Fundus Photography using Digital Cameras and Camera Mobile Phones

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History

The concept of fundus photography dates back to mid 19th century after the introduction of photography in 1839. In 1851, Herman von Helmholtz introduced the Ophthalmoscope and in 1861, James Clerk Maxwell presented a colour photography method. Henry Noyes and Abner Mulholland Rosebrugh in 1860s, assembled fundus cameras and first tried on animals.

The first report of the use of smart phones in fundus photography by Lord et al in 20101], and showed that these optical devices could be used for many clinical and educational purposes.

Fundus photography is an essential part of an ophthalmic practice as it allows for photo-documentation of intraocular pathologies and for diagnosis and sharing of encrypted data with colleagues and patients. Acquisition of high quality fundus images require a combination of optics and illumination with a condensing lens and a coaxial light source2 .

Traditional fundus cameras are much expensive, inconvenient, incompatible and not portable as compared to smart phones, but Smartphone are worldwide available, relatively inexpensive, compatible across all systems, very easy to operate, for which these are ideal for use outside the traditional office settings and remote areas.

Various uses of Smartphone & Digital Cameras in Ophthalmology

1. As a digital camera for photo documentation
2. As an Image transfer device
3. As a fundus camera with hardware attachment
4. As a fundus camera without hardware attachment

Digital camera

High-megapixel still cameras with anti-shake technologies and full HD (high definition) video facilities with flash light facilities are the important features in smartphones. Initially smartphone fundoscopy used +78 or +90 fundus lens and the smartphone attached to the slit-lamp eyepiece were attempted but with this technique high quality imaging could not possible. However using smartphone for photography is better in anterior segment imaging rather than posterior segment and fundus .

Figure 1. The EyeGo anterior segment adapter clipped over an iPhone case.

Figure 2. The EyeGo posterior segment adapter in action, showing the retina of coinventor Alexandre Jais.

Figure 3. Multiple hemorrhages in the macula (inverted view).

Figure-4. iExaminer adapter designed to attach the PanOptic Ophthalmoscope to the iPhone 4 and 4S

Figure-5. Volk Panretinal 2.2 indirect ophthalmoscopy condensing lens mounted to iPhone 5

Figure-6. Branch retinal vein occlusion using the mechanical prototype adapter with 3D printed lens holder

Welch Allyn , Skaneateles Falls , NY prepared the iExaminer the first smartphone-based imaging adaptor system that can attaches and aligns with an iPhone(Apple Inc, Cupertino, CA) to PanOptic Ophthalmoscope made by WelchAllyn for fundus photography and was approved by the FDA in January 2013. iPhone captures photos of the fundus with the help of iExaminer App3. This device captures fundus image without dilation of the pupil with 250 field of view. The ophthalmicDocs Fundus is a 3D printable adapter which converts any smartphone into a retinal camera when used with a condensing lens, has 400 field of view, the device has been streamlined for 3D printing4.

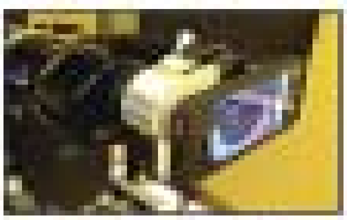

Figure-7. Top left image shows EyePhotoDoc Adapter mounting an iPhone to the Haag Streit slit lamp. Top Right image shows Zarf's iPhone adaptor which fits a variety of different slit lamps. Image to the left shows the Keeler portable slit lamp iPhone image adaptor

Various Indian manufacturers like M/S Joja surgical have also now started marketing various smartphone adaptors for anterior and posterior segment photography as well.

Image transfer device

The easy availability of smartphones with high-megapixel still camera and high definition video capability and extensive mobile-phone networks make these devices ideal for Telemedicine. Ophthalmic digital software enables transfer of images from and to these devices. These images can then be easily sent from remote places to expert for consultation.

Camera with hardware attachment

Hardware attachments for smartphone fundoscopy have been developed with built-in-optical devices to image the retina without any external equipment. Giardini et al5 recently reported on a new adaptor for the Samsung (Ridgefield park, NJ) galaxy s III smartphone which is a low cost alternative to direct ophthalmoscope and captures high quality fundus images. Russo et al6 recently reported on the use of the D-Eye adaptor (Si14 S.p.A., Padua, Italy) which magnetically attaches to the smartphone and can capture fundus images of an approximately 2000 field of view. Presently there are at least three pocket-sized adapters that improve magnification and lighting, enabling smartphones to capture high-quality pictures of the eye. These include the Portable Eye Examination Kit (PEEK; Peek Vision; www.peekvision.org), the Ocular CellScope (CellScope; http://cellscope.berkeley.edu/health/ocular-imaging/), and the EyeGo(Stanford University School of Medicine;http://med.stanford.edu/ism/2014/march/eyego.html).

Figure8. (left) showing D-Eye adapters magnetically attached to smartphones

Figure9. (right) showing Mechanical prototype of lens-to-smartphone mount with 3D printed Panretinal 2.2 condensing lens holder

Camera without hardware attachments

Built-in flashlights of smartphones allow imaging of the fundus using the principles of indirect ophthalmoscopy. Haddock et al7 described a smartphone fundoscopy technique of indirect ophthalmoscopy using the smartphone video camera, inexpensive app, and a +20D lens, this technique turns the iPhone into an indirect ophthalmoscope, using the constantly emitted flash of the coaxial LED light source in video camera mode. As constant emission of flash light is not possible in still camera mode, video mode is chosen. A light source, a video app, a still image extraction app like MovieToImageTM (DreamOnline Inc., Tokyo, Japan), Video2PhotoTM (PacoLabs, Paris, France) and a +20D or +28D condensing lens is needed in this technique. Snap shot can be taken from the recorded Video by clicking the snapshot option while played in certain players like VLC media player.

SmartPhoneography Applications

In the developing world as there is severe shortage of eye care specialists to care for burgeoning eye disease in combination with limited resources, the need for devices such as the PEEK, Ocular Cellscope, or EyeGo is felt

Newer Applications

Suto et al8 reported on a technique for performing fluorescent fundus angiography(FFA) using a smartphone device. Smartphone FA could be beneficial for bedridden patients, infants, and patients in poor resource settings. This technique used several peripheral devices including a separate light source to control light intensity and excitation and barrier filters for the FA image acquisition. Newer iPhones models have available apps that can control light intensity , obviating the need for an external light source wuth this technique

Maamari et al9 described Ocular CellScope, a prototype widefield lens attachment for the smartphone , which can slide into the phone and captures widefield images, capturing approximately 550 of the fundus in a single image.

Future Applications

Limitaions of smartphone fundoscopy technique and its applications lie in the image quality and field of view , as well as universalizing its accssibilty on all types of smartphones including Windows(Microsoft Inc., Redmond, Washington, USA), iOS(Apple Inc., 1 Infinite Loop, Cupertino, California, USA), Android(Google Inc., Googleplex, Mountain View, California, USA), and other operating systems.

It is promising to integrate smartphone fundoscopy into our everyday ophthalmolgical practice which needs additional validation studies . and could expand the reach of ophthalmic screening, diagnosis, and documentation in reduced costs.

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