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SHORT COMMUNICATION

Utility of a smartphone-enabled otoscope in the instruction of otoscopy and middle ear anatomy

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Abstract

Purpose To present the utility of a smartphone-enabled otoscope as a teaching adjunct in pre-clinical otoscopy training.

Methods 60 pre-clinical medical students were randomized into either a control group using a conventional otoscope or an experimental group using a smartphone-enabled otoscope. Participants in each group were trained to use their assigned device and were given time to practice on a colleague's ear. Participants then completed a questionnaire indicating their ability to visualize anatomical landmarks of the middle ear as well as their confidence in performing a middle ear examination using their device.

Results Compared to participants using the conventional otoscope, significantly more students using the smartphone-enabled otoscope identified the umbo (93% versus 63%, $P=0.005$), the short process of the malleus (67% versus 33%, $P=0.008$), the cone of light (100% versus 70%, $P=0.001$), and the pars flaccida (60% versus 33%, $P=0.03$). Furthermore, participants who used the smartphone-enabled otoscope reported significantly increased confidence in performing otoscopy compared to those who used a conventional otoscope (4.1 ± 0.7 versus 2.8 ± 0.9, $P<0.001$). Finally, participants rated the smartphone-enabled otoscope as an excellent teaching aid for otoscopy training.

Conclusion The smartphone-enabled otoscope serves as a valuable teaching tool for pre-clinical otoscopy education. After using the device, pre-clinical students were more confident in performing a middle ear examination and in identifying important anatomical landmarks of the middle ear.

Keywords Otoscope · Otoscopy · Education · Technology · Smartphone

Introduction

Otoscopy is an important component of the general physical examination that can reveal critical pathologies of the middle ear. However, consistency and confidence in performing middle ear examinations using an otoscope has knowingly declined amongst medical students and non-otolaryngologist providers [1–3]. This deficiency may in part be secondary to poor otoscopy instruction and insufficient exposure of otolaryngology as part of core clinical skills training in medical school and primary care graduate education [4–10].

Considering that otolaryngology-related disorders comprise a significant portion of common medical visits, various techniques have been devised to improve otoscopy instruction [11, 12]. Web-based videos, camera-mounted binocular microscopes, and simulation models have been previously reported as teaching aids for otoscopy, but they can be of poor image quality, not easily accessible, and costly [13, 14]. Moreover, most of these educational adjuncts do not allow for practice on a live patient. With these disadvantages in mind, the need for an effective and practical method of improving otoscopy instruction is ever-present.

Smartphone-enabled otoscopes have become increasingly accessible and affordable, allowing users to perform and digitally record middle ear examinations for as little as $30. Prior investigations have demonstrated the value of these

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portable devices as effective diagnostic and telemedicine aids in the clinical setting [15–18]. However, the potential use of a smartphone-enabled otoscope in the realm of pre-clinical medical education has yet to be explored. As such, the purpose of this study was to determine the utility of an inexpensive smartphone-enabled otoscope as a teaching aid in pre-clinical otoscopy training.

Materials and methods

As this investigation involved quality improvement of standard medical care and all data were unidentified, it was granted Institutional Review Board exemption from the Rosalind Franklin University of Medicine and Sciences Institutional Review Board. The KZYEE Universal Serial Bus (USB)-Enabled Otoscope was purchased for $30 and its accompanying application was downloaded onto a Samsung Galaxy S7 smartphone. This device consists of a 0.3 Megapixel camera offering 640 × 480P resolution that attaches to USB-compatible devices (Fig. 1). It also comes with reusable otoscope specula that were cleaned between use by means of an alcohol-based disinfectant.

Eligible participants were first- and second-year (pre-clinical) medical students. Exclusion criteria included previous otoscopy training outside of the medical school curriculum. A computer-based random allocation sequence (Research Randomizer Version 4.0) was used to randomly assign each participant to either use a conventional otoscope (CO) or a smartphone-enabled otoscope (SEO).

Students in both study arms were given an identical didactic introduction on otoscopy and middle ear anatomy, followed by a demonstration on the use of their device. Participants were then given a 20-min period to practice using their assigned otoscope on their colleagues' ear. During this time, students in both study groups received feedback and guidance from clinical instructors with experience using both devices. Feedback consisted of adjustments in device handling to better centralize and visualize the tympanic membrane.

After each practical session, participants completed a paper-based questionnaire which asked them to rate their ability to visualize their colleagues' umbo, cone of light, short process of the malleus, and pars flaccida by circling "Yes", "No", or "Unsure". These structures were selected based on guidelines set forth by the Objective Structured Clinical Examination. For visualization of the above-mentioned structures, means and standard deviations were calculated and then compared using the Fisher's exact test. They were then asked to rate their confidence in performing a middle ear examination using their assigned otoscope on a Likert scale of 1 (not at all confident) to 5 (extremely confident). Additionally, the experimental group was asked to rate the usefulness of a smartphone-enabled otoscope in teaching otoscopy on a Likert scale of 1 (not at all useful) to 5 (extremely useful). For Likert score data, means and standard deviations were calculated and then compared using the Mann–Whitney *U* test.

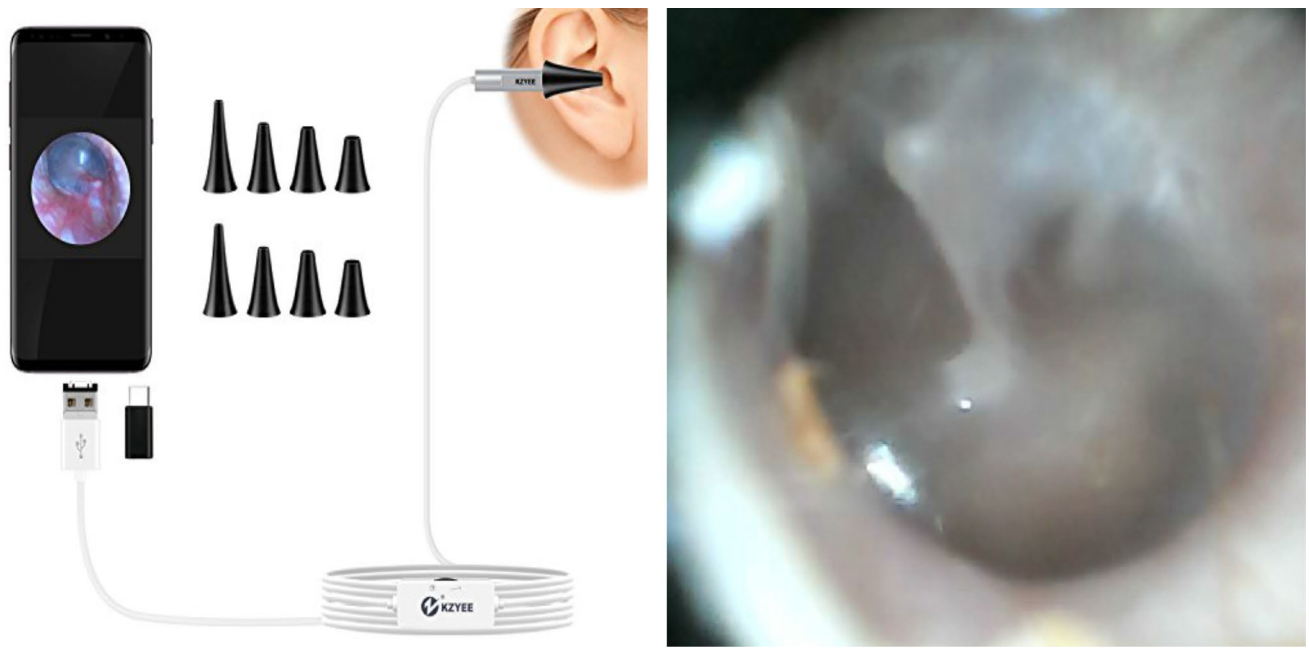

Fig. 1 KZYEE USB-enabled otoscope (left); tympanic membrane photograph taken using the USB-enabled otoscope (right)

Results

60 students volunteered to participate in this study, including 30 first-year medical students ($n=15$ in each group) and 30 second-year medical students ($n=15$ in each group). Compared to participants using the CO, significantly more students using the SEO identified the umbo (93% versus 63%, $P=0.005$), the short process of the malleus (67% versus 33%, $P=0.008$), the cone of light (100% versus 70%, $P=0.001$), and the pars flaccida (60% versus 33%, $P=0.03$) (Table 1). Similar trends were seen when comparing performance across each class subgroup.

Reported Likert confidence ratings among participants using the SEO were significantly higher than those reported by participants using the CO (4.1 ± 0.7 versus 2.8 ± 0.9, $P<0.001$). Participants using the SEO rated the device to be very useful as a teaching aid (4.7 ± 0.5).

Discussion

Billions of dollars are spent each year on otitis media, a diagnosis for which diagnostic skills are suboptimal. In fact, the Center for Disease Control has identified improvement in otoscopy skills as a key intervention to reduce inappropriate antibiotic prescribing patterns [19]. One of the primary difficulties in learning and teaching otoscopy using a conventional otoscope stems from the device's inherent inability to share the user's view of the tympanic membrane with an instructor [16]. The SEO overcomes this barrier by magnifying the user's visual field onto a larger screen, thus offering several noteworthy advantages. First, it allows instructors to provide immediate constructive feedback on students' ability to properly centralize the tympanic membrane. This immediate feedback is critical to skill acquisition, and has been previously demonstrated to substantially improve medical students' clinical performance and learning [20, 21]. Furthermore, the magnified screen gives instructors the opportunity to demonstrate middle ear anatomy on live subjects, thus providing students with a real-time guide to define important landmarks. Finally, this shared view allows for open discussion among instructors and students, providing both diagnostic and educational value beyond that of a CO [22].

Another important characteristic of the SEO is its relatively low cost and portability. Several currently available simulation devices and camera-mounted microscopes can cost upwards of $800 and require the assembly of many bulky pieces. The low cost of a $30 handheld USB-enabled otoscope in conjunction with the widespread prevalence of USB-compatible devices makes incorporation of this teaching device both practical and easily accessible in the classroom and clinical settings.

Our presented study has several limitations. First, all middle ear examinations were performed on young and healthy students. These subjects may be more cooperative and their tympanic membranes better visualized than many patients. However, our study offers students a basic understanding of otoscopy and middle ear anatomy which has the potential to translate to improved otoscopy technique on real patients. Furthermore, an important limitation of this educational tool is that it does not assess participants for all of the skills that are required for a comprehensive clinical examination of the middle ear. Nevertheless, this exercise addresses two of the more difficult aspects of the exam: visualization of the tympanic membrane and identification of important landmarks. To be more comprehensive, this educational tool should be supplemented with teaching modalities focused on additional aspects of the examination, pathology recognition, and clinical decision-making.

As our current study focused on healthy patients with normal-appearing tympanic membranes, it is critical for future studies to investigate student otoscopy proficiency when examining patients suffering from acute and chronic otopathology. Furthermore, whereas our investigation focused on first- and second-year medical students, the SEO can serve as a practical and financially feasible adjunct in other educational settings like nursing school and residency. The incorporation of SEO in the clinical setting is still in its infancy. Future investigations should explore the impact an SEO has on clinical decision-making as well as diagnostic accuracy among non-otolaryngology providers and students.

Table 1 Comparison of self-reported visualization of middle ear structures and confidence in performance between participants using a conventional versus smartphone-enabled otoscope

Total students' reported findings			
	Conventional otoscope ($n=30$)	Smartphone-enabled otoscope ($n=30$)	P value
Cone of light	21 (70%)	30 (100%)	0.001
Umbo	19 (63%)	28 (93%)	0.005
Short process of the malleus	10 (33%)	20 (67%)	0.008
Pars flaccida	10 (33%)	18 (60%)	0.025
Confidence*	2.8 ± 0.9	4.1 ± 0.7	<0.001

*Likert scores are reported as mean ± standard deviation

Conclusion

The smartphone-enabled otoscope is an effective teaching aid for pre-clinical otoscopy training. The potential use of this device to increase accuracy and confidence in otoscopy

makes this an attractive alternative to currently available training adjuncts during pre-clinical training and beyond.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Research involving human participants This study was granted IRB exemption by the Rosalind Franklin University of Medicine and Science IRB committee specifically reviewed by Dr. Kristin Schneider and Dr. Monica Oblinger. It was determined that since this study involved quality improvement of standard medical care and all data are unidentified, this study does not require IRB oversight.

Informed consent Informed consent was obtained from all individual participants included in the study.

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