

**Review Article**

Techniques and Automation in Eye Care and Vision Testing Using Smartphone

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Abstract: This article presents the overview of smartphone applicability in the field of ophthalmology. Eye and vision health is the most essential part in the human life span. According to the national surveys eye vision loss is the most common fear among the humans and everyone expect for good eye care facility, and desire for lifetime enjoyment of good vision. With the advancement in use of smartphone among the masses has increased exponentially. Smartphones are multifunctional electronic device with the computing capabilities and connectivity's. Smartphone not only serve the purpose of telephone calls and texting but they have advanced multiple functionality and ability to run the advanced applications. With the dramatic rise in the need of ophthalmic devices and ophthalmic care in the health sector there is a rapid need of equipments which are cost effective and can be beneficial rural people especially for the developing nations like India where most of the population reside in rural areas under constraint conditions and low availability of health care facilities. Ophthalmological applications which are turning the smartphones into the medical devices include Peek vision app, Sightbook app, Digisight app etc.

Keywords: Visual Acuity, Smartphone Applications, Rretinal Imaging, Eye Testing

1. Introduction

Eye and vision health is the most essential part in the human life span, eye are the lamp of the body. Despite of this fact eye disease cannot be located among the top chronic diseases priorities enlisted by Department of Health and Human Services [1]. Nearly 550 million almost half of the Indian population is suffering from vision problems [2]. According to the national surveys, Vision loss is the most common fear among the humans and they expect for good eye care facility, and hope for lifetime enjoyment of good vision. 87.5% of respondents associated with the good and healthy vision have high quality life too [3].

Despite of facts and fears related to vision loss, it has been reported through the surveys that patients approach to the health care center at the critical stages of eye disorder. According to Medicare Access and CHIP Reauthorization Act (MACRA) they are working towards providing the fertile environment to enhance the eye health across the nation. With the change in time and technology, it is becoming important

for the eye care community to engage teachers, scientists, researchers, employees, technology institutes and business people for the betterment of health care system as well as to come up with the vision improvement health strategies [4].

Ophthalmological examinations consist of number of tests related to vision and other eye disorders. These examinations require use of different diagnostic tools under the clinical settings. Visual acuity testing is the most commonly done in clinic practices by the Snellen chart method. This method is limited due to its non-geometric progression in letters sizing from line to line and its inconsistent number of letters per line [5]. According to the standard definition Visual acuity (VA) is defined as the acuteness or clearness of vision, which is dependent on the sharpness of the retinal focus within the eye, the sensitivity of the nervous elements, and the interpretative faculty of the brain [6]. Apart from the visual acuity test eye testing include the detection of various eye diseases and disorders which could lead to the acute eye vision loss. The most common and harmful eye disorders include diabetic retinopathy, age related muscular degeneration and glaucoma.

Retinal imaging is one of the most important tools for the detection and treatment of these harmful disorders. Early detection of these disorders can prevent the permanent vision loss in patients [7-10]. Ophthalmic images were photographically recorded since the 19th centuries [11, 12]. The data collected shows that India's smartphone user base touched 300 million in 2016, while the number of mobile Internet users in India is projected to double and cross the 300 million mark by 2017 from 159 million users at present, as reported by new report by Internet and Mobile Association of India (IAMAI) [13].

Recent smartphones are capable of capturing images of high quality this application of mobile phones can be utilized in the field of eye testing to capture images of retina and fundus of eye with the help of other components. It can be hypothesized that the ophthalmic diagnosis will be automated through the use of smartphones, with the support of healthcare system, educational institutes and non-ophthalmic specialist. This advancement in technology requires the integration of mobile software's and hardware technology to create evidence based algorithms that create a database for patient specific action recommendation [14, 15].

Eye vision or eye sight is one of the most precious gifts of nature given to the human lives. It is only because of the eyes nature is able to enjoy the beauty of the nature and world. It is completely impossible for someone with a sight to imagine a life without it. Eye is small and most complex organ in the human body. Like other body parts various sorts of disorders or problems are linked to eye which can occur to anybody in their life spans. The most common eye disorder is refractive error or in common terms need of spectacles or eye lenses. This problem basically occurs due to the alteration in the length and shape and capacity of eye. Another common eye disorders include Age related Macular degeneration, Cataract, Diabetic retinopathy, Glaucoma. Age related macular degeneration refers to the condition [16].

Glaucoma is the condition which often has no symptoms, in case it is not detected and treated at the early stages. It causes visual impairment and it is usually induced by raised intraocular pressure. It can only be prevented by the routine checkups from ophthalmologists for the people at the risk of it.

All the diabetic persons are at the risk of diabetic retinopathy, which if cannot be detected can results in the blindness, therefore early detection and diagnosis of the disease is critical [17]. To prevent the permanent vision loss due to diabetic retinopathy effective control of diabetes, blood pressure and cholesterol levels. Color blindness is predominately an inherited condition which has no cure to it [18].

2. Smartphone Applicability

2.1. Vision Testing Applications Using Smartphones

Smartphones are multifunctional electronic device which provide computing capabilities and global connectivity's. Smartphone not only serve the purpose of telephone calls and

texting but they have advanced multiple functionality and ability to run the advanced applications. Advancement in the technology and reduced cost of the devices and applications had led to the massive increase in the use of smartphone [19-21]. Most of the smartphones now launched with one or other healthcare application with advanced features. Ophthalmological applications which are turning the smartphones into the medical devices include Digisight app, Sightbook [22] app and Peek vision app [23] etc [20]. According to the surveys apple iOS and android are the most commonly used platforms among the health care professionals. There are various smartphone applications present ranging from simple flashcards to virtual surgery exposures and familiarization [20, 24]. Peek vision application is designed based on the Snellen chart and ETDR-based tumbling E-logmar chart. This application is written in android and installed to the test devices which display letter E in 4 different orientations. Tester need to touch the screen to swipe accordingly this has reduced the verbal and nonverbal clues, on the basis of this response the visual acuity measure is shown to the patient [23]. Sightbook app by Digisight Technologies allow the patients to check their vision, color acuity, contrast, Amsler grid and other test, all the test results are displayed and stored in the device. This application is based on the ETDR distance chart and Rosenbaum Near card. Patient's information is securely stored on the website and patients can choose the physicians for further treatments [25]. Eye Handbook app [26] can be used for visual acuity testing, color vision testing etc. Somewhat similar application to this is Eyetube, which include the growing library of ophthalmology videos [27]. iSnellen is another mobile application which shows the Snellen chart in display and tester need to keep the devices as specified distance for the test. Eye 2 Phone is similar to above mentioned applications which include near acuity testing, visual acuity test, Ishihara color testing, Amsler grid testing, fixation target testing and a pupil gauge test. Pocket eye app contains OKN strip, pupil chart, Snellen chart, red desaturation test and Ishihara test [28].

One of the most advanced applications developed by the MIT students is Netra (Near eye tool for refractive assessment) eye care device to estimate the refractive error. This device is simply attached to the mobile phone, it is cost effective tool for meeting the goal of vision 20/20 to eradicate the avoidable blindness and warrants the testing in the resource poor settings [29].

Devi et al. [14] had designed the system to check the visual acuity in patients, They developed a hardware system which consist of a box that contain different set of lenses mounted on a wheel attached to motor and a display for visualizing different size letter based on Snellen chart and user has to give his input by keyboard and result will be displayed on the monitor based on the lens by which patient is able to visualize the word properly. The system is also used to color blindness and night blindness test as well as to measure the time duration of drops in patients. The hardware can also be used to measure the time duration for pupil dilation. The system is completely automatic and does not need any manpower to operate.

2.2. Informative Applications Tools for Patients

Informative applications tools include the use of smartphones as the educational mode for the patients which include instruction sheets, educational brochures and videos for the appropriate understanding of their medical conditions. High resolution images, documents and videos can be reproduced by the smartphones. With the help of these tools person can even download all the information, review it and even share among friends and family to easily explain his ophthalmological condition. Some of the applications available contain lists of ocular conditions commonly found in routine ophthalmological practice, with brief description of its clinical features along with the treatment options.

With the advancement these applications can be beneficial for the patients in some cases for self-diagnosis in the absence of physician. Most popular patient education applications are "Eye Handbook", "IKONION".

Eye Handbook is one of the easy to use freely available applications on android play store and iTunes which is also called virtual call bag application. Apart from that it includes the instant access to an atlas of ophthalmic photographs, quick reference manuals, calculators for glaucoma risk [27].

Ikonion app is another reliable app available for iPhone, which is helpful for patient education it provides them information related to their disease and its process, along with the brief description and high resolution pictures related to their disease condition [30].

2.3. Retinal and Fundus Imaging by Smartphone

Retinal examination is the fundamental aspect of ophthalmology for which the use of smartphones appears to be as promising and reliable aspect. Traditionally and in current system direct or indirect ophthalmoscope is used for the fundus and retinal imaging of eyes in clinical settings. Von Helmholtz in 1851 invented the direct ophthalmoscope [31]. With the advancement in technology ophthalmoscope had undergone stages of development which include incorporation of concave, convex lens and camera for the clarity of the images seen by correcting errors of refraction in patients and /or the observer and for the documentation purpose. The indirect ophthalmoscope has been developed by Giraud Teulon which undergone various stages of development from attachment of video camera, teaching mirror for ar hiving, teleconsultation, and for the education purpose [31] Despite of all these advances the instrument is relatively bulky and need steep learning and it is unaffordable. Smartphone ophthalmic instruments especially for imaging of fundus and retina, are important and found there applicability for the mass screening in eye camps for outreach areas, apart from that it will be helpful in imperfect examination situations like in emergency or casualty rooms [31, 32]. Scientist has come up with the new solution which is the use of smartphone and 20D lens which is more affordable and cost effective for low cost settings, as phones are available readily and cost effective easy to use, portable and always available resource and advanced technology for capturing images seems a good alternative.

Thus teleophthalmology which is the use of electronic communication and information had come up as a major subject to provide diverse activities for eye care. Most of the studies have been focused on the use of smartphone like iPhone, Samsung in addition to some other apps easily available on android and iOS software to enhance the quality of images retinal images [33].

Ademola-Popoola and Olatunji [34] carried out a research on the use of Blackberry Z-10 along with the 20D lens to obtain the indirect images from fundus. Total of twelve patients were diagnosed for the retinal disorders in them from refer retinal imaging article which include retinoblastoma, and other anterior segment pathologies in retina.

Lord et al. [35] described approach to acquire the images of fundus on smartphone by holding 20D lens in one hand while holding iPhone for capturing image in other hand. This method was found to be laborious and impractical in some conditions. This method was rather found inconvenient to use and made the acquisition of good quality images difficult. Later on the technique became more comfortable with the incorporation of flashlight feature in the smartphones.

Haddock et al. [36] described the similar technique of smart phone fundus photography by iPhone with the help of 20D lens. Filmic pro app was used to control the intensity of light, exposure and focus. For manual adjustment of light intensity micropore paper medical tape is used by wrapping it over the light source. The images were taken in the clinic setups, the app's video recording was activated and video of fundus was captured. The still images were extracted then edited using the iPhone editing function. The high quality images from the patients were archived into the medical record or for telemedicine. The smart phones used in this technique were encrypted and the images were transmitted via institutional mail with encryption of attachments.

Dyaberi et al. [37] have described the technique in which they have used 28D lens as a result they showed it as more convenient than that of 20D lens as it can be held closer to the patient's eye and is more stabilizing as well as give wider field of view, with lesser magnification compared to the 20D lens using smart phone camera and 20D and 28D lens to capture the high quality fundus images of patient's eye. The light intensity and flash light setting was done manually, they used the micropore paper tape which they stick over the LED light to reduce its intensity, while in case of android phone and iPhone Filmic Pro app is used to control the intensity of light.

3. Challenges

Many smartphone applications are proposed to give best results but still there is a scope for improvement. Use of smartphones in the eye health care sector has several challenges and limitations especially related to the regulations and standardization of performed tests and quality of the retinal images captured through these devices. There is a need of interdisciplinary study and examination among IT professionals and health care professionals to check for the validity and efficacy of all the smartphones based applications

in this field. It is utmost important that health care professionals are well trained and aware of the possibilities and limitations due to the use of smartphones. One of the big challenges is the use of smartphones in the lab settings and care rooms in hospitals, use of smartphone in these settings may lead to the problem of contamination as smartphones cannot be properly sanitized unlike other lab equipments.

All the data collected on the smartphones need proper security and data encryption especially regarding the proper confidentiality and consent of patients. The images and test performed by the smartphones need to be properly validated and results sharing should be end to end encrypted. On the other the use of the light source is one of the challenges.

4. Summary and Conclusion

This article provides useful reference which will help research groups to design and module more improved versions of apps and hardware's. With the dramatic rise in the need of ophthalmic devices and ophthalmic care in the health sector there is a rapid need of equipments which are cost effective and can be beneficial for the developing nations like India where most of the population reside in rural areas under constraint conditions and low availability of health care facilities. The smartphone has become common among masses in all sections of society, so with the help of these devices there is need of simple inexpensive technique which can be used in eye testing and the technique need be friendly and easy to be understood by common people as a first line of diagnosis on their own and then to go to specialist. Today around 45% of all mobile phone subscriptions are associated with smartphones, compared with around 40 percent in 2014 [38]. Retinal photography is one of the important of ophthalmology practice in eye health care. The most common cause of blindness among people is retinopathy disorders like diabetic retinopathy, hypertensive retinopathy etc. Early detection and treatment of these disorders can be helpful for the patients in long run. Smartphone ophthalmoscopy is becoming popular day by day as it is reliable and simple to handle. Hence the Proper utilization and validation of smartphone application in the ophthalmology can lead the advancement in the health care sector and that will be beneficial for each section of society.

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