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Clinical Application of Endoscopy Using Smartphone

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－ ABSTRACT －

Background and Objectives：From patient monitoring and diagnostics to more efficient medical education and communication, smartphones serve a vital role in the practice of medicine today. This study was to evaluate the diagnostic capability of the smartphone installed with endoscopy adapter, as compared to the traditional endoscope, and to its investigate clinical utility. M**aterial and Methods**：This study enabled observation of internal body status using the portable light source device and camera of smartphone and rigid endoscope inside the ear, nose, and throat of adult man which cannot be directly observed with eyes of human, and obtained the image using the display and recording function of smartphone. **Results**：This study evaluated the photos obtained and use of endoscope examination using the smartphone. In the evaluation of photo image obtained, it obtained low score in comparison with the photo taken using the existing endoscope of clinics but no statistical significance was found. In the evaluation on use of endoscope examination using the smartphone, only ease of endoscope replacement and convenience on actual use showed statistical significance. **Conclusions**：In a clinical environment, satisfaction score showed relatively lower compared with the existing endoscopy, but it's considered useful using for examination and diagnosis from U-healthcare, telemedicine, and emergency situation at low cost. **(J Clinical Otolaryngol 2016;27:103-111)**

KEY WORDS：Endoscopy · Smartphone · U-health care · Mobile smart devices.

Introduction

Mobile health is a term used for the practice of medicine and public health and is supported by mobile devices, such as mobile phones, smartphones, tablet computers, and PDAs (personal digital assistants). Mobile health is now pushing the limits of how we acquire, transport, store, process, and secure raw and processed data to deliver meaningful results. Mobile health also supports health care workers who perform clinician-like duties where there are no doctors and can help to keep track of patients, which may not have been possible in the past.[1)] With the development of smartphone technology, mobile health can support daily practice in the field of telemedicine.

Smartphones are being manufactured by numerous companies and are one of the fastest growing sectors in the technology industry. From patient monitoring and diagnostics to more efficient medical education and communication, smartphones serve a vital role in the practice of medicine today.[2)]

The widespread adoption of the modern smartphone

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now allows everyone, including physicians, to easily capture photographs and videos during a patient encounter. This trend is poised to explode as seamless mobile data encryption and uploading to cloud storage becomes widespread.[3] A number of adapters exist that enable practitioners to capture otorhinolaryngology photos by attaching a smartphone or equivalent to a endoscope via simple adapters that mount the smartphone to one of the ears, nose, throat.

Our group sought a way to simplify ear, nose and throat image capture with a smartphone that did not require designed specific adapter or coupler. Our group designed a "minimalist" endoscopy system for imaging that combines the following three elements 1) a low-cost adapter, 2) stability of grip an endoscope, and 3) a mounting system universal to all smartphones. Here, we report the development of our smartphone endoscopy, compact, user-friendly, attachment and clinical photos obtained with it. The key feature is that it is a lightweight low-cost adapter that reversibly couples with all smartphones. With it, we were able to quickly photodocument a variety of ear, nose and throat without the need for coupler.

Material and Methods

Designing a specific adapter device

The concept of the smartphone-based endoscope is to make a connection between the smartphone's camera and the endoscope. In developing our smratphone health technology, the technical part of this study was challenging due to the lack of a commercial adapter to connect the smartphone and endoscope. While many adapters that can be connected to smart phone have been introduced, there are problems such as high price or in that it needs installation of separate coupler or it cannot be installed to all kinds of smartphones.[4,5] The challenge of our study was the need to create a adapter using all smartphone and portable light source.

We designed an adapter to align the optical access of the endoscope with the camera of the smartphone, which was employed to capture the images. For the smartphone-based endoscopy, we designed a unique adapter (Fig. 1) to connect the endoscope to the smartphone. Terminal/endoscope setting plate (transparency plate) consists of 3 setting frames, 2 fixing screws or rubber bands. Scope lens of endoscope is closely

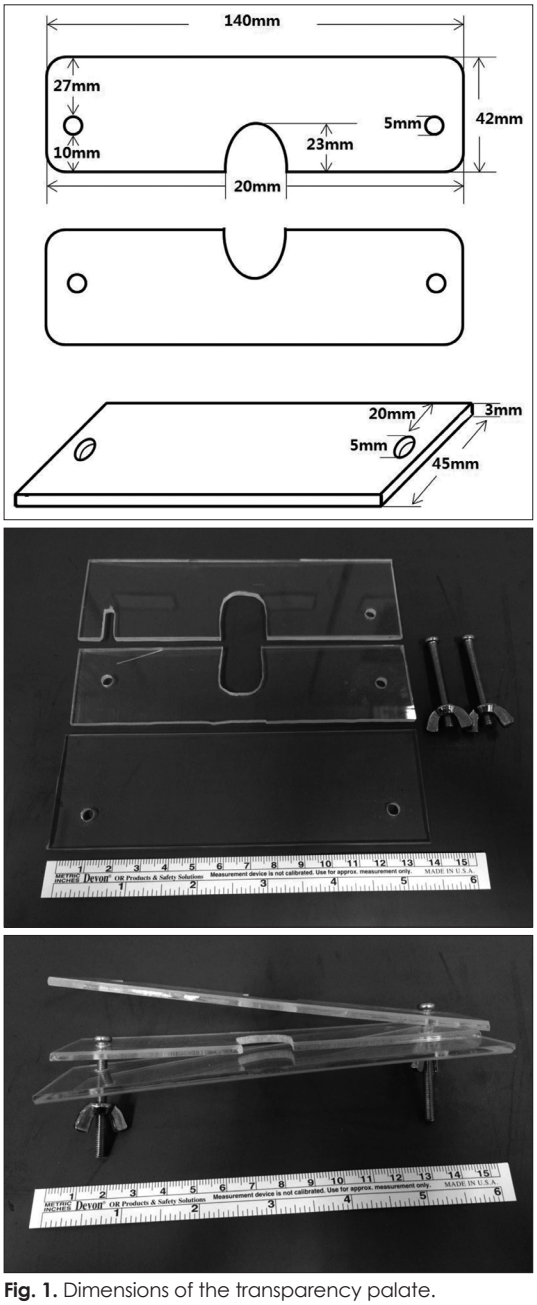

Fig. 1. Dimensions of the transparency palate.

contacted to the camera of mobile communication terminal and fixed with fixing plate and fixing screw. Before fixing, it was checked through the screen of mobile phone that camera and scope lens of endoscope are accurately contacted and connected.

Materials and procedures

This study realized observation of internal body status using the portable light source device and camera of smart phone and rigid endoscope inside the body which cannot be directly observed with eyes of human, and used the display and recording function of smart phone. This examination device using the smart phone with camera function consists of smartphone, terminal/endoscope fixing plate (transparency plate, nut and bolt) and endoscope (Storz endoscopy),

Fig. 2. The connection of the endoscope and adapter. Left : laryngoscope and portable strobe light source, Right : otoscope and portable light source.

portable light source device (U-MEDICAL, UMT-511) and rubber band.

As for mobile communication terminal, we selected smart phone mounted with Android operation system, the software of global IT company, Google which are most widely used in Korea (LG, Optimus G Pro), since universality can be obtained with selection of the popular smart phone. For endoscope, endoscope (otoscope 4 mm 0-degree, rhinoscope 4 mm 30-degree, laryngoscope 6 mm 70-degree) of Karl Storz was used.

Fig. 2 shows the connection of the endoscope and adapter, which we refer to as the smartphone-based endoscope. However, the smartphone-based endoscope will not work without a portable light source.

As a result, we designed a portable light source, which was modified from a commercial electric Light-Emitting Diode (LED) flashlight. The external LED light source of the device was powered by rechargeable batteries. The complete unit was extremely portable and easy to manipulate. No additional power supply unit or electrical sockets were required.

Since one hand is to hold the endoscope and the other hand is to examine the ears, nose or neck of the patient during examination, it may be difficult to perform the examination without assisting staff. To overcome such situation, voice recognition function of smart phone was used to take pictures with free hands. One of authors who was diagnosed with normal, volunteered to undergo both laryngeal videostroboscopy and endoscopy for evaluation of ears, nose, and throat status.

In this study, all endoscopic images were captured using a smartphone (LG, Optimus G-pro) with a built-in 13-megapixel camera with autofocus, and zoom functions. A freely available Web-based real-time communication application platform (Google Plus Hangouts) was used to transmit the endoscopic images via a long term evolution-advanced (LTE-A) network.

Eardrum, nasal cavity and larynx area were examined, respectively to compare utility of the traditional endoscope and the smart phone endoscope. For stability of endoscope grip, convenience and accuracy of examination, voice recognition function was used to take pictures. First, movement of vocal cords of subject was taken through the endoscope using smart phone and laryngoscope. During larynx endoscope examination, 1) comfortable sustained phonation, 2) pitch gliding, 3) falsetto phonation, 4) inhalation was performed to record various movement of vocal cords (AVI, still image). Second, ear endoscope and nasal endoscope are used to take pictures of eardrum and nasal cavity of subjects (still picture).

Data analysis

For evaluation of results, 10 otolaryngologists checked information of images obtained through examination without information on endoscope in the spate separate from clinics, and then evaluated physical observation for evaluation of anatomical structure, quality of color, clarity and accuracy of diagnosis, and satisfaction of image in 4 stages (excellent, good, moderate, poor), and expressed their opinions on image quality. In addition, after overall evaluation on image, they were actually provided with endoscope device using smartphone and explained on the process of installation. With demonstration on subjects who voluntarily applied for, opinion on actual use were evaluated in terms of reliability of adaptation, reliability of replacement, usability and satisfaction of usage.

Results

Endoscopy image

To examine utility of endoscopy of smart phone, we took pictures of ear, nose and neck status and compared them with image from traditional endoscopy (Fig. 3−7).

Clinical utility

To compare clinical utility of smartphone-based endoscope and clinical endoscope of clinics among 10 otolaryngologists, 9 items were evaluated in 4 point scale. To identify difference of two devices, it was tested with non-parametric Mann-Whitney U test and the

result is as shown in Table 1.

While endoscope of clinics showed higher records as a result of comparing averages of 9 items, statistically significant difference was found only in reliability of replacement and satisfaction of usage as a result of statistical analysis ($p < .05$). With this, we found out

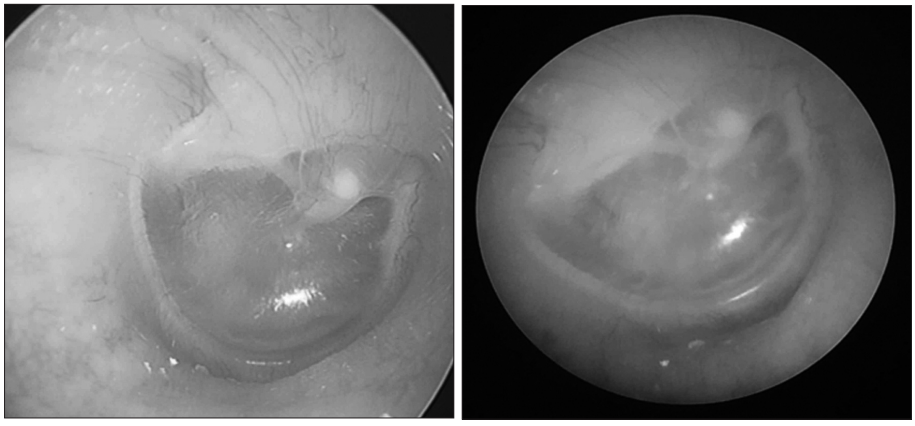

Fig. 3. Otoscope image. Left : clinical endoscopy, Right : smartphone endoscopy.

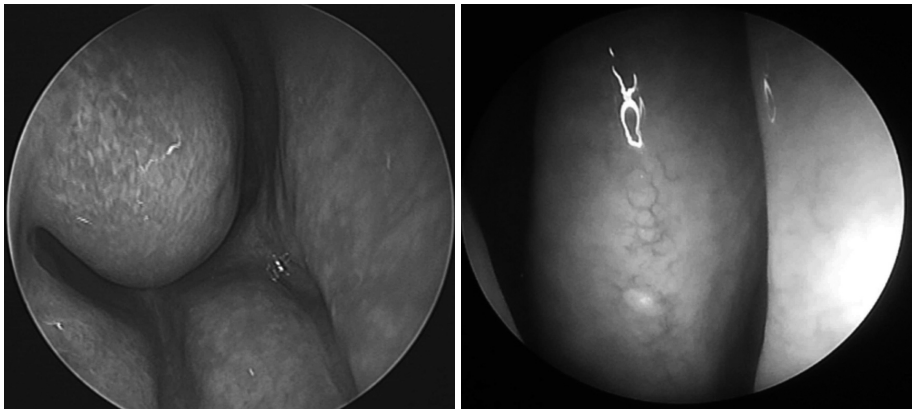

Fig. 4. Rhinoscope image. Left : clinical endoscopy, Right : smartphone endoscopy.

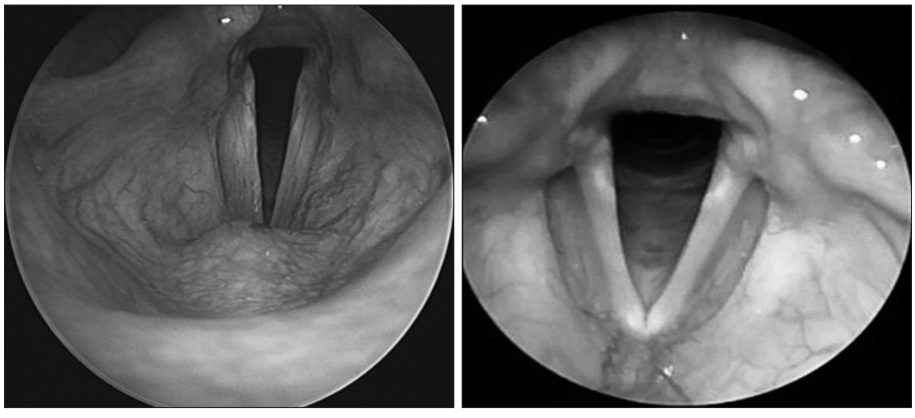

Fig. 5. Laryngoscope image. Left : clinical endoscopy, Right : smartphone endoscopy.

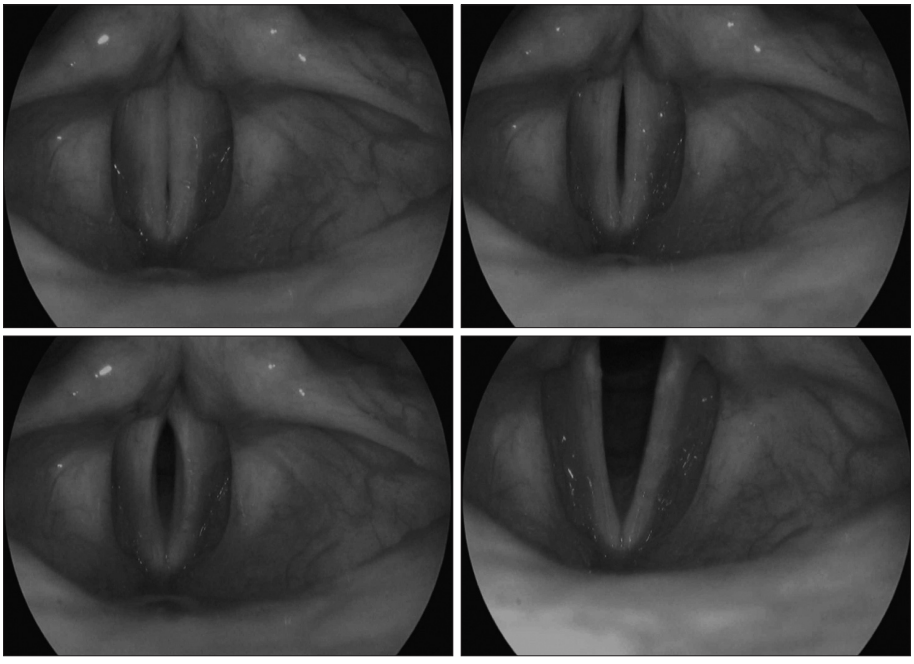

Fig. 6. Clinical laryngeal stroboscope image.

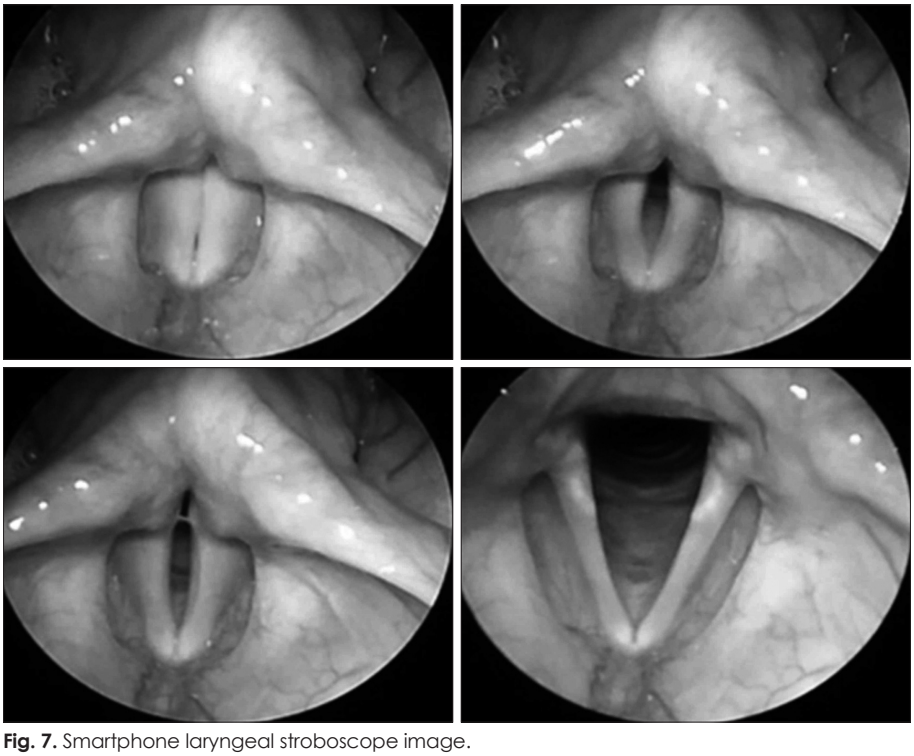

Fig. 7. Smartphone laryngeal stroboscope image.

Table 1. To compare clinical utility of smartphone endoscope (n=10)

Clinical utility	Clinical(M±SD)	Smartphone (M±SD)	z
Anatomical structure	3.3±.48	3.1±.56	−.801
Color of image	3.3±.82	2.7±.48	−1.849
Clarity	3.0±.82	2.8±.63	−.577
Accuracy of image	3.0±.00	3.00±.00	−1.000
Satisfaction of image	3.4±.52	3.1±.32	−1.510
Reliability of adaptation	3.3±.48	3.1±.32	−1.090
Reliability of replacement	3.3±.48	2.8±.42	−2.193*
Usability	3.2±.42	2.7±.48	−2.193*
Satisfaction of usage	3.1±.57	2.8±.42	−1.296

* : $p<.05$

possibility of using smartphone endoscope clinically.

Discussion

The authors have worked out the ways of applying to medical environment, and using smart phone which come into wide use among people. As a part of this effort, we have conducted researches to overcome systematic limit of existing medical service site and to effectively process clinical information at the medial service site without limit of time and space by utilizing endoscope examination through smart phone while this examination was only possible at the place with suitable medical facility due to limitation of devices.

Commercial products that enable examination using endoscope with application of smart phone are already on sale and some researchers have introduced devices that have improved shortcoming of each product. Chung (2013) developed the adapter that connects I-phone to soft nasal endoscope.[6] This device magnifies the image taken with endoscope 3 times. Filmed screen can be explained to other doctors and it is useful to trace record and manage progress of patients. This adapter is improved more, commercialized and sold at www.clearsightscope.com under the name of 'Clearsight' smartphone adaptor (ECL-CS1000) including portable light source at the price of $599. It can be used by connecting various endoscopes including 2.4 mm flexible endoscope and can be installed on various smartphones such as Blackberry, I-Phone and Android phone.

George et al., introduced 'Endoscopy-i' that could be installed on the smart phone to perform endoscopy. It can be used for soft, hard nasal endoscope and hard laryngendoscope useful for examination of otolaryngological diseases. Endoscope using smart phone can be directly checked and shared, but it was not recommended as diagnostic tool since there is a limit in screen resolution of smart phone while it is recommended for resident training or simple use at wards only.[4]

Recently, Wu et al., also introduced smart phone-based 'Otorhinoendoscope' and evaluated ear and nose disease such as allergic rhinitis, nasal polyp, nasopharynx tumor, atrophic scar of the tympanic membrane, acute otitis media, eardrum perforation on 6 patients by connecting the portable light source device, endoscope and adapter specially developed by researchers, to the smart phone. However, they reported difficulty in diagnosis since the quality of 17% of images obtained was low. In addition, since it is the adapter designed for specific smart phone only, there is a disadvantage that other smart phone cannot be used.[7]

Sohn et. al., presented docking system that optimized coupling of smart phone to the existing endoscope. Using this, cystoscopy and urethroscopy were performed to compare results of image. While cystoscopy showed quality of image that can be accepted, urethroscopy showed quality of image poorer than that of existing endoscopy.[5]

The conditions of smartphone endoscope camera include the following; first, grip feeling should be stable and convenient in order not to hurt during examination. Second, it is required to develop the adapter that can be applied to all smart phones for easy use since types and specifications of smart phone are diverse. Third, it should be devised to allow easy attachment and detachment in order to examine ears, noses and necks with one smart phone. Fourth, it should be stably fixed and used so that smart phone is not detached unexpectedly, causing harm to patient or damage to endoscope.

These researchers have stabilized the grip feeling during use by fixing the smart phone inside out (or upside down) in consideration of the above, and designed the adapter that can be applied to all kinds of smart phones. And overall stability was obtained using the rubber band so that smart phone, adapter and endoscope are not easily separated. Adapter of the authors devised this way can be easily manufactured by any one and can be used without any knowledge on device other than endoscope, as long as the user reads and understands simple explanation on usage.

As well as the still picture of ear, nose and neck using the single light source of portable light source device, stroboscope using smart phone was conducted through portable stroboscope device, which has not been examined in other studies. Glottal closure, amplitude, mucosal wave, non vibrating portion, phase, symmetry, periodicity, level difference can be checked using fast, slow and fix function according to stroboscope light source.

Recently, we can obtain clean images with supplementation of small hand shaking pointed out in previous studies as the optical image stabilization function of the existing optical camera was added due to development of smartphone camera technology.

Using the device connecting the endoscope and smart phone with the adapter devised by the authors, we examined the ear, nose and neck area of actual applicants and transferred the image using commercial cloud system. With this, it was conformed that information on examination opinion can be easily shared with health care staffs, converted to and used as medical records. While this process was limited to only authorized users to prevent access of non medical staffs and protection of personal information, more aggressive safety device is required to protect information if the patient is treated using this at the place other than hospital. Safety and accuracy of mobile medical app can be obtained in the near future by adding the standards on receiving of biometric information through sensor by all mobile medical apps, rather than mobile medical web selectively allowing user input type. Furthermore, smart device should be able to secure stability and effectiveness when the smart device plays a role as a medical device.

Conclusion

Endoscopy is necessary to check the ear, nose and neck status of the patient in otolaryngological terms.[8] Since other image device as well as basic endoscope should be prepared for endoscopy, there are limits in performing endoscopy at the environment other than clinics. To compensate this, the authors devised the device that can connect and use endoscope device to smart phone and conducted studies of comparing it with the images of the endoscope at clinics. While smart phone based endoscope examination using adapters of authors showed slightly lower satisfaction of image quality compared to the case of using endoscope device that could be done at clinics, we can draw conclusion that it is not serious to the extent that it may cause a problem in basic examination or diagnosis required for treatment of patient. It was also confirmed that examiner or subject suffered from no inconvenience during endoscopy. In addition, image transfer function was considerably superior than the portable device reported earlier. Taking into account easy carrying and satisfaction of examination, it can be easily utilized at the environment other than clinics, or at remote site or in situation when it is difficult to visit the hospital, giving considerable help to remote

treatment in the future. In addition, it is also expected to use for screening test during emergency situation so as to provide basic information of patient to upper medical institution in transit, to request further evaluation, resulting in prompt medical accessibility and suitable first aid.

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