Smartphones and their Applications in Health care - A Review

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Abstract

The incorporation of lightning quick processors along with high resolution digital cameras within the smartphones have led to their significant growth even in the healthcare sector. Their excellent imaging capabilities have had tremendous applications in specialities that primarily depend on visual interpretation like pathology, radiology and dermatology. As a result, smartphone applications (apps) have become increasingly prevalent in medicine and dentistry. The purpose of this review is to illustrate how smartphones and tablets can be used by dental faculty including trainee students in academics or research and to introduce most relevant applications that are currently available.

Keywords: Smartphones, Applications, Apps, Digital Pathology, Digital Radiology, Tele pathology

1. Introduction

The cell phones have become part of our everyday life. It is as important as your wallet to carry with you wherever you go. According to Statista, currently there are 3.3 billion smartphone users worldwide. This means that in the world of wireless, 42.63% of the world's population have a smartphone today. The number is expected to increase further by several hundred million in the next few years. China, India, and the United States are the countries with the highest number of smartphone users, with each country easily surpassing the 100 million user mark[1]. Mobile applications or apps (mini computer programs) are designed for mobile devices such as smartphones and tablets. These are developed by 'App developers' who are trained in the computer languages. As of 2020 the number of mobile app developers in the world is approximately 14 million worldwide[2].

Today, devices with faster processors, improved memory, high quality cameras with pixel dense, colour rich touch screens, global positioning systems and highly efficient operating systems coupled with long lasting batteries are capable to process many different advanced functions, especially apps, that currently affects our personal and work environments[3].

When devices with such high specifications coupled with massive number of apps being constantly available, efforts have been made by many app developers in conjunction with healthcare providers and researchers to rely on them as a convenient, portable screening, imaging, diagnostic, photo microscopic, teleconsulting, or research tool. In this direction many such applications are introduced and being used in the field of health care providers. The following are the relevant smart phone and its applications that are used in the practice of medicine or dentistry including research, teaching and learning process.

2. Apps / Hardware Used in Screening/ Examination of High Risk Lesions

2.1 Cancer Screening

Arunan Skandarajah et al. evaluated automated tablet-based mobile microscope and their own app called CellScope as an adjunct for telemedicine-based oral cancer screening[4]. Their samples were from brush biopsy with a simplified staining procedure and a tablet-based mobile

microscope to aid in local collection of digital images and remote evaluation of the images by expert clinicians. The tablet-based mobile microscope (CellScope device) combined an iPad Mini with collection optics, LED illumination and Bluetooth-controlled motors to scan a slide specimen and capture high-resolution images of stained brush biopsy samples. Researchers used the instrument to collect and send randomly selected images of each slide for telepathology review. Evaluation of the concordance between histology, conventional microscopy cytology, and remote pathologist review of the images was performed. Observations indicated that the instrument successfully collected images of sufficient quality to enable remote diagnoses that show concordance with existing techniques.

2.2 High Resolution Cameras in Screening Oral Potentially Malignant Disorders

Nabihah Haron et.al in 2017 examined the concordance in clinical diagnosis of high-risk oral lesions in sixteen patients and referral decisions between clinical oral examination (COE) and tele dentistry using images captured by high resolution smart phone cameras[5]. In their study, five areas of the oral cavity were photographed by three dentists using mobile phone cameras with 5 MP-13 MP resolution. On the same day, the patients were examined by two oral medicine specialists and 3 weeks later, they reviewed the images and concordance was examined between the two by Kappa statistics. The Kappa values in determining the presence of lesion, category of lesion (OPMD or not), and making referral decision were moderate to strong (0.64–1.00). The overall sensitivity was more than 70% and specificity was 100%. The false negative rate decreased as the camera resolution increased. This study provides evidence that images can be used for communication between primary care and oral medicine specialists.

2.3 High Resolution Cameras in Screening Melanomas

Rosado et al. in 2012, tried to extract the ABCDE rule from images captured from the skin lesions[6]. They developed a prototype for patient-oriented system for skin lesions using a smart phone. This system collected, processed and stored information through automatic extraction of specific visual features. The features were based on ABCDE rule that is followed for malignant melanoma lesions. The algorithm used to extract the features are based on the images captured by the smart phones.

3. Apps Used in Pathology

There are numerous applications that can be mentioned here, however, the most recommended are listed below (Figure 1).

Figure 1- Examples of applications developed for pathology and dermatology practice

3.1 UPMC Pocket Pathologist

A free to download mobile application launched in August 2013, available as UPMC (University of Pittsburgh Medical Center) Pocket pathologist app in iOS app store (not available for Android users). Hartman et al. in 2014 developed an iPhone application called Pocket Pathologist to facilitate rapid diagnostic pathology expert teleconsultation utilizing a smartphone[7]. This app offers an easy to use convenient and cost effective way to digitally capture microscopic images and upload to UMPC's digital pathology consultation server through a secured connection drastically reducing case turnaround time and resources. This also enables the users to connect with international specialist pathologists whenever one need's a second opinion to improve

diagnostic efficiency. The interface is very user friendly. The user can first register, create a case by submitting microscopic images and other patient details and finally to receive an official acknowledgement in the app itself.

3.2 GP-Helper

General Pathology Helper (Figure 1). A free to download app released in July 2015. This app helps to integrate offline and online data about pathology with an additional interactive external place such as "community" in order to represent a reference tool for general pathologists[8]. The app has permanent information (offline data) about different pathology protocols (TNM latest edition, protocols regarding management of tumors of unknown primary origin, and flowcharts for some of the most difficult tumors to diagnose) and a database with more than 5000 immunohistochemistry results from different tumors. Online data have links to more than 1100 reference pathology video lectures, 250 antibodies information, more than 70 pathology association websites, 46 pathology providers, and 78 outstanding pathology journal websites. Besides this information, the app has two interactive places such as "FORUM GP-HELPER" and "COMMUNITY GP-HELPER" that let users to stay in touch everywhere and every time. Expert consult section is also available. This app also received an award at XXXI International Congress of international academy of Pathology and 28th congress of European Society of pathology (2016).

3.3 DADEK

An iOS app to evaluate work involving immunohistochemistry. Wilfrido et al. in 2016 developed a app based on the practice that Control tissues playing an important role in diagnostic immunohistochemistry[9]. The app was designed to be customizable database for pathologists who practice immunohistochemistry using in-house immunohistochemistry. Images of control material for each antibody are available for viewing accompanied by a descriptive few sentences that explain the expected staining pattern in said tissue. This includes which cell type and localization, with the latter specific to either plasma membrane, cytoplasmic or nuclear. Because of inconsistencies in the naming of antibodies, alias' are provided as additional information. Other information included are the appropriate control for each specific antibody and the tissue components that comprise that antibody's control block. The authors conclude that the app format also allows for on-the-fly modifications, so that any new antibodies that are added, or control tissue that is changed for a particular antibody, are integrated in a seamless manner and also it can be customized to the needs of any laboratory or institution that would want to use it. However, currently as of 2020, the app is removed from the iOS app store for unknown reasons.

3.4 Other Pathology Related Apps That Can be Used in Education / Teaching and Learning

Pathology Guide, Case files pathology, Surgical pathology, Pathology Patashala, Cytoatlas, Anatomic pathology, Smart histology Lite, Rubin's Pathology, Pathology Dictionary, Pathology selector, Ophthalmic pathology, Digital pathology, Leeds pathology, Pathology terminology, Atlas of pathology.

3.5 Smart Phone Based Low Cost Whole Slide Imaging Systems / Low Cost Digital Pathology

The regular microscope attached with a smart phone can easily capture high quality photomicrographs. These photomicrographs can be stitched seamlessly using the common image editing software like adobe Photoshop to obtain a high resolution "whole slide image". Spoorthi et al. in their paper on image montaging technique[10] have discussed step wise easy practical method in creating such virtual histological slide. Many researchers have detailed the best practices involved in capturing photomicrographs using smart phones and different microscopes[11,12].

4. Apps Designed for Dermatology

Currently there are numerous applications (>200) that are developed in relation to dermatology[13]. However, the following are the most reviewed and frequently used apps (Figure 1).

4.1 Visual Dx

Free to download, available on iOS and android platforms. This app is for diagnostic clinical decision, reference category app, searchable by symptoms, signs and patient factors. This app helps a clinician/pathologists to visually confirm a diagnosis by comparing medical images to the patient's presentation. The clinician can also quickly search for diagnosis for next steps on management. It also helps to build a custom differential based on patient's signs and symptoms. It also offers more than 40,000 drug interactions.

4.2 Dermatology A-Z

This is official app from the American Academy of dermatology. This app is specifically designed to people looking for skin health information. This provides expert insights, real time UV index etc. That can be used in patient education and diagnostics. Free to download.

4.3 Miiskin- Melanoma Skin Cancer

This is a personalised skin tracking app. A simple tool to assist and help and explore and track changes on the patient's skin and pigmented lesions.

There are other numerous other mobile teledermoscopy systems consist of a mobile application that can acquire and identify moles in skin images and classify them according their severity[14]. Some examples include- Doctor Mole Application, Mole detective, Scanoma-mole check, MoleScope, MelApp, Online Derm Clinic.

5. Apps Designed for Radiology

There are more than 81applications for radiology in the following five categories: diagnostic reading, decision support applications, medical books, interactive encyclopaedias, and journal reading programs.[15]

Diagnostic reading applications available for smart phones support raw data, and they also allow for basic manipulation of the images such as zooming, windowing, rotation, distance measurement, and changing the contrast and brightness.

5.1 Diagnostic Reading Applications

Some of the free diagnostic reading apps (Figure 2) are[1] Mobile MIM, Resolution MD (iOS), ImageVis3D (iOS), DICOM Droid (Android), Centricity Radiology Mobile Access 2.0 (iOS), Siemens syngo® via Web Viewer (iOS)

Mobile MIM: It is a DICOM viewer app to view images in different modalities including CT, MRI, nuclear medicine scans, diagnostic X-ray and ultrasound in iOS only. The first app of its kind to undergo FDA approval in 2011. Mobile MIM has introduced image intensity values, distance measurement, display measurement lines, annotations and regions of interest. It also performs multiplanar reconstructions out of the box[16].

Figure 2: Examples of applications developed for radiology practice

Resolution MD received FDA clearance for diagnostic medical image viewing on Android mobile device and iPhone in April 2013. It helps healthcare providers view images in 3D, collaborate with others, and access more patient information[16].

Some of the paid diagnostic reading apps include OsiriX (iOS), iClarity (iOS), CoActiv (iOS), iPaxera (iOS)

Osirix is mainly for use on Macintosh, this version (Osirix MD) is FDA approved for diagnostic use but the iPhone versions of the software by the same developers are not approved for diagnostic use. They can however be used to

maintain personal libraries of interesting images and for teaching[16].

5.2 Decision Support Applications

Today, efforts to avoid unnecessary diagnostic procedures and to reduce patient radiation are being emphasized. Mobile technology can be a key part of this effort.

Radiation Passport is an iPhone app aimed to educate the healthcare professional about the radiation exposure one can receive and the potential risk factors associated with different imaging modalities.

Rad-Rx is an Android app made for radiologists, radiographers and emergency personnel. The Rad-Rx app provides quick and convenient access to algorithms for the treatment of allergic responses to intravenous contrast. It also includes advice on how to dose and administer iodinated and gadolinium-based contrast for patients with renal insufficiency

iRefer from The Royal College of Radiologists is a multi-platform reference app that provides guidelines for physicians in the selection of the most appropriate imaging investigation or intervention for a given diagnostic or imaging problem based on the best available evidence, together with expert medical and radiological opinion.

5.3 Medical Books as Smartphone Applications

These are not just scanned, typed or pdf. versions of real textbooks, but fully functioning applications in their own right. Text can be underlined, highlighted or crossed out, and handwritten notes can also be added to these documents. Some of the book apps include HD Radiology[17] (iOS) and Radiology Ray X[18] (iOS)

5.4 Interactive Encyclopaedias as Smart Phone Applications

These are more versatile than e-books, and they might be a valuable tool for many learners. With these in hand, the user does not only read a text passively, but scans through the axial slices of a CT scan. The studying becomes more efficient and newer practical skills may be gained with them. Some of the encyclopaedia apps include Radiology Assistant – Medical Imaging Reference & Education (iOS) Radiology 2.0, iRadiology (iOS) and the SonoAccess iPhone App (iOS). The **Radiology Assistant** is an app for iPhone and more recently Android phones that provides users with peer- reviewed educational articles on a wide variety of radiological topics. **SonoAccess** is an iPhone app consisting of a comprehensive library of clinical and instructional ultrasound videos and documents available on-demand.

5.5 Journal Access an a Mobile Device as Application

It is very easy and convenient to access the contents of our favourite medical journals on the go, and now there are several applications for that. The **mySNA** subsection of RSNA.org for which membership to the Radiological Society of North America (RSNA) is required, it is a personalised online portal that enables users to receive full access and regularly updated information from the Radiology and RadioGraphics journals where users can access the latest and the archival papers. **European Radiology**, is another example that is an official publication of the European Society of Radiology is available as a free app for the iPhone and Android with the latest developments in radiology and extensive research.

EDiR is another app designed for those who are interested to take the European Diploma in radiology examination (EDiR) or European Board of Radiology. This app provides a direct channel between the students and the association. The App users can access to its full blog to find related news and useful information and case studies.

6. Apps Designed for Research and Laboratory Services

6.1 Cell Migration Assay Based on Smartphone Imaging

Mobile sensing principle based on combination of microfluidic device and smartphone lead to a technology called MS^2 technology. This has

helped many app developers to develop apps focused on research. Many cell functional assays could be developed based on this principle. Yang et al. in 2018[19] developed a MS^2 based cell functional assay for evaluating cell migration which they called as M-Kit. Their system included microfluidic chips and an imaging platform that is based on a smartphone. They used phone apps for capturing and analysing the data for performing cell migration assay. The authors in their observations demonstrated that M-kit can effectively measure neutrophil chemotaxis. Their observations lead to conclude that the M-kit provides an easy and integrated platform for cell migration related research.

6.2 Detection and Quantification of Subtle Changes in Red Blood Cell Density Using a Smartphone

Edward et al. in their experiment on fabricating a low cost cell phone based system for separating cells based on the magnetic levitation technique, came up with a system that not only differentiates cells types but also differentiates same cell types based on their densities[20]. In their experiment they introduced a cell phone-based device that integrates the magnets, capillary, and a lens into a compact and portable unit that acquires images with the phone's camera. To demonstrate the effectiveness of magnetic levitation in cell density analysis they carried out levitation experiments using red blood cells with artificially altered densities, and also levitated those from donors. They could distinguish red blood cells of an anaemic donor from those that are healthy.

6.3 DNA Sequencing and in Situ Mutation Analysis Using Mobile Phone Microscopy

Malte et al. designed and 3D-printed light-weight optomechanical attachment that is integrated with the existing camera module of a mobile phone[21]. This optical attachment contained two compact laser diodes (at 532 and 638 nm) for multicolour fluorescence imaging and a white light-emitting diode for bright-field transmission imaging. With the so developed phone based microscope the authors demonstrated that targeted next-generation DNA sequencing reactions and in situ point mutation detection assays in preserved tumour samples could be imaged and analysed using mobile phone microscopy, achieving a new milestone for tele-medicine technologies.

7. Smartphone Apps for Teaching and Learning

Using smartphones during the class is no longer an offence. In-fact to make the class more interactive, usage of many interesting apps designed specifically for such purpose should be encouraged. There are more than few hundreds of apps designed for this purpose. Enlisting and providing information on all those is beyond the scope of this review. However, the most common apps that can be used in routine medical/dental class include Kahoot, Google classroom, Teach Learn Lead, Seesaw, Slack, Remind, Doceri, TED, Evernote and many more. In fact, many social media apps like Facebook and WhatsApp are been used in teaching and learning. Goyal et al. in 2016 evaluated the effectiveness of incorporating social media plat forms like WhatsApp in training pathology postgraduate students[22]. In their study they observed that the group (Pathology on the Go) that they had created for the purpose had 69 participants who shared a sizeable number of posts on case discussions, quizzes, interesting discussions on the cases they had in 4-week period. Post study, the participants found the method to be very useful and minimal disruption of their daily routine. The authors concluded the need to include Web2.0 tools in postgraduate training teaching methods.

Many applications like Citrix GoTo meeting have been developed to conduct online training or online web conferences or webinars to conduct the “virtual” conferences.

8. Conclusion

Smartphones today have penetrated every field of life and health care is no exception. By comparison, it is almost laughable what used to be called a personal computer. Smart phones are far more personal as they have now become the primary communication device. Smartphone applications have changed the way of presentation and availability of clinically resourceful materials for medical professions. In specialties such as pathology, dermatology and radiology visual pattern recognition is of vital

importance. Image-based apps are of great benefit especially for the specialities mentioned above. Such app developments are constantly increasing with absolutely zero dull duration in the industry. Medical and health care apps are the third-fastest growing category for iPhones and Android phones[23]. There are countless benefits of using these handheld devices in our routine day to day practice including research and telemedicine/telepathology or tele radiology services. However, this smartphone havoc does have its own disadvantages. Describing all the possible disadvantages is beyond the scope of this review. However, it is important to mention the few very important ones. Though the specialists and the patients have started to use these smartphones captured medical images for consultations and may be even for actual final diagnosis sometimes, this raises some serious concerns with regard to safety of images downloaded onto an individual's smartphone. These images are highly vulnerable to a breach of patient confidentiality should that device become lost or stolen or even misused. Hence, some degree of regulation is needed to ensure that such mishaps should not happen. Numerous cases of nosocomial infections acquired because of use of smartphones in hospital and clinical settings have been recorded[25]. Hence quality control and regulatory mechanisms have to be put in place for a better overall practice in using smartphones in clinical practice. All of these factors should be taken into account when deciding where, when, and how to use mobile devices for the display of medical data. This digital field is as wide open and connected as today's open world. Expected technological advancements are sure to make this field even more interesting and challenging in the coming years.

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