Original Article

Dilated Smartphone Imaging for the Detection and Grading of Diabetic Retinopathy

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ABSTRACT: The recent interest in the efficacy of smartphones for fundus imaging to screen for diabetic retinopathy (DR) warrants further research due to its accessibility, portability, connectivity, and relatively low cost. This study aims to determine the diagnostic efficacy of dilated smartphone fundus imaging for the detection and grading of diabetic retinopathy. This is a single institution, hospital-based, prospective diagnostic validation study. Twenty-eight adult patients with diabetes (55 eyes) underwent dilated fundus imaging through two modalities: (1) iPhone 6s (Apple, Inc., Cupertino, California, USA) and (2) ultrawide field Optos fundus camera. An independent trained retina specialist graded both iPhone and Optos images for DR and diabetic macular edema (DME). A second retina specialist adjudicated grading discrepancies. Agreement between smartphone and 100-degree Optos image grading for DR was good to excellent (kappa= 0.79, 95% confidence interval [CI], 0.67-0.92; weighted kappa= 0.90, 95% CI, 0.85-0.96). Compared to 100-degree Optos fundus imaging, the sensitivity and specificity of dilated smartphone fundus imaging for the detection of referable DR, defined as at least moderate nonproliferative DR and/or DME, were 93.6% (95% CI, 78.6-99.2) and 100% (95% CI, 85.1-100), respectively. All of the patients who underwent dilated smartphone fundus imaging experienced no discomfort or untoward adverse events. In summary, dilated smartphone fundus imaging is a highly specific and sensitive tool for the detection of patients with DR. Given the inherent capability of the smartphone to transmit images, this technique is a promising and effective means for eye care professionals in remote and/or resource-poor areas to screen and monitor patients with DR with guidance from retina subspecialists from afar.

Keywords: *detection; diabetic retinopathy; screening; smartphone; telemedicine*

INTRODUCTION

Diabetic retinopathy remains a leading cause of blindness and decreased quality of life in both developed and developing countries. Early detection and treatment of diabetic retinopathy can prevent severe vision loss.[1] Unfortunately, the recognition, monitoring, and treatment of diabetic retinopathy in resource poor settings remains to be a challenge due to the limited number of specialists, high cost of screening equipment, and poor access to eye care.[2] Given this, remotely interpreted fundus imaging, also described as telemedicine, has emerged as a cost-effective screening method for diabetic retinopathy.[3]

The current standards of care for diabetes require that a dilated eye examination be performed by an ophthalmologist within five years of diagnosis for type 1 diabetes, and at the time of diagnosis for type 2 diabetes. This should be followed by regular annual or semi-annual eye examinations, based on the evidence of retinopathy.[4]In areas where access to ophthalmologists or retina subspecialists is limited, fundus photography with remote reading by a trained eye care provider is an acceptable means of screening for diabetic retinopathy. Clinical examinations are necessary when the fundus photos are ungradable or when retinal abnormalities are detected. [4]

Unfortunately, utilization of eye care services remains low, particularly in poor and far-flung communities where access to health care is problematic.[5]The utility of smartphones for capturing fundus images to screen for diabetic retinopathy has been suggested but its efficacy remains undocumented. In contrast to standard fundus cameras, the major advantages of smartphone fundus imaging include accessibility, portability, connectivity, and relatively low cost.[6]Because of its possible application in areas with limited access to retina specialists and fundus cameras, studies on this technique in the context of telemedicine are relevant. In the Philippines, the potential use of this technology has yet to be explored. This study aimed to determine the diagnostic efficacy of dilated smartphone fundus imaging for the detection and grading of diabetic retinopathy compared to the standard of care and describe patient experiences during dilated smartphone fundus imaging.

METHODOLOGY

Population and Sample

Twenty-eight patients were consecutively recruited from the outpatient clinic of the Department of Ophthalmology at The Medical City in Ortigas Avenue, Pasig City from August 15, 2017 to September 15, 2017. The sample size was computed based on the target kappa value of 0.80 and assumed baseline kappa value of 0.50 with alpha of 5% and power of 80%. Patients were eligible for the study if the following inclusion criteria were met: (1) age of at least 18

years old and able to give informed consent, (2) diagnosed clinically with diabetes mellitus, defined as currently taking anti-diabetic medications or laboratory evidence of elevated fasting blood sugar (FBS) or glycated hemoglobin (HBA1c), and (3) willingness to undergo dilated fundus photography using iPhone 6s and Optos fundus camera. Exclusion criteria included: (1) any external adnexal pathology and overt media opacity, such as corneal opacities and dense cataracts that may obscure fundus images, (2) contraindication to pupil dilation: elevated intraocular pressure (IOP), defined as >21 millimeters of mercury by Goldmann applanation tonometry or anterior chamber angle narrowing by gonioscopy, (3) unstable vital signs, defined as systolic blood pressure >140 millimeters of mercury and pulse rate >100 or <60 beats per minute, (4) history or evidence of hypersensitivity to tropicamide 0.5% and phenylephrine 0.5% eye drops for dilation, and (5) history or evidence of hypersensitivity to proparacaine hydrochloride 0.5% eye drops for topical anesthesia. Patient eligibility was determined through a review of each prospective study subject's medical record at the time of that patient's routine visit at the eye clinic. This study was approved by the Institutional Review Board of The Medical City, Pasig City.

Methods

Study Setting

The study was conducted after each patient's eye examination, which included a dilated fundus exam, at the outpatient clinic.

Clinical Assessments

The following study procedures were performed during a single visit: (1) smartphone fundus imaging, (2) ultrawide field fundus imaging, and (3) survey on patient comfort during dilated smartphone fundus imaging. Prior to the study procedures, a member of the study team obtained the written informed consent. Baseline characteristics, which included demographics, medical and ocular history, were gathered from the outpatient record of the patient.

Smartphone Imaging

The principal investigator performed dilated smartphone fundus imaging using an iPhone 6s (Apple, Inc., Cupertino, California, USA) and a 20 diopter lens (Volk Optical, Mentor, OS). Each patient was asked to sit on a couch in a dark room at the Eye Center. Proparacaine hydrochloride 0.5% eyedrops were administered to the patient's eyes as topical anesthesia. A member of the study team manually retracted the patient's eyelids to expose the cornea during the procedure. The iPhone 6s was set on video mode with default settings at 1080 pixels and 30 frames per second. The camera's flashlight was turned on and served as the coaxial light source. The 20 diopter lens was held 8 to 10 centimeters in front of the patient's eye by the examiner's thumb and index finger in one hand. The middle, ring, and little fingers were used to stabilize the hand and the lens on the patient's brow.

Continuous videos of five fields of the retina: nasal, superior, temporal, inferior and posterior pole were recorded. To achieve this, the patient was instructed to look at a distant target in the direction of the area being examined (e.g., right eye: nasal – look left, superior – look upward, temporal – look right, inferior – look downward, posterior pole – look straight ahead).

The camera was held 10 to 35 centimeters from the lens along the patient's pupillary axis. The 20 diopter lens was placed close enough to the patient's eye to ensure that the pupil was centered on the screen. Once properly centered, the lens was moved further away from the corneal surface until the retina could be viewed. It is important for the patient's eye, lens and smartphone to be on the same axis in order to minimize light reflections and aberrations.

The principal investigator reviewed all recorded videos. A screen shot of the best representative image was captured for all five fields (Fig 1A). Using the Adobe Photoshop Express (Adobe Systems, United States) application for iPhone, the screen shot was inverted and cropped. A black border was also placed on each image (Fig 1B). All images were exported to Google Drive and subsequently downloaded to the computers in The Medical City Eye Center Reading Room.

Patient Comfort Survey

Patients were asked to assess their level of comfort during dilated smartphone fundus imaging by a member of the study team. The following scale adapted from a user feasibility study was used to answer the following question: "How comfortable were you during fundus imaging using the smartphone?": 1 – Very uncomfortable, 2 – Somewhat uncomfortable, 3 – Neutral, 4 – Somewhat comfortable, 5 – Very comfortable.[7]

Ultra wide field imaging

Ultrawide field fundus imaging was performed by a trained ophthalmic technician using the Optos fundus camera (Dunfermline, Scotland, United Kingdom). Images were reacquired until the best image quality was obtained. All Optos images were masked in the periphery to produce 100-degree views of the retina based on Early Treatment Diabetic Retinopathy Study (ETDRS) standards (Fig 2). These served as the gold standard for grading diabetic retinopathy and diabetic macular edema.

Image Grading Protocol

Fundus images from the smartphone and from the Optos camera were coded using an identification number and randomly graded by a masked independent retina reader (R.P.S.) for the presence and severity of diabetic retinopathy and diabetic macular edema. The smartphone images were graded prior to the 100-degree Optos images.

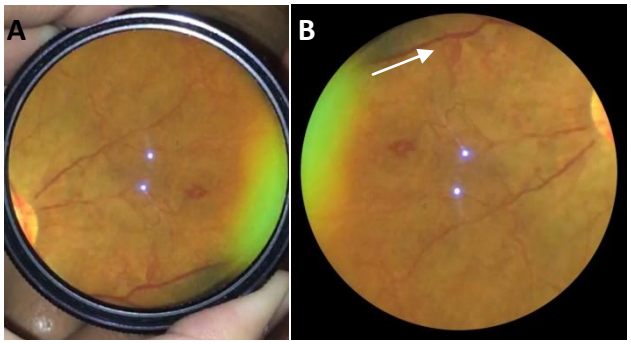

Figure 1. (A) A snapshot from a video of the retina taken with an iPhone 6s and a 20 diopter lens. Like indirect ophthalmoscopy, the image is inverted and laterally reversed. (B) Edited smartphone fundus image using Adobe Photoshop Express (Adobe Systems, United States). New vessels are signs of proliferative diabetic retinopathy (white arrow).

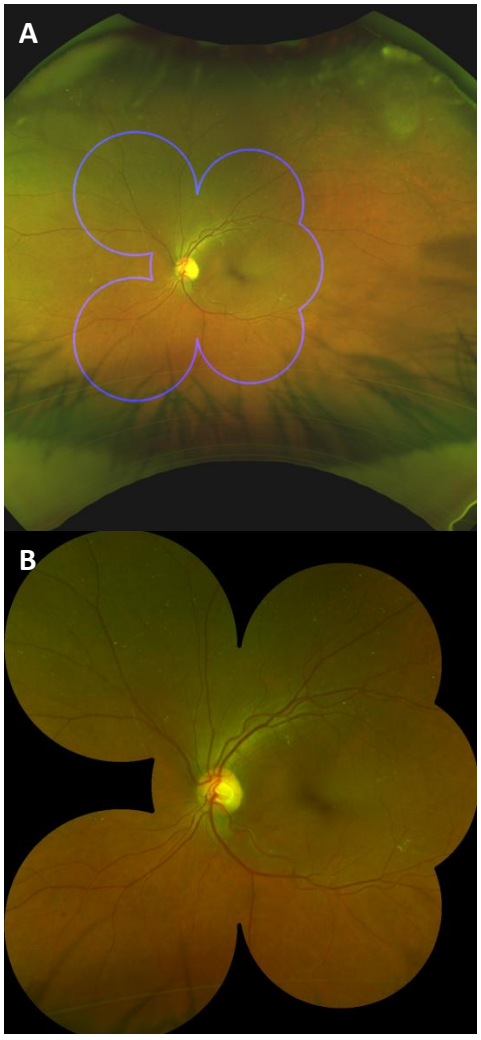

Figure 2. (A) Ultrawide field Optos 200-degree image with superimposed blue grid for 100-degree Early Treatment Diabetic Retinopathy Study (ETDRS) image. (B) Optos 100-degree image based on 30-degree 7-standard field 35-mm color ETDRS photograph.

The following scale based on the ETDRS was used for grading DR severity: No retinopathy, Mild non proliferative diabetic retinopathy (NPDR), Moderate NPDR, Severe NPDR, Proliferative diabetic retinopathy (PDR), High Risk PDR, and Ungradable. Diabetic macular edema (DME) was graded as: No DME, DME, Clinically significant macular edema (CSME), and Ungradable.

All images were reviewed at The Medical City Eye Center reading room through a 27-inch wide screen monitor (Asus; Asustek Computer Inc, Taiwan) with 1920 x 1080 resolution. Microsoft Office 2010 Picture Manager was used to adjust the contrast, brightness, and midtone of each image by the retina reader as needed. Disagreements regarding DR severity between smartphone and 100-degree Optos images were adjudicated by a second masked retina reader (P.S.S.). The adjudicated image grading for DR and DME were used in the data analysis.

Analysis

The agreement of DR and DME grading of images obtained via smartphone versus images obtained via Optos ultrawidefield camera was assessed using the kappa statistic (simple and linear weighted). Interpretation of kappa values was based on Landis and Koch (0.0 to 0.2 = slight agreement; 0.21 to 0.40 = fair agreement; 0.41 to 0.60 = moderate agreement; 0.61 to 0.80 = substantial agreement; and 0.81 to 1.00 = almost perfect agreement). In addition, the sensitivity, specificity, positive predictive value, and negative predictive value of dilated smartphone fundus imaging for the detection of referable and vision-threatening diabetic retinopathy were calculated assuming that the 100-degree Optos images provided the true diagnosis. The 95% confidence intervals were also computed.

Referable DR was defined as: at least moderate NPDR and/or DME. Vision-threatening diabetic retinopathy (VTDR) was defined as: at least severe NPDR and/or CSME. Statistical analyses were performed using SAS software version 9.2 (SAS, Inc, Carey, North Carolina, USA).

RESULTS

A total of 28 patients (55 eyes) completed the study [the 56th eye was excluded due to a media opacity (dense cataract) that obscured the fundus (exclusion criteria)]. Baseline characteristics of patients are reported in Table 1. The mean age ($\pm$ standard deviation) was 59.5 $\pm$ 10 years. Twenty-three (82.1%) patients were female. The mean duration of diabetes was 9.6 $\pm$ 7.3 years. Of the 55 eyes, 40 eyes (72.7%) had a best-corrected visual acuity greater or equal to 20/40 but less than 20/20. Thirty-seven (67.3%) were phakic and 18 eyes were pseudophakic (32.7%). Based on 100-degree ETDRS Optos imaging, 47 eyes had DR (85.1%), 8 eyes had DME (14.5%) and 12 eyes had CSME (21.8%).

Table 1. Baseline Demographics, Medical and Ocular Characteristics

Demographics (n = 28 patients)	
Age (years) [a]	59.5 ± 10 (34 to 85)
Gender [b]	
Female	23 (82.1%)
Male	5 (17.9%)
Medical characteristics (n = 28 patients)	
DM duration (years) [a]	9.6 ± 7.3 (0.6 to 25)
Ocular characteristics (n = 55 eyes)	
ETDRS visual acuity [b]	
≥ 20/20	9 (16.4%)
<20/20 to ≥ 20/40	40 (72.7%)
<20/40 to ≥ 20/100	1 (1.8%)
<20/100	5 (9.1%)
Lens [b]	
Phakic	37 (67.3%)
Pseudophakic	18 (32.7%)
Retinopathy severity [b,c]	
No DR	7 (12.7%)
Mild NPDR	17 (30.9%)
Moderate NPDR	8 (14.5%)
Severe NPDR	7 (12.7%)
PDR	11 (20.0%)
High risk PDR	4 (7.3%)
Ungradable for DR	1 (1.8%)
Total with DR	47 (85.1%)
Macular edema severity [b,c]	
No DME	30 (54.5%)
DME	8 (14.5%)
CSME	12 (21.8%)
Ungradable for DME	5 (9.1%)

DM – diabetes mellitus; DR – diabetic retinopathy; NPDR – nonproliferative diabetic retinopathy; PDR – proliferative diabetic retinopathy; DME – diabetic macular edema; CSME – clinically significant macular edema

a – Data presented as mean ± standard deviation (range)

b – Data presented as number (%)

c – Grading based on 100 degree ETDRS Optos photographs as gold standard (n = 55 eyes)

Diabetic retinopathy detection by the two imaging modalities: smartphone and 100-degree Optos fundus camera is presented in Table 2. Out of the 55 eyes, only 1 eye (1.8%) was ungradable by both 100-degree Optos imaging and by smartphone imaging due to media opacity. Among 54 gradable eyes for DR, exact agreement of DR severity between 100-degree Optos images and smartphone images was seen in 46 eyes (84%) with a simple κ of 0.79 (95% CI, 0.67 to 0.92) and weighted κ of 0.90 (95% CI, 0.85 to 0.96).

A total of 21 eyes (38.2%) did not have an exact match in the level of DR after evaluation of smartphone and 100-degree Optos images. After independent adjudications of smartphone and 100-degree Optos images, discrepancies in the DR level remained in 9 eyes (16.4%). The source of the discrepancies was found to be the missed detection of a single lesion-type in all 9 eyes. These lesions were hemorrhages/ microaneurysms (HMA) in 4 eyes, intraretinal microvascular abnormality (IRMA) in 3 eyes, and new vessels on the disc (NVD) in 2 eyes. Discrepancies in lesion detection were attributed to poor image quality by smartphone in 8 eyes and in Optos in 1 eye.

Diabetic macular edema detection by the two imaging modalities is presented in Table 3. Out of the 55 eyes, 5 eyes (1.8%) were ungradable by 100-degree Optos imaging due to media opacities obscuring the macula. Two of the 5 eyes were graded with no DME by smartphone. Among 50 gradable eyes for DR, exact agreement of DR severity between 100-degree Optos images and smartphone images was seen in 40 eyes (80%) with a simple κ of 0.63 (95% CI, 0.44 to 0.82) and weighted κ of 0.64 (95% CI, 0.44 to 0.85).

Data for sensitivity, specificity, and predictive values for referable diabetic retinopathy and vision-threatening diabetic retinopathy are presented in Table 4 and Table 5, respectively. Compared to 100-degree Optos fundus imaging, the sensitivity and specificity of dilated smartphone fundus imaging for the detection of referable DR were 93.6% (95% CI, 78.6-99.2) and 100% (95% CI, 85.1-100), respectively. The positive predictive value and negative predictive value of dilated smartphone fundus imaging for the detection of referable DR were 100% (95% CI, 88.1-100) and 92% (95% CI, 74.0-99.0), respectively. On the other hand, the sensitivity and specificity of dilated smartphone fundus imaging for the detection of VTDR were 92.0% (95% CI, 74.0-99.0) and 96.6% (95% CI, 82.2-99.9), respectively. The positive predictive value and negative predictive value of dilated smartphone fundus imaging for the detection of VTDR were 95.8% (95% CI, 78.9-99.9) and 93.3% (95% CI, 77.9-99.2), respectively.

As presented in Table 6, all 28 patients felt comfortable during dilated smartphone imaging with 13 patients (46.4%) rating their experience as "somewhat comfortable" and 15 patients (53.6%) rating their experience as "very comfortable".

DISCUSSION

Few studies have compared smartphone fundus imaging to standard imaging equipment.[8] This study is the first to compare dilated smartphone imaging using an iPhone 6s to an ultrawide field imaging fundus camera. The fundus images obtained with the smartphone had a high rate of accuracy for grading DR severity. Agreement between smartphone and 100-degree Optos image grading was good to excellent for DR, and good for DME. The smartphone was also sensitive and specific for detecting referable DR and vision-threatening DR. One reason for the higher agreement, sensitivity and specificity of smartphone images in this study as compared to previous studies may be the imaging of five fields: nasal, superior, temporal, inferior and posterior pole.[8] The average number of images reviewed per study eye was 13 (minimum: 7, maximum: 21).

This allowed the acquisition of a larger field of the retina giving more information to the grader.

Several techniques for smartphone imaging have been reported and differ according to use of adapters and applications. A study reported the sensitivity and specificity of dilated smartphone imaging with an iPhone 5 using the FilmIc Pro application to be 50% and 94%, respectively, compared to dilated fundus imaging.[3] Another study compared dilated smartphone imaging of a single field with an iPhone 5s and the Paxos Scope adapter to clinical grading and demonstrated a sensitivity and specificity of 91% and 99%, respectively.[8] In our paper, the authors preferred to perform smartphone imaging using the default settings of the iPhone with no additional adapters as demonstrated in previous techniques.[9]

Table 2. Cross-Tabulation of Level of Diabetic Retinopathy in 100-degree ETDRS Optos Imaging and Smartphone Imaging

		100-degree ETDRS Optos Imaging							
	DR Grading	No DR	Mild NPDR	Moderate NPDR	Severe NPDR	PDR	High Risk PDR	Ungra-deable	Total for Smart-phone (%)
Smartphone Imaging	No DR	6	3	0	0	0	0	0	9 (16.4)
	Mild NPDR	1	14	1	0	0	0	0	16 (29.1)
	Moderate NPDR	0	0	7	2	0	0	0	9 (16.4)
	Severe NPDR	0	0	0	5	1	0	0	6 (10.9)
	PDR	0	0	0	0	10	1	0	11 (20.0)
	High Risk PDR	0	0	0	0	0	3	0	3 (5.5)
	Ungradeable	0	0	0	0	0	0	1	1 (1.8)
	Total for Optos (%)	7 (12.7)	17 (30.9)	8 (14.5)	7 (12.7)	11 (20.0)	4 (7.3)	1 (1.8)	55 (100)

DR – diabetic retinopathy; NPDR – nonproliferative diabetic retinopathy; PDR – proliferative diabetic retinopathy
κ statistic for agreement did not include images that were ungradable for diabetic retinopathy by 100-degree Optos imaging (n=1)
Simple κ statistic, 0.79 (95% confidence interval, 0.67 to 0.92)
Weighted κ statistic (linear), 0.90 (95% confidence interval, 0.85 to 0.96)

Table 3. Cross-Tabulation of Level of Diabetic Macular Edema in 100-degree ETDRS Optos Imaging and Smartphone Imaging

		100-degree ETDRS Optos Imaging				
	DME Grading	No DME	DME	CSME	Ungradeable	Total for Smartphone (%)
Smartphone Imaging	No DME	27	2	2	2	33 (60.0)
	DME	0	3	0	0	3 (5.5)
	CSME	3	3	10	0	16 (29.1)
	Ungradeable	0	0	0	3	3 (5.5)
	Total for Optos (%)	30 (54.5)	8 (14.5)	12 (21.8)	5 (9.1)	55 (100)

DME – diabetic macular edema; CSME – clinically significant macular edema
κ statistic for agreement did not include images that were ungradeable for diabetic macular edema by 100-degree Optos imaging (n=5)
Simple κ statistic, 0.63 (95% confidence interval, 0.44 to 0.82)
Weighted κ statistic, 0.64 (95% confidence interval, 0.44 to 0.85)

This study also shows that smartphone imaging was a relatively comfortable procedure, similar to the results of another study.[7] In addition, the average time it took to complete the imaging of five fields per eye was 1 to 2 minutes which is comparable to previous studies.[7]

The study has some limitations. First, a resident ophthalmologist with training in indirect ophthalmoscopy performed the smartphone imaging, and the same quality of images and therefore reproducibility of study results may not be achieved by non-ophthalmologists. Second, this study utilized a non-standard image output from a fundus camera as the gold standard. That is, the ultrawide field image that originally shows 200 degrees of the fundus was artificially masked to show 100 degrees based on ETDRS standards. Another study that compares the smartphone images to the unmasked 200-degree ultrawide field images may provide different results. Third, this study was performed in a tertiary hospital setting where patient demographics and disease characteristics may be different from a remote area.

Table 4. Sensitivity and Specificity of Smartphone Imaging for Referable Diabetic Retinopathy

		100-degree Optos Imaging						
		Not Referable DR	Referable DR[a]	Total (%)	Sensitivity (95% CI)	Specificity (95% CI)	Positive Predictive Value	Negative Predictive Value
Smartphone Imaging	Not Referable DR	23	2	25 (46.3)				
	Referable DR[a]	0	29	29 (53.7)	0.94 (0.79 to 0.99)	1.00 (0.85 to 1.00)	1.00	0.92
	Total (%)	23 (42.6)	31 (57.4)	54 (100)				

DR – diabetic retinopathy; CI – confidence interval

Data excludes images that were ungradable for diabetic retinopathy by 100-degree Optos imaging (n=1)

a – Referable diabetic retinopathy defined as at least moderate nonproliferative diabetic retinopathy and/or diabetic macular edema

Table 5. Sensitivity and Specificity of Smartphone Imaging for Vision-threatening Diabetic Retinopathy

		100-degree Optos Imaging						
		Not VTDR	VTDR[a]	Total (%)	Sensitivity (95% CI)	Specificity (95% CI)	Positive Predictive Value	Negative Predictive Value
Smartphone Imaging	Not VTDR	28	2	30 (55.6)				
	VTDR[a]	1	23	24 (44.4)	0.92 (0.74 to 0.99)	0.97 (0.82 to 1.00)	0.96	0.93
	Total (%)	29 (53.7)	25 (46.3)	54 (100)				

VTDR – vision-threatening diabetic retinopathy; CI – confidence interval

Data excludes images that were ungradable for diabetic retinopathy by 100-degree Optos imaging (n=1)

a – Vision-threatening diabetic retinopathy defined as at least severe nonproliferative diabetic retinopathy and/or clinically significant macular edema

There are also inherent limitations to smartphone fundus imaging. For instance, the need for pharmacologic dilation may limit the application of smartphone fundus imaging to ophthalmologists. With mobile transmission of images and data, assuring patient confidentiality and privacy may be problematic and should also be addressed.[10]The technique of smartphone fundus imaging is technically similar to indirect ophthalmoscopy and requires time, practice, and experience to acquire high quality images.[9,11]Image quality in smartphone fundus imaging is also largely affected by several factors—pseudophakic eyes tend to result in decreased image quality due to a higher rate of reflections and aberrations.[12]Since light intensity is not modifiable for the iPhone 6s video mode, images on the retina for pseudophakic eyes appear pale as compared to phakic eyes (Fig 3). Image quality from the smartphone is also dependent on the skill of the photographer. Consequently, an experienced photographer is preferable to standardize the technique in this study.[3]

Nonetheless, given its relatively high sensitivity and specificity for detection of referable diabetic retinopathy and possible integration into a telemedicine platform, smartphone fundus imaging is a promising adjunct tool for

screening and monitoring in areas with limited access to standard fundus cameras. Considering the scarcity and disproportionate urban distribution of retina subspecialists in the Philippines, and given that smartphone imaging is cost-effective, relatively easy to learn, and accessible, a compelling argument can be made to incorporate this technique in the training of new ophthalmologists.

Table 6. Patient Comfort during Dilated Smartphone Imaging

Level of Comfort (n=28 patients)	
Very Uncomfortable	0 (0%)
Somewhat Uncomfortable	0 (0%)
Neutral	0 (0%)
Somewhat Comfortable	13 (46.4%)
Very Comfortable	15 (53.6%)

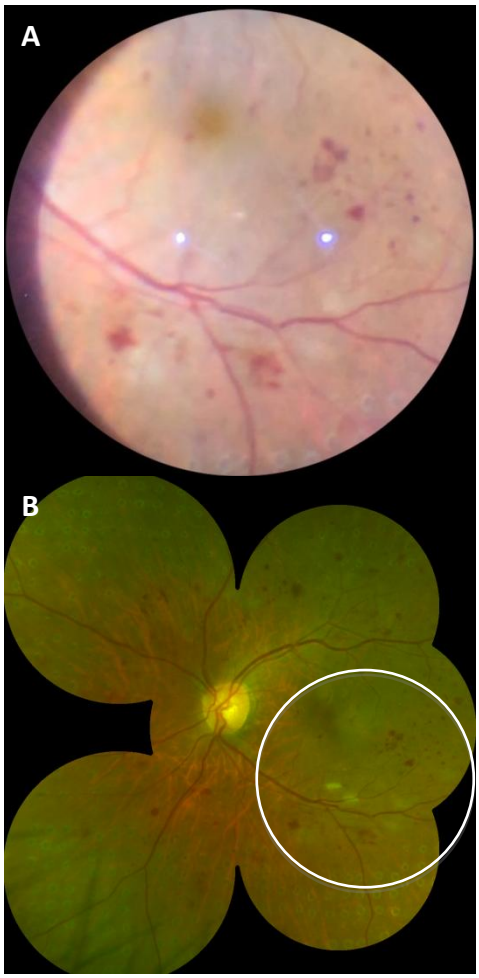

Figure 3. (A) Smartphone fundus image of a pseudophakic eye. Note the pale appearance of the retina compared to Optos 100-degree image of the same eye. (B) Optos 100-degree image of the same eye. A white circle encloses the area corresponding to the first image.

CONCLUSION

Dilated smartphone fundus imaging is a highly specific and sensitive tool for the detection of patients with DR. Given the inherent capability of the smartphone to transmit images, this technique is a promising and effective means for eye care professionals in remote and/or resource-poor areas to screen and monitor patients with DR with guidance from retina subspecialists from afar.

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REFERENCES

[1] Early Treatment Diabetic Retinopathy Study Research Group. (1991). Early photocoagulation for diabetic retinopathy. ETDRS report number 9. *Ophthalmology* 1991;98(5 Suppl): 766-85.

[2] Bastawrous A, Giardini ME, Bolster NM, Peto T, Shah N, Livingstone I. (2016). Clinical validation of smartphone based adapter: peek retina for optic disc imaging in Kenya. JAMA *Ophthalmol* 2016 February;134(2):151-58.

[3] Ryan M, Rajalakshmi R, Prathiba V, Anjana R, Ranjani H. (2015). Comparison among methods of retinopathy assessment (CAMRA) study: smartphone, nonmydriatic, and mydriatic photography. *Ophthalmology* 2015 October; 122(10):2038-43.

[4] American Diabetes Association. (2016). Standards of medical care in diabetes—2016. *Diabetes care* January; 39 (Suppl 1):S74-76.

[5] Silva P, Cavallerano J, Paz-Pacheco E, Aiello L. (2012). Diabetic retinopathy in southeast asia: A call for ocular telehealth programs. *J ASEAN Fed Endocr Soc*: 27(2):1-11.

[6] Micheletti J, Hendrick A, Khan F, Ziemer D, Pasquel F. (2016). Current and next generation portable screening devices for diabetic retinopathy. *Journal of Diabetes Science and Technology*; 10(2):295-300.

[7] Ludwig CA, Murthy SI, Pappuru RR, Jais A, Myung DJ, Chang R. (2016). A novel smartphone ophthalmic imaging adapter: User feasibility studies in Hyderabad, India. *Indian J Ophthalmol* 64.

[8] Toy B, Myung D, He L, Pan C, Chang R. (2016). Smartphone-based dilated fundus photography and near visual acuity testing as inexpensive screening tools to detect referral warranted diabetic eye disease. *Retina*;36(5):1000-08.

[9] Jalil M, Ferenczy S, Shields C. (2017). iPhone 4s and iPhone 5s imaging of the eye. *Ocul Oncol Pathol*;3:49-55.

[10] Bastawrous A. (2012). Smartphone fundoscopy. *Ophthalmology*. 119(2):432.

[11] Haddock LJ, Kim DY, Mukai S. (2013). Simple, inexpensive technique for high-quality smartphone fundus photography in human and animal eyes. *J Ophthalmol* 2013;1-5.

[12] Adam MK, Brady CJ, Flowers BS, Juhn AT, Hsu J, Garg SJ. (2015). Quality and diagnostic utility of mydriatic smartphone photography: the smartphoneophthalmoscopy reliability trial. *Ophthalmic Surg Lasers Imaging Retina*, 46:631-37