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A Prototype 3D Printed Suction Port Adapter for a Wireless Otoendoscope

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ABSTRACT

Objective: To design and fabricate a suction port adapter to use various sizes of suction cannulas with a wireless otoendoscope enabling ear cleaning under endoscopic guidance demonstrated using an ear examination simulator.

Methods:

Design:	Instrument Innovation
Setting:	Tertiary Private Training Hospital
Patient:	Ear Examination Simulator

Results: The fabricated suction port adapters were able to hold the wireless otoendoscope and suction cannulas together, allowing simultaneous inspection of the ear canal and suctioning of ear canal debris using the Ear Examination Simulator.

Conclusion: Our prototype 3D-printed suction port adapters for a wireless otoendoscope may improve ear cleaning by enhancing the accuracy of suctioning debris and decreasing duration since they hold the suction cannulas in place under endoscopic guidance. They may aid ENT physicians in easier visualization and simultaneous ear cleaning of patients and improve ear cleaning techniques and times, especially among less experienced physicians, but actual clinical trials are needed to confirm this.

Keywords: *3D printing; cerumen; suction adapter; wireless otoendoscopy; otoscopy*

The development of smartphones has paved the way for the creation of affordable, pocket-sized, pen-shaped otoendoscopes that can transmit images to mobile devices. These devices are often equipped with an ear pick and are marketed as tools for ear cleaning. However, the replaceable ear pick lacks durability, and if used by individuals without proper training, can potentially cause harm to the ear canal and tympanic membrane.

After conducting a thorough review of the existing literature from MEDLINE (PubMed and PubMed Central), HERDIN Plus, EMBASE, Google Scholar, Directory of Open Access Journals (DOAJ) and Science Direct we could find no tool currently available on the market that offers the flexibility required to seamlessly integrate widely available wireless otoendoscopes with standard ENT instruments such as suction cannulas.

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Thus, we aimed to develop a lightweight, compact, user-friendly 3D printed suction port adapter to use various sizes of suction cannulas with a wireless otoendoscope, that can assist ENT physicians in performing ear cleaning procedures in an out-patient setting while ensuring excellent visualization, and to test our prototype using an ear examination simulator.

METHODS

This instrumental innovation was exempted from review by the University of the East – Ramon Magsaysay Memorial Medical Center Research Institute for Health Sciences Ethics Review Committee (RIHS ERC Code: 1592/H/2023/164). We designed and fabricated suction port adapters that could accommodate varying sizes of preexisting suction cannulas using a wireless otoendoscope. The simulation was performed on an Ear Examination Simulator.[1]

A. Wireless Otoendoscope

The commercially available Bebird M9 Pro wireless otoendoscope (Heifeng Zhizao (Shenzhen) Technology Co., Ltd., Shenzhen, Guangdong, China)[2] with a body measuring 12.5 cm long, lens tube measuring 2.5 cm, and lens diameter measuring 3.5 mm was selected for this study. *(Figure 1)* The Bebird was Ingress Protection Code (International Protection Code) IP67 rated with IP code 6 denoting solid protection from contact with harmful dust and IP code 7 denoting temporary protection from immersion in water. It has a 10-megapixel camera with 20 fps, 300W HD Endoscope and a high-end Wi-Fi chip. It comes with screw-on replaceable earpicks.

B. Suction Cannulas

Three different commercially available unbranded suction cannulas were selected with the following outer diameters: 2 mm, 1.5 mm and 1 mm. *(Figure 2)*

C. 3D Printed Suction Port Adapters

The fabrication of the adapters was started with a computer aided design (CAD) model of a suction port customized to the wireless otoendoscope and the suction cannulas. The suction port adapters were designed using SketchUp Free (Trimble Co., Westminster, CO, USA).[3] Three suction port adapters were designed to fit different sizes of suction cannulas using the otoendoscope.

The prototype was designed with the following dimensions: inner diameter for the otoendoscope was 3.5 mm, the inner diameter for the suction cannula was 2 mm, the thickness was 1 mm and the length of the adapter was 22 mm. The over-all height was 7 mm and the over-all width was 5 mm. The port for the suction cannula was beveled to accommodate different angulated suction tips. *(Figure 3)* Two more adapters were printed with inner diameters for suction cannulas of 1.5 mm and 1 mm, respectively. The adapters were 3D printed using PLA 1.75 mm filament in a Creality Ender 3 Pro (Cordol Technology (Hong Kong) Co., Ltd., Hong Kong, China). *(Figure 4)*

D. Downloading And Using The Software

The Bebird Ear Care Specialist mobile application version 5.2.33 for Apple (Black Bee Intelligent Manufacturing, Shenzhen Technology Co., Ltd., Shenzhen, China)[4] was downloaded from the App store. The mobile application is also available to android phones. The program was opened and synced to the Bebird M9 Pro via direct Wi-fi.

E. Assembly of the Suction Port and Simulated Use of the Device

After 3D printing the suction port adapter, the Bebird wireless otoendoscope was inserted inside the port **A** and the suction cannula was likewise inserted inside the port **B** as illustrated in *Figure 5.* Their tips visualized the ear canal and tympanic membrane structures 2 cm away from the endoscope. *(Figure 6A)* The fit was snug enough so that no additional adhesives needed to be applied. A suction connecting tube was attached to the other end of the suction cannula. *(Figure 6B)* Using the Ear Examination Simulator, *(Figure 7A-C)* brown sugar granules were placed in the ear canal of the simulator to mimic the size and consistency of cerumen. *(Figure 7D)* The suction tip was advanced to the ear canal and the debris were easily suctioned. *(Figure 8A, B)*

RESULTS

The 3D printing of the suction port adapters and assembly were easily performed and the simulated use on the ear examination stimulator was easily replicated with both authors successfully assembling and suctioning the simulated debris. The process was successfully repeated using all three adaptors with the corresponding suction tips.

The fabricated suction port adapters were able to hold the wireless otoendoscope and suction cannulas together allowing simultaneous inspection of the ear canal and easy suctioning of ear canal debris using the Ear Examination Simulator.

DISCUSSION

We designed and fabricated a prototype suction port adapter to use various sizes of suction cannulas with a wireless otoendoscope enabling ear cleaning under endoscopic guidance and demonstrated this ability using an ear examination simulator. The design of the adapter allows it to securely hold the suction cannula at an adjustable distance from the external auditory canal and affords the potential to be operated single-handedly while the other hand of the operator retracts the ear canal.

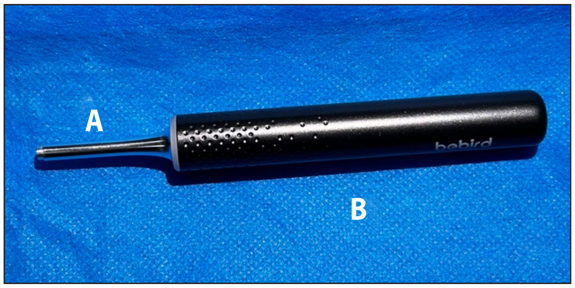

Figure 1. Bebird M9 Pro wireless otoendoscope typically used to visualize the ear canal and its contents and additional appliances may be attached for ear cleaning such as ear pick. **A** The lens tube with a length of 25 mm and a 3.5 mm camera lens diameter. **B** Body of the otoendoscope which stores the rechargable battery and Wi-Fi chip

Figure 2. Three different suction cannula sizes. **A** suction cannula with outer diameter of 2 mm. **B** suction cannula with outer diameter of 1.5 mm. **C** suction cannula with outer diameter of 1 mm.

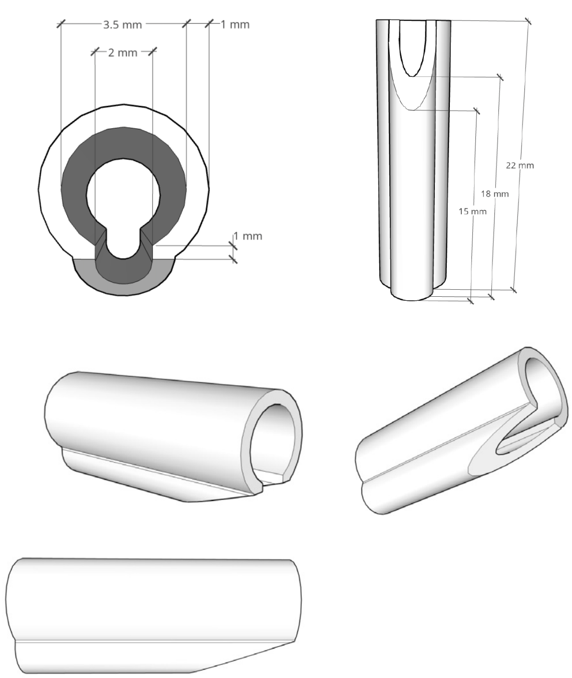

Figure 3. Prototype design with the following dimensions: inner diameter for otoendoscope of 4 mm, inner diameter for suction cannula of 2 mm, thickness of 1 mm and length of adapter of 22 mm. Over-all height of 9 mm and over-all width of 7 mm. Two similar adapters were designed for 1.5 mm and 1.0 mm suction cannulas, respectively.

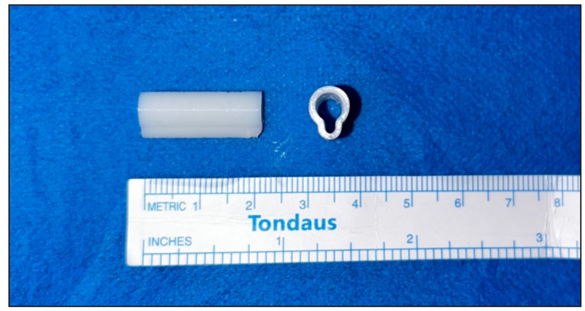

Figure 4. The 3D printed suction port adapter showing the actual dimensions from the front view with a width of 7 mm and side view with a length of 22 mm

Figure 5. The Bebird wireless otoendoscope was inserted inside the port A and the suction cannula was inserted inside the port B

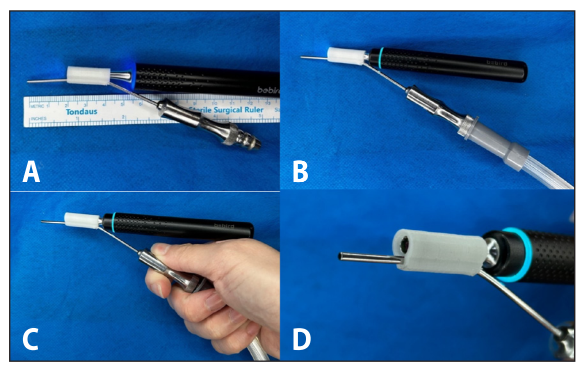

Figure 6. The assembled device showing: **A** The suction tip visualized 2 cm away from the otoendoscope. **B** The assembled device with the attached suction connecting tube. **C** Proper way of holding the suction cannula attached to the wireless otoendoscope. **D** 45 degrees view of the suction cannula attached to the wireless otoendoscope

Ear cleaning of the external auditory canal can be difficult because its structure follows a confined, curved space with a diameter of 6 to 8 mm and an average length of 2.5 cm.[5] that limits entry of light. It can be even more challenging when dealing with uncooperative patients such as those with various disabilities, children or the elderly. Inadequate visualization during cleaning poses risks including iatrogenic ear canal or tympanic membrane injuries. Various techniques like irrigation, manual extraction and suctioning are used for aural toilette[6] but they

Figure 7. The Ear Examination Simulator used as a makeshift myringotomy simulator: **A** anterior view; **B** posterior view; **C** lateral view; and **D** Actual view from the wireless otoendoscope showing the simulated ear canal with brown sugar granules placed in the canal to mimic the size and consistency of cerumen.

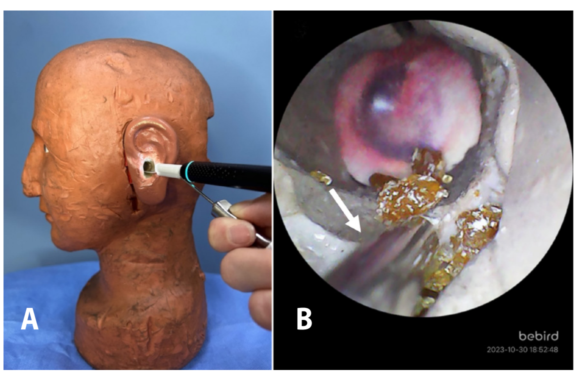

Figure 8. Demonstration of the following: **A** holding the suction cannula within the simulated ear canal. **B** Actual view from the wireless otoendoscope showing the suction cannula (arrow) inside the simulated ear canal suctioning the debris.

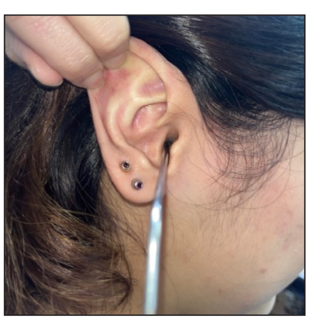

Figure 9. Demonstration of suction cannula obstructing the whole external auditory canal meatus upon aural toilette

have drawbacks. Ear irrigation with a syringe can lead to complications like dizziness, infection and tympanic membrane perforation.[6] Manual extraction and suctioning under direct visualization may be performed using a good headlamp, binocular microscope, loupes or endoscopes. Head lamps offer low visualization due to the tortuosity of the ear canal, and when performing aural toilette there are times when the suction cannula obstructs the entire external auditory canal meatus, *(Figure 9)* or some instruments may cause iatrogenic injuries to the ear canal due to poor visualization. In contrast, binocular microscopes and loupes offer superior visualization but are relatively expensive. Endoscopes have gained popularity among ENT physicians providing visualization and real-time imaging. However, their adoption is limited due to high associated costs and affordability issues for equipment such as video monitors processors and light sources.

In recent years, cost-effective, portable, pen-shaped otoendoscopes that wirelessly transmit images to mobile phones have become available. These devices are advertised for ear cleaning but are hindered by flimsy ear picks that may cause further ear canal damage. Our adapter was designed to address various challenges and to achieve the following goals:

1. enhancing poor visualization when using headlamps;
2. upgrading from a flimsy ear pick to a more effective suction cannula for ear cleaning;
3. eliminating the requirement for a two-handed approach in endoscopy, where one hand is dedicated to the scope and the other is employed for the suction cannula; and
4. overcoming limited access to micro suctioning using loupes or microscopes.

The production cost of our 3D printed suction adapter prototype was PhP 1,367 which is 0.07% - 1.82% of the market price for endoscopes and loupes which range from PhP 75,200 to PhP 1,919,750 each depending on the brand and number of accessories included. Moreover, the suction ports may accommodate various sizes of suction cannulas for both adult and pediatric patients and are designed to insert only the suction tip within the ear canal while maintaining good visualization. *(Figure 8A,B)* The 3D printed suction port enables secure placement of the suction cannula alongside the otoendoscope, ensuring stable endoscopic guidance and minimizing the potential for inadvertent damage to the ear canal. Additionally, physicians can remove debris while the patient is watching on their phone screen. In contrast to the expensive rigid endoscopes used in the hospital setting, the pen-shaped otoendoscopes offer the advantage of wireless real-time image transmission to mobile phones, enhancing portability. This feature is particularly beneficial for independent ENT physicians not affiliated with any hospital, particularly those dedicated to providing care in underserved rural outpatient settings.

It is essential to acknowledge the limitations of our suction port prototype, including the absence of formal trials by multiple operators and the need for clinical testing on live patients. We recommend conducting clinical trials and exploring the integration of a locking mechanism for different sizes of suction cannulas, potentially using materials like thermoset materials or siliconized materials for mass production. It is possible to upgrade functionality by adding ports for alligator forceps, cerumen scoops/probes, a myringotomy knife and polyethylene ventilating tube applicators.

In conclusion, our prototype suction port adapters were able to hold the wireless otoendoscope and suction cannulas together, allowing simultaneous inspection of the ear canal and easy suctioning of ear canal debris using the Ear Examination Simulator. They may aid ENT physicians in easier visualization and simultaneous ear cleaning of patients and improve ear cleaning techniques and times especially among less experienced physicians but actual clinical trials are needed to confirm this.

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