Department of Biomedical Engineering
UNIVERSITY OF WISCONSIN–MADISON

Dual Handheld and Video Otoscope

Preliminary Report

BME 200/300
10/11/2023

Client:

Dr. Lara Tomich- University of Wisconsin Veterinary School

Amy Nichelason-University of Wisconsin Veterinary School

Advisors:

Justin Williams- Professor of Biomedical Engineering Adjunct faculty of Neurological Surgery

Team Members:

Sam Tan- BSAC/TeamLeader

Grace Boswell- Communicator

Haoming (Bobby) Fang- TeamLeader

Jose Ramirez- BWIG

Declan McHugh- BWIG

Zakki Miraz- BPAG

Abstract

Teaching otoscope techniques for animals poses a challenge, particularly for novices, where guidance from instructors is crucial for student success. Otoscopes can be broadly categorized into two types: handheld and video. While a video otoscope is powerful for examinations, it is practiced differently than a handheld otoscope, the primary tool used in animal exams for students at the UW Vet School. However, a challenge arises with handheld otoscopes as they do not provide live feedback and video relay to an instructor during examinations. Therefore, there is a need for a new otoscope design that can effectively transfer live images or video to a distant instructor while providing students an experience similar to using a handheld otoscope. This is not only essential for the success of students but also for the well-being of animal subjects during practice. The team has proposed various redesigns, additions to the current otoscope, and methods to enhance the student experience. Our overarching goal is to design, fabricate, and test prototypes that can be effectively employed in real-life scenarios. This endeavor aims to address client requirements while maintaining a reasonable budget.

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Introduction

Motivation/Global Impact

The use of an otoscope for examining the ear is a vital diagnostic method for identifying otitis externa, and it is an integral part of a thorough physical examination for canine patients. However, teaching such techniques still relies heavily on practicing with live dogs and is challenging for many veterinary students without proper instructions.[1] The development of a dual handheld otoscope, which seamlessly combines the time-tested technique of traditional optical otoscopy with live video capabilities, represents a significant leap forward in the field of veterinary medicinal education on a global scale. This innovative device promises to transform the way veterinarians are trained and educated by not only enabling real-time assessment and immediate feedback for improvement but also facilitating a comprehensive learning experience. With its integrated recording capability, this dual otoscope allows for a later review of the diagnostic process, enhancing the educational value of each examination. As a result, veterinary students and professionals around the world can access a more immersive and thorough training experience that better prepares them for the complexities of clinical practice, ultimately benefiting animal healthcare on a global scale.[2]

<u>Existing Devices & Current Methods</u>

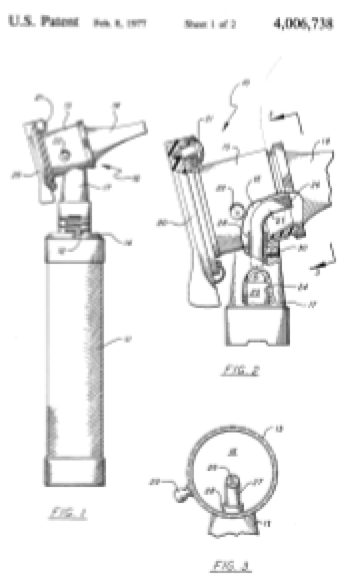

Figure 1: Structure of handheld otopscope[3]

Figure 2: Endo World Video Otoscope [4]

Current methods and existing devices for otoscopy training predominantly revolve around handheld otoscopes, as in Figure 1. These devices are the traditional otoscopes widely used in clinical practice. However, one significant limitation is their inability to provide instructors with real-time assessment and feedback capabilities. Trainees often struggle to replicate the precise techniques required for accurate ear examinations. Without immediate feedback, they may inadvertently develop suboptimal habits or fail to understand what they are looking at. In addition, inadequate usage of the otoscope also may be painful for the animals.

On the other hand, video otoscopes, as an example presented in Figure 2 [4], are another avenue for otoscopy training. While they offer certain advantages, such as the ability to record examinations for later review [5], as well as slightly higher accuracy [6], they often function differently from the optical otoscopes commonly used in clinics. This variation can create a disconnect between the training experience and real-world practice, potentially hindering students' ability to seamlessly transition to clinical settings.

Problem Statement

Current handheld otoscope designs in veterinary practice either cannot stream live videos of examinations to remote devices or feature video functionality instead of the traditional lens view, which is essential for simulation training. The team aims to develop a handheld otoscope that combines live video capabilities, enabling faculty members to assess student-performed examinations in real-time.

Background

Physiology and Biology Research

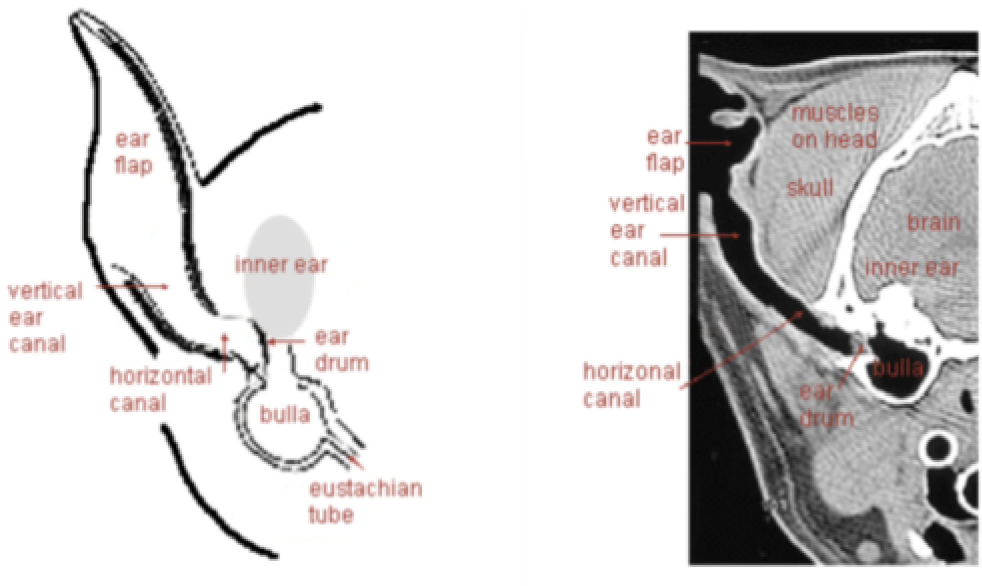

Figure 3,4 : Front and CT Diagram of Dog's Ear [7]

The anatomy of a dog's ear consists of various structures shown in Figure 3 above. There are three main areas that veterinarians define as the outer, middle, and inner ear. Within the outer ear, it consists of an ear flap which is also known as the pinna. Next is the middle ear, which is known to be fragile. This is important to note in the team's design due to our device needing to be safe for the clients and the dogs they will be using it on. The middle ear also consists of three bones, an air-filled cavity (bulla), and a thin tube (eustachian tube). Finally, is the inner ear which connects to the brain, has nerves, and is involved in hearing and balance [7].

Design Research

A one-way mirror, or a transparent mirror, is an essential part of the design and a crucial element in achieving the success of implementing video relay capabilities into a traditional otoscope. This idea was first developed way back before the semester even started when group members were proposing this project. The use of a one-way mirror is to reflect only a portion of light hitting the surface This allows the rest, usually a very small portion, to get through the mirror thus viewable as a transparent glass from the other side of the mirror. A one-way mirror, unlike a normal mirror, has a thinner silvering on the surface. This thin coating allows the described feature to be achieved. The reflective molecules on this layer of coating make the mirror half opaque. However, there must be a brightness difference between the two sides of the mirror for this to be successful. The bright side is the reflected side thus lights are reflected so it acts as a mirror. The darker side is a normal glass [8].

Another crucial component to making this project successful is a micro camera, or a camera small enough to fit within certain ranges to be discussed later during fabrication time. From individual research, the team came to an agreed conclusion that micro cameras are expensive and might be over the budget of our work and off from our ability to control the performance.

Client Information

The clients, Dr. Lara Tomich and Dr. Amy Nichelason, are employees of the University of Wisconsin School of Veterinary Medicine. They came to this group looking for a device that incorporates a handheld eyepiece that also relays a video feed to a faculty member from a distance [9].

Design Specifications

The following design specifications are found in Appendix A. This device needs to be lightweight, held in the hand comfortably, to minimize perceptual differences between the lens and camera, and easy to work with for new veterinary students. This device will include an external light source used for reflection and to assist the camera, as well as video relay ability. The ideal weight of this device is between 0.453592 to 0.907185 kilograms and its measurements will be nearly 196.48 mm in length, 24.5 mm long on the top head, and 30.92 mm in diameter [10]. These measurements are based upon those of the Welch Allyn Pneumatic Otoscope given to the team by the client. This device should be able to withstand debris within an animal's ear. The shelf life of this device is determined by the proper care. Storage should have a temperature between -20℃ and 55℃ and a humidity limitation of 10% to 95%. The atmospheric pressure limitation of the device will be between 500hPa and 1060hPa [11]. By meeting these criteria the device will reduce perceptive differences between the student and faculty member watching on the monitor.

Preliminary Designs

I. One-way mirror

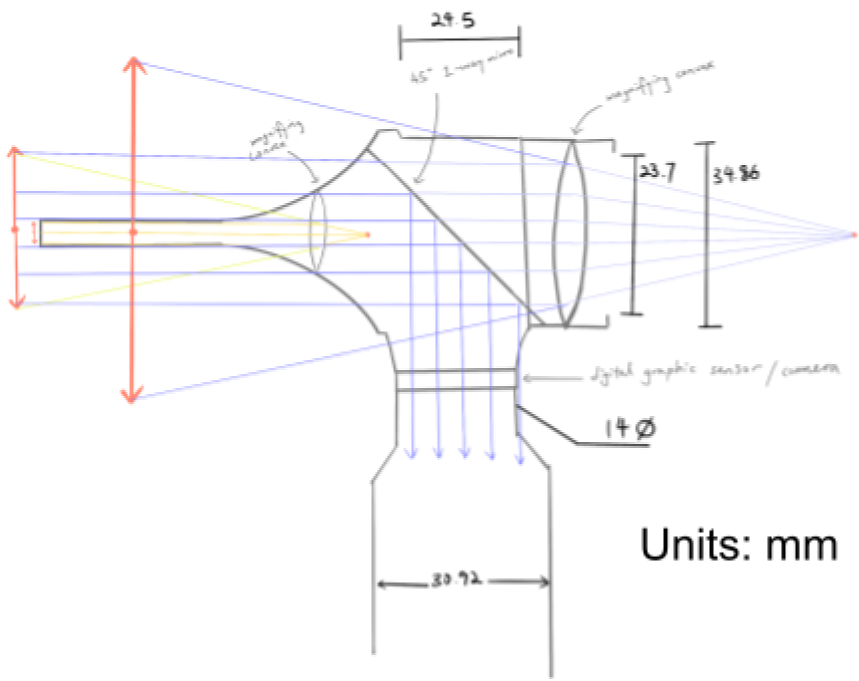

Figure 5: Design Drawing of One way mirror [12]

This design, figure 5, utilizes two convex lenses to achieve a magnifying goal. The real image goes through the tip of the specula into the first lens positioned just at the beginning of the otoscope body that projects a larger virtual image to the back. Image 1 then goes through a 45-degree arranged 1-way mirror that reflects only 70% of light. The rest is through another convex lens to enlarge the image for the local viewer. This view must keep close contact with the otoscope thus providing a dark environment for the 30% remainder light to be viewable. The 70% reflected light is captured by a camera below which is transferred to a distant viewer. The light source is located around the camera.

II. Add on module

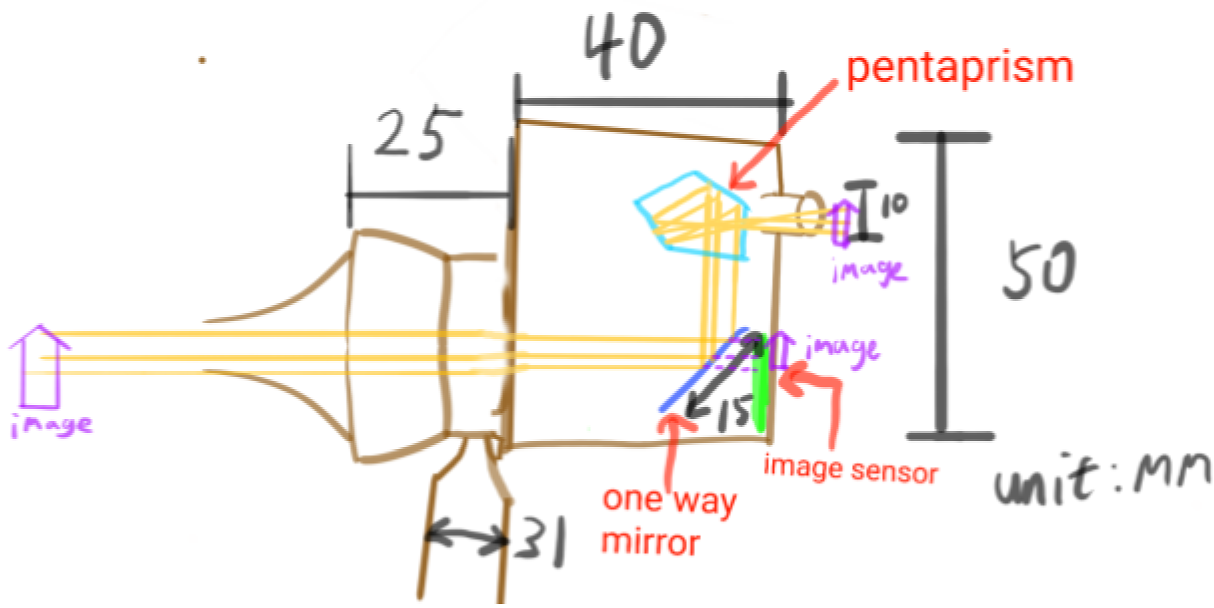

Figure 6: Design Drawing of Add on module [13]

This design, figure 6, is for an external module to be added to regular handheld otoscopes to integrate video output capacity while maintaining the original optical output, to keep the perceptive difference minimal between the digital and optical output, and also ensure that users can effortlessly transition between these modes. As shown in image 2, the otoscope should fit on the regular otoscope's magnifying lens side. The optical output would first be reflected by a 50 percent polarizing mirror, with part of the image going through the mirror directly to the image sensor, and the rest of the image reflected upward into a pentaprism, to eventually flip the image back up-right and to the visual lens.

III. Hidden camera

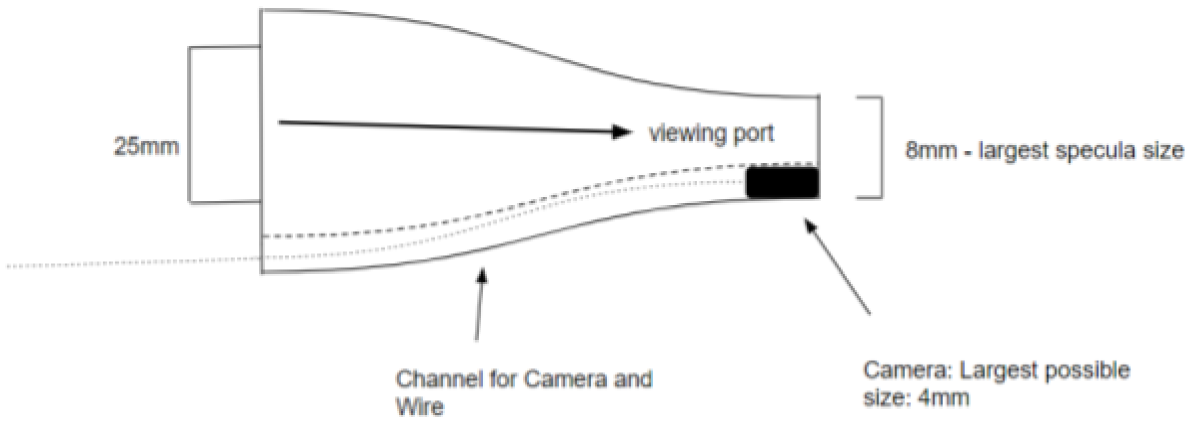

Figure 7: Design Drawing of Hidden Camera Design [14]

This design, figure 7, uses a camera inside the nozzle attachment that would be affixed around the specula cone. The total diameter of the attachment would be a maximum of 5mm. The camera would have a wired connection to either a video output device (e.g.: laptop, phone, etc.) or a wireless wifi-box that an external device would connect to. Ideally, the camera and wire would not be obtrusive to any form of functionality because the nozzle would essentially act as a second larger specula cone. The wire would be secured onto the otoscope so it is not a disturbance to the user.

Preliminary Design Evaluation

Criteria (Weight %)	Design1: 1-way Mirror	Design 2: Add on Module	Design 3: Hidden Camera
Effectiveness (25)	4.5/5	4.5/5	3.5/5
Ease of Fabrication (20)	2/5	2/5	3/5
Ease of Usage (15)	4/5	2.5/5	4/5
Adjustability (10)	2.5/5	4/5	2/5
Safety (10)	4/5	4/5	3/5
Size/weight (10)	4/5	2.5/5	4/5
Cost (10)	3/5	3/5	4.5/5
Total = 100	**69.5**	**65**	**68.5**

Table 1: Design Matrix

Design Matrix Summary

To evaluate the preliminary designs listed above, a design matrix was developed to rank the three designs based on various criteria. Each category for each design was ranked on a scale from 0 to 5. The design that scored the highest in effectiveness, ease of usage, safety, size/weight, and cost was the 1-way mirror otoscope. To evaluate the design effectively all aspects of the design had to be considered and the criteria had to receive a different weight based on its importance to the client. The designs were visualized through drawings and the handheld otoscope that was gifted from the client due to the fact the team does not have any prototypes to test at the moment [10].

The one-Way Mirror design was accepted as the design that would fulfill the client's requirements the best due to its winning categories. One design flaw of this design is the ease of fabrication will be difficult due to the modifications needed to be done to the inside of the otoscope.

The Add-On Module was not accepted as the winning design due to the foreseen difficult fabrication and usage. Based on the client's requirements, the device needs to be usable for first-year veterinary students. This device, due to its large weight and size, would not fulfill these requirements because the add-on module is bulky and would be more difficult to control while used on a live animal.

The Hidden Camera design was not accepted by the group due to its rated effectiveness and adjustability. The hidden camera would require a microcamera to fit inside the specula. This type of camera would be expensive and would not allow for adjustability of the specula size. One aspect of this design the team was fond of, as it decreased fabrication complexity, was that it did not involve modifying the inside of an otoscope.

Proposed Final Design

The One-Way Mirror design will allow the veterinary student to examine a dog's ear canal while the faculty members can view the same image from a distance on a monitor. This design will minimize the perceptive difference between the two viewers due to the reflection of the light on the mirror. The figure above shows the planned dimensions of the device and the projected head shape of the otoscope. The team plans to use Bluetooth connections between the One-Way Mirror Otoscope and the monitor it is viewed on. To use this device the Bluetooth connection will need to be confirmed, then the student will turn on the light and insert the otoscope into the dog's ear.

Fabrication/Development Process

Materials

Anything to be fabricated needs to be within a doable range by consideration to the MakerSpace or Teamlab [15]. Parts to be manufactured must be either 3D printed, laser-cut, or lathed/milled. Material options will be determined after consultation with professional staff in these areas, ensuring they possess similar structural properties to the example otoscope provided by the client. Designs 1 and 3 both require specific parts to be ordered from external suppliers. This may include the one-way mirror, camera, Bluetooth transmitter, and any lenses used in the design. Following calculations and an evaluation of options by the group, specific materials, and their prices will be added to the expense chart and purchased through our designated contact at the UW School of Veterinary Medicine.

Methods

The fabrication methods for the device are yet to be determined. The assembly method for Design 1 figure 5, involves following a series of guided rules. The initial step is assembling any internal structure, such as the one-way mirror and camera. This ensures that the parts fit properly within the external shell, which then closes for aesthetic and ergonomic purposes. The fabrication of a one-way mirror involves applying a reflective film or coating to a glass trimmed to fit within the otoscope. For Design 3 figure 7, Hidden Camera, the fabrication methods include 3D printing the modified specula. Additional fabrication or assembly methods for both designs will be detailed in individual protocols later on.

Final Prototype

There is no prototype currently available. A handheld otoscope from the client can serve as a rough estimate of the final design, for reference only. However, the design timeline is strictly followed to ensure the delivery of the final prototype.

Testing

There are no tests conducted at this stage. Plans for testing include vet school professional evaluation and comparison between current otoscopes and the final prototype, comparison between transferred image and lens image[1]. The tests are expected to meet design specifications detailed in Appendix A.

Results

There remains no testing conducted at this stage of the process, thus no results were obtained as well. However, the team had made decisions regarding some material options and made adjustments to current designs that delivered valuable results. The results are expected to meet specifications, client requirements, and expectations.

Discussion

No final prototype nor any results from any conducted tests at the current stage. Once the team makes progress on building our initial prototypes the team will test and refine our designs when necessary and come to conclusions on the best decisions to be made accordingly. At this

[1] Lens image is obtained through a camera captured image from the lens, while transferred image is video relayed image.

point, the team has thought of future aspects of the device and how it can be used in various applications. One proposal is supporting telediagnosis. Since the digital image can be viewed live and recorded, with an internet connection added, the design not only allowed for tele-diagnosis by distant health professionals but potentially also through AI. Such implementation might be beneficial to places with limited veterinary healthcare resources. This diagnosis method supports the ongoing trend of artificial intelligence in healthcare and might bring significant advancement in the field.

Conclusions

Current handheld otoscope designs either cannot stream a video feed of the student's view to a remote device or they utilize a video digital view of the area of interest instead of a traditional lens view, which is essential for simulation training. Our goal is to combine these two features into one handheld otoscope. Despite the added difficulty that simultaneously pursuing two distinct designs entails, the team believes that doing so is the best course of action to ultimately realize a successful final design. Throughout the development of one design, the team hopes to gain valuable insight that could potentially apply to the alternative design. The team aspires to create an innovative design that could serve practical and effective instructional use here at the School of Veterinary Medicine as well as at other teaching institutions. Moreover, even serving as a foundation for future innovations and designs that attempt to tackle a similar issue, is in itself a worthwhile endeavor. It is incontestable that innovation is not a product of any sole person or group, but rather a culmination of effort and passion directed towards a common goal of advancement.

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Acknowledgements

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Appendices

Appendix A: Product Design Specifications

Dual Handheld and Video Otoscope - BME 200/300 Section 310

Product Design Specifications
September 21, 2023

Team: Grace Boswell, Sam Tan, Bobby Fang, Jose Ramirez, Declan McHugh, and Zakki Mirza

Client: Dr. Lara Tomich and Amy Nichelason

Advisor: Professor Justin Williams

Function:

A typical handheld otoscope consists of three main parts: head, tail, and the speculum. The speculum is a thin tube that inserts into the ear canal of animals with a light source at the tip. This part of the otoscope is designed to be able to comfortably create light pathways to go through and direct lights into the head component of the otoscope. The head of the otoscope is a box with a magnifying lens, which is usually convex, that projects a virtual enlarged image of the ear canal to the observer. The tail of the otoscope is for holding, and storage for camera and other essential processing components of the otoscope. Video otoscopes come in a variety of designs. Without the need of a magnifying glass, a video otoscope can be smaller in size. The Dual Handheld and Video Otoscope is needed to integrate functions of video otoscope to a typical handheld otoscope for distant viewers. While maintaining the features and the three main parts of a handheld otoscope, a digital camera is needed to feed live.

Client requirements:

- The otoscope resembles features of a traditional handheld otoscope (lenses)
- The otoscope has video relay ability
- External Light Source
- Maintain expenses below the budget
- Capable for using currently existing speculums

Design Requirements:

1. Physical and Operational Characteristics

    a. *Performance requirements:* The redesign of the handheld otoscope must meet basic otoscope features, this includes: allow light to emit, reflect, and gather back to the viewer. The video relay to a distant viewer must be stable, smooth. Although no requirements from the client, the resolution and framerate of the camera should maintain industry specification for a video otoscope at a sensor resolution of 1280 x 1024 and frame rate of 30 FPS [1].

    b. *Safety:* During student examination, a trained handler or veterinary technician should also be present all the time of the examination to assist with collecting data and analysis on performance. This can be the exam instructor as the distant viewer or someone who is familiar with the process and the device. This is to avoid injuries for both students and the animal subject during the process. The otoscope should also not consist of exposed electrical components and potentially sharp edges that could cause harm to both student and animal subject [2]. Users or students need to check the basic functions and each part of the otoscope to make sure the otoscope is in functional shape and each component on the otoscope is working to their intended function only, prior to the use of animal subjects and handled with care to avoid animal abuse. Users or students also need to consider examination duration to avoid overheating from the light source and possible damage to camera functions.

    c. *Accuracy and Reliability:* Magnifying lenses of the otoscope should accurately enlarge the real image. Image through the lens should resemble similar details to the camera captured images. A minimum of 50 percent accuracy should be achieved when two images overlap and are compared.

    d. *Life in Service:* Otoscopes tend to have long lives in service, the product should run 10,000 exams without major failures. The battery life should be sustained one day in a vet clinic each time fully charged if batteries are used.

    e. *Shelf Life:* Power off, disconnect all electrical connections when not in use and store properly. If batteries are used, store them in a dry environment. Storage temperature limitation between -20℃ and 55℃, humidity limitation of 10% and 95% [3].

f. *Operating Environment:* The otoscope operates between the temperature limitation of 10℃ and 49℃, humidity limitation of 30% and 90%, atmospheric pressure limitation of 500hPa and 1060hPa [3].

g. *Ergonomics:* The device will feature a comfortable grip, intuitive controls, and an optimally balanced weight distribution to reduce strain on the user's hand and wrist. The product should not be bulky and avoid sharp edges and corners for user comforty. Additionally, the ergonomic design will take into account the ease of cleaning and maintaining the otoscope to uphold the highest standards of hygiene in clinical settings.

h. *Size:* The size of the otoscope will be based on the size of the otoscope gifted to us by the client. The brand of the otoscope is Welch Allyn Veterinary Pneumatic Otoscope [4]. Its measurements are 196.48 mm in length, 24.5 mm long on the top head, and 30.92 mm in diameter. Different sized ear speculum are placed at the front of the otoscope. This device will be portable because it will be used for everyday use.

i. *Weight:* This device will range from 0.453592 to 0.907185 kilograms based on the materials chosen for the camera and video transmission to the monitor. This device needs to be lightweight due to students having to carefully examine dogs with it.

j. *Materials:* 3D printers from the UW maker space will be used to print 3D prototypes of the product [5]. The printing method chosen will most likely be FDM/FFF methods. A laser cutter from the maker space will be used ideally. The laser cutter will be the Universal ILS9.150D [6]. A ESP-32 CAM module along with a 75mm OV2640 is the current solution for the replacement of the digital camera portion of the tail [7].

k. *Aesthetics, Appearance, and Finish:* The appearance and finish should remain mostly similar to currently in used ones for recognizability.

2. Production Characteristics

a. *Quantity:* One or two. More upon request by client.

b. *Target Product Cost:* Cost of a typical video otoscope on the market is relatively inexpensive, around $25.99 to $49.99 [8]. Although the client does not have a target cost of the product, maintaining the cost relatively close to the market price is ideal and friendly to all labs and teaching faculties.

3. Miscellaneous
    a. *Standards and Specifications:* The product will not be mass produced, so there's no manufacturer-required standards. According to the FDA otoscopes fall into the generic category and do not need FDA clearance. Manufacturers are required to register their device. [9]

    b. *Customer:* There is a slight preference for the camera feed to be wirelessly connected to the monitor/viewing device, however it is completely adequate to have a wired connection for the video feed. Additionally, a recording function to be able to review footage is desirable. Lastly, there is a preference for having the viewing experience be on a monitor rather than a cellular device.

    c. *Patient-related concerns:* The otoscope cannot harm the patient in any way and must be as comfortable as possible for the user and patient while being used. The patient should react the same way as it reacts to previously used otoscopes.

    d. *Competition:* Many video otoscopes and handheld otoscopes are available to purchase online. Their price varies based on functionality. However, these designs are often for human use, options for animal otoscopy are not often available to pick and choose from. Out of those available, some are either handheld otoscopes with no video feature, or video otoscopes that aren't handheld for student examination. One competing design is the Wispr Digital Otoscope [10]. This video otoscope is a close replacement for the handheld otoscope, and comes with video function in replacement for the lenses. However, this does not satisfy the lens requirements and is extremely costly considering the teaching faculty and budget for animal exams.

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