TELE-MICROSCOPY SYSTEM BASED ON MOBILE TELEPHONE FOR DISTANCE DIAGNOSIS OF TUBERCULOSIS IN REMOTE AREAS OF PARAGUAY

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ABSTRACT

Optical microscopy provides a simple and cost-effective method of laboratory diagnosis, which is essential for the diagnosis of infectious and hematological diseases. In many regions of the world, especially in remote areas, there are no health personnel trained for performing a quality diagnosis of these diseases. Therefore, a tele-microscopy system that helps health professionals at national reference centers through remote interpretation of the obtained images will be very important. Tuberculosis remains a major public health problem in Paraguay. Diagnosis and monitoring of treatment are based mainly on bacilloscopy (examination of a sputum smear to verify the presence of specific bacilli). This test can be carried out in a laboratory with minimal resources such as Ziehl Neelsen reagents and a microscope. Most of the primary care centers in Paraguay have these resources. It is a simple, efficient and low-cost test. The objective of this project is to develop a tele-microscopy system for the efficient diagnosis of tuberculosis in remote areas of Paraguay using transmission technology and data storage via mobile networks. This tele-microscopy system will be initially applied to remote interpretation of the cases and evaluation of the smears within the quality control framework of tuberculosis diagnosis carried out at the Central Laboratory of Public Health. Furthermore, its application could be extended to the diagnosis of other diseases of public health importance in Paraguay such as Chagas disease, malaria, leishmaniosis and superficial and deep mycosis.

KEYWORDS

Tele-Microscopy, Tuberculosis, Smartphone, Diagnosis, Internet

1. INTRODUCTION

Light microscopy is an essential instrument in the health service (Breslauer, Maamari, Switz, Lam, & Fletcher, 2009). Historically, microscopic image was taken through a permanently mounted camera unit on a microscope, attaching a camera to an ocular lens or to a port in a trinocular head using a C-mount adapter. Two main types of camera sensors are typically attached to microscopes – charged couple devices (CCD) and complementary metal oxide semiconductor (CMOS) sensors (Park, Pantanowitz, & Parwani, 2012). CCD cameras were preferable for the highest quality image. However, CMOS cameras have narrowed the difference in quality and essentially are equivalent for the majority of photomicrographs. Both types of sensors capture more pixels than is often necessary for acquiring optimal photomicrographs (Park, Pantanowitz, et al., 2012).

Since smartphones were introduced, phones had integrated cameras utilizing CMOS sensors (Park, Parwani, Satyanarayanan, & Pantanowitz, 2012). Cell phone cameras have undergone significant improvements with each new phone release. They are potentially suitable for high quality image acquisition of photomicrographs taken from smears via a microscope.

Many investigators have studied the use and quality of image capture using smartphone cameras from bright-field and fluorescent microscopes (Bellina & Missoni, 2009; Breslauer et al., 2009; McLean, Jury, Bazeos, & Lewis, 2009; Zhu, Yaglidere, Su, Tseng, & Ozcan, 2011). Images were captured either using manual positioning of the phone camera against the microscope eyepiece (Bellina & Missoni, 2009) or by using a modified handheld imaging device for image capture (without using a microscope) (Tseng et al., 2010; Zhu et al., 2011). Several authors have found that the images acquired via cellphone adapters are comparable with standard captured images (Lehman & Gibson, 2013; Wimmer et al., 2012).

In remote rural areas where people affected by endemic diseases such as tuberculosis live, diagnostic resources are insufficient as well as the means of verifying interpretations or performing quality control of diagnoses. Much of the power of light microscopy, especially fluorescence imaging, the opportunity for remote consultation and electronic record keeping, remains inaccessible in these places due to prohibitive equipment and training costs. This is especially problematic since the diagnosis, screening, and monitoring of treatment for diseases such as tuberculosis depend on light microscopy as a screening tool or a definitive diagnostic test (Dawson, Kim, World Health Organization, Regional Office for the Western Pacific, & Stop TB Special Project, 2003; Steingart et al., 2006). The advent of digital imaging has improved the diagnosis by means of telemedicine, which sends sending images to more technologically advance health centers for consultation, evaluation and quality control. Build tele-microscopy networks may help overcome clinical microbiology infrastructure challenges that are present in resource-limited areas of the world (Rhoads, Mathison, Bishop, da Silva, & Pantanowitz, 2015).

Taking advantage of the increase in the coverage of mobile networks, telephones equipped with digital cameras, 3D printing and web-type applications, the goal of the study was to develop a tele-microscopy system for clinical diagnosis and registration of diseases of public health significance in Paraguay such as tuberculosis. The tele-microscopy system was implemented through the integration of different sustainable technologies that include mobile networks, web applications, cell phone camera and coupling with a 3D printed microscope. Laboratory personnel in remote rural areas was able to capture images of smears using smartphones attached to a light microscope in order that a more detailed analysis could be carried out by medical experts located at the central headquarter. The system will also allow storage, management and analysis of the medical records (images, diagnosis, treatment, and geolocation) to monitor endemic diseases and provide quality control of remote interpretations of the smears.

2. MATERIALS AND METHODS

Phone-microscope adapter: An adapter was designed for various types of telephones and microscopes. It was printed in a 3D printer with plastic PLA due to its rigidity. It was designed in AutoCAD 3D in its 2014 version. Figure 1 shows the assembly and use of the support for the tele-microscopy system.

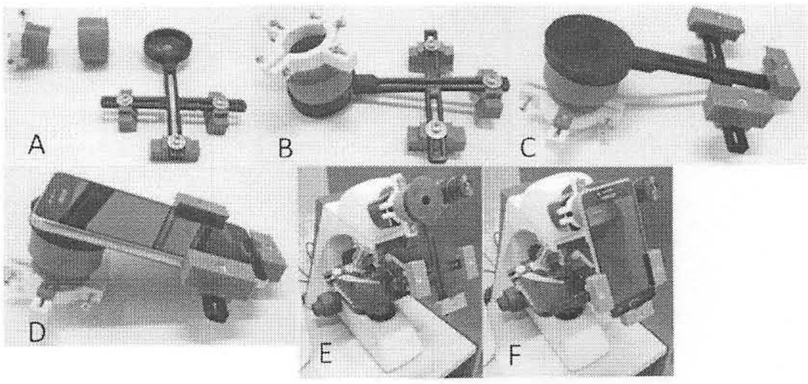

Figure 1. Adapter printed in a 3D Printer: A-C: parts; D: attached to the Phone; E and F: coupled to the Phone and Microscope

Design of the 3D printed adapter allowed a firm attachment to the microscope avoiding the effect of movement in the captured photograph. The quality of the images was evaluated by the laboratory personnel.

WEB Application: A software application was developed to create a computer record as a clinical electronic record for the patient personal data and smear images. The features of the application are as follows : a) it uses HTML5 and JavaScript as an access interface for the client; b) PHP as a server-side programming language; c) The Apache HTTP server as a server of WEB pages, and d) the data is stored in a database management system called MariaDB. To manage the support of the Centos 7 operating system, a DELL R720 server was used. The web access to the system is the URL www.iics.una.py/tm. Figure 2 shows different displays of the web application for the registration and monitoring of clinical electronic records of the tele-microscopy system.

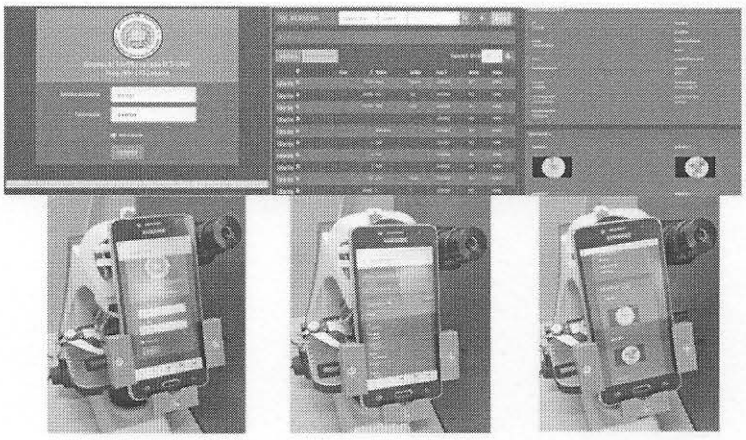

Figure 2. Interface of the WEB Application from the Computer and from the Mobile Phone

Access to the web application by the cell phone of the health personnel in remote rural areas allows the registration of patient data that includes personal identification and images obtained from the microscope by the smartphone camera. Access to previously registered information can be made from any device connected to the internet for later use.

The WEB application transmits information using "Secure Sockets Layer" (SSL) connections, and the data is encrypted in the database for greater security.

Mobile phones equipped with iOS 6 or higher and Android 4.0 "Ice Cream Sandwich" or higher can use an input type = "file" with a capture attribute that has the value "camera". This will launch the camera application and the photo taken by the user will be sent when the HTML form containing the input type = "file" is sent. The incorporation of images to the WEB application file is made during the fillingof this, avoiding the storage of images in the mobile phone.

In addition, the application incorporates a mechanism to prevent simultaneous edition of the registry by different users. All the user actions (Entries / Exits / created registries / modified registries / deleted registries) are stored in a registry of the system.

3. RESULTS

The adapter was successfully tested with several samples under the optical microscope. Once the microscope and the mobile phone were coupled, clear photos were taken without difficulty. In the AutoCAD design, some coupling details were considered in order to be compatible with the majority of microscopes and mobile phones In addition, the ergonomic design aspects was taken into account for the use of the phone coupling.

With half a kilo of PLA plastic, low cost printing of several couplings was achieved, eliminating the need to buy commercial adapters.

The transmission of information in real time over the internet allowed the patient data (personal and images) to be available for diagnosis or control in real time, and from several central and remote points through the WEB application of the tele-microscopy system. The WEB application also allowed listing, and classification of sendings and receptions according to the user and profile assigned.

The WEB application had two profiles for the users; 1) Issuer: It allowed creation of the electronic files with the personal data of the patient and the images captured from the microscope attached to the mobile phone as well as an interpretation of the images. 2) Receiver: It allowed editing of the electronic files created and to issue a diagnosis of the received data and images. These profiles were used according to the type of remote or central point as appropriate. The users were identified at the beginning of the session through their credentials (username and password) that associated them with the institution to which they belonged.

4. CONCLUSION

In this first phase of the project, an adapter for most optical microscopes and mobile telephones, and a web system for the management of clinical electronic files of patients that allows the attachment of images were developed. The electronic file developed allowed the integration of patient data with the images obtained from the mobile phone coupled to the microscope. Access to this file through the Internet helped to interpret the study performed remotely through the diagnosis of specialists at the central level. In addition, quality control was carried out without the physical remission of the smears from the remote laboratory to the reference level.

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