Today, applications of teleophthalmology take multiple forms: providing access to eye specialists for patients in remote areas; allowing ophthalmic disease screening, diagnosis, and monitoring over any distance; and even supporting distant learning. None of this would be possible, however, without the enabling technology. As rapid innovations in the tech world continue to arise, devices are being developed and upgraded specifically to facilitate the practice of teleophthalmology. Of primary importance are the capture and transfer of clinical images and video. Below is an overview of several devices that are enhancing how users obtain, store, and send visual data to provide improved patient care anywhere in the world.

**D-Eye**

The D-Eye Portable Retinal Imaging System (Figure 1A) attaches to a smartphone, creating a modern-day ophthalmoscope capable of recording and transmitting high-definition videos and still images for clinical assessment. The lens attaches to the smartphone via a specially designed, lightweight magnetic bumper attachment. By using the smartphone camera focus feature, aiming at the retina, and approaching the cornea to 1 cm of distance, vivid videos can be recorded and saved to the D-Eye ImageVault, a secure, cloud-based patient record system, for further assessment and long-term storage for patient history.

D-Eye can be used to conduct routine eye exams and retina screenings for detection of a variety of disorders. Users can see the optic nerve head without use of dilating drops, look for neurologic disorders associated with the eye, record images of children and infants without dilation (Figure 1B), examine bed-ridden patients, perform emergency room evaluations, and review before-and-after treatment images with patients or family members. Major pathologies that can be seen with D-Eye include glaucoma, intermediate-stage diabetic retinopathy, and age-related macular degeneration.

D-Eye can be used on dilated or undilated eyes. When
the pupil is dilated, the D-Eye lens captures a field of view of approximately 20° in a single fundus image. According to the company, videos allow the user to angle the lens to capture more of the outer edges of the retina than still photos. In video mode, an acquisition protocol would allow the user to pan the retina, starting from the posterior pole and moving to the peripheral retina and the equator. Color digital images and videos of the retina can be obtained, encompassing the entire posterior pole, including the macula, optic disc, and peripheral retina.

D-Eye is portable, requiring no external power or lighting, and is noninvasive and ergonomic. Users can record multiple high-definition images or videos and store information in a built-in patient file. D-Eye images and videos can also be stored in a private and secure cloud-based system.

D-Eye is available in a model designed for veterinary use in animal eyes.


visoClip and visoScope

Recognizing challenges associated with the purchase and portability of fundus cameras in developing countries, oDocs Eye Care sought to develop a retinal imaging device that was accurate, accessible, and affordable. The company developed the visoClip and visoScope (Figure 2) to help users transform their iPhones into anterior segment and retinal cameras.

The visoClip anterior segment imaging adapter clips onto an iPhone and transforms it into an anterior segment microscope, capable of up to 10X optical magnification. Users can quickly capture high-resolution photos and videos using focused, angled illumination. The visoClip can be used to visualize acute corneal lesions and is ideal for referrals, according to company literature.

The visoScope retinal imaging adapter adds retinal imaging capability to the iPhone when a direct ophthalmoscope is not available, the company says. The specialized optics and high-quality antireflective crown lens provides a 50° field of view, comparable to that of a conventional fundus camera.

The corresponding oDocs app features a range of eye tests.


PEEK

The Portable Eye Examination Kit (Peek; Peek Vision) is a mobile phone–based ophthalmic testing system developed to perform comprehensive eye exams (Figure 3). Shortages in ophthalmic personnel, high costs, and difficulty transporting equipment have made it challenging to offer eye care in many rural areas. According to the company, Peek offers a solution to overcome barriers of limited access to traditional ophthalmic testing methods. It has been pilot-tested on adults in Nakuru, Kenya.

Used with the Peek app, Peek Retina combines a traditional ophthalmoscope and a retinal camera in a mobile phone, providing a portable, affordable, and user-friendly way to carry out comprehensive eye exams. The high quality of the images enables users to view cataracts clearly enough for treatment classification and to detect signs of glaucoma, macular degeneration, diabetic retinopathy, and signs of nerve disease, according to company literature.

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There are important applications for a handheld autorefractor in the clinical setting. A portable but powerful handheld autorefractor such as the SVOne (Smart Vision Labs; Figure 1) can be used in place of a desktop unit if, for instance, the desktop unit malfunctions or needs servicing. The SVOne adds flexibility to the clinic because it is transportable. This can improve patient flow dynamics, taking the testing modality to the patient rather than having the patient leave the exam room to go to a testing station. A handheld autorefractor serves to relieve bottlenecks if a testing station is occupied; it also allows clinicians to carry the technology to satellite offices that may not have the same diagnostic equipment as the main office.

Where a handheld autorefractor such as the SVOne could have its greatest impact, however, is in teleophthalmology settings. In certain rural areas, there are coverage gaps where patients often have to travel great distances to be seen by an eye care provider. Using the SVOne, which is a Hartmann-Shack wavefront sensor affixed to an iPhone, it would not take much to design a protocol to remotely screen patients to detect refractive errors in need of follow-up.

Smart Vision Labs recently released updated versions of this technology called SVOne Pro and SVOne Enterprise. Among other features, these versions provide the ability for patients to take readings themselves; such versatility adds to the potential to use these devices in remote settings.

I participate in a mission trip every year to Grenada in partnership with St. George’s University. Each time we go, we bring surgical supplies and medicines in addition to the luggage we carry as individuals. Hauling the equipment we need to deliver appropriate eye care creates real logistic challenges. The beauty of the SVOne is that I can put it in my suitcase and, at the expense of carrying less than 2 pounds, I have with me a powerful, verified autorefractor.

The second-generation SVOne Pro automatically captures the patient’s refraction after averaging three readings, instead of five with the previous model. The company is also looking for other ways to enhance the potential for remote screening.

Figure 1. The SVOne Pro in use in the clinic (A-C).

A new offering from Smart Vision Labs called Enterprise serves as an on-demand prescription service. In effect, this is a natural extension of the self-guided autorefractor concept: The patient performs a self-guided examination, and that data is shared with an eye care professional over the cloud and then passed along to a provider who makes the required glasses or contact lenses.
Teleophthalmology in the ER

According to a recent study published in JAMA Ophthalmology, teleophthalmology could play a role in mitigating coverage gaps in emergency ophthalmic care. “Emergency eye care exhibits significant coverage gaps, especially in rural settings with greater distances between emergency eye care facilities,” the study authors wrote. “Multiple studies since the latter part of the 20th century have suggested that applying telemedicine to eye care in emergency situations may assist with patient flow in remote emergency departments and help fill coverage gaps in two main ways: assistance with triage within and between remote emergency departments, and performance of remote ophthalmic consultations for patients presenting with emergency eye conditions.”

As part of their study, the investigators remotely administered surveys to 187 of the 254 emergency departments throughout California from June 30 through September 23, 2014. Emergency department nurse managers and physicians from all emergency departments listed in the California Office of Statewide Health Planning and Development database were individually surveyed to assess facility characteristics and resources as well as the perceived usefulness of teleophthalmology consultation. Main outcome measures were the perceived availability of ophthalmology consultation coverage and the perceived effect of teleophthalmology consultation at each facility.

Of the 187 emergency departments surveyed, 18 of 37 rural facilities (48.6%) reported availability of emergency ophthalmology coverage, compared with 112 of 150 nonrural facilities (74.7%). Rural facilities reported a mean of 23.72 miles (standard deviation [SD], 14.15 miles) between the facility and referral location, while nonrural facilities reported a mean of 4.41 (SD, 10.23) miles (19.3% difference).

On a scale of 1 to 5 (in which 1 signifies very low value and 5 signifies very high value), 124 of 187 nurse managers (66.3%) and 80 of 121 physicians (66.1%) rated teleophthalmology as having high or very high value for triage purposes. The most frequently cited potential advantages of emergency teleophthalmology were assistance in patient triage and immediate real-time electronic communication. The most frequently cited potential disadvantages were unknown cost of contracting and maintenance and concern that eye trauma might make photographs or videos less conclusive.

“Although teleophthalmology is not currently widespread or considered the standard of care (except in specific settings such as screening for diabetic retinopathy), it may have value for acute patient triage and consultation, particularly in rural settings,” the study authors concluded. “Recognizing the inevitable challenges in integrating teleophthalmology into clinical workflow, further development and investigation into teleophthalmology technology, delivery, and reimbursement systems is warranted, particularly in the current policy landscape with continued interest in reducing access disparities, caring for a growing patient population, and providing high-value, efficient health care.”

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The Peek vision test is based on one letter: a tumbling-E shape, making it simple for patients to recognize. The tumbling E does not rely on an individual knowing the English language, yet this test has been shown to give the same results as traditional visual acuity tests, according to the company. The patient uses his or her finger to indicate how he or she thinks the E is positioned. With Peek SightSim, users can see a live simulation of how a patient sees the world compared with those who have normal vision.

Images and patient information can be securely stored in and shared from the Peek app for off-site review. Whether Peek is being used to transfer information between practitioners or from a remotely based health worker to a treatment clinic, all images are available to send whenever the phone has a data or Wi-Fi connection so that diagnoses can be carried out by a trained eye care specialist.

The company is currently evaluating tests it has developed for color blindness and for contrast sensitivity.