42.

28 Ludwig CA, Murthy SI, Pappuru RR, *et al*. A novel smartphone ophthalmic imaging adapter: User feasibility studies in Hyderabad, India. *Indian J Ophthalmol* 2016;64(3):191-200.

29 Fink W, Tarbell M. Smart ophthalmics: a smart service platform for tele-ophthalmology. *Invest Ophthalmol Vis Sci* 2015;56(7):4110.

30 Adhikari S, Bajimaya S, Ranjitkar EP. Validation of smartphone-based screening for retinopathy of prematurity in a low-resource setting. *J AAPOS* 2021;25(5):274.e1-274274.e5.

31 Hong KR, Collon S, Chang D, *et al*. Teleophthalmology through handheld mobile devices: a pilot study in rural Nepal. *J Mob Technol Med* 2019;8(1):10.7309/jmtm.8.1.1.

32 Han YS, Pathipati M, Pan C, *et al*. Comparison of telemedicine screening of diabetic retinopathy by mydriatic smartphone-based vs nonmydriatic tabletop camera-based fundus imaging. *J Vitreoretin Dis* 2021;5(3):199-207.

33 Sheikh A, Bhatti A, Adeyemi O, *et al*. The utility of smartphone-based artificial intelligence approaches for diabetic retinopathy: a literature review and meta-analysis. *J Curr Ophthalmol* 2021;33(3):219-226.

34 Schuster AK, Erb C, Hoffmann EM, *et al*. The diagnosis and treatment of glaucoma. *Dtsch Arztebl Int* 2020;117(13):225-234.

35 Muhsen S, Roto A, Al-Sabbagh MQ, *et al*. Smartphone ophthalmoscopy versus slit-lamp biomicroscopy for optic nerve head evaluation: a digital apparatus into medical education. *Eur J Ophthalmol* 2023;33(1):341-351.

36 Russo A, Mapham W, Turano R, *et al*. Comparison of smartphone ophthalmoscopy with slit-lamp biomicroscopy for grading vertical cup-to-disc ratio. *J Glaucoma* 2016;25(9):e777-e781.

37 Idriss BR, Tran TM, Atwine D, *et al*. Smartphone-based ophthalmic imaging compared with spectral-domain optical coherence tomography assessment of vertical cup-to-disc ratio among adults in southwestern Uganda. *J Glaucoma* 2021;30(3):e90-e98.

38 Feldman S, Mahan M, Osborne B. The efficacy of photographic evaluation of the optic nerve to determine the presence of acute optic nerve head elevation. *Invest Ophthalmol Vis Sci* 2019;60(9):3598.

39 Bastawrous A, Giardini ME, Bolster NM, *et al*. Clinical validation of a smartphone-based adapter for optic disc imaging in Kenya. *JAMA Ophthalmol* 2016;134(2):151-158.

40 Lin B, Markatia Z, Mittal A, *et al*. Evaluating a smartphone-based optic nerve imaging device as a glaucoma screening tool in an outpatient clinic setting. *Invest Ophthalmol Vis Sci* 2022;63(7):1423.

41 Scarpa F, Berto A, Colonna A, *et al*. Development of an automated analysis for glaucoma screening of videos acquired with smartphone ophthalmoscope. *Invest Ophthalmol Vis Sci* 2020;61(7):4542.

42 Tan TE, Wong TY. Diabetic retinopathy: looking forward to 2030. *Front Endocrinol* (*Lausanne*) 2022;13:1077669.

43 Russo A, Morescalchi F, Costagliola C, *et al*. Comparison of smartphone ophthalmoscopy with slit-lamp biomicroscopy for grading diabetic retinopathy. *Am J Ophthalmol* 2015;159(2):360-364.e1.

44 Sengupta S, Sindal MD, Baskaran P, *et al*. Sensitivity and specificity of smartphone-based retinal imaging for diabetic retinopathy: a comparative study. *Ophthalmol Retina* 2019;3(2):146-153.

45 Bilong Y, Katte JC, Koki G, *et al*. Validation of smartphone-based retinal photography for diabetic retinopathy screening. *Ophthalmic Surg Lasers Imaging Retina* 2019;50(5):S18-S22.

46 Prathiba V, Rajalakshmi R, Arulmalar S, *et al*. Accuracy of the smartphone-based nonmydriatic retinal camera in the detection of sight-threatening diabetic retinopathy. *Indian J Ophthalmol* 2020;68(Suppl 1):S42-S46.

47 Tan CH, Kyaw BM, Smith H, *et al*. Use of smartphones to detect diabetic retinopathy: scoping review and meta-analysis of diagnostic test accuracy studies. *J Med Internet Res* 2020;22(5):e16658.

48 Vujosevic S, Aldington SJ, Silva P, *et al*. Screening for diabetic retinopathy: new perspectives and challenges. *Lancet Diabetes Endocrinol* 2020;8(4):337-347.

49 Yusuf AM, Lusobya RC, Mukisa J, *et al*. Validity of smartphone-based retinal photography (PEEK-retina) compared to the standard ophthalmic fundus camera in diagnosing diabetic retinopathy in Uganda: a cross-sectional study. *PLoS One* 2022;17(9):e0273633.

50 Wintergerst MWM, Mishra DK, Hartmann L, *et al*. Diabetic retinopathy screening using smartphone-based fundus imaging in India. *Ophthalmology* 2020;127(11):1529-1538.

51 Patel TP, Kim TN, Yu G, *et al*. Smartphone-based, rapid, wide-field fundus photography for diagnosis of pediatric retinal diseases. *Transl Vis Sci Technol* 2019;8(3):29.

52 Day LM, Wang SX, Huang CJ. Nonmydriatic fundoscopic imaging using the pan optic iExaminer system in the pediatric emergency department. *Acad Emerg Med* 2017;24(5):587-594.

53 Lekha T, Ramesh S, Sharma A, *et al*. MII RetCam assisted smartphone based fundus imaging for retinopathy of prematurity. *Indian J Ophthalmol* 2019;67(6):834-839.

54 Dickson D, Fouzdar-Jain S, MacDonald C, *et al*. Comparison study of funduscopic exam of pediatric patients using the D-EYE method and conventional indirect ophthalmoscopic methods. *OJOph* 2017;7(3):145-152.

55 Wintergerst MWM, Petrak M, Li JQ, *et al*. Non-contact smartphone-based fundus imaging compared to conventional fundus imaging: a low-cost alternative for retinopathy of prematurity screening and documentation. *Sci Rep* 2019;9:19711.

56 Patel M, Mukherjee D, Farsiu S, *et al*. Estimation of gestational age *via* image analysis of anterior lens capsule vascularity in preterm infants: a pilot study. *Front Pediatr* 2019;7:43.

57 Pujari A, Lomi N, Goel S, *et al*. Unmodified iPhone XS Max for fundus montage imaging in cases of retinoblastoma. *Indian J Ophthalmol* 2019;67(6):948-949.

58 Muiesan ML, Salvetti M, Paini, *et al*. Ocular fundus photography with a smartphone device in acute hypertension. *J Hypertens* 2017;35(8):1660-1665.

59 George G, Murphy DC, Jeffry Hogg HDJ, *et al*. Evaluation of a low-resource screening strategy for ophthalmic pathologies and associated neurological morbidity in an older Tanzanian HIV-positive population. *Sci Rep* 2022;12(1):1434.

60 Faber H, Berens P, Rohrbach JM. Ocular changes as a diagnostic tool for malaria. *Ophthalmologie* 2022;119(7):693-698.

61 Andres Monteoliva G, Saidman G. Congenital toxoplasmosis m-health network in Argentina. *Invest Ophthalmol Vis Sci* 2017;58(8):4830.

62 Ademola-Popoola DS, Olatunji VA. Retinal imaging with smartphone. *Niger J Clin Pract* 2017;20(3):341-345.

63 Sarkar S, Gokhale T, Farnaz Y, *et al*. Smartphone-assisted retinal evaluation in COVID-19 admitted patients. *Indian J Ophthalmol* 2021;69(10):2884-2885.

64 Khachatryan T, Mozaffar T, Mnatsakanyan L. Utility of video-fundoscopy and prospects of portable stereo-photography of the ocular fundus in neurological patients. *BMC Neurol* 2022;22(1):61.

65 Evangelista VRP, Mermelstein SA, da Silva MM, *et al*. Bedside video-ophthalmoscopy as an aid in the diagnosis of central vestibular syndromes. *J Neurol* 2022;269(1):217-220.

66 Zafar S, Cardenas YM, Leishangthem L, *et al*. Opinion and special articles: amateur fundus photography with various new devices: our experience as neurology residents. *Neurology* 2018;90(19):897-901.

67 He G, Dunn HP, Ahmad KE, *et al*. Fundoscopy use in neurology departments and the utility of smartphone photography: a prospective prevalence and crossover diagnostic accuracy study amongst neurology inpatients. *Eur J Neurol* 2022;29(8):2463-2472.

68 Hartley MJ, Bartley GB. Ophthalmology and direct ophthalmoscopy in contemporary medical education. *Am J Ophthalmol* 2022;238:xv-xvi.

69 Liao J, Wright RR, Vora GK. The decline of basic ophthalmology in general medical education: a scoping review and recommended potential solutions. *J Med Educ Curric Dev* 2024;11:23821205241245635.

70 Kwok J, Liao W, Baxter S. Evaluation of an online peer fundus photograph matching program in teaching direct ophthalmoscopy to medical students. *Can J Ophthalmol* 2017;52(5):441-446.

71 Androwiki JE, Scravoni IA, Ricci LH, *et al*. Evaluation of a simulation tool in ophthalmology: application in teaching funduscopy. *Arq Bras Oftalmol* 2015;78(1):36-39.

72 Douglass A, Cham KM, Jaworski A, *et al*. The equivalency of the binocular indirect ophthalmoscope simulator to peer practice: a pilot study. *Optom Vis Sci* 2021;98(11):1239-1247.

73 Kim Y, Chao DL. Comparison of smartphone ophthalmoscopy vs conventional direct ophthalmoscopy as a teaching tool for medical students: the COSMOS study. *Clin Ophthalmol* 2019;13:391-401.

74 Mamtora S, Sandinha MT, Ajith A, *et al*. Smart phone ophthalmoscopy: a potential replacement for the direct ophthalmoscope. *Eye* (*Lond*) 2018;32(11):1766-1771.

75 Dunn HP, Marks S, Teo KZ, *et al*. eFOCUS 2: a randomised crossover trial of smartphone fundoscopy and direct ophthalmoscopy aiming to improve optic disc interpretation by medical students with e-learning support. *Clin Exp Ophthalmol* 2021;49(7):704-713.

76 Kim YJ, Chao D. Comparison of a portable digital ophthalmoscope to the conventional direct ophthalmoscope as a teaching tool for medical students. *Invest Ophthalmol Vis Sci* 2018;59(9):4622.

77 Hakimi AA, Lalehzarian SP, Lalehzarian AS, *et al*. The utility of a smartphone-enabled ophthalmoscope in pre-clinical fundoscopy training. *Acta Ophthalmol* 2019;97(2):e327-e328.

78 Dunn HP, Kang CJ, Marks S, *et al*. Perceived usefulness and ease of use of fundoscopy by medical students: a randomised crossover trial of six technologies (eFOCUS 1). *BMC Med Educ* 2021;21(1):41.

79 Nagra M, Huntjens B. Smartphone ophthalmoscopy: patient and student practitioner perceptions. *J Med Syst* 2019;44(1):10.

80 Schrimpf B, Dalby M, Mülhaupt M, *et al*. Interaktives training mittels smartphone-videoskiaskop. *Ophthalmologe* 2020;117(4):384-388.

81 Balland O, Russo A, Isard PF, *et al*. Assessment of a smartphone-based camera for fundus imaging in animals. *Vet Ophthalmol* 2017;20(1):89-94.

82 Peng M, Park B, Harikrishnan H, *et al*. A smartphone based method for mouse fundus imaging. *Exp Eye Res* 2021;206:108530.

83 Jansen LG, Shah P, Wabbels B, *et al*. Learning curve evaluation upskilling retinal imaging using smartphones. *Sci Rep* 2021;11(1):12691.

84 Panchal B. Commentary: Retinopathy of prematurity screening made simple-Smartphone-based fundus imaging. *Indian J Ophthalmol* 2019;67(6):839.

85 Leon L, Huz JI, Yadgarov A, *et al*. Smart phone retinal photography: Uses and experiences with the novel retinal imaging technique. *Invest Ophthalmol Vis Sci* 2015;56(7):4106.