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SMARTPHONES FOR OPHTHALMIC FUNDUS IMAGING: A REVIEW

Ian Roberts Martínez-Aguirre MD, Yrbani Lantigua Dorville MD, José Manuel Alonso Maroto MD, Mercedes Tabares Sánchez MD, María Ester Zarzosa MD, Francisco Javier Jiménez Benito MD,PhD.

Ophthalmology Department. Hospital Universitario de Burgos. Burgos, Spain

i.roberts.ma @ gmail.com

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Comment of the reviewer Dr. Fernando Giusio, MD. Profesor en Medicina. Telemedicina. Médico de Planta del Servicio de Oftalmología. Jefe del Área de Oftalmología Legal y Ocupacional. Hospital Italiano de Buenos Aires. Argentina

Comment of the reviewer Marcelo Bursztyn, MD. Fellow Retina y Vitreo. Servicio de Oftalmología. Hospital Italiano de Buenos Aires. Argentina

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RESUMEN: REVISIÓN: SMARTPHONES PARA FOTOGRAFIAR EL FONDO DEL OJO

Los oftalmoscopios (directos e indirectos) junto con el retinoscopio, son los instrumentos más utilizados para explorar y fotografiar el fondo de ojo en oftalmología. Los retinoscopios tradicionales ofrecen imágenes de buena calidad pero son voluminosos, requieren un espacio físico, precisan de un técnico y son costosos.

El uso extendido de los teléfonos móviles con cámaras fotográficas de alta resolución incorporadas, ha permitido su aplicación en la oftalmología para la obtención de imágenes del fondo del ojo. Los dispositivos móviles pueden permitir la obtención de imágenes del fondo del ojo en lugares remotos que carecen de consultorios médicos, en proyectos humanitarios en países en desarrollo, incluso en centros de salud, plantas hospitalarias, servicios de urgencias y quirófanos.

Este artículo revisa algunas de las técnicas y dispositivos más recientes para la obtención de imágenes del fondo del ojo con teléfonos móviles.

PALABRAS CLAVE: Imagen retiniana. Retinoscopia. Fundoscopia. Oftalmoscopio. Cámara de fondo de ojo. Teléfono inteligente.

SUMMARY:

Ophthalmoscopes (direct and indirect) and fundus cameras are the most often used instruments to explore and photograph the eye fundus in ophthalmology. Traditional fundus cameras offer good-quality images but are bulky, technician dependent, costly and require a physical space.

The actual extended use of smartphones with their integrated high resolution cameras has allowed their application into the fundus imaging field. Smartphone fundus imaging devices provide the chance of capturing fundus images in remote areas such as rural areas with no medical settings, humanitarian projects in developing countries, medical surgeries, hospital wards, emergency rooms and operating theatres.

This paper reviews some of the recent techniques and devices for smartphone fundus imaging.

KEY WORDS: Retinal imaging. Retinoscopy. Fundoscopy. Ophthalmoscope.Fundus camera. Smartphone.

INTRODUCTION

The increasing use of mobile phones has become universal. Over 65% of the population, in both developed and developing countries, own a mobile phone. This rate increases among the medical community[1]. A survey conducted by Devices 4 Limited in the United Kingdom in 2010 showed that 80% of junior doctors owned a smartphone.

Using such universally available consumer device for fundus imaging may offer a new era of possibilities for diagnosis and screening of retinal and optic nerve diseases. smartphones enable ophthalmologists without a fundus camera to document and share findings in a more economical way. Furthermore, literature demonstrates that telemedicine has been successfully used in ophthalmology and established a connection between specialists and people in remote locations[2-5].

METHOD OF LITERATURE SEARCH:

A systematic literature search was performed in PubMed using the following key words: "retinal imaging", "fundus camera", "ophthalmoscope", "handheld", and "smartphone fundus camera".

The original relevant articles and reviews were retrieved and evaluated. As the review focuses on latest technological advancements in fundus imaging, Google search engine was also consulted for these key words.

The information about commercial products was obtained from the online articles and web pages of the respective companies.

The review was relative to articles written in English.

RESULTS:

Smartphone based fundoscopic cameras:

The aforementioned smartphone widespread availability and the mobile phone cameras resolution improvement have led to different methods of capturing retinal images. In 2010 Lord et al. reported a simple method of fundoscopy which consisted in holding a pen torch and a smartphone with one hand and a 20 diopters (D) lens in the other, in front of a patient with dilated pupils. After finding and holding the lens and the smartphone at the correct distance from the patient's dilated eyes, the smartphone camera would then autofocus onto the retinal image through the lens, allowing the capture of a digital image[6].

Light-emitting diode (LED) light source has been introduced to the smartphones in the last years. The LED light source of the mobile can be used to illuminate the fundus, avoiding the need to balance a torch alongside the phone, a technique labeled "smartphone fundoscopy". This system allows to capture high quality retinal images as some authors have shown[7-11].

Although the LED introduction reduced the complexity of the procedure, it requires a level of skill generally only exhibited by ophthalmologists or trained eye-care personnel. Therefore, Myung et al. used 3D printing technology to simplify the procedure. The authors designed a plastic arm which holds the lens at a fixed distance from the camera, allowing the entire system to be held and moved as a single unit[12].

Hong reported a similar, publically available design allowing anyone with access to a 3-D printer to build the system[13]. This product, called oDocs Fundus, is still available online as an open-source smartphone fundus camera design for Do-it-yourself (DIY) spirits. The company oDocs also sells the upgraded model oDocs VisoScope. It consists of an arm that clips to the mobile phone on one side, and to a 20D lens on the other side. It is compatible with iPhone 5 / 5S / SE / 6 / 6S / 6plus / 6Splus / 7 / 8 (Apple Inc., Cupertino, USA), and has 50° FOV. It is available in the market for around 300€Although the quality of the images is good, it requires darkness during capture as there is no cover between the smartphone and the lens to protect the light from coming in and provoking reflexions. The distance between the lens and the eye is not fixed and therefore, a degree of skill is still required to acquire the retinal image.

The iExaminer (Welch Allyn, Skaneateles Falls, NY) turns the PanOptic Ophthalmoscope (Welch Allyn, Skaneateles Falls, NY.) into a mobile digital imaging device using an iPhone 6, 6S and 6 Plus. It allows the capture of retinal images with 25° field of view (FOV) without having to dilate the pupil. Its previous model, designed for the iPhone 4, was the first device to achieve US Food and Drug Administration approval in 2013[13]. The system, excluding smartphone, costs over 1000€

CellScope (Cellscope, Inc., San Francisco, USA) is another external smartphone hardware adapter with custom built software for iPhone capable of taking widefield retinal photographs. It uses a single 54D ophthalmic lens. The illumination is provided by three white LEDs powered by the iPhone itself. Although a cross-polarization technique is used, artefacts are seen in the final image[8].

The portable eye examination kit (PEEK) (Peekvision.org, UK) is a clip-on hardware that comes along with an application for retinal image acquisition. It costs over 200€ and only allows capturing 30° FOV[14]. D-Eye system, by Si14 (Si14, Padova, Italy), also uses a clip system to get attached to the smartphone, it allows a capture of 20° FOV and costs over 400€It is designed to work with Galaxy S4, S5, iPhone 5, 5s, and 6[15]. Recently, a study compared the accuracy and reliability of the D-Eye with a slit-lamp biomicroscope to grade diabetic retinopathy[16] and the results were favourable.

Dr. Jaitra presented another smartphone based fundus camera, the Jaiz RetiCam plus, at KOSCON and VRSI Annual conferences in India in 2015. It consists of a metallic tube where a 20D lens is fit in at one end and a silicone case that allows the iPhone attachment at the other end. The device needs to be fit-in in a slit lamp. It costs over 200€lens and mobile device excluded. It has the disadvantages of being slit lamp dependent and presenting artefacts in the final image.

Toslak et al. have just reported the creation of a new prototype of a wide-field smartphone fundus video camera based on miniaturized indirect ophthalmoscopy. This prototype has been tested with a Samsung Galaxy S6 (Samsung Electronics Ltd., Suwon, South Korea) mobile phone and it has been reported to achieve 92° FOV in a single-shot fundus image[17]. It sounds promising but it is still not commercialized.

Limitations of smartphone-based cameras:

Safety of the iPhone 4[18], iPhone 6 and iPhone 6 plus[19] were proved, but the light sources of other smartphone models need to be verified against safety standards.

Beam alignment is problematic with the use of smartphone-based imaging systems and even more when mobile and lens are separately handhold, only ophthalmologist and trained personnel can achieve good alignment. This problem is partially solved with the devices that fix the lens to the camera but still the eye-lens distance has to be achieved by the explorer for optimal quality image captures.

Most of these smartphone based fundoscopic cameras are made for iPhones, not being useful for other manufacturer's mobile phone devices. Furthermore, the cases of the adaptors are usually prepared for one single smartphone model, not allowing the use of upgraded models.

LED light in most phones cannot be switched on prior to obtaining a photo in most imaging mobile applications on photography mode, therefore it is recommended to obtain a video, as most of the applications allow to continuously turn the light on during video mode. Another solution is to use photograph applications that allow switching the light during photograph mode, as Raju et al[9] do, or even designing specific applications for these devices as some aforementioned manufacturers have done.

Despite the price of these new devices has made fundus imaging affordable in developed countries, they are still hardly affordable in regions where these innovations are most needed. The use of teleophthalmology with smartphones will be a good way to improve the vision quality all over the world [20].

CONCLUSIONS:

Despite the immense potential of these smartphone based fundus cameras, still full integration of these devices has not been achieved into health care systems. One reason could be the failure to keeping pace with the constantly developing mobile phone market. If these handset smartphone adapters were universal, in the way that different devices could be adapted to them, the adaptors would last longer and would become updated just by the mobile upgrade.

Smartphone-based devices offer high potential for specialist to share images from a distance. Resident or training ophthalmologists may find this technique of imaging very useful for getting advice from senior colleagues, particularly in on-call situations.

We expect that the quality of the images achieved using these smartphone-based devices will continue to improve with the upcoming higher-resolution cameras and image stabilization systems that are being incorporated into newer smartphones.

Eye diseases such as glaucoma, age-related macular degeneration, diabetic retinopathy, and retinopathy of prematurity are the most common causes of blindness in many countries. The use of teleophthalmology with smartphones will be a good way to improve the vision quality all over the world. Numerous studies have shown that teleophthalmology is similar to the conventional eye care system in clinical outcomes and even provides more patient satisfaction as it saves time and cost.

The price of these new devices has made fundus imaging affordable in developed countries. However, they are still hardly affordable in regions where these innovations are most needed. Therefore, governments should think about establishing trials and programs to provide various packages for screening the prevalent diseases, and to have a suitable collaboration with health and vision-related organizations and help them to attack avoidable blindness in developing areas.

REFERENCES

1. Bolster NM, Giardini ME, Bastawrous A. The Diabetic Retinopathy

Screening Workflow: Potential for Smartphone Imaging. J Diabetes Sci Technol. 2015;10(2):318-324.

2. Surendran TS, Raman R. Teleophthalmology in Diabetic Retinopathy. J Diabetes Sci Technol. 2014;8(2):262-6. Epub 2014/05/31.

3. Strouthidis NG, Chandrasekharan G, Diamond JP, Murdoch IE. Teleglaucoma: ready to go? Br J Ophthalmol. 2014;98(12):1605-1611.

4. Kandasamy Y, Smith R, Wright I, Hartley L. Use of digital retinal imaging in screening for retinopathy of prematurity. J Paediatr Child Health. 2013;49(1):E1-5.

5. Rudnisky CJ, Tennant MT, Weis E, Ting A, Hinz BJ, Greve MD. Web-based grading of compressed stereoscopic digital photography versus standard slide film photography for the diagnosis of diabetic retinopathy. Ophthalmol. 2007;114(9):1748-54.

6. Lord RK, Shah VA, San Filippo AN, Krishna R. Novel uses of smartphones in ophthalmology. Ophthalmol. 2010;117(6):1274- e3.

7. 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.

8. 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.

9. Raju B, Raju NS, Akkara JD, Pathengay A. Do it yourself smartphone fundus camera - DIYretCAM. Indian J Ophthalmol. 2016;64(9):663-7.

10. Shanmugam MP, Mishra DK, Madhukumar R, Ramanjulu R, Reddy SY, Rodrigues G. Fundus imaging with a mobile phone: a review of techniques. Indian J Ophthalmol. 2014;62(9):960-962.

11. Furdova A, Furdova A, Krcmery V. Our experience with smartphone and spherical lens for the eye fundus examination during humanitarian project in Africa. Int J Ophthalmol. 2017;10(1):157-160.

12. Myung D, Jais A, He L, Blumenkranz MS, Chang RT. 3D Printed Smartphone Indirect Lens Adapter for Rapid, High Quality Retinal Imaging. J Mobile Tech Med. 2014;3(1):9-15.

13. Hong SC. 3D printable retinal imaging adapter for smartphones could go global. Graefe's archive for clinical and experimental ophthalmology. Graefes Arch Clin Exp Ophthalmol. 2015;253(10):1831-1833.

14. Navitsky C. The Portable Eye Examination Kit. A smartphone-based system brings ophthalmic diagnostic tests to remote settings. Retina Today. 2013;24-27.

15. Russo A, Morescalchi F, Costagliola C, Delcassi L, Semeraro F.

Comparison of smartphone ophthalmoscopy with slit-lamp biomicroscopy for grading diabetic retinopathy. Am J Ophthalmol. 2015;159(2):360-4 e1.

16. Russo A, Mapham W, Turano R, Costagliola C, Morescalchi F, Scaroni N, et al. Comparison of Smartphone Ophthalmoscopy With Slit-Lamp Biomicroscopy for Grading Vertical Cup-to-Disc Ratio. J Glaucoma. 2016;25(9):e777-81.

17. Toslak D, Ayata A, Liu C, Erol MK, Yao X. Wide-Field Smartphone Fundus Video Camera Based on Miniaturized Indirect Ophthalmoscopy. Retina. 2017.

18. Kim DY, Delori F, Mukai S. Smartphone photography safety. author reply 1. Ophthalmol. 2012;119(10):2200-1;

19. Hong SC, Wynn-Williams G, Wilson G. Safety of iPhone retinal photography. J Med Eng Technol. 2017;41(3):165-9.

20. Mohammadpour M, Heidari Z, Mirghorbani M, Hashemi H. Smartphones, tele-ophthalmology, and VISION 2020. Int J Ophthalmol. 2017;10(12):1909-18. Epub 2017/12/21.

CORRESPONDENCE:
Ian Roberts Martínez-Aguirre
Servicio de Oftalmología
Hospital Universitario de Burgos, Planta 0, Bloque C.
Avda. Baleares n° 3.
09006, Burgos. España
Email: i.roberts.ma @ gmail.com

Comment of the reviewer Dr. Fernando Giusio, MD. Profesor en Medicina. Telemedicina. Médico de Planta del Servicio de Oftalmología. Jefe del Área de Oftalmología Legal y Ocupacional. Hospital Italiano de Buenos Aires. Argentina.

Es indudable que la tecnología ha llegado a nuestros días para quedarse en todos los aspectos de nuestras vidas, y la salud, no es la excepción.

Todos los dispositivos tecnológicos al servicio del paciente tienen un costo elevado, por tal motivo, su instrumentación debe ir acompañada de políticas sanitarias nacionales para que aquellos que menos tienen puedan tener acceso a ellas.

Comment of the reviewer Marcelo Bursztyn, MD. Fellow Retina y Vitreo. Servicio de Oftalmología. Hospital Italiano de Buenos Aires. Argentina.

Siendo la retinografía un estudio dependiente de tecnología de alto costo, el desarrollo de técnicas y suplementos para incorporar los smartphones a la práctica médica brinda a la atención primaria una herramienta que acerca a solo "un click de distancia" la posibilidad de registrar un examen de fondo de ojos.

La posibilidad de realizar una interconsulta a un oftalmólogo en un sitio donde no se encuentre presencialmente es ahora posible si se cuenta con acceso a Internet. No ha de sorprendernos que en los próximos años veamos una masiva incorporación de herramientas basadas en smartphones no sólo para la práctica de consultorio, sino también en los centros de atención secundaria o terciaria, reduciendo los costos en salud y globalizando el acceso a los especialistas donde no los hubiese.