International Journal of Engineering Trends and Technology
ISSN: 2231 – 5381 /doi:10.14445/22315381/IJETT-V69I10P225
Volume 69 Issue 10, 200-203, October, 2021


# Design And Realization of An Innovative Adapter For The Visualization And Direct Exploitation of Endoscopy Images On Smartphones

Yassine Baskoun[1], Salah Dine Qanadli[2], Moha Arouch[3], Mohamed Taouzari[4]

[1,3]*Laboratory of Engineering, Industrial Management and Innovation, Faculty of Science and Technology, University Hassan 1st, Settat, Morocco*

[2]*Cardio-Thoracic and Vascular Unit, Department of Radiology, University Hospital of Lausanne, Bugnon 46, 1011 Lausanne, Switzerland*

[4]*Laboratory LISA, National School of Applied Sciences Berrechid, University Hassan 1st, Settat, Morocco*

[1]y.baskoun@uhp.ac.ma

***Abstract*** *- In this study, a novel design of smartphone endoscope adapter is introduced. The different parts of the proposed adapter are firstly designed in consideration of the use of flashlight smartphones as the light source in order to securely fit the endoscope with the smartphone. The entire system combining Smartphone and endoscope via this adapter is then designed in 3D. As a result, Simulation shows strong results in terms of fitting this system. The prototype of the proposed adapter is printed by the 3D printer and is then tested by combining Karl Storz endoscope of 0°, 4mm, 50mm, and iPhone 6s. The inner hand can be considered as dark interior as similar of the nose, ear, etc., is chosen to make this test, in which the significant photo with acceptable color and resolution is obtained. It can be concluded that this system provides a good benefit of its use in continuous development countries (LMICs) and in difficult times such as COVID-19 so that the health care providers can easily share these photos between specialists themselves or and with the patient through the internet especially for the accuracy treatment.*

**Keywords —** *Smartphone; flashlight; camera; endoscopy; telemedicine; Mhealth; adapter; low- and middle-income countries; 3D printing; COVID-19.*

## I. INTRODUCTION

In recent years, endoscopy has become a necessary diagnostic and therapeutic tool in many modern clinical specialties, including otorhinolaryngology, gastroenterology, and urology, etc. As a consequence, in the year 1843, Antonin Jean Desormeaux was the first who proposed a basic endoscopy that utilized a kerosene lamp that burned alcohol and turpentine and a concave 45° mirror to reflect light into the bladder. In the year 1956, Harold H. Hopkins has developed a novel endoscopy used the rod-lens optical system. In the year 1960, Karl Storz suggested the use of fiberoptic light transmission in order to obtain the modern endoscope, which is still more required in medicine [1], [2].

In general, the endoscopic tower system presented in Figure 1 consists of a tower, monitor, lightbox, video box, camera, and cables. Even though this system offers many features, but it still suffers from disadvantages in terms of implementation and cost. It is cumbersome and stationary that is not conducive to remote locations such as emergency departments or patient wards, or other areas outside hospitals where no electricity. In other words, its use is limited in low- and middle-income countries (LMICs) where this system is not able to be used in telemedicine [3]. In other words, the Telemedicine technique is known as the main part of telehealth that permits real-time virtual contact between providers of health care who are located in different areas with smartphones, tablets, and laptops, etc. [4]. In addition, Telemedicine is becoming the needed technique in rural areas or developing countries in which there are no specialists and lack of materials [5],[6]. As mentioned previously, the Endoscopic tower has features like a smartphone, including also display, light, a camera that enables a record of photos and videos. Consequently, Smartphone has the great ability to use it as a medical device in telemedicine in order to exploit its developed and sophisticated cameras and led light. As a result, these features provide specialists in this field to make significant medical acts such as ophthalmology, dermatology, and endoscopy [7-8].

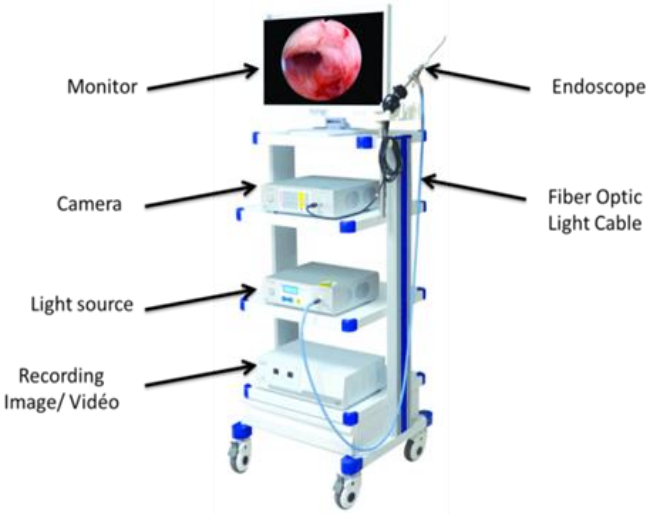


**Fig. 1 Standard endoscopic tower**

Due to many medical acts based on endoscopy, some approaches, studies, and commercial products, as presented in Figure 2 that discuss the ability to improve endoscopic examination and surgery, are reported in references [9,29]. In the ref.[9,10] and Figure 2(a), Endoscope-I proposed by George and .all is one of the device endoscopies that is based on the use of iPhone models and connecting its suitable adapter for nasal and oto-endoscopy examination and sharing results. In the ref. [11,12], Endoscope-I is then used to teaching for residents and trainees. In the ref. [13–15] and Figure 2(b), the authors have proposed to add Camkix adapter [16] connecting with endoscopy in order to finally obtain Endockscope. In addition, the use of Endokscope is based on iPhone 5/5S and 6/6S and Samsung s8 to be shared with experts, colleagues, and trainees for real-time consultation, case presentation, discussion, and education. In the ref. [17–19], Kirkland N. Lozada and al. are suggested the Mobileoptx adapter Figure 2(d) using only iPhone 4S to the recording of flexible fiberoptic nasopharyngolaryngoscopy into smartphones and transmitting information between residents and physicians in real-time. Clear scope adapter Figure 2(c) utilizing different smartphone models is one of the adapters that can be used for several interventions such as nasopharyngolaryngoscopy, otoscopy, and neurosurgery, likewise it becomes strong useful so that the interventions have been improved in LMICs [20–25]. RVA smart-clamp Figure 2(e) that can also be used with different models smartphone is the adapter for flexible or rigid endoscopy [26,27]. As a conclusion for the different adapters mentioned above, there are also several adapters, such as DIY adapters. Figure 2(f,g), which are tested and improved in large endoscopic exams and situations for different countries, especially for LMICS [28,29].

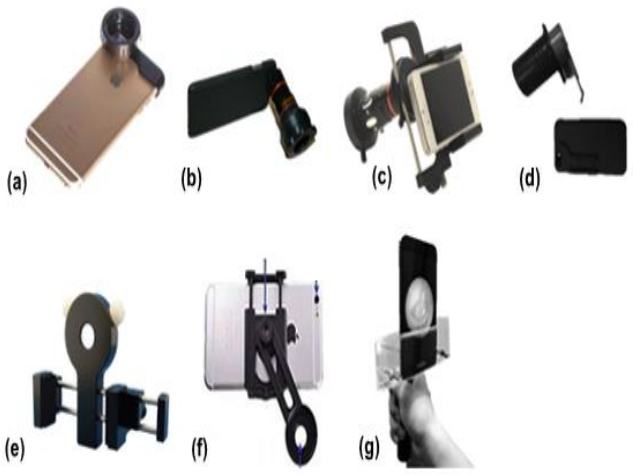


**Fig. 2 Photograph of different adapters in literature.**

Concerning light sources, it is considered as one of the main parts of the endoscopy procedure. This procedure, it is normally utilizing light by different methods, including lightbox and portable light sources. Therefore, the light box source suffers from many disadvantages such as difficulty to move between the distant places that are required the trolley, electrical failure, and changing the bulb. Due to lightbox difficulties, many studies have been suggested using smartphone flashlights that allow providing enough illumination; therefore, it is needed the help of an assistant during the ongoing endoscopy procedure cannot make a significant intervention [30–35]. In previous work, a first functional prototype was produced to demonstrate the feasibility of using the smartphone flashlight in endoscopy using an adapter to easily center the cable with the light [36], and then Yanbo Guo et al. used an adapter to evaluate the image quality in real exams [37].

Consequently, the objective of this work is to propose a novel method based on flashlight smartphone connecting with adapter in order to have a sufficient intervention for medical acts utilizing endoscopy procedure in LMCIs especially. The rest of this paper is organized as follows: Section I presents the 2D and 3D methodology design of the proposed Adapter using CAO software. Section II provides a prototype of an adapter printed with the 3D printer. Section III discusses the Test and results. A conclusion and future works are given in the last section.

## II. DESIGN AND DESCRIPTION OF THE PROPOSED ADAPTOR

As mentioned previously, several adapters and mobile light sources have been designed to replace a standard endoscopic tower by using the mobile camera phone so that they are facilitating using mobile endoscopic to surgeons. In addition, the use of the mobile camera phone connected to an endoscopy device via the suitable adapter has become a vital device to perform the examinations for any clinician. However, the use of the light source of the mobile phone via cable guide is still a serious problem for the clinician in order to perform accurate examinations.

Based on works that have been achieved [36], [38], [39]. So, the purpose of the work presented in the paper is to design a novel adapter that has the ability to use the camera and lights mobile phone to solve the problem of the light source based on the need for an assistant. As a result, the proposed adapter shown in Figure 3a demonstrates the different steps of the design in 2D. In addition, the final design connecting endoscopy with the camera and light mobile phone via the proposed adapter is presented in 3D, as shown in Figure 3c. While, Figure 3b illustrates the design of each component, including reflecting space, smartphone mounting brackets, endoscope fixation support, and fiber optic of this adapter. For the strong fitting by using this adapter, the steps are proposed in order to obtain this fitting where the endoscope eyepiece is fixed with smartphone camera by endoscope fixation support and smartphone mounting brackets, and then direct the reflecting space to smartphone flashlight in order to have fixation of the whole system, and flashlight is guided to endoscopy light entrance via fiber optic as the final step.

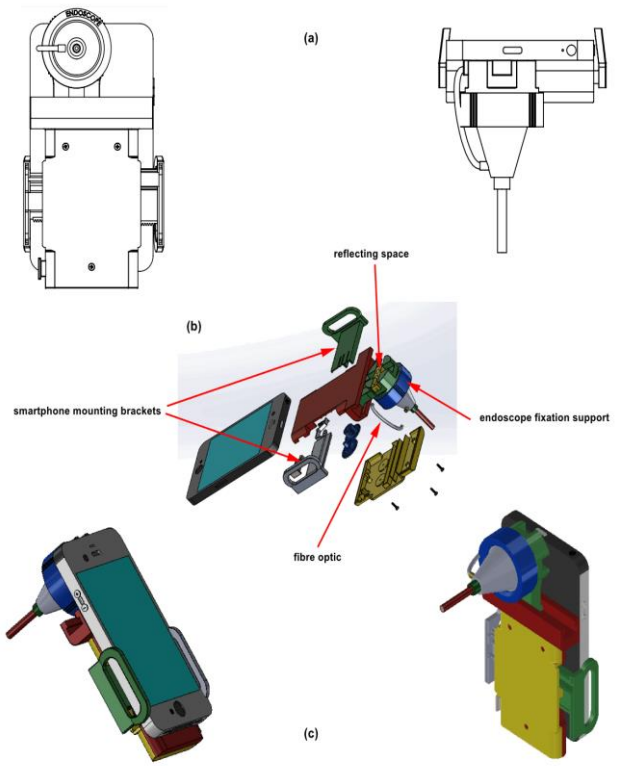


**Fig. 3 Design of the proposed smartphone endoscope adapter, (a) 2D model, (b) different pieces, (c) 3D model**.

## III. EXPERIMENT AND RESULTS DISCUSSION

In order to validate the proposed smartphone endoscope adapter using its camera and light, the prototype is fabricated by using a 3D printer, as shown in Figure 4a. To test, an iPhone 6s, a Karl Storz endoscope 50 mm 0° 4mm, the hand as dark interior (e.g., ear, nose ...) are used. Figure 4a also shows the system which works by combining the endoscopy with the proposed adapter, which fits on the smartphone. The proposed adapter is securely attached endoscopy to the smartphone. In addition, this system has many advantages, such as being portable, compactness, cost-effective, and easy to use. As a result, this system is can therefore be used by subspecialties to obtain high-definition endoscopic imaging of the nose, throat, nose, etc. Furthermore, the images or videos obtained using this system are of superior quality, and examples are shown in Figure 4b, which are often stored in smartphone applications so that this system provides accurate information to the clinician to make a significant diagnosis. It can also make efficient diagnoses to the patient while the images are obtained in real-time and can easily store and share these photos easily, as shown in the synoptic figure 4c. It can be concluded that acceptable results in terms of good color and resolution are obtained. The table.1 presents the features of the proposed smartphone endoscopic adapter in comparison with studies published in the literature examining the effects of smartphone endoscope adapters.

**Table 1. Comparison of the proposed adapter performances with the published ones**

| Device | Smartphone Compatibility | Light Source |
|---|---|---|
| Proposed adapter | All smartphone's brand and size | External & smartphone flashlight |
| Endoscope-I [9], [10] | Iphone séries | External |
| Endockscope [13]–[15] | Iphone series and samsung s8 | External |
| Mobileoptx [17]–[19] | Iphone séries | External |
| Clearscope [20]–[25] | All smartphone's brand and size | External |
| Rva smart-clamp [26]–[27] | All smartphone's brand and size | External |
| Diy adapters[28]–[29] | All smartphone's brand and size | External |

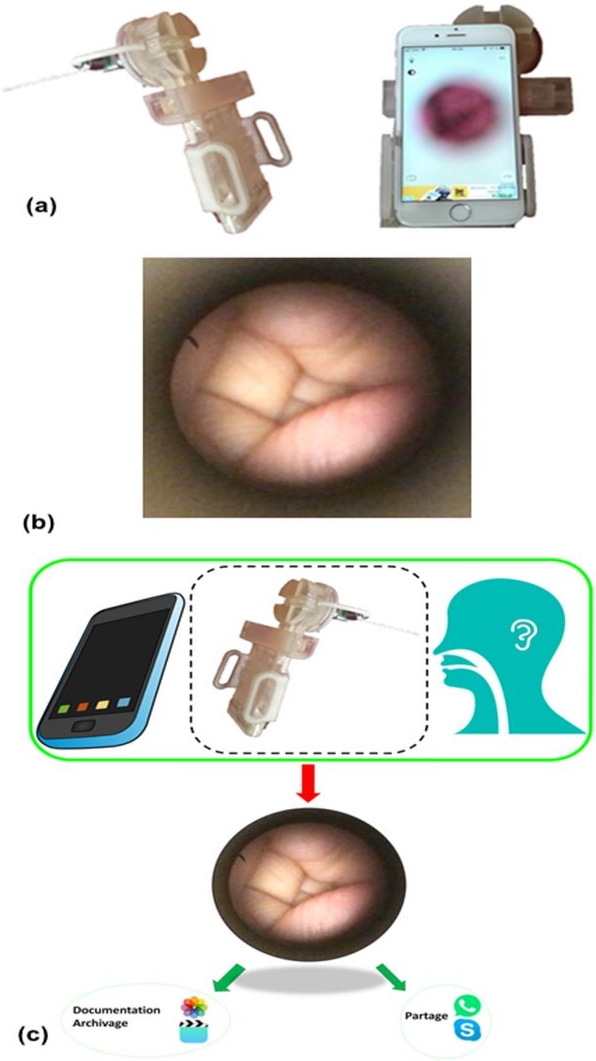


**Fig. 4 Printing and test of the proposed smartphone endoscope adapter, (a) prototype photograph, (b) Adapter test by capturing of inner hand photo, (c) synoptic of useful adapter for treatment by storing and sharing.**

## IV. CONCLUSION

A new, compact and cost-effective smartphone endoscope adapter is well designed, fabricated and tested in this paper. In comparison with alternatives adapters on the market, this adapter fulfils the need of use flash light of smartphone as a source light by offering a highly portable and simple to utilize endoscopic system. As a smartphone technology, it has served to allow a significant a real-time feedback to the patient by sharing the photos and videos for the accurate diagnoses. Consequently, this system has the ability to use in urgent cases, caravans and LMCs.

## V. ACKNOWLEDGEMENTS

The authors would like to thank the HealthCare Foundation (HCAF) for the support and funding to achieve this research work.

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