Ovine Endoscopic Ear Surgery - Accessible Smartphone-Based Training Model

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Abstract

Background: Understanding middle ear anatomy, in addition to endoscopic surgical skill acquisition, is an arduous task. Mastering 3-dimensional conceptualization and surgical dexterity may take many years. The coronavirus pandemic has made training difficult and complicated due to social distancing and risk of aerosolized viral spread in cadaver dissection. In this study we suggest a smartphone-based endoscope ovine head cadaveric dissection which is a simple, safe, and affordable training model for residents as an initial step in otologic endoscopic surgery training.

Methods: A stepwise depiction of endoscopic ovine middle ear surgery; from cadaver and equipment acquisition, setting preparation, to surgical explanation and procedural steps.

Results: The smartphone-based endoscopic otological ovine dissection model provides a low-cost, easily accessible and easily deployable training model for the novice surgeon world-wide. This model permits the novice surgeon a comprehensive anatomical understanding, middle ear proprioception, as well as a "safe" practicing model for diverse middle ear procedures.

Conclusions: The ovine cadaver otological smartphone-based endoscopic surgery training model is an affordable, easy, reproducible, and transportable model, which makes it an ideal model from implementation in both low-middle and high-income countries.

Introduction

Otological surgery, and in particular endoscopic middle ear surgery, requires a multitude of skills that are obtained during a long training period. The skills required for an endoscopic otological surgeon range from manual ones—handling the endoscope, manipulating different instruments at different angles—to knowledge and proficiency of working in small spaces. Furthermore, a knowledge of the anatomy, which includes a 3-dimensional understanding of the middle ear anatomical structures and their relative relationships, is crucial. To obtain this panoply of skills, the resident is often required to perform multiple cadaveric temporal bone dissections as well as to participate in endoscopic/non endoscopic middle ear surgical procedures[1].

During the coronavirus disease 2019 (COVID-19) pandemic, we assume there has been an unexpected decrease in planned surgical procedures, which has led to a decline of mentorship programs through surgical participation. Furthermore, the reduction in hospital resources due to reallocation of funds to treat COVID-19 patients,[2] as well as an increased risk in dissecting human cadavers with an unknown COVID-19 status[3], has led to difficulties in obtaining learning opportunities for novice endoscopic ear surgeons. In addition, the inability of organizing national/international dissection courses due to worldwide social distancing restrictions[4] and flights cancellations poses an additional challenge to training. Therefore, other innovative routes to acquire surgical proficiency are required.

Middle ear anatomy and structural relationships are complex and require hours of training prior to operating on patients[5]. We believe that acquisition of middle ear anatomical knowledge and hand-eye coordination are facilitated when hands-on training is combined with classical textbook learning[6].

Alicandri-Ciufelli et al.[6] presented a planned surgical skills acquisition schema for obtaining surgical skills required for endoscopic ear surgery which requires human patient/cadaveric dissection only. In this article, we suggest a preliminary stage to the Alicandri-Ciufelli et al. model based on ovine dissection that greatly facilitates subsequent human cadaveric stages and is readily available, affordable and safe in the COVID-19 era.

It has been shown that the ovine temporal bone is a good model for middle ear anatomical training[7]. In general, anatomical structures and their relationships are relatively similar to that of humans. When comparing different structures of the ovine model to that of humans, Andre Gurr et al.[8] measured a shorter external ear canal ~ 12.5 mm in the ovine model versus 25 mm in humans, and a smaller diameter of the external ear canal (approximately 3 mm versus 7 mm). When studying the bony external ear canal orientation in the ovine model, it was found to be similar to that of humans in regard to the tympanic membrane. When comparing the middle ear of the ovine model to that of humans, it was noted that the tympanic membrane diameter was comparable (8mm), ossicles were of similar size with slight variations (+/-0.5-1 mm). The hypotympanum (regarded as hypotympanon in the ovine) a large bullous structure (12 mm in depth, 2.5 mm in length and 4 mm in width) when compared to the human was found to be 1-4 mm larger on all axes. In addition, the ovine mastoid is both smaller and has no pneumatization. Despite these differences the ovine model has been proposed as an adequate model for myriad endoscopic-based surgical procedures, including round window cochlear implant electrode insertion[9], stapedectomy,[10] and endoscopic ear surgery, due to the similarity of the ossicles, position of the stapes in the oval window niche, and the relationship to the facial canal and nerve to the ossicular chain.

Given the prolonged learning curve required for performing endoscopic ear surgery, which has become widely used in different surgical middle ear pathologies,[11] we aimed to explore an innovative training technique for residents which is safe, accessible and affordable.

In this paper, we propose a novel training technique using a smartphone-based assisted endoscope and an ovine cadaver skull for otologic middle ear anatomical training. The preparation, technical equipment acquisition, and surgical steps described may be easily implemented. The availability of smartphones and affordable endoscopes may allow the development of such a program globally and not only in high-income countries (HIC), where the facilities as well as equipment are already available. This technique is adaptable to low- and middle-income countries (LMIC), making endoscopic middle ear surgical training possible anywhere.

Materials And Methods

This study was exempt from Institutional Ethical Board Review due to the fact that we acquired ovine cadaver skulls from a local butcher. The study used Squire 2.0 the revised standards for quality improvement reporting excellence for reporting our findings.

Surgical ear equipment that was allocated for cadaveric training use only was obtained from our operating room and a domestic Dremel drill (China) was obtained (Figure 1).

Ovine skull & equipment preparation:

Ovine heads were delivered on the day of butchering, thoroughly skinned and severed at the spine superiorly; ensuring all anatomical structures remain intact. Flesh and residual skin were removed with a 20' surgical blade.

Following flesh removal, the skull can be immediately dissected or stored in 4% formaldehyde 4-8 weeks. When dissecting a "fresh" ovine cadaver, tissue pliability resembles that of humans. Upon formaldehyde storage, the tissue becomes more rigid and less easily dissectible. Nevertheless, the anatomical structures and their relationships are maintained. Cadaver heads may be further cut coronally for manipulation ease. To permit easier dissection of middle ear structures, excess soft tissue as well as the cartilaginous external auditory canal must be removed, in addition to widening of the bony auditory canal with removal of the meatal lining tissue using the Dremel drill (Figure 2). We connected a $3 USD smartphone-based endoscope (Visual ear cleaner Model: i96, purchased online) able to connect via micro-USB or USB-C to any smartphone or tablet. Following the connection of the smartphone-based endoscope, we installed a freeware application (OTG Endoscope by GameDNA, China) which allowed for high-quality endoscopic video/photographic recording. Before endoscopic procedures, the smartphone/tablet should be comfortably positioned in front of the trainee, and upward alignment should be marked on the endoscope for correct orientation.

Results

Initial endoscopic view reveals a thinned tympanic membrane (TM) due to formaldehyde preservation, the head of malleus and the lenticular process. After anatomical landmark identification, a myringotomy was performed and a tympanostomy tube (TT) was inserted (Figure 3).

Due to absence of an annular ligament, it is impossible to raise a tympano-meatal flap. The tympanic membrane may be dissected from the malleus to allow access into the middle ear cleft.

Upon TM removal, middle ear exploration and ossicular movement may be performed. Removal of the TM allows endoscopic entry to the middle ear cleft, revealing middle ear anatomy, allowing further anatomical exploration, including relationship of the stapes and the facial nerve, which is similar to human anatomy relationship (Figure 4).

Ossiculoplasty may be performed by dislocating the incudo-malleolar and incudo-stapedial joints with a Rosen needle, extracting the incus, and remodeling it in order to regain ossicular continuity using incus interposition (Figure 5A, B). In addition, a stapedotomy may be performed by gently fracturing the stapedial crura from the footplate and perforating the foot plate (figure 6).

Discussion

Acquiring anatomical and surgical skills in otology is a rigorous task. Of utmost importance is continuous hands-on experience: this allows for hand-eye coordination improvement, acquiring knowledge of surgical maneuverability in a confined area, learning the handling of both tissue and instruments, as well as gaining knowledge of the complex relationships of different anatomical structures in a confined space.

One of the consequences of the COVID 19 pandemic is the limitation of personal and academic funding, which has led to an even greater imbalance between LMICs and HICs in the possibility of training in specialized surgical procedures. Different training models have been proposed including cadaveric dissections, various animal models, 3D printed models and virtual or augmented reality. A comprehensive comparison of available models concluded that cadaveric models remain the best platform for temporal bone training[12]. The major drawback of any animal model is the lack of anatomical validity, but when we compare both availability and cost, the animal model superseded the cadaveric one.

Although 3-dimensional surgical models of the temporal bone—specifically virtual reality (VR) and 3-D printing - have been shown to be applicable and shorten the learning curve in training the otological surgeon[12], [13], these methods are still in their infancy. Printable models may highly resemble bony structures, but the addition of soft tissue (nerves, blood vessels, connective tissue) in these structures complicates the production process and makes these models both expensive and inaccessible[14]. Furthermore, tactile sensation in a 3-D model does not resemble ovine cadaveric dissection, which is adequately similar to human cadaveric dissection. In comparison to the model we present, any given 3-D printed model would be more expensive and require both software/hardware that may be unobtainable in some low-resource settings.

Ovine heads are abundant almost anywhere in the world and can be acquired with minimal or no cost in most countries. Specimen preparation and manipulation are easily learned as we have shown in a stepwise fashion. No specialized materials are necessary, and even house-hold drills can be used for bony work.

Another advantage of the ovine model is the resemblance of both outer and middle ear anatomy to that of humans. While acquiring both surgical/manual expertise, one acquires anatomical understanding of the tympanic membrane, its placement and relationship to the malleus, the understanding of the ossicular chain as well as the placement of the facial nerve and its various relationships.

In 2 studies published by Clark et al.[15], [16] the authors state several benefits that may be attained from the implementation of endoscopic ear surgery in LMIC. The first, both pathology and operative technique can be equally observed by the surgeon and the staff, which is an essential step for education. Secondly, the ease of transportation and storage of equipment, as well as the ease with which the technique would lend itself towards telemedicine roles may be noted. Reduced post-operative pain and an increase in same day surgery rates are also an advantage in LMICs. The one challenge, stated by the authors, is the obstacle of providing effective medical education in ear endoscopy in LMIC, taking into account both the greater time and resource constraints in these countries[17]. The authors further state, that a virtual, high-technology simulator would be unrealistic in LMICs, and a simulator should be cost effective, avoid the need for maintenance and disposable components, having realistic dimensions and layout, providing a range of tasks to perform, and be easily transportable. The endoscopic ear training model, presented in our paper, fulfils all these roles. It takes all the benefits and succeeds in succumbing the aforementioned constraints by reducing the need for expensive surgical equipment and enabling a realistic "feel" of both tissue and surgical procedure. Our model enables error-based learning, standardization of learning processes and personal skill acquisition[18]. which is the basis for developing a capable surgeon anywhere in the world.

In another study published by Luu et al.[19] which had an aim of assessing the face and constructing the validity of a specific ear simulator constructed by the authors, the authors have shown that simulation training can allow individuals to gain otological skills in a low-resource settings, they even state that low-fidelity physical models have been shown to achieve similar levels of learning as virtual reality simulators[20], making our model even more appealing since it is both high-fidelity and low-cost.

In this paper we propose, a stepwise training guide depicting photographed anatomy, seen in the figures attached (Fig. 1-6), as well as a written and video-assisted guide for surgical procedures including: TT placement, ossicular removal, stapedotomy, and middle ear debris removal without harming important neighboring structures (e.g., facial nerve, chorda tympani).

The limitations of the ovine model are as follows: the accentuated bullous hypotympanum as well as lack of the annular ligaments, make performing a tympanoplasty almost impossible, the hardened mastoid bone with lack of pneumatization prevents mastoidectomy training and necessitates a Dremel drill in order to perform a meatoplasty. We should add to this the fact that a validation process of the ovine model has not been extensively performed, so some of our presumptions may be unbased.

Due to these limitations, we are now conducting a rigorous validation study of the ovine training model towards human endoscopic surgery.

In our opinion, our smartphone based endoscopic ear training model is ideal for training both students and residents in otolaryngology everywhere and in particular in LMIC where other endoscopic training opportunities may be limited.

Conclusions

We have demonstrated the feasibility and applicability of an original, reproducible, affordable and easily constructable smartphone-based endoscopic ovine middle ear surgical model in the COVID-19 era. We think that this model may permit both LMIC as well as HIC residents to ameliorate their basic surgical skills locally and without major expenses incurred.

Abbreviations

HIC – high income countries, LIC – low-income countries, TT – tympanostomy tube, COVID-19 – Corona virus disease 2019, TM – tympanic membrane, VR – virtual reality

Declarations

1/ Ethics committee waiver – The Ethics Committee of Assuta Ashdod granted a waiver to this project due to the fact that the ovine heads were obtained from the meat industry.

2/ Consent for publication – Not applicable in this case.

2/ Availability of data and materials – All data generated or analysed during this study are included in this published article [and its supplementary information files].

3/ Competing interests - The authors declare that they have no competing interests.

4/ Funding – No funding was received for this project.

5/ Authors' contribution – All authors have contributed to the manuscript in concept, design, data acquisition, analyzing and writing. The paper has been read and approved for submission by all the named authors.

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Figures

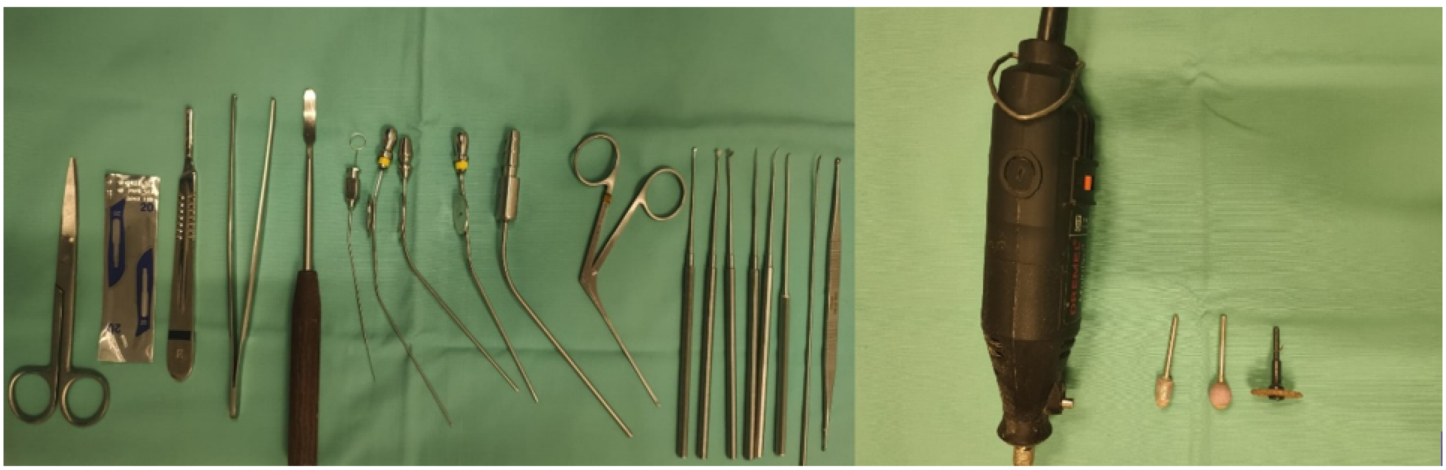

Figure 1

(left to right) Scissors, 20 blade, 20 blade handle, Adson forceps,

Joseph curette, various suction tubes, alligator forceps, round knives, Rosen pick, ear curette, house held Dremel drill with different Dremel burrs

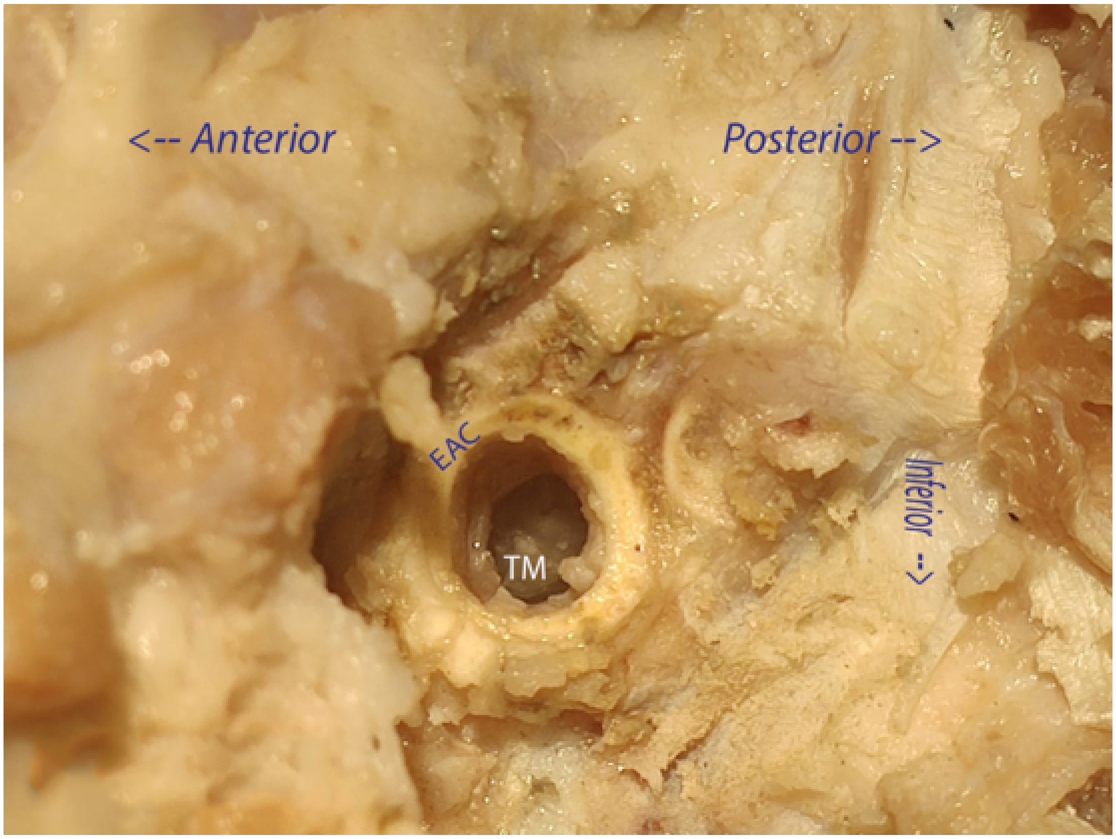

Figure 2

Ovine skull, elongated cartilaginous auditory canal and residual tissue removed, drilling of bony canal with round Dremel burr, tympanic membrane (TM) may be seen and remaining bony external auditory canal (EAC)

Figure 3

Myringotomy and ventilation tube (VT) placement in right TM in anterior inferior quadrant

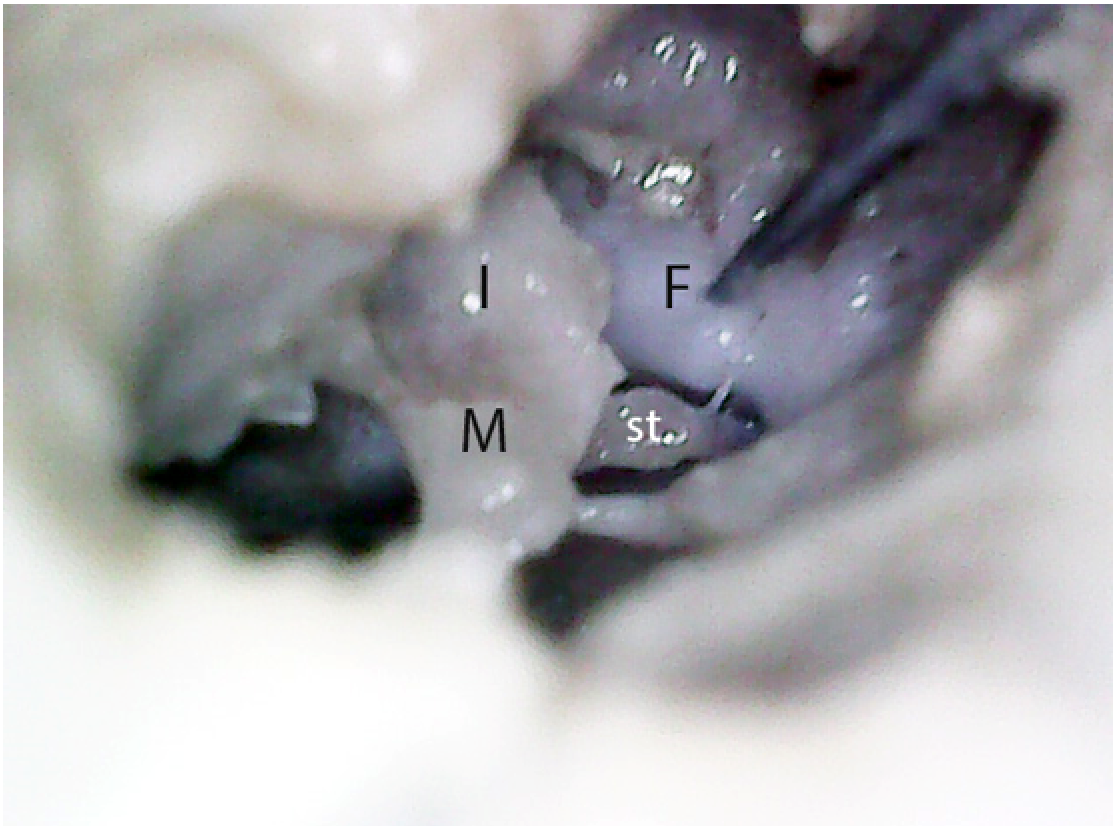

Figure 4

Left middle ear; Malleus head (M), Incus head (I), facial nerve (F) above stapes (st) (incus long process partially removed)

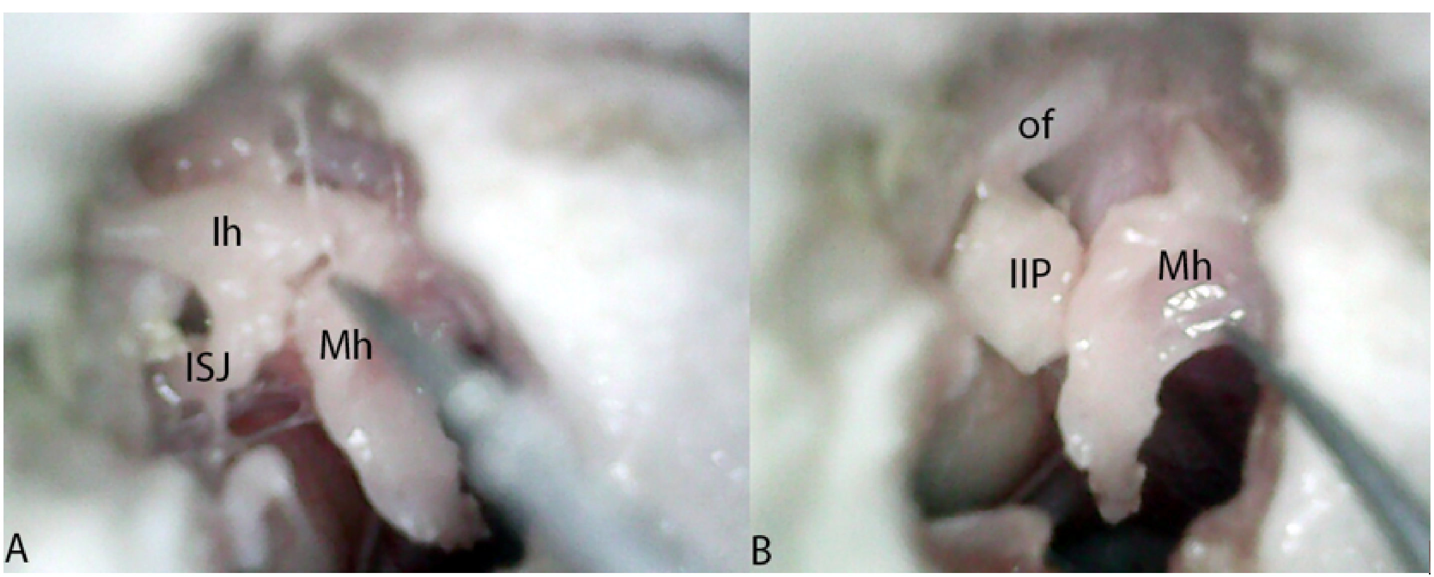

Figure 5

a: Right ear; Ossicle gentile exploration – Incus head (Ih) attachment to malleus head (Mh), incudostapedial joint (ISJ) seen, incumalleolar joint dislocation with subsequent incus remval

b: Incus interposition (IIP) regaining ossicular continuity. Overhanging facial nerve (of) may be seen, malleus head (Mh)

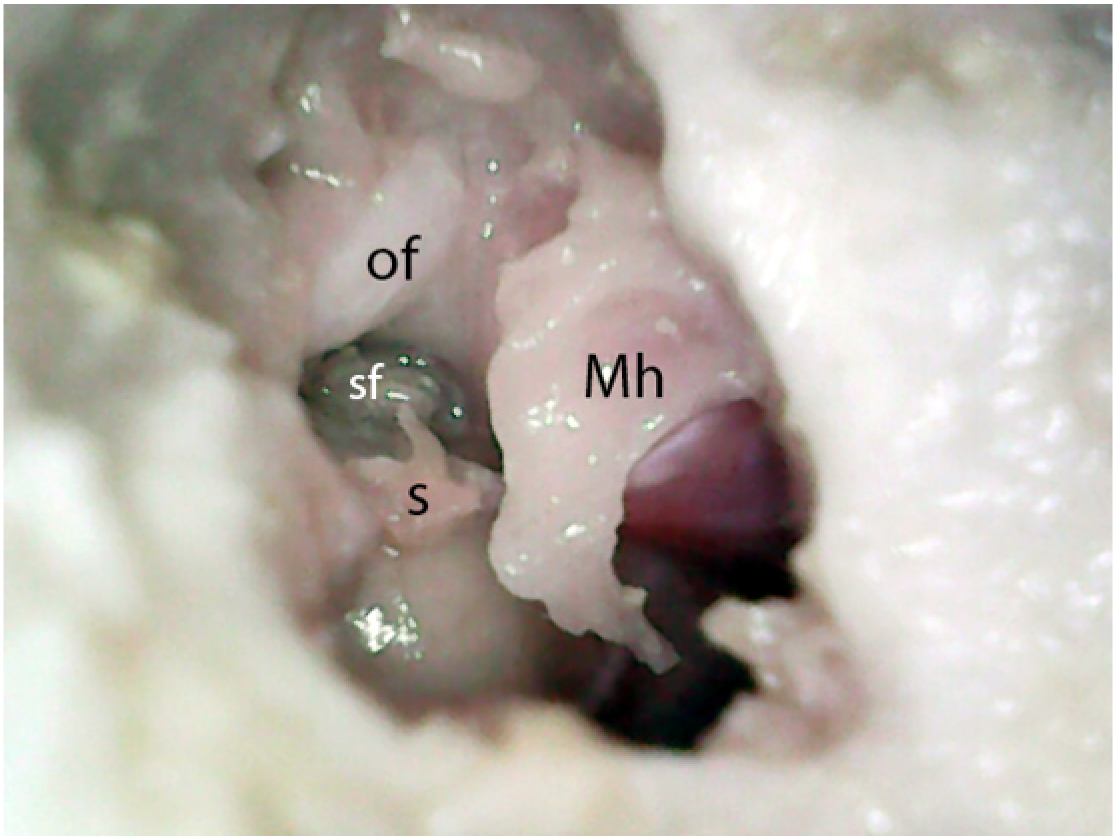

Figure 6

Stapedotomy – Stapes superstructure (s) gently separated at anterior and posterior crura leaving the footplate (sf) in place for later prosthesis placement. Overhanging facial nerve (of), malleus head (Mh)