Journal of Medical Diagnostic Methods

Hong et al., J Med Diagn Meth 2015, 4:3
DOI: 10.4172/2168-9784.1000.180

Research Article Open Access

A Low Cost Integrated Retinal-Imaging System for Smartphone

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Received date: Jul 31, 2015, **Accepted date**: Aug 10, 2015, **Published date**: Aug 17, 2015

Abstract

Purpose: To design and develop a low cost downloadable universal smartphone retinal-imaging system and to illustrate its potential clinical application as a teleophthalmology system.

Methods: The system involves a phone adapter and a software. The adapter was designed with a computer aided design software and 3D printed. The soft copy of the 3D model were made available online for download and 3D printing in a different region of the world. The software was a custom-designed multifunction iOS application that serves as a teleophthalmology platform. Retinal images were taken from a patient and compared to that of a standard fundus camera.

Results: The system was successfully developed and the retinal image taken were of sufficient quality and comparable to the retinal photograph acquired with a standard fundus camera.

Conclusions: Our study confirmed that a low cost universal smartphone adapter could be downloaded and 3D printed instantly for retinal photography. The integration of the custom-designed mobile application made it novel and user-friendly.

Keywords: Smartphone retinal imaging; Teleophthalmology; Telemedicine

Introduction

The first application of telemedicine in ophthalmology was a 1987 project developed at the Johnson Space Center in Houston for real-time monitoring of retinal blood vessels [1].

Conventional teleophthalmology systems require sophisticated, expensive and bulky equipment. However, with the advancement in mobile technology, smartphones are becoming the ideal piece of equipment for teleophthalmology. In 2014, it is estimated that there are more than 1.75 billion smartphone owners worldwide [2].

Smartphone indirect ophthalmoloscopy is a well-known technique described by several investigators [3,4]. It can be used with the phone's own flash light in video mode or with a third party mobile applications [4]. D-Eye is another smartphone retinal imaging adapter that uses the principle of direct ophthalmoscopy [5].

Following the publication by Hong [6] regarding a low cost 3D printable smartphone retinal imaging adapter, we decided to further the study by developing a low cost system which integrates both the hardware and software component to facilitate retinal imaging.

Materials and Methods

The system is comprised of a smartphone, a 3D printed retinal-imaging adapter, a low cost acrylic +20 diopter condensing lens (Sensor Medical Technology, WA, USA) and the iOS application. The system was tried on one voluntary ophthalmic patient. The retinal photograph taken from the smartphone was then compared with those taken from a conventional fundus camera (Topcon TRC series).

3D Printed Adapter

As described by Hong [6], the adapter was designed with computer aided design (CAD) software (Figure 1A) and printed with a 3D printer (Figure 1B). The files of the devices are created in Standard Tessellation Language (STL) format which is compatible with standard Fuse Deposition Modelling (FDM) 3D printers. It requires eight M3 hexagon bolts and nuts, one M8 hexagon bolt and nut, and one +20 diopter lens.

iOS Application

To complete the system, a software is required to facilitate storage and image acquisition. A mobile application was developed, it is known as OphthDocs Eye App which comes with a variety of visual tests such as visual acuity charts, paediatric optotypes, Ishihara chart, and Amsler's grid. The application also allows the user to control the light intensity and to take either video or still retinal images. The images would be stored separately with password protection within the application.

Results

The retinal-imaging adapter and the iOS application were tried on the most popular smartphones from Apple (Apple, Cupertino, CA) namely iPhone 5S, iPhone 6, and iPhone 6 plus.

With informed consent, the system was tried on one volunteer with chronic open angle glaucoma. Figure 1C is the disc image captured with the described smartphone retinal imaging system while Figure 1D was captured with a Topcon TRC fundus camera. The smartphone acquire image was then presented to a practising ophthalmologist who successfully identified the pathology.

Discussion

Our report further consolidates the concept of smartphone retinal-imaging. Even though only the iPhones were used in this study, the retinal-imaging adapter was designed to be a universal adapter that could fit a variety of smartphones and even tablet devices.

The strength of this system lies in the integration of the hardware and the software. Unlike previously described application (FilmicPro, Camera Awesome, and ProCamera), our iOS application is tailored specifically for eye care. We believe this system is a better option as it solves problems such as large file size, security, storage and still image extraction. Furthermore, the described system is far cheaper than any current available smartphone retinal imaging system, the cost to self-manufacture the entire device including the lens is USD 50.00.

The fact that the entire system is electronically transferrable, it defies the traditional way of manufacturing ophthalmic instrument. With the files made available online, healthcare providers all around the world could download the files and 3D print the retinal imaging adapter locally. The mobile application which is freely available from Apple App store can easily be downloaded onto any iPhones.

One of the limitations of this system is that the images are two dimensional (2D) therefore users lose depth perception. Also, the quality of the retinal images acquired depends heavily on the technique and lighting condition of the room. It is prone to unwanted glare and reflection which could degrade the quality of the photograph.

Smartphones are beginning to play a central role as health monitoring and medical diagnostic tools. Their accessibility, computational power, speed, portability and connectivity will only keep improving. Most importantly, they are becoming more reliable and increasingly affordable. Given the relatively low cost of the system described, it may be most promising for use as a smartphone-based teleophthalmology system in resource-poor regions or non-tertiary medical centres.

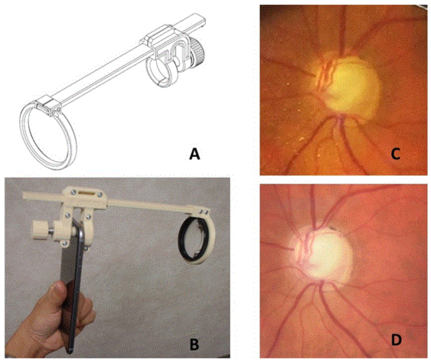

Figure 1: Smartphone retinal imaging system. (A) Computer Aided Design (CAD) of the retinal imaging adapter. (B) A functional prototype of the device on an iPhone 6 plus. (C) Smartphone captured image of a glaucomatous disc. (D) Image of the glaucomatous disc taken with a conventional fundus camera.

Acknowledgments

We would like to thank Daniel Dillen from Vivenda for his technical advice on 3D printing and Hanna Eastvold-Edwins from The Popcorn Collective for her engineering advice.

Conflict of Interest

All authors certify that they have no affiliations with or involvement in any organization or entity with any financial interest, or non-financial interest in the subject matter or materials discussed in this manuscript.

Informed Consent

The participant shown in Figure 1C and 1D had given informed consent for the use of the photograph.

Funding

The study was fully funded by the authors of this article.

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