Smartphones become 'eye-phones' with low-cost devices developed by Stanford

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Human eye. Image: Wikipedia.

Researchers at the Stanford University School of Medicine have developed two inexpensive adapters that enable a smartphone to capture high-quality images of the front and back of the eye. The adapters make it easy for anyone with minimal training to take a picture of the eye and share it securely with other health practitioners or store it in the patient's electronic record.

"Think Instagram for the eye," said one of the developers, assistant professor of ophthalmology Robert Chang, MD.

The researchers see this technology as an opportunity to increase access to eye-care services as well as to improve the ability to advise on patient care remotely.

Ophthalmology resident David Myung, MD, PhD, lead author of two upcoming papers describing the development and clinical experience with the devices, began the project with Chang about two years ago, just before Myung began his residency at Stanford. The papers will be published online March 7 in the *Journal of Mobile Technology in Medicine*.

The standard equipment used to photograph the eye is expensive—costing up to tens of thousands of dollars—and requires extensive training to use properly. Primary care physicians and emergency department staff often lack this equipment, and although it is readily available in ophthalmologists' offices, it is sparse in rural areas throughout the world.

"Adapting smartphones for the eye has the potential to revolutionize the delivery of eye care—in particular, to provide it in places where it's less accessible," said Myung. "Whether it's in the emergency department, where patients often have to wait a long time for a specialist, or during a primary-care physician visit, this new workflow will improve the quality of care for our patients, especially in the developing world where ophthalmologists are few and far between.

"A picture is truly worth a thousand words," he added. "Imagine a car accident victim arriving in the emergency department with an eye injury resulting in a hyphema—blood inside the front of her eye. Normally the physician would have to describe this finding in her electronic record with words alone. Smartphones today not only have the camera resolution to supplement those words with a high-resolution photo, but also the data-transfer capability to upload that photo securely to the medical record in a matter of seconds."

Chang, who is the senior author of the two papers, added that ophthalmology is a highly image-oriented field. "With smartphone

cameras now everywhere, and a small, inexpensive attachment that helps the ancillary health-care staff to take a picture needed for an eye consultation, we should be able to lower the barrier to tele-ophthalmology," he said.

Adapters are available to attach a smartphone to a slit lamp—a microscope with an adjustable, high-intensity light—to capture images of the front of the eye. But Myung found this process time-consuming and inconvenient, even with commercially available adapters designed for this purpose. Given the fast pace of patient care, he wanted point-and-shoot ability in seconds, not minutes, with instant upload to a secure server. More importantly, the team envisioned the device to be readily usable by any health-care practitioner, not just eye doctors. So Myung decided to bypass the slit lamp, a complicated piece of equipment.

"I started entertaining the idea of a pocket-sized adapter that makes the phone do most of the heavy lifting," he said. After numerous iterations, he found a combination of magnification and lighting elements that worked.

"It took some time to figure out how to mount the lens and lighting elements to the phone in an efficient yet effective way," said Myung, who built the prototypes with inexpensive parts purchased almost exclusively online, including plastic caps, plastic spacers, LEDs, switches, universal mounts, macrolenses and even a handful of Legos.

After successfully imaging the front of the eye, he then focused on visualizing the inside lining of the back of the eye, called the retina. "Taking a photo of the retina is harder because you need to focus light through the pupil to reach inside the eye," said Myung.

To optimize the view through a dilated pupil, Myung used optics theory to determine the perfect working distance and lighting conditions for a

simple adapter that connects a conventional examination lens to a phone. Myung and chief ophthalmology resident Lisa He, MD, shot hundreds of photos with various iterations of the adapter, consulting with Chang and Mark Blumenkranz, MD, retina specialist and chair of the ophthalmology department, until they got it right. Then Stanford mechanical engineering graduate student Alexandre Jais constructed computerized models of these "screwed-and-glued" prototypes to produce 3D-printed versions. Jais made the first of these prototypes on his own 3D printer before moving to the Stanford Product Realization Lab to manufacture higher-resolution adapters.

Chief resident He is leading a clinical study grading the quality of images taken using the adapters in the Stanford emergency department. A second study, spearheaded by resident Brian Toy, MD, will test the ability of the adapters to track eye disease in patients with diabetes.

Myung and Chang have recently been awarded seed grants from the School of Medicine and the Stanford Biodesign Program to fund the production of the initial batch of adapters, currently dubbed EyeGo, for distribution and continued evaluation. The initial adapters will be available for purchase for research purposes only while the team seeks guidance from the Food and Drug Administration. "We have gotten the production cost of each type of adapter to under $90 but the goal is to make it even lower in the future," Chang said. Recently, a team from the University of Melbourne in Australia used the two adapters on a medical mission trip to Ethiopia and told Chang they were excited about the results.

Myung, Chang, Jais and He co-authored both articles and Blumenkranz co-authored the article on the retinal-imaging adapter. Stanford's Office of Technology and Licensing is managing the intellectual property.

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