Quality of images obtain from a novel Smartphone-based nasal endoscope recorder and conventional nasal endoscope recorder

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This research is submitted in partial fulfillment of the requirement for Dr. Narinthorn Saksriyuttana Certificate of Otolaryngology-Head and Neck Surgery of Medical Council 2017

หนังสือรับรองจากสถาบัน

ข้าพเจ้าขอรับรองว่ารายงานวิจัยฉบับนี้เป็นผลงานของ พญ.นรินธร ศักดิ์ศรียุทธนา ที่ได้ทำการวิจัยขณะรับการฝึกอบรมตามหลักสูตรฝึกอบรมแพทย์ประจำบ้านสาขาโสต ศอ นาสิกวิทยา คณะแพทย์ศาสตร์ โรงพยาบาลรามาธิบดี มหาวิทยาลัยมหิดล ระหว่างวันที่ 1 กรกฎาคม 2558 ถึง30 มิถุนายน 2561 และมีส่วนร่วมสำคัญในการทำวิจัยจริง

และงานวิจัยนี้ได้มีการดำเนินการตามมาตรฐานการทำวิจัยอย่างถูกต้องทุกประการ

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ลงชื่อ อาจารย์ที่ปรึกษาวิจัยหลัก

(ผู้ช่วยศาสตราจารย์ นายแพทย์ ธงชัย พงศ์มฆพัฒน์)

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ลงชื่อ อาจารย์ที่ปรึกษาวิจัยร่วม

(อาจารย์ นายแพทย์ ปวิน นำธวัช)

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(ผู้ช่วยศาสตราจารย์นายแพทย์ชัย อยู่สวัสดิ์)

หัวหน้าภาควิชา โสต ศอ นาสิกวิทยา

คณะแพทยศาสตร์โรงพยาบาลรามาธิบดี มหาวิทยาลัยมหิดล

Acknowledgements

The author would like to thank staffs, Section for Clinical Epidemiology and Biostatistics, Faculty of Medicine, Ramathibodi Hospital for retrieving full papers of included studies and providing software used for analysis, and Department of Otolaryngology, Faculty of Medicine Ramathibodi Hospital for paper submission.

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คุณภาพของภาพจากอุปกรณ์เชื่อมต่อกล้องส่องจมูกกับ โทรศัพท์เคลื่อนที่แบบใหม่เมื่อเทียบกับอุปกรณ์เชื่อมต่อกล้องส่องจมูกแบบดั้งเดิม

(Quality of images obtain from a novel Smartphone-based nasal endoscope recorder and conventional nasal endoscope recorder)

นรินธร ศักดิ์ศรียุทธนา, พ.บ., ผ.ศ. ธงชัย พงศ์มฆพัฒน์, พ.บ., ปวิน นำธวัช, พ.บ. ปร.ด.,

บทคัดย่อ

ในปัจจุบันกล้องส่องจมูกเป็นอุปกรณ์ที่ใช้กันอย่างแพร่หลายในการวินิจฉัยโรคทางไซนัส โดยกล้องส่องจมูก มีหลายรูปแบบ ได้แก่ 1.กล้องส่องจมูกที่มีเฉพาะเลนส์ (eyepiece endoscope) 2.กล้องส่องจมูกที่สามารถต่อเข้ากับคอมพิวเตอร์(computer-based nasal endoscope) 3.กล้องส่องจมูกแบบที่มีหน้าจอติดกับอุปกรณ์ (camera system nasal endoscope) ชนิดที่นิยมที่สุดคือ กล้องส่องจมูกที่สามารถต่อเข้ากับคอมพิวเตอร์(computer-based nasal endoscope) แต่อุปกรณ์นี้มีข้อเสียได้แก่ ราคาแพง และ เคลื่อนย้ายไม่สะดวก ในทางกลับกัน อุปกรณ์ แบบดั้งเดิม(eyepiece endoscope) ราคาถูกและสามารถเคลื่อนย้ายได้ แต่มีข้อเสียคือแพทย์ผู้ตรวจจะต้องมองผ่านเลนส์ด้วยตาโดยตรง ไม่สามารถดูภาพร่วมกับแพทย์ผู้อื่นได้ เนื่องด้วยเทคโนโลยีที่ทันสมัยมากขึ้น จึงมีการพัฒนาอุปกรณ์แบบที่สาม(camera system nasal endoscope) ซึ่งสามารถเคลื่อนย้ายได้ และ บันทึกภาพได้ แต่เนื่องจากราคาที่ค่อนข้างสูงจึงยังไม่เป็นที่นิยมมากนัก

วัตถุประสงค์ ระยะแรกเพื่อพัฒนาอุปกรณ์เชื่อมต่อกล้องส่องจมูกกับโทรศัพท์มือถือ (smartphone-based nasal endoscope) โดยออกแบบและผลิตจากการพิมพ์สามมิติ ระยะที่สองเพื่อเปรียบเทียบภาพที่ได้จากการส่องกล้องจมูกผู้ป่วยในอุปกรณ์ทั้ง 2 ประเภท และเพื่อวัดระดับความพึงพอใจของแพทย์และผู้ป่วย เปรียบเทียบระหว่างอุปกรณ์เชื่อมต่อกล้องส่องจมูกกับโทรศัพท์มือถือ กับกล้องส่องจมูกที่มีเฉพาะเลนส์(eyepiece endoscope) และที่สามารถต่อเข้ากับคอมพิวเตอร์(computer-based nasal endoscope)

วิธีการศึกษา พัฒนาอุปกรณ์ที่มีลักษณะเฉพาะเพื่อเชื่อมต่อกล้องส่องจมูกและโทรศัพท์มือถือ(smartphone-based nasal endoscope) จากนั้นส่องกล้องและถ่ายภาพจมูกผ่านโทรศัพท์มือถือ และคอมพิวเตอร์(computer-based nasal endoscope) ในผู้ป่วยทั้งหมด15 ราย จากนั้นให้ แพทย์โสต ศอ นาสิก 19 ท่าน ทำแบบประเมินวัดคุณภาพของภาพทั้งหมด 30 ภาพ

ผลการศึกษา พบว่าคะแนนความเจ็บปวดของผู้ป่วยที่ใช้อุปกรณ์ทั้งสองแบบไม่แตกต่างกันอย่างมีนัยสำคัญทางสถิติ คุณภาพของภาพเมื่อเปรียบเทียบระหว่างสองอุปกรณ์ ไม่แตกต่างกันอย่างมีนัยสำคัญทางสถิติในทุกหัวข้อ ยกเว้น ด้านความสว่างของภาพ ซึ่งอุปกรณ์ใหม่มีคะแนนสูงกว่า นอกจากนี้คะแนนเฉลี่ยความพึงพอใจของแพทย์ในอุปกรณ์ใหม่ ด้านการเคลื่อนย้ายอุปกรณ์ และความสะดวกในการถ่ายภาพรวมถึงส่งต่อภาพเพื่อปรึกษาสูงกว่าอุปกรณ์ดั้งเดิม

สรุป พบว่าความพึงพอใจของแพทย์ผู้ใช้อุปกรณ์เชื่อมต่อโทรศัพท์มือถือกับกล้องส่องจมูก ด้านความสะดวกในการเคลื่อนย้ายอุปกรณ์ ความสะดวกในการถ่ายภาพและส่งต่อภาพ มากกว่าอุปกรณ์ดั้งเดิม นอกจากนี้ยังพบว่าคุณภาพของภาพจากอุปกรณ์ใหม่ไม่แตกต่างจากอุปกรณ์เดิมอย่างมีนัยสำคัญ จึงสามารถนำอุปกรณ์ใหม่ดังกล่าวไปใช้งานได้จริง

1 ภาควิชาโสต ศอ นาสิกวิทยา คณะแพทยศาสตร์โรงพยาบาลรามาธิบดีมหาวิทยาลัยมหิดล

2 ภาควิชาระบาดวิทยาคณะแพทยศาสตร์โรงพยาบาลรามาธิบดีมหาวิทยาลัยมหิดล

Quality of images obtain from a novel Smartphone-based nasal endoscope recorder and conventional nasal endoscope recorder

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Abstract

Background Nasal endoscopy is widely used in the diagnosis and investigation of a variety of paranasal diseases. Computer-based nasal endoscope is often used to record images capture by the nasal endoscope. However, the instrument is relatively expensive and large therefore limiting the mobility of users. With advances in mobile telephone technology, an endoscopic smartphone-based camera system is possible to be developed.

Objective The first phase of this study was to develop a prototype of smartphone-based nasal endoscopy recorder using a specialized adapter to connect between a smartphone and a nasal endoscope. The second phase of this study was to evaluate the quality of this smartphone-based nasal endoscope, the patient and doctors' satisfactions, as compared to that of a conventional computer-based nasal endoscope and without using camera (eyepiece).

Methods We invented a specialized adaptor to connect the nasal endoscope and smartphone to create smartphone-based nasal endoscope. The prototype was designed and assembled utilizing 3D printing technology, which enables easy reproduction and modification. Then, we capture nasal endoscope images on fifteen patients through both computer-based nasal endoscope and smartphone-based nasal endoscope. Patients rated the pain score from both techniques. Nineteen otolaryngology staffs and residents blinded to the technique then rate the quality of thirty images from both types of nasal endoscope.

Results We found no significant difference in the patients' pain score. Similarly, we found that the image quality ratings between smartphone-based and computer-based nasal endoscope has no statistically significant difference in all topics except illumination and brightness in which smartphone-based nasal endoscope has better scores. Staffs also rated higher satisfaction in portability and sharing-feature.

Conclusions Our finding suggests that smartphone-based nasal endoscope system has higher clinician satisfaction, especially in portability, time required to capture, and sharing feature. Image quality were comparable with conventional computer-based nasal endoscope system, which indicated that the smartphone-based nasal endoscope system may reasonably and practically be used in clinical practice.

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CHAPTER 1

BACKGROUND

1.1 Introduction

At this moment, communication technologies are highly developed. Information and communication technologies which support health are electronic heath. Mobile health is sub segment of electronic health using mobile devices. Many people in the world use smartphone for communication, clinician also. Smartphone facilitated effective communication among clinicians, and result in higher diagnostic accuracy rate comparing without visual information. Moreover, clinician can use telemedicine to give diagnosis and treatment to patient. Telemedicine is a technology which's capability for real-time virtual online communication.

Each year there are many patients desperately need Nasal endoscope for a disease examination. In 2016, out of 89,169 out-patients, 3,601 out-patients in department of otolaryngologist of Ramathibodi hospital were examined with nasal endoscope. Some of which were bedridden patients, people with disabilities and unconscious patients. These patients were difficult to mobilize to examination room.

The common indications for diagnostic nasal endoscopy are to evaluate for chronic sinonasal symptoms unexplained by anterior rhinoscopy, to assess interval response to medical or surgical therapy in patients with chronic sinusitis and recurrent acute sinusitis, to monitor for recurrence of nasal polyps, to evaluate and manage epistaxis, to perform endoscopically guided cultures, to assess facial pain suggestive of rhinogenic origin, to evaluate clear rhinorrhea suggestive of cerebrospinal fluid leak and to perform initial diagnosis and interval surveillance for sinonasal neoplasms.

Nowadays, the Nasal endoscope is widely used in the diagnosis and investigation of a variety of paranasal diseases. The common types of Nasal endoscope are 1.eyepiece nasal endoscope 2.Computer-based nasal endoscope, and 3.camera system nasal endoscope

The first type (5.1) is eyepiece nasal endoscope. The clinician will perform the examination by moving his/her eyes closer to the lens (eyepiece) of the endoscope. This type of endoscope is maneuverable and economical. However, only the clinician who examines the patient can see the visual result. The image was not able to record and send to another clinician. Furthermore, the clinician will have higher chance for contacting airborne diseases from patient.

The second type (5.2) is Computer-based nasal endoscope. This type of endoscope has advantages in the capability to record and share the visual examination result to other clinicians. In addition, the performing doctors are not required to get closer to the patients, eliminating the disadvantage of eyepiece nasal endoscope. Nevertheless, due to its size, this type of endoscope is importable and required spaces to set up. Also, the cost is higher than the first type.

The last type (5.3) combines the advantages of the first and second type. The endoscope has a small screen embedded in the instrument and has a capability to record and share the images. However, it is the higher cost compare with first type endoscope, and is inconvenient to record and share the images.

1.2 Objectives

Primary Objective

1. To develop a specialized adapter to connect between an endoscope and a smartphone, creating a smartphone-based nasal endoscopy system

Secondary objectives

1. To compare the image quality of rigid endoscopic examination of nasal cavity between the smartphone-based nasal endoscope and the conventional nasal endoscope

2. To compare the satisfaction of doctors who used a smartphone-based nasal endoscope in terms of convenience, practicality, image quality, recording and sharing capability with the conventional nasal endoscope

1.3 Expected benefits

1. A developed specialized adapter using 3D printing technology with lower price than commercial adapter
2. This instrument will enable the dissemination of instrument to the rural areas or in developing countries where is insufficient of high technology and costly instrument.
3. This instrument will enable clinicians to share information obtained from patients and enabling tele-conferences and tele-consultations.

1.4 Ethical consideration

Respect for person: Only patients who agreed to be evaluated using both Computer-based nasal endoscope (conventional) and smartphone-based nasal endoscope were enrolled in this study. All patient data were fully concealed and no any direct contact. Moreover, all procedures were approved by the research ethics committee of Ramathibodi hospital

This study obtained ethical clearance from Ramathibodi Ethical Committee (ETHIC NUMBER ID 05-60-26)

CHAPTER 2
LITERATURE REVIEW

2.1 Literature review

Cheng-Jung Wu et al. from department of Otolaryngology, Head and neck surgery, Kaohsiung Veterans General hospital, Taiwan, developed an instrument connecting smartphone with otorhinoendoscope to record video and image and mobile communication application to perform teleotolaryngology(1). They created specific adapter and portable light source. Then, they evaluated diagnostic quality with six patients compare between face to face diagnostic and telediagnostic. In this study, all otorhinoscopic images were captured using a smartphone (Samsung, Galaxy Note II) with a built-in 8-megapixel camera with autofocus, macro mode, and zoom functions. They used freely available web-based real-time communication application platform (Google Plus Hangouts) to transmit the images via a third-generation network. An internet connection was made available for the three teleconsultants who were professional otolaryngologists from a tertiary medical center in Taiwan. Six images were acquired from six patients. The same otolaryngologist performed the face-to-face diagnosis, using a conventional scope and smartphone-based endoscope. Then, the raw data without information about clinical conditions were transmitted to each teleconsultant for a primary telediagnosis using real-time communication platform. After first telediagnosis was done, The second telediagnosis was made by the three teleconsulatants with patient's clinical conditions. The three teleconsultants were also asked to judge the quality of each image using the following scale: poor, fair and good.

Research from Hao Liu et al. compared video quality and diagnostic accuracy between mobile endoscopy and video tower (computer-based nasal endoscopy)(2). They designed a prospective controlled blinded comparison of mobile and videos recording. They used adapters that connected a mobile phone directly to endoscopes or other optical devices. The purpose of study was to directly compare mobile endoscopy against conventional video capturing devices. The recording method was switched during the middle of the examination, but the endoscope and light source remained constant. They used a commercially available mobile endoscopy adapter to enable recoding of mobile phone videos (ClearScope; Clearwater Clinical Limited, Ottawa, Canada) and associated software (Modica; Clearwater Clinical Limited). The mobile adapter was coupled to an iPhone 5s. They sent 60 ten-second videos (30 video pair from the same patient) to 13 skilled observers to rate the quality on Liker scale from poor to excellent and to give the diagnosis in questionnaire. Video quality was rating in five areas: illumination, ability to identify orientation, ability to identify important landmarks, picture clarity/texture and contrast/sharpness. They found no statistically significant difference in the video qualities rating of mobile and tower videos across all video qualities categories and diagnostic accuracy between both methods.

Apart from these two researches, we could not find any study that report the satisfaction of patient underwent endoscopic examination by the instruments. Moreover, there are no reported satisfactions of clinician who used smartphone-based nasal endoscope. We therefore generated questionnaire for each patients and clinicians to compare between conventional and smartphone-based techniques.

CHAPTER 3 METHODS

3.1 Study design

This study was divided into two phases. The first phase of the study was to develop a self-designed prototype of smartphone-based nasal endoscope using an adapter to connect a smartphone and a nasal endoscope. The prototypes were designed and assembled by utilizing 3D printing technology. Different prototypes were built and modifications were made to finalize the design of the instrument.

The second phase of the study was to evaluate the diagnostic capability, in terms of image quality, of the smartphone-based nasal endoscope, and the patients' satisfaction and the doctors' satisfaction, as compared to that of the eyepiece type and computer-based nasal endoscope. This preliminary experiment was performed in outpatient of otolaryngology department of Ramathibodi hospital from 1st February 2016 – 31st December 2017 after obtaining ethical clearance.

First phase: developing the instrument

We invented a specialized adaptor to connect the nasal endoscope and smartphone to create smartphone-based nasal endoscope. First, we measured size of eyepiece end of the nasal endoscope (Karl-Storz Hopkins 0-degree Rigid Endoscopes, Karl Storz GmbH and Co., Tuttlingen, Germany), and size of smartphone we intended to use base on hospital staffs' personal phone preferences (iPhone 6, Apple Inc., California, US). We calculated and measured focal distance from eyepiece to camera of smartphone and then designed the tool in 3D program (123D design program, AutoDesk Inc., California, US) to created 3D model then specialized adapter plastic prototype was generated by utilizing 3D printing technology. We did a modification upon the first version due to user's uncomfortably in handling the instrument. The modifications were made and 3D printed out again. Second version of the instrument was found to be mismatched between mobile and endoscope and changes were made.

Third version of the instrument was found to be good enough to test on actual use. (See Figure)

Second phase*: *Preliminary trial use in patients

The second phase of the study was to evaluate the diagnostic capability of the smartphone-based nasal endoscope, the patients' satisfaction and the doctors' satisfaction, as compared to that of the conventional eyepiece type and computer-based type nasal endoscope.

First, clinician of outpatient clinic of Otolaryngology Department, Faculty of Medicine Ramathibodi Hospital were explained about objectives and steps of research. Patients who were schedule to have nasal endoscopy were invited to join the study. Only patients who meet the inclusion criteria and willing to participate were recruited.

Next, local anesthetics were given by spraying both nasal cavities with 10% xylocaine and 1% ephedrine, 2 puff each, by the experienced nurse. This protocol is the current standard practice in our clinic. Patients were then placed under supine position in the endoscopy room with their eyes covered with a sheet of cloth and each patient received nasal endoscopy twice, which was with conventional or smartphone-based instrument. Order of the instrument were randomly allocated by computer-generated randomization list with the set of randomization seed by the statistician not involved in caring of the patient, and the list of order were placed in a sealed opaque enveloped to ensure allocation concealment.

Still images of endoscopy from both instruments were recorded. In the conventional group, we use the camera provided by the endoscope manufacturer (Telecam DX II, Karl Storz GmbH and Co., Tuttlingen, Germany) connected with the personal computer running image capture program (PowerProducer, Cyberlink Corp, Taipei, Taiwan) and the captured images were saved in JPEG format. In the smartphone-based group, the connected phone was placed with the instrument and images were captured using the smartphone's own original camera software on default image quality setting with the adjustment of image to fill the screen. Only residents with at least one year of endoscopic experience or staffs were allow to do the endoscopy in our study.

Clinicians who performed the endoscopy were asked for satisfaction in the following areas: 1) Handling, 2) Portability, 3) Time required to capture, 4) Sharing-feature, and 5) Direct patient contact. Satisfaction Questionnaire was done by all fifteen clinicians using smartphone-based nasal endoscope in patients to compare with both eyepiece type and computer based type. Pain scores using 10-point pain rating scale were then given to the patients and the patients were allowed to freely rate the pain from both instrument.

All Images from each patient who enrolled in this study were collected. We randomized images from both techniques with the similar randomization technique and present the images to 19 otolaryngology residents and staffs. Residents and staffs were shown the images in a dimmed lighted room under a large projector-type screen. Image quality rating were then scored by following categories: 1) Illumination and brightness, 2) Ability to identify important landmarks/ structures, 3) Artefacts, background noise, 4) Contrast, border, sharpness, and 5) Overall satisfaction. This method of measurement is similar to measurements done by previous report(2, 3).

3.2 Inclusion criteria

1. Patient who presented at outpatient department of Otolaryngology department, Faculty of Medicine Ramathibodi Hospital, Mahidol University and had conforming indication of nasal endoscope.
2. Age of the patient was more than fifteen years
3. Patient agreed to be evaluated using the conventional and smartphone-based nasal endoscope

3.3 Exclusion criteria

1. Patient who refused to evaluate with nasal endoscope.
2. Patient who refused to a second time evaluation with endoscope.
3. Emergency patient who need specific and urgency treatment.
4. Patient who cannot speak or communicate in Thai language.

3.4 Outcome assessment

Three outcomes of interests were patient's pain score in both computer-based and smartphone-based nasal endoscope using 10-point visual analog scale, clinician's satisfaction of smartphone-based nasal endoscope compared with eyepiece type and computer based type nasal endoscope, and image quality score.

Satisfaction scores were rated on a Likert scale of 1 (poor) to 5 (excellent) in areas of handling, portability, time required to capture, sharing-feature, and direct patient contact. Image quality rating scores were also measured in 5 categories: illumination and brightness, ability to identify important landmarks/ structures, artefacts and background noise, contrast/border and sharpness, and overall satisfaction with picture quality. Each image quality score were rated on a Likert scale of 1 (poor) to 5 (excellent).

3.5 Data collection

Demographic information (age, gender) were collected. Pain scores, image quality rating scores and satisfaction scores were collected in paper-based forms and entered into a computerized database file for statistical analysis.

3.6 Data analysis

Due to the small number of sample, we reported the pain score and the doctor's satisfaction scores using both median/range and mean/standard deviation. We compared the pain scores of both instrument using sign-test. Image quality of both instruments were analyzed using mixed linear regression model with instrument and doctor number as covariate.

3.7 Population and sample size estimation

Because of preliminary nature of the experiment and new instrument, we designed in pilot study and decided to use fifteen patients in this study, and all doctors in the department who had experience with endoscopic were invited to rate the quality score).

3.8 Protocol flow chart

Patients who required the nasal endoscopy in outpatient clinic of Otolaryngology department, Faculty of Medicine Ramathibodi

↓

Inclusion criteria:

1. Patient who presented at outpatient department and had conforming indication of nasal endoscope.
2. Patient had never been evaluated by nasal endoscope before.
3. Age of the patient was more than fifteen years
4. Patient agreed to be evaluated using the conventional and smartphone-base nasal endoscope

Exclusion criteria:

1. Patient who refused to evaluate with nasal endoscope.
2. Patient who refused to second time evaluate with endoscope.
3. Emergency patient who need specific and urgency treatment.
4. Patient who cannot speak or communicate in Thai language.

↓

Informed consent were obtained

↓

Local anesthesia was applied

↓

Endoscopy with first instrument (random order)

↓

Endoscopy with second instrument (random order)

↓

Patient filled the pain questionnaire

↓

Images were obtained and stored

↓

Images obtained from all patients were shown on the screen on random order

↓

Residents and staffs rated the image quality scale

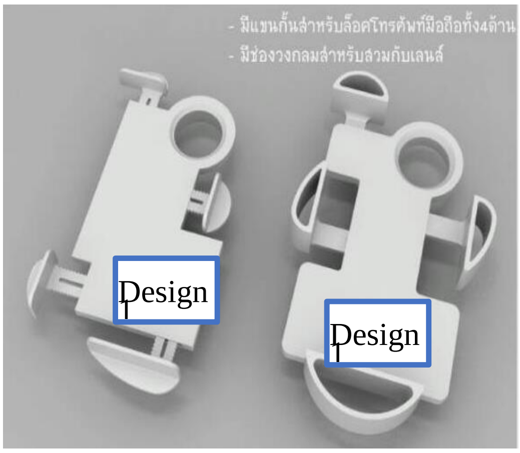
CHAPTER 4

RESULT

First phase: developing the instrument

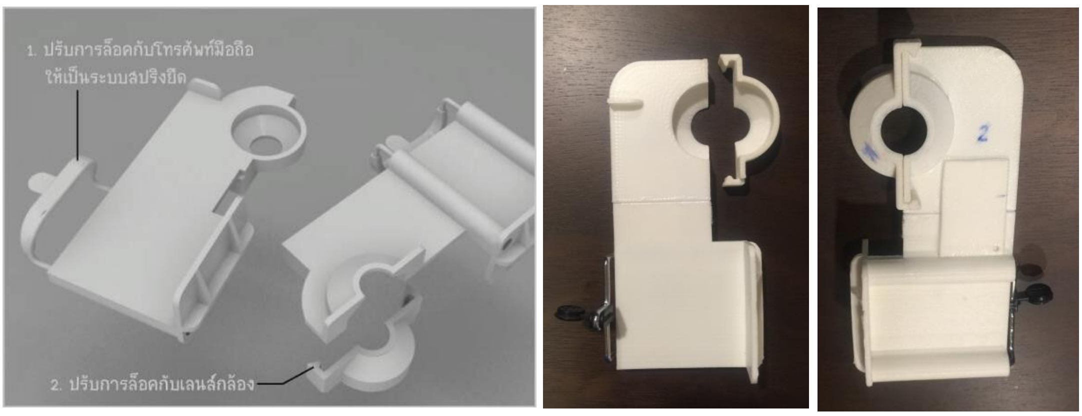
We developed a prototypes in three versions. The first prototype was designed and printed with specification based on dimension of the endoscope and the smartphone. However, the prototype was not working due to loosening of contacts between both smartphone to the prototype and the prototype to the endoscope.

Figure 1. Version 1 of the instrument



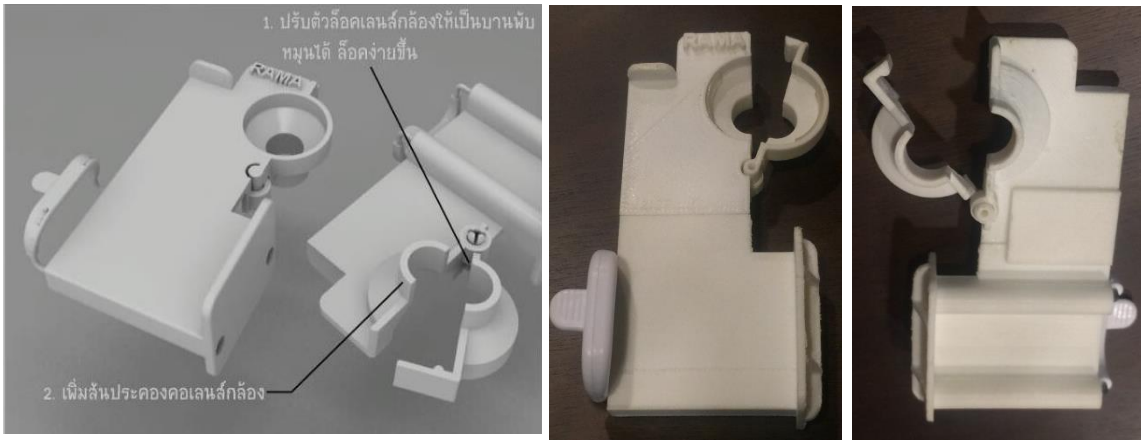
To tighten up the contact, we modified the prototype into second version, which used commercially available spring smartphone holder system in the prototype to hold the smartphone and make latches to lock the endoscope into the prototype adaptor. However, due to the latch mechanism requires the prototype to be separated into 2 pieces we decided to make a modification to keep the instrument in single unit.

Figure 2. Version 2 of the instrument



In the final version, we use hinge mechanism to keep two pieces of the instrument in single unit. Finished adapter use spring system to hold the smartphone and hinge mechanism to keep instrument in one piece.

Figure 3. Version 3 of the instrument



Second phase*: *Preliminary trial use in patients

4.1 Demographic data

A total number of 15 patients were recruited. **Table 1** describes the demographic data of all patients. Of these, 9 were male (60%) and 6 were female (40%). Mean age was 52.8 years old.

Table 1. demographic data of 15 patients.

Patient no.	Sex	Age	Patient's pain score using computer- based nasal endoscope	Patient's pain score using smartphone-based nasal endoscope (2)
1	M	66	4	3
2	F	60	0	3
3	M	70	0	0
4	F	60	4	0
5	M	69	10	7
6	M	19	5	1
7	F	35	4	2
8	M	50	2	0
9	M	32	1	1
10	F	38	3	2
11	F	61	2	2
12	M	51	0	10

13	M	53	3	3
14	F	67	5	1
15	M	61	5	5

4.2 Patient pain score

Patient reported pain score were comparable between computer- based nasal endoscopy group and smartphone-based endoscopy group with median of 2. There is no statistically significant difference when Wilcoxon sign-rank test was performed ($p=0.1094$), see Table 2.

Table 2. Patient pain score

Instrument	Computer- based	Smartphone-based
Mean pain score (SD)	3.20 ± 2.62	2.67 ± 2.79
Median pain score (range)	3 (1-5)	2 (1-3)

4.3 Clinician's satisfaction

Clinician's satisfaction of each instrument were compared among eyepiece type, computer-based type and smartphone-based type endoscope. Smartphone-based nasal endoscope type has highest mean score in portability (4.93), time required to capture (4.93), and sharing feature (5). Computer based nasal endoscope type shares the similar score with smartphone-based instrument in handling and patient direct contact topic (see Table 3).

Table 3. Clinician's satisfaction of using each instrument compare among eyepiece type, computer-based type and smartphone-based type

Topic		Eyepiece type	Computer- based	Smartphone-based
1. Handling	Mean Median	3.53 4	4.53 5	3.93 4
2. Portability	Mean Median	4.6 5	2.13 2	4.93 5
3. Time required to capture	Mean Median	1.33 1	4.2 4	4.93 5
4. Sharing-feature	Mean Median	1.2 1	3.46 4	5 5
5. Direct patient contact	Mean Median	1.6 1	4.67 5	4.27 4

4.4 Image quality rating scores

Smartphone-based nasal endoscope's mean score in all 4 categories except overall satisfaction are higher than computer-based nasal endoscope's mean score. Mean score in overall satisfaction with picture quality is similar between 2 groups.

Table 4. Image quality scores from both instrument

Topic		Computer- based	Smartphone- based
Ability to identify important landmarks/ structures	Mean Median	3.31 3	3.57 4
Illumination and brightness	Mean Median	3.57 4	3.63 4
Artefacts and background noise	Mean Median	3.42 3	3.49 4
Contrast, border, sharpness	Mean Median	3.51 4	3.55 4
Overall satisfaction with picture quality	Mean Median	3.51 4	3.51 4

We compared the scores from both instrument by fitting mixed regression models with each score as the outcome and doctor and instrument as covariate. Statistically significant difference were found in illumination and brightness, as mean difference between instrument was 0.26, i.e., smartphone-based nasal endoscope had 0.26 score higher than computer-based nasal endoscope (p value<0.001) but there were no statistically significant differences in the other categories (see Table 5).

Table 5. Result of mean differences from mixed linear regression model by score category

Score category	Mean differences from mixed linear regression model	P value from mixed linear regression model
1. Illumination and brightness	0.26	<0.001
2. Ability to identify important landmarks/ structures	0.06	0.39
3. Artefacts, background noise	0.07	0.23
4. Contrast, border, sharpness	0.04	0.56
5. Overall satisfaction with picture quality	0	0.29

CHAPTER 5
DISCUSSION

5.1 Discussion

At this moment, communication technologies are highly developed. Many people in the world use smartphone for communication with more and more advanced instrument were introduce in clinical setting. Smartphone has already facilitated effective communication among clinicians, and result in higher diagnostic accuracy rate comparing without visual information. Moreover, it is possible for clinician to use telemedicine to give remote diagnosis and treatment.

Each year there are many patients desperately need for endoscopic examination of the nasal cavity. Some of which were bedridden, people with disabilities and unconscious patients. These patients were difficult to transfer to proper examination room. Moreover, there are many patients in rural area which has no access to trained subspecialist. Thus, smartphone- based nasal endoscope will help clinician to record and refer image and video of patients to subspecialist then result in higher diagnostic accuracy rate.

Nowadays, the nasal endoscope is widely used in the diagnosis and investigation of a variety of paranasal diseases. The common types of nasal endoscope are 1. eyepiece nasal endoscope 2. computer-based nasal endoscope, and 3. camera system nasal endoscope. The ideal endoscope should be low in price, portable, have high image quality and have desirable sharing-feature, which is why we developed a self-designed prototype of smartphone-based nasal endoscope using an adapter to connect a smartphone and a nasal endoscope.

The prototype was designed and assembled by utilizing 3D printing technology. Then we evaluated the diagnostic capability of the smartphone-based nasal endoscope which uses the camera of smartphone as the image receiver without the use of additional lenses, the patients' satisfaction and the doctors' satisfaction, as compared to that of the eyepiece type and computer- based type nasal endoscope. The advantage of this technique utilizing 3D printing technology are relatively low price and ability to share prototypes and modifications with others. In the past, many styles of smartphone-based endoscope were created but the price was expansive and mass production is required to manufacture.

After using new smartphone-based nasal endoscope in patients, we found no significant difference in the patients' pain score. Similarly, we found that the image quality rating between Smartphone-based and Computer- based Nasal endoscope has no statistically significant difference in all topic except illumination and brightness which has better score in Smartphone-based nasal endoscope. However, we found that Smartphone-based Nasal endoscope has higher satisfaction rating in portability and sharing-feature.

Compare to Cheng-Jung Wu et al., they developed an instrument connecting smartphone and mobile communication application to perform teleotolaryngology. They evaluated diagnostic quality only six patients compare between face to face diagnostic and telediagnostic. Only three teleconsultants who were asked to judge image's quality using scale (poor, fair and good). In our research, we evaluated 15 patients with both conventional and smartphone-based techniques. The nineteen otolaryngology staffs and residents blinded to the technique then rate the quality of thirty images from both type in specific details of image's quality. Furthermore, we evaluated patient and clinicians' satisfactions.

Compare to Hao Liu et al., They used a commercially available mobile endoscopy adapter to enable recoding of mobile phone videos and associated software. They sent 60 ten-second videos from 30 patients to 13 skilled observers to rate the quality on Liker scale and to give the diagnosis in questionnaires. In the other hand, we created the specialized adapter to connect between an endoscope and smartphone using 3D printing technology. we evaluated patient and clinicians' satisfactions.

Apart from these two researches, we could not find any study that report the patient's satisfaction underwent endoscopic examination by the new instrument. Furthermore, there are no report about clinicians' satisfactions who used the smartphone-based nasal endoscope. We therefore generated questionnaire for each patients and clinicians to compare between conventional and smartphone-based nasal endoscope

Our finding suggests that Smartphone-based Nasal endoscope may reasonably and practically be used in clinical practice.

5.2 Study limitation

Because of self-designed prototype of smartphone-based nasal endoscope which creating adapter to fit between endoscope and smartphone. The smartphone that we chose was iPhone 6 which was popular in that time. Many otolaryngology residents and staff have their own iPhone 6 that why we chose iPhone 6 for prototype. This specific adapter can be used with only iPhone 6 or subsequent phone with the same dimensions, but this can be solved by easily modified prototype using 3D printing technology. Second, there are only 15 cases of patients in these series and we only evaluated the quality of the image, needing for a large full-scale study. Lastly, recording of image was done by the iPhone default camera software which was a little difficult in manually setting the zooming, orientation, adjustment of white balances, and focusing system. Future direction should be modification of the software side to further adjust the image quality and ease of use.

5.3 Conclusion

Our finding suggests that smartphone-based nasal endoscope system has higher clinician satisfaction, especially in portability, time required to capture, and sharing feature. Image quality were comparable with conventional computer-based nasal endoscope system, which indicated that the smartphone-based nasal endoscope system may reasonably and practically be used in clinical practice.

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Data sheet

แบบประเมิน ความพึงพอใจ จากการใช้งานจริง โดยเปรียบเทียบอุปกรณ์ในการส่องกล้อง โดยเรียงลำดับคะแนนจาก 1 (แย่ที่สุด) ไปถึง 5 (ดีที่สุด) กรุณาทำเครื่องหมาย ☐ ในช่อง ☐ ตามความเห็นของท่าน

หัวข้อ	แบบที่ 1 มองภาพผ่าน**เลนส์** โดยตรง	แบบที่ 2 มองภาพผ่าน**อุปกรณ์เชื่อมต่อกับคอมพิวเตอร์** (อุปกรณ์มาตรฐาน)	แบบที่3 มองภาพผ่าน**อุปกรณ์เชื่อมต่อกับโทรศัพท์มือถือ** (อุปกรณ์ใหม่)
1. ความถนัดในการจับอุปกรณ์ (HANDLING)	☐ 1 แย่ที่สุด ☐ 2 ☐ 3 ☐ 4 ☐ 5 ดีที่สุด	☐ 1 แย่ที่สุด ☐ 2 ☐ 3 ☐ 4 ☐ 5 ดีที่สุด	☐ 1 แย่ที่สุด ☐ 2 ☐ 3 ☐ 4 ☐ 5 ดีที่สุด
2. ความสะดวกในการเคลื่อนย้ายอุปกรณ์ เพื่อไปตรวจผู้ป่วยติดเตียงตามวอร์ดต่างๆ (MOBILILTY)	☐ 1 แย่ที่สุด ☐ 2 ☐ 3 ☐ 4 ☐ 5 ดีที่สุด	☐ 1 แย่ที่สุด ☐ 2 ☐ 3 ☐ 4 ☐ 5 ดีที่สุด	☐ 1 แย่ที่สุด ☐ 2 ☐ 3 ☐ 4 ☐ 5 ดีที่สุด
3. ความสะดวกรวดเร็วในการบันทึกภาพ (TIME REQUIRED TO CAPTURE)	☐ 1 แย่ที่สุด ☐ 2 ☐ 3 ☐ 4 ☐ 5 ดีที่สุด	☐ 1 แย่ที่สุด ☐ 2 ☐ 3 ☐ 4 ☐ 5 ดีที่สุด	☐ 1 แย่ที่สุด ☐ 2 ☐ 3 ☐ 4 ☐ 5 ดีที่สุด
4. ความสะดวกในการส่งภาพเพื่อปรึกษา (SHARING)	☐ 1 แย่ที่สุด ☐ 2 ☐ 3 ☐ 4 ☐ 5 ดีที่สุด	☐ 1 แย่ที่สุด ☐ 2 ☐ 3 ☐ 4 ☐ 5 ดีที่สุด	☐ 1 แย่ที่สุด ☐ 2 ☐ 3 ☐ 4 ☐ 5 ดีที่สุด
5. การลดโอกาสการติดเชื้อจากผู้ป่วย ผ่านทางการไอ จาม (PATIENT CONTACT)	☐ 1 แย่ที่สุด ☐ 2 ☐ 3 ☐ 4 ☐ 5 ดีที่สุด	☐ 1 แย่ที่สุด ☐ 2 ☐ 3 ☐ 4 ☐ 5 ดีที่สุด	☐ 1 แย่ที่สุด ☐ 2 ☐ 3 ☐ 4 ☐ 5 ดีที่สุด

ความเห็นอื่นๆ: ____

** แพทย์ 1ท่าน ใช้ แบบประเมินเพียง 1ใบ โดยสรุปจากผลการใช้งานจริง

ขอบคุณที่ตอบแบบสอบถาม

แบบประเมิน คุณภาพของภาพ โดยเปรียบเทียบอุปกรณ์ในการส่องกล้อง โดยเรียงลำดับคะแนนจาก 1 (แย่ที่สุด) ไปถึง 5 (ดีที่สุด)

กรุณาทำเครื่องหมาย ☐ ในช่อง ☐ ตามความเห็นของท่าน

ภาพ	ความสว่างของภาพ (Illumination & brightness)	ความสามารถในการแยกตำแหน่งสำคัญ(ability to identify important landmarks)	สีและจุดรบกวนของพื้นหลัง (artefacts, background noise)	ความคมชัดของภาพ (contrast, border, sharpness)	คุณภาพของภาพโดยรวม (Overall satisfaction with picture quality)
1	☐ 1 แย่ที่สุด ☐ 2 ☐ 3 ☐ 4 ☐ 5 ดีที่สุด	☐ 1 แย่ที่สุด ☐ 2 ☐ 3 ☐ 4 ☐ 5 ดีที่สุด	☐ 1 แย่ที่สุด ☐ 2 ☐ 3 ☐ 4 ☐ 5 ดีที่สุด	☐ 1 แย่ที่สุด ☐ 2 ☐ 3 ☐ 4 ☐ 5 ดีที่สุด	☐ 1 แย่ที่สุด ☐ 2 ☐ 3 ☐ 4 ☐ 5 ดีที่สุด
2	☐ 1 แย่ที่สุด ☐ 2 ☐ 3 ☐ 4 ☐ 5 ดีที่สุด	☐ 1 แย่ที่สุด ☐ 2 ☐ 3 ☐ 4 ☐ 5 ดีที่สุด	☐ 1 แย่ที่สุด ☐ 2 ☐ 3 ☐ 4 ☐ 5 ดีที่สุด	☐ 1 แย่ที่สุด ☐ 2 ☐ 3 ☐ 4 ☐ 5 ดีที่สุด	☐ 1 แย่ที่สุด ☐ 2 ☐ 3 ☐ 4 ☐ 5 ดีที่สุด
3	☐ 1 แย่ที่สุด ☐ 2 ☐ 3 ☐ 4 ☐ 5 ดีที่สุด	☐ 1 แย่ที่สุด ☐ 2 ☐ 3 ☐ 4 ☐ 5 ดีที่สุด	☐ 1 แย่ที่สุด ☐ 2 ☐ 3 ☐ 4 ☐ 5 ดีที่สุด	☐ 1 แย่ที่สุด ☐ 2 ☐ 3 ☐ 4 ☐ 5 ดีที่สุด	☐ 1 แย่ที่สุด ☐ 2 ☐ 3 ☐ 4 ☐ 5 ดีที่สุด
4	☐ 1 แย่ที่สุด ☐ 2 ☐ 3 ☐ 4 ☐ 5 ดีที่สุด	☐ 1 แย่ที่สุด ☐ 2 ☐ 3 ☐ 4 ☐ 5 ดีที่สุด	☐ 1 แย่ที่สุด ☐ 2 ☐ 3 ☐ 4 ☐ 5 ดีที่สุด	☐ 1 แย่ที่สุด ☐ 2 ☐ 3 ☐ 4 ☐ 5 ดีที่สุด	☐ 1 แย่ที่สุด ☐ 2 ☐ 3 ☐ 4 ☐ 5 ดีที่สุด
5	☐ 1 แย่ที่สุด ☐ 2 ☐ 3 ☐ 4 ☐ 5 ดีที่สุด	☐ 1 แย่ที่สุด ☐ 2 ☐ 3 ☐ 4 ☐ 5 ดีที่สุด	☐ 1 แย่ที่สุด ☐ 2 ☐ 3 ☐ 4 ☐ 5 ดีที่สุด	☐ 1 แย่ที่สุด ☐ 2 ☐ 3 ☐ 4 ☐ 5 ดีที่สุด	☐ 1 แย่ที่สุด ☐ 2 ☐ 3 ☐ 4 ☐ 5 ดีที่สุด
6	☐ 1 แย่ที่สุด ☐ 2 ☐ 3 ☐ 4 ☐ 5 ดีที่สุด	☐ 1 แย่ที่สุด ☐ 2 ☐ 3 ☐ 4 ☐ 5 ดีที่สุด	☐ 1 แย่ที่สุด ☐ 2 ☐ 3 ☐ 4 ☐ 5 ดีที่สุด	☐ 1 แย่ที่สุด ☐ 2 ☐ 3 ☐ 4 ☐ 5 ดีที่สุด	☐ 1 แย่ที่สุด ☐ 2 ☐ 3 ☐ 4 ☐ 5 ดีที่สุด
7	☐ 1 แย่ที่สุด ☐ 2 ☐ 3 ☐ 4 ☐ 5 ดีที่สุด	☐ 1 แย่ที่สุด ☐ 2 ☐ 3 ☐ 4 ☐ 5 ดีที่สุด	☐ 1 แย่ที่สุด ☐ 2 ☐ 3 ☐ 4 ☐ 5 ดีที่สุด	☐ 1 แย่ที่สุด ☐ 2 ☐ 3 ☐ 4 ☐ 5 ดีที่สุด	☐ 1 แย่ที่สุด ☐ 2 ☐ 3 ☐ 4 ☐ 5 ดีที่สุด
8	☐ 1 แย่ที่สุด ☐ 2 ☐ 3 ☐ 4 ☐ 5 ดีที่สุด	☐ 1 แย่ที่สุด ☐ 2 ☐ 3 ☐ 4 ☐ 5 ดีที่สุด	☐ 1 แย่ที่สุด ☐ 2 ☐ 3 ☐ 4 ☐ 5 ดีที่สุด	☐ 1 แย่ที่สุด ☐ 2 ☐ 3 ☐ 4 ☐ 5 ดีที่สุด	☐ 1 แย่ที่สุด ☐ 2 ☐ 3 ☐ 4 ☐ 5 ดีที่สุด
9	☐ 1 แย่ที่สุด ☐ 2 ☐ 3 ☐ 4 ☐ 5 ดีที่สุด	☐ 1 แย่ที่สุด ☐ 2 ☐ 3 ☐ 4 ☐ 5 ดีที่สุด	☐ 1 แย่ที่สุด ☐ 2 ☐ 3 ☐ 4 ☐ 5 ดีที่สุด	☐ 1 แย่ที่สุด ☐ 2 ☐ 3 ☐ 4 ☐ 5 ดีที่สุด	☐ 1 แย่ที่สุด ☐ 2 ☐ 3 ☐ 4 ☐ 5 ดีที่สุด