REVIEW

The Use of Smart phones in Ophthalmology

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ABSTRACT

Smart phones are being increasingly used among health professionals. Ophthalmological applications are widely available and can turn smart phones into sophisticated medical devices. Smart phones can be useful instruments for the practice of evidence-based medicine, professional education, mobile clinical communication, patient education, disease self-management, remote patient monitoring or as powerful administrative tools. Several applications are available for different ophthalmological examinations that can assess visual acuity, color vision, astigmatism, pupil size, Amsler grid test and more. Smart phones can be useful ophthalmic devices for taking images of anterior and posterior eye segment. Professional literature and educational material for patients are easily available with use of smart phones. Smart phones can store great amount of informations and are useful for long term monitoring with caution for patient confidentiality. The use of smart phones especially as diagnostic tools is not standardized and results should be carefully considered. Innovative role of smartphone technology and its use in research, education and information sharing makes smart phones a future of ophthalmology and medicine.

Key words: smartphone, smart phone, information technology, telemedicine, tele-ophthalmology

1. INTRODUCTION

A smartphone, or smart phone, is a multifunctional electronic device–mobile phone with advanced computing capability and connectivity. The use of smartphone enables not only telephone calls and text messaging, but also provides advanced functionality and ability to run multiple advanced applications, surf the web, send and receive e-mails, create and display photos, videos and office documents (1, 2, 3). Technological advances with increasing number of available applications, as well as reduced costs, led to a massive use of smart phones. The assumed number of smartphone users in the world in 2012 was 1 billion and is estimated to increase to 1.75 billion in 2014 (4).

There is significant increase of smartphone users among health professionals, from estimated 30% in 2001 to 64% in 2009 (5, 6). Currently, 86% of health professionals daily use smart phones for various purposes (7). Smart phones can combine many commonly used tools for clinical evaluation and education into one easy to use, portable interface (8). Medical applications make smart phones useful tools in: the practice of evidence-based medicine, mobile clinical communication, patient education, disease self-management and remote patient monitoring (5).

Purpose of this article is to present various useful applications of smart phones in ophthalmology.

2. SMARTPHONE APPLICATIONS IN OPHTHALMOLOGY

Ophthalmological applications are turning smart phones into medical devices and currently there are more than 342 different ophthalmological applications available (1). In period from 2009 to 2012 there has been a 9-fold increase in the number of available surgical applications for smart phones (9). Currently, there are 621 different surgical smartphone applications available, where 121 are dedicated to ophthalmology (9). Generally Apple's iOS and Google's Android are two most used platforms among healthcare professionals (2, 10). Some surveys determined the Apple iPhone to be the most popular smartphone among the ophthalmologists worldwide (2, 11). There is a wide range of smartphone applications ranging from simple flashcards to virtual surgery applications that provide surgical exposure and familiarization with common operative procedures (9).

Smartphone applications can be divided into three groups by the targeted user: healthcare professionals, medical or nursing students and patients (5). Smart phones may have many potential functions in the field of ophthalmology and its uses may be classified into following categories (2):

- Patient assessment tools;
- Patient education–visual aids;
- Health care profession education and reference;
- Patient records–administrative tools; and

- Multiple functions.

2.1. Patient assessment tools

Ophthalmological examination requires use of different diagnostic tools. These examinations can be easily performed in clinical settings, but in conditions of outpatient or inpatient consults and emergency room visits, the use of smartphone applications for different visual tests can be very useful (2, 5, 8, 12). Patient assessment tools include several applications. These applications can assess visual acuity using the Snellen visual acuity test or modern interactive visual acuity tests for pre-school children and illiterate people. Some of the applications have tests for color vision, astigmatism, pupil size, Amsler grid test, oculomotor reflexes, a Worth 4 dot test and accommodation targets, red desaturation test and OKN drum simulator (2, 8, 13). It is important to note the possible use of fluorescein light and pen light which are useful in non-ideal settings. In these conditions the examiner will have to increase the screen brightness to maximum and reduce the surrounding light to minimum (3). Smart phones can be used as paediatric fixation targets which are bright, with motion and sound, which can entertain paediatric patients (8). "Eye Handbook" is one of the most used applications which include almost all of the mentioned testing tools and other popular applications are: "iSight test", "Vision test", "Macula tester" and "Color blind test".
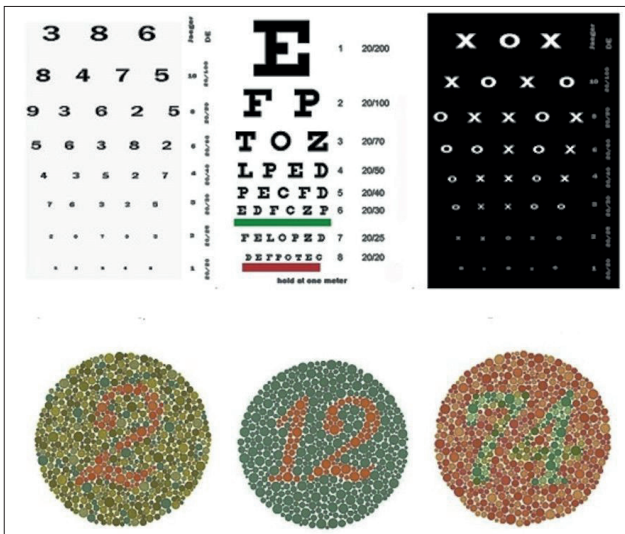

Figure 1. *Near vision cards and Ishihara colour plates*

The use of smart phones for ophthalmic photography has become increasingly popular. New generation of smart phones has cameras with resolution of 5 mega pixels and higher, which enables its users to capture high quality images. There are several photoadapters available for smart phones which make them useful ophthalmic devices for taking images of both, anterior and posterior eye segment (Picture 2). When used, photoadapters require that the smartphone's camera is aligned with the optical axis and placed close enough to the slitlamp eyepiece. There are adapters designed to attach to the "PanOptic Oph-

Figure 2. *Magnifi photoadapter for iPhone (www.arcturuslabs.com) and iExaminer PanOptic Ophthalmoscope (www.welchallyn.com)*

thalmoscope" for capturing fundus photos through undilated pupil. It is also possible to make quality picture of retina using only smartphone and indirect lens (8, 14). The examiner can watch the smartphone display and evaluate the real time images of the anterior and posterior eye segment with other practitioners, record and share the findings (15). Smartphone using pinhole adaptor (Near Eye Tool For Refractive Assessment–NETRA) can be used to estimate the refractive error (Subjective Spherical Equivalent) without statically significant difference from subjective refraction (16). When interpreting the examination results, the examiner–ophthalmologist should have in mind the fact that the testing tools are not ideally standardized and should be used by the eye care professionals using their professional experience and judgment (3, 8).

2.2. Patient education–visual aids

Patient management includes not only patient examination and treatment, but also patient education in order to improve patient understanding of ophthalmic diseases and its processes. Clinician led patient education in disease prevention and management with use of smart phones is convenient and effective (5). Educational materials include instruction sheets, brochures and videos and can be used for the patients' better understanding of their condition. Smart phones are capable of reproducing high resolution images, videos and office documents that contain different information about medical conditions (8). High-resolution images of the various ocular conditions can easily explain anatomy and pathology as well as various treatment procedures and options to the patient (3, 8). Patients can download the application and the informative material to their own smartphone, review the information and show it to friends and relatives, relieving them of the burden of translating sometimes complicated explanations of their ophthalmological condition (2).

Several applications contain the list of various common ocular conditions that are encountered in everyday ophthalmology practice, with a short de-

scription of clinical features and treatment options (3). These informations can be presented or even e-mailed to the patient and his family. In this way there is possibility in some cases for making self–diagnosis without presence of the physician (10). Currently two most popular patient education applications are "Eye Handbook" and "IKONION". With the "Eye Hand-book", physician can e-mail the required education material to the patient directly from his smartphone, which is a great feature (3). Patients with severe visual impairment can use applications such as voice–activated assistant to cope with daily activities (17). Smart phones can be also used for tracking and monitoring of disabled patients with use of its Global Positioning System (GPS) (10).

2.3. Health care profession education and reference

Professional development is essential for healthcare professionals. With limited number of hours available for professional development it is difficult to catch up on the latest results from the studies (2). With implementation of information technology namely use of smart phones the latest results and findings are with "click" away from the practitioners. All classifications and grading systems such as angle anatomy, diabetic retinopathy, macular holes, optic nerve oedema and melanoma are easily available (3). Several applications provide access to clinical trials database and literature search in biomedical literature databases such as PubMed/MEDLINE. Most popular database search applications are "PubSearch" and "PubMed on Tap". These applications also allow sharing information with both, patients and colleagues (5).

Other smartphone applications have videos, color atlas images which are very useful in training process and surgical skills development. These applications may help in patient follow up, calculating intra-ocular lens (IOL) or surgically induced astigmatism (SIA) (2). Some applications include a list of diagnoses not to miss, with definition and differential diagnosis, a color–coded diagram of retinal drawings, question-naires for commonly encountered ophthalmic diseases and a summary of benchmark randomized control trials in ophthalmology (3).

Patient records–administrative tools

The number of applications for smart phones that can be used in medicine is constantly growing. With use of smart phones communication between the physicians and hospitals is continuously improving (10). Dynamic interface has great functionality and potential for future growth in the field of ophthalmology (8). Applications for Hospital Information Systems (HIS) allow secure access to patient's records from remote locations (2, 5). These applications such as "OsiriX" and "MEDITECH" enable use of information's from hospitals picture archiving and communication system (PACS), their secure transfer from one physician to another and from one location to another. Other useful informations including visual acuity and intraocular pressure values, eye images taken from mobile or stationary ophthalmic camera, optical coherence tomography findings, corneal topography images or even patients complete electronic health record (EHR) can be transferred too (5).

Tele-ophthalmology presents the use of electronic communication and information technologies to provide or support a diverse group of activities related to eye care (12). Smartphone applications enable true appliance of tele-ophthalmology, while it covers many medical activities, including making diagnoses, treatment, prevention, education and research. Transferred information's can be later analyzed in detail or compared to previous findings. Tele-ophthalmology makes the practice of eye care independent of location or time (12). It is important to mention that there are some applications dealing with coding diseases according to The International Classification of Diseases–9 (ICD) which can be very helpful and time saving (8).

2.4. Multiple functions

There are several applications that include many of the previously mentioned functions in one package. These features including reference search, links to journals, eye atlas, various tests, recording patient details, collaboration with other colleagues, tool kit to calculate eye related calculations (intraocular lens calculation, surgically induced astigmatism, vertex distance etc.) and patient information images with videos for explanation of different conditions (2). On the other side, there are several general medical smartphone applications designed for providing information on general health conditions, including symptoms, diagnosis, differential diagnosis, pathogenesis and treatment options that can be helpful for ophthalmic patients too (5). Most popular are "Medscape", "Epocrates" and "UpToDate" which provide most recent information useful for practicing evidence based medicine (5).

There are several applications such as "Normal Lab Values" or "Pocket Guide to Diagnostic Tests", which offer information's regarding common laboratory tests, including reference values and interpretation, causes for abnormal values and laboratory unit conversations. Smart phones enable use of drug reference applications, such as "Skyscapes RxDrug"s or "SafeMed Pocket", which offer names of drugs, their indications, dosages, pharmacology, drug–drug interactions, contraindications and costs. Other applications such as "MedMath" and "MedCalc" offer options for calculating various clinical scores, individual drug dosing etc (5). Smartphone applications with multiple functions generally can be very useful in limited resources settings with poor implementation of information technology such as Bosnia and Herzegovina (18).

3. LIMITATIONS

The use of smart phones in diagnosis of different ocular conditions has several limitations mainly re-

garding the regulations and standardization of performed tests and quality of captured images (10). Although many researches confirmed safety and efficacy of smartphone use, interpretation of these results should be careful and based on examiners experience. Nevertheless it is important that health professionals are trained and aware of possibilities and limitations of smartphone use. Younger health professionals are more likely to adopt the new technologies and recommend the use of smartphone technologies for their patients (5, 10, 17). Also, younger patients are more likely to use and become familiar with smart phones technology which might be a problem for older patients (17). Patients' data security can also be an issue, because when performed, data transfer should be secure with use of different encrypting standards with special emphasis on patient's confidentiality (3, 8). Use of smart phones in different settings namely laboratory carries a risk for contamination and special attention should be given on its decontamination.

4. CONCLUSION

Smart phones have already made a great impact on ophthalmology and medical practice in general. There is an increasing number of available smartphone applications and ophthalmologists are becoming more familiar with use of smart phones in their practice. Innovative role of smartphone technology and its use in research, education and information sharing makes smart phones a future of ophthalmology and medicine.

CONFLICT OF INTEREST: NONE DECLARED.

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