Original Article

Retinal Imaging with Smartphone

DS Ademola-Popoola, VA Olatunji

Department of Ophthalmology, University of Ilorin and University of Ilorin Teaching Hospital, Ilorin, Kwara State, Nigeria

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Abstract

Background: The use of smartphones for various purposes among health professionals is increasing, especially with the availability of different applications. On account of cost, fundus cameras are not readily available in ophthalmic practice in developing countries. Since smartphones are readily available, easy to use and portable, they may present a cheap alternative in a resource-limited economy. **Aim and Objectives:** to explore the use of smartphone (Blackberry Z-10) for retinal imaging in a resource-limited economy. **Methods:** A smartphone (Blackberry Z-10) was used to acquire retinal images with the use of +20D lens in patients with dilated pupils by activating the video mode of the camera. **Results:** Clear retinal images were obtained in different clinical conditions in adults and children including branch retinal vein occlusion with fibrovascular proliferation, chorioretinal scarring from laser photocoagulation, presumed ocular toxoplasmosis, diabetic retinopathy, retinoblastoma, ocular albinism with fundus hypopigmentation. **Conclusion:** The ability to have low cost fundus imaging from readily available smartphones in an eye clinic in Nigeria presents a major boost to patient care and also offers an innovative role in research, education, and information sharing.

Keywords: *Retinal imaging, smartphone (Blackberry Z-10), software*

Introduction

Fundus examination/imaging is an important aspect of ophthalmology for which the use of smart phones appears promising. In order to view the retina, an ophthalmoscope which may be direct or indirect is traditionally employed. The direct (Augenspiegel-eye-mirror) ophthalmoscope was invented by Von Helmholtz in 1851.[1] Since then, it has undergone various stages of development including incorporation of concave and convex lens, attachment of a camera all in a bit to improve clarity of the image seen by correcting errors of refraction in the patient and/or the observer, and for documentation purposes. The limitation is in its field of view and cost of the camera attachment.

The indirect ophthalmoscope, first developed by Giraud-Teulon which has a wider field of view and stereopsis, has also passed through series of developments, from the attachment of teaching mirror useful for training to the inclusion of video camera attachment in the digital version which can be used for archiving, teleconsultation, and education.[2] The digital indirect ophthalmoscope is relatively bulky, has a steep learning curve, and is largely unaffordable for ophthalmology practice in Africa.

The use of smartphones for various purposes is said to be on the rise among health workers; rising from 30% in 2001 to 64% in 2009 and 86% in 2013;[3,4] they have been put to different uses in patient care in various specialties of medicine by virtue of the availability of various applications on the phones.[5] In the field of ophthalmology over 300 ophthalmological applications are in use today.[6,7] Some applications enhance the education of health professionals and patients.[10] Other medical applications are useful in clinical evaluation and patient management.

Smartphones may be useful in clinics or operation rooms on adults and especially in young children who may be too young to use the traditional fundus camera. They

Address for correspondence: Dr. Dupe S. Ademola-Popoola, Department of Ophthalmology, University of Ilorin and University of Ilorin Teaching Hospital, Ilorin, Kwara State, Nigeria. E-mail: dupsyp@yahoo.com

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are also applicable for mass screening as in eye camps/ outreaches[9] and in imperfect examination situations like in the accident and emergency room where fundus camera and indirect ophthalmoscope may not be readily available due to cost and portability.

Sometimes when these equipment are even available, using them may also not be feasible due to poor supply of electricity in an underdeveloped economy. The fundus camera costs about 10,000 US dollars while a smartphone and the 20D lens go for about 500 US dollars. Since phones are readily available, inexpensive, easy to use, portable and always accessible, their advanced technology of capturing fundus images seems a good alternative.

Of particular advantage is the ability of Smartphones to acquire and store the images, and with data connectivity, enables sharing of images for consultation. Thus, teleophthalmology, which is the use of electronic communication and information technology to provide diverse groups of activities related to eye care, is made more convenient. With this, location and time no longer constitute constraints to eye care. Direct ophthalmoscopy[10] and fluorescein angiography[11] using smart phones have also been previously described.

Most studies have described the use of iPhone or Samsung phones with additional apps/software such as the Filmic pro to obtain retinal images.[12,13] Oluleye, in Nigeria also compared the iPhone with the Android phone Techno phantom, he found that even though both obtained clear retinal images, the iPhone was of a superior quality.[13]

The aim of this study is to explore the use of smartphone (Blackberry Z-10) for retinal imaging in a resource-limited economy.

Materials and Methods

This study was carried out between May and June 2015 at the eye clinic of the University of Ilorin Teaching Hospital. Twelve consecutive consenting patients of the clinic were recruited for the study. Ethical clearance was obtained from the hospital ethical review committee and informed consent was also taken from patients or their care givers. Blackberry Z-10 (manufactured by Blackberry Limited) was used with a noncontact lens (+20D) by Volk to obtain indirect images from fundus of patients after dilating the pupils using phenylephrine (2.5% for children and 10% for adults) and 1% tropicamide eye drops. Children were wrapped with white linen bedsheet and lid speculum was used to keep children's eyes opened after instillation of topical anaesthetic eye drops.

With the patient in the supine position, the video mode of the phone camera was activated and the flashlight which is usually in continuous mode was turned on and directed through the 20D lens to the pupil to provide illumination for the retina. The phone was held by the examiner in one hand and the +20D lens in the other hand. The smartphone was held over the palm of the right hand with the screen facing up while the thumb of the same right hand was used to operate the camera icon to turn on/off the video; no assistance was required for this.

The approximate distances between the patient's eye and the 20D lens was 9 cm, and 14.5 mm between the 20D lens and the blackberry Z-10 phone, making 23.5cm between the eye and the smart phone. The patients' eyes, the +20D lens, and the camera flashlight were all maintained in the same axis just like when using the binocular indirect ophthalmoscope. The 20D lens is moved appropriately until the fundus image fills the 20D lens completely, this is an important step to ensure clarity of the image. Fine adjustment and tilting of the lens was done as the examination continues in order to avoid light reflection, get a clear image of the fundus centered on the phone. No additional software was downloaded into the phone for the video or still image capture, the only software used was that which was basic to the phone.

Peripheral views of the fundi were captured when the eyes were directed to look in different directions of gaze. Still images of interesting fundus areas were captured on the phone as the video recordings were on-going this was used for patient education in this format. They were however transferred to a laptop for further editing (cropping) with the window media player by playing the video and when a frame was judged clear, the pause button was clicked and print screen of the laptop was used to copy the frame which was transferred to Microsoft word and cropped appropriately. This laptop editing was done for the purpose of archiving for sharing and publication.

Results

A total of 12 patients (including 3 children); 6 females and 6 males with age range between 15 months and 61 years with various diagnosis [Table 1] were involved in the study, which involved obtaining retinal image using the blackberry Z-10 phone. Clear retinal images were acquired from the fundi in both children and adults with clear media. Figure 1abc shows normal fundus images, Figure 2 a shows fibrous proliferation in a case of branch retinal vein occlusion, and Figure 2 b is that of peripheral laser scars.

In cases of retinoblastoma with highly reflective tumour

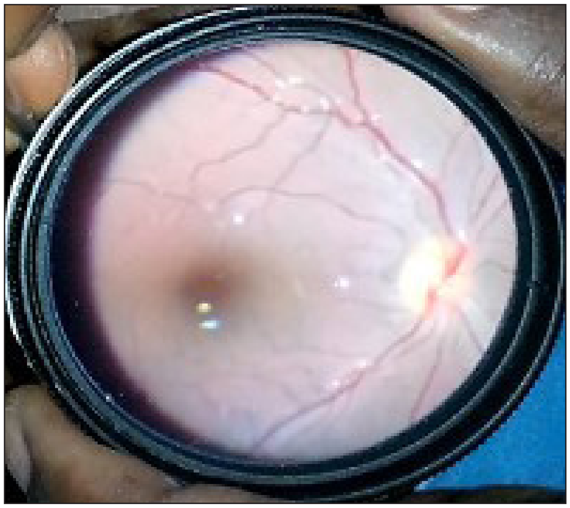

Figure 1: (a) Normal fundus images

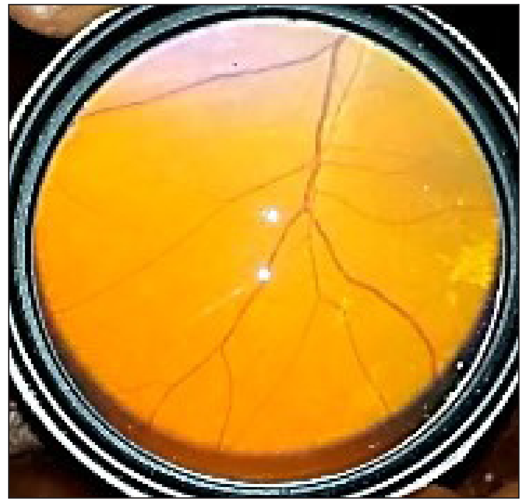

Figure 1: (b) Normal fundus image

Figure 1: (c) Normal undus image

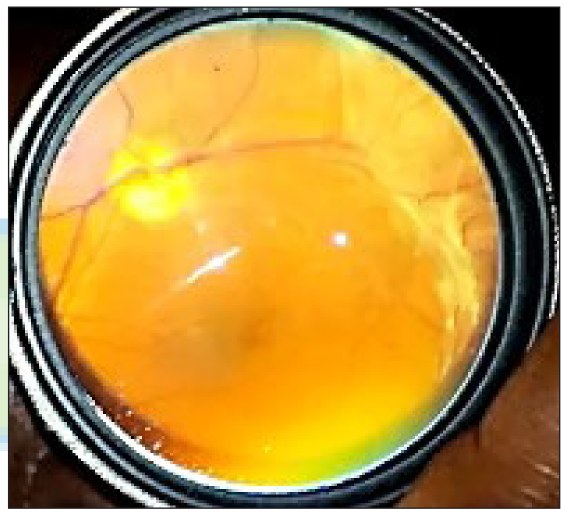

Figure 2: (a) Fibrovascular tissue with straightening of vessels

Figure 2: (b) Peripheral laser scars

Figure 2: (c) Retinoblastoma with a reflective tumor mass

Figure 2: (d) Multiple vitreous seeds and mass

Figure 3: (a) Right hypopigmented fundus in a 15-month old with iris heterochromia

mass Figure 2c,d, the images were not as clear as with traditional fundus camera. The same phone was also used to document the retinal findings in anterior segment pathologies like in the case of a 15-month old who presented with iris heterochromia and bilateral hypopigmented retina [Figure 3 a,b].

Discussion

Traditional fundus camera is not as readily available as a smartphone in most eye clinics in Nigeria on account of limited resources, this is even more challenging when retinal imaging is desirable in children and especially when parents need greater motivation in terms of being able to relate to the specific pathology in their children in order to follow the course of treatment. It was previously observed that use of a fundus camera is limited by patient morbidity, high equipment cost, and shortage of trained personnel.[12]

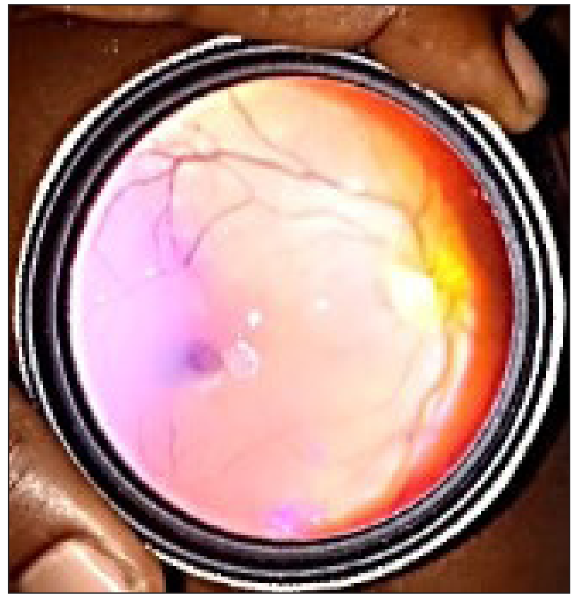

Figure 3: (b) Left hypopigmented fundus in a 15-month old with iris heterochromia

Table 1: Diagnosis of retinal imaging from Blackberry Z-10 phone smartphone

	Age	Sex	Diagnosis
1.	32 yrs	Male	Normal fundus
2.	61 yrs	Male	Branch retinal vein occlusion with fibro vascular proliferation
3.	45 yrs	Female	Chorioretinal scarring from laser photocoagulation
4.	16 month	Female	Retinoblastoma Group B
5.	15 month	Male	Ocular albinism with fundus hypopigmentation
6.	18 month	Male	Retinoblastoma Group C
7.	56 yrs	Male	Nonproliferative diabetic retinopathy
8	18 yrs	Female	Presumed ocular toxoplasmosis with multiple chorioretinal scar
9.	45 yrs	Female	Retinitis pigmentosa
10.	60 yrs	Male	Macular hole
11.	59 yrs	Female	Central retinal vein occlusion
12.	36 yrs	Female	Optic atrophy

The ability to have low cost fundus imaging from readily available and popular smartphone in an eye clinic in Nigeria is a major boost to patient care. This has the capacity to enhance the training of other eye care workers, teleophthalmology, and also improve patient's understanding of the disease process. It will also facilitate treatment plans and compliance with treatment which is usually a major challenge with care process in our clinics.

Even though it was noted that the use of smart phones as diagnostic tools is not standardized and results should be carefully considered; its innovative role in research, education, information sharing, and the potential to revolutionize the practice of ophthalmology and medicine is acknowledged.[13]

Most of the previous descriptions from India, USA, and Ibadan in Nigeria on the use of mobile phone for fundus imaging have mostly been with iPhones or the Samsung phones.[8,11,12,14-16] Studies have reported the use of additional software like the Filmic pro with the iPhone which allows independent control of the light intensity as well as focus.[12,13]

However in the present study, clear images were still acquired by the smartphone using only the software which is original and basic to the phone, the laptop computer was used for video editing/still image cropping purposes for archiving, sharing, and publication because of the larger screen and storage capability of the laptop. This method seems very convenient for telemedicine as also previously reported.[10,13]

Some challenges were identified. First was the need to engage both hands of the examiner while video recording was on going, this is especially important in children and uncooperative adults where rotation of the eye in a particular direction is desirable. Clarity of the image could be compromised in the presence of media opacity from cataract. The need to have mid to fully dilated pupil for clear images was also noted as compared to some fundus cameras or indirect ophthalmoscopes that have the capability to obtain images through undilated pupils.

Even though the safety of the light from the iPhone was previously described,[17] vigilance though continuous research to ensure the safety of the smartphone light for the eye over time remains important.

Conclusion

Clear retinal images can be obtained in both children and adults in the absence of media opacity without any additional software to that basically available in the relatively accessible blackberry Z-10 smartphone and a +20D lens. The ability to have low cost fundus imaging from readily available and popular smartphones in an eye clinic in Nigeria presents a major boost to patient care and also offers an innovative role in research, education, and information sharing.

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Conflicts of interest

There are no conflicts of interest

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