

# Advances in Smartphone Photography of the Eye

Pocket-sized adapters improve magnification and lighting, enabling smartphones to capture high-quality pictures of the eye.

**BY ROBERT CHANG, MD; AND DAVID MYUNG, MD, PhD**

**M**ore eye care providers are carrying smartphones at work these days, and mobile health systems are rapidly gaining popularity. In March 2013, Kantar Media conducted a survey of more than 3,000 physicians and found that three-quarters of them were using their smartphones for professional purposes, including communicating with colleagues, checking e-mails, performing clinical calculations, and referencing drug and research data.<sup>1</sup> In ophthalmology, clinicians rely heavily on imaging, and thus it makes sense to harness the powerful cameras, instant messaging capabilities, and Wi-Fi connections integrated into every smartphone. However, a 2013 survey by Deloitte identified the main barriers to physician smartphone adoption as ability to keep work and personal uses separate, concerns over privacy and encryption, and lack of applications (apps) suited to physician needs.<sup>2</sup>

Use of smartphone photography, sometimes referred to as *smart phoneography*, expanded when the resolution of cellphone cameras began to exceed 5 megapixels. Multiple commercial and homemade adapters have been described for attaching the iPhone (Apple) or equivalent devices to slit lamps, operating microscopes, and ophthalmoscopes, including the iExaminer (Welch Allyn), which connects an iPhone 4 or 4S to a PanOptic ophthalmoscope (Welch Allyn). In 2012, Shah and colleagues described photographing the anterior and posterior segments by holding up diagnostic lenses to capture images of the eye with the phone alone; a detailed description of this technique was published by Haddock and colleagues the following year.<sup>3,4</sup>

Presently there are at least three pocket-sized adapters that improve magnification and lighting, enabling smartphones to capture high-



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

quality pictures of the eye. These include the Portable Eye Examination Kit (PEEK; Peek Vision; [www.peekvision.org](http://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>).

## **SMART PHONEOGRAPHY APPLICATIONS**

What is the need for devices such as the PEEK, Ocular Cellscope, or EyeGo? An obvious need can be seen in the developing world, where there is a severe shortage of eye care specialists to care for burgeoning eye disease in combination with limited resources. Most gold-standard diagnostic eye equipment is expensive and not



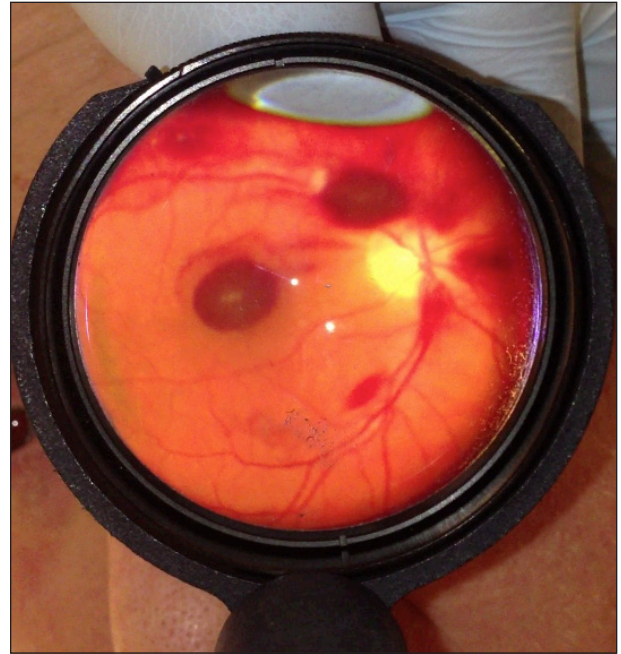
**Figure 2.** The EyeGo posterior segment adapter in action, showing the retina of coinventor Alexandre Jais.

easily portable, and it requires trained technicians to operate. Even small handheld digital cameras made for the eye, such as the Pictor Plus (Volk) or the EyeQuick (EyeQuick), cost several thousand dollars and require the user to carry an additional, bulky piece of equipment.

In the developed world, too, there are opportunities for a digital photo acquired by a nonophthalmologist to aid in the triage and management of an eye complaint. For example, a patient in an emergency department may be waiting to be seen by an ophthalmologist on call, and a photo of the eye texted to the consulting physician could help assess the urgency of the condition to speed delivery of care (often already utilized by the ophthalmology resident on call). In this setting, the availability of a technology that adds value, saves time, and does not disrupt existing workflow is crucial to providing the best possible care. Likewise, if the technology is easy to use and the cost is low enough, smartphone photography may make telemedicine applications in ophthalmology more feasible and mass eye screenings more cost-effective.

### **THE EYEGO ADAPTER**

In two recently published articles,<sup>5,6</sup> we and our coauthors outlined a proof-of-concept demonstration for an inexpensive, simple, compact smartphone adapter, the EyeGo, that can be combined with a smartphone to image both the cornea and retina (dilated) without much additional training. The adapter facilitates the standard examination techniques of the cornea at a portable slit lamp and the retina through indirect ophthalmoscopy, while lowering the bar so that any operator can perform them. The key differentiator of the EyeGo hardware adapter is its minimalist design; it is foldable,



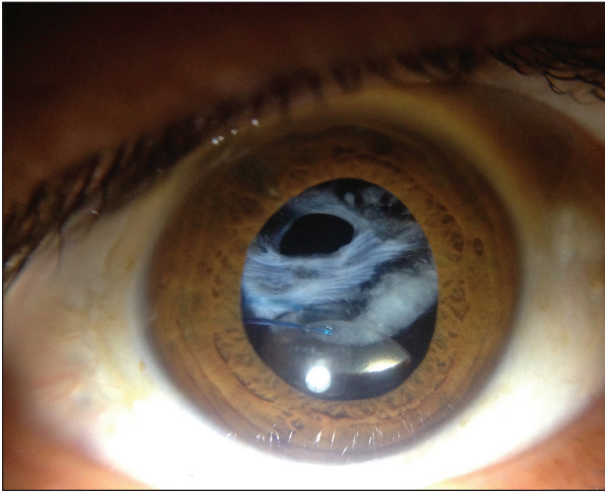
**Figure 3.** Multiple hemorrhages in the macula (inverted view).

extremely lightweight, and helps align condensing and macro lenses at the correct distance so that any health care provider can automatically capture a high-quality photo quickly and at low cost.

The EyeGo adapter can be used with Filmic Pro (Cinegenix) or a stock camera app, but it is also being paired with a beta version of the Sightbook (DigiSight Technologies) iPhone app, which is a cloud-based platform featuring various consumer vision tests linked to an online portal. The integrated camera portion of the app simplifies image capture and takes care of privacy and encryption concerns by immediately uploading images securely to cloud storage for image sharing.

PEEK, which is similar in many ways to EyeGo, uses a direct ophthalmoscopy lens approach for fundus images, providing a smaller field of view. EyeGo is optimized for a full view of the posterior pole in a dilated eye using any standard indirect ophthalmoscopy lens, such as the Volk Panretinal 2.2, 20D, or 28D. Similar to PEEK, CellScope uses a custom-designed novel attachment with a 54.00 D lens that has a diffuser and polarizer with a mask to reduce reflected light artifacts.<sup>7</sup>

The EyeGo anterior segment adapter has been described in its current prototype form.<sup>5</sup> The images acquired under diffuse light illumination provide triage-quality images of the lids, conjunctiva, cornea, iris, and lens, but the adapter is currently limited in its ability to capture finer details such as cell and flare. A posterior segment prototype adapter has also been described.<sup>6</sup>



**Figure 4.** An inferiorly subluxated three-piece IOL.

Both adapters are being studied for clinical validity and would need regulatory approval before they can be marketed. However, during institutional review board-approved research, we found that anterior and posterior segment photos, sent from the emergency department in the early morning hours with minimal equipment, can help a consulting ophthalmologist feel comfortable triaging relatively benign pathology, such as a subconjunctival hemorrhage, from more acute conditions such as a traumatic hyphema or corneal ulcers.

In one instance, Dr. Myung was called for an inpatient consult in the hospital. His indirect ophthalmoscope battery was drained, and he did not have his charger with him, but he did have his iPhone, EyeGo adapters (Figures 1 and 2), and lenses in his coat pocket. He was able to check the patient's vision with his app and capture anterior segment and dilated posterior segment photos, demonstrating that the vision was reduced as a result of retinal hemorrhages due to leukemic retinopathy (Figure 3). An example of the usefulness of the

anterior segment photo capability was in a pseudophakic patient who presented to urgent care with painless blurring of vision in one eye. Dilated exam revealed a subluxated IOL, explaining the change in vision, and this was nicely captured with the iPhone (Figure 4).

Perhaps the most useful setting where photos such as these are sent to an eye specialist could be from the point of care, particularly when no ophthalmologist is immediately available, or during large-scale eye screenings where there is a shortage of ophthalmologists. This type of technology may make telemedicine in ophthalmology more affordable where it is needed most. The PEEK device has undergone a large study in Kenya, and EyeGo is currently undergoing similar testing in other countries including China and India.

## SUMMARY

Mobile health is an exploding space right now, and we will most likely see more health diagnostics and sensor coupling and integration into mobile devices, particularly minimally invasive tests that can be miniaturized and can take advantage of the computing power of smartphones. The medical field appears to be turning full circle: The doctor's black satchel of the past is being reincarnated as the modern smartphone. ■

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*\* For more information on the EyeGo adapter, contact the team at eyegotech@gmail.com.*

## TAKE-HOME MESSAGE

- Most gold-standard diagnostic eye equipment is expensive, not very portable, and requires trained technicians to operate.
- Smartphone photography of the eye has great potential in the developing world, where there is a severe shortage of eye specialists to care for burgeoning eye disease as well as limited resources.
- In the developed world, there are opportunities for digital photos acquired by nonophthalmologists to aid in the triage and management of eye complaints.

1. Emery D. How physicians use smartphones. *Kantar*. July 19, 2013. Available at: <http://www.us.kantar.com/business/health/how-are-physicians-using-smartphones-for-professional-purposes/>. Accessed August 7, 2014.
2. Physician adoption of health information technology: implications for medical practice leaders and business partners. Deloitte. Available at: [http://www.deloitte.com/assets/Dcom-UnitedStates/Local%20Assets/Documents/Health%20Care%20Provider/us\\_dchs\\_2013PhysicianSurveyHIT\\_051313%20\(2\).pdf](http://www.deloitte.com/assets/Dcom-UnitedStates/Local%20Assets/Documents/Health%20Care%20Provider/us_dchs_2013PhysicianSurveyHIT_051313%20(2).pdf). Accessed August 7, 2014.
3. Shah VA, Chhablani J, Kaja S. Smartphones in ophthalmology. *Indian J Ophthalmol*. 2012; 60(2):127-131.
4. Haddock LJ, Kim DY, Mukai S. Simple, inexpensive technique for high-quality smartphone fundus photography in human and animal eyes. *J Ophthalmol*. 2013;2013:518479.
5. Myung D, Jais A, He L, Blumenkranz M, Chang RT. Simple, low-cost smartphone adapter for rapid, high quality ocular anterior segment imaging: a photo diary. *J Mobile Tech Med*. 2014;3(1):2-8.
6. Myung D, Jais A, He L, Chang RT. 3D printed smartphone indirect lens adapter for rapid, high quality retinal imaging. *J Mobile Tech Med*. 2014;3(1):9-15.
7. Maamari RN, Keenan JD, Fletcher DA, Margolis TP. A mobile phone-based retinal camera for portable wide field imaging. *Br J Ophthalmol*. 2014;98(4):438-441.