Teaching Middle-Ear Anatomy and Basic Ear-Surgery Skills: A Qualitative Study Comparing Endoscopic to Microscopic Techniques

Lukas Anschuetz[1], MD; Till Siggemann[1], MD; Cilgia Dür[1], MD; Corinne Dreifuss[2], MSc; Marco Caversaccio[1], MD; Sören Huwendiek[2], MD, PhD, MME

[1] Department of Otorhinolaryngology, Head & Neck Surgery, Inselspital, University Hospital and University of Bern, Bern, Switzerland

[2] Institute for Medical Education, Department for Assessment and Evaluation, University of Bern, Bern, Switzerland

Conflict of Interest: The authors declare that they have no conflicts of interest

Funding: None

Corresponding author: Lukas Anschuetz, MD

Department of Otorhinolaryngology, Head & Neck Surgery, Inselspital, University Hospital and University of Bern, 3010 Bern, Switzerland

Email: anschuetz.lukas@gmail.com, Tel: +41-31-6322654; Fax: +41-31-6324872

Author contributions

Anschuetz: Study design, conduction of interviews and data acquisition, analysis and interpretation of results, manuscript edition and final approval.

Siggemann: Conduction of interviews, data acquisition and analysis, interpretation of results, manuscript edition and final approval.

Dür: Conduction of interviews, data acquisition, critical revision and final approval of manuscript.

Dreifuss: Data acquisition, analysis and interpretation of results, critical revision and final approval of manuscript.

Caversaccio: Study design, analysis and interpretation of results, critical manuscript revision and final approval.

Huwendiek: Study design, analysis and interpretation of results, senior supervision of study, manuscript edition and final approval.

Key words: Endoscopic ear surgery; anatomy; education; surgical skills; qualitative research; focus groups

Abstract

Objective: Endoscopic ear surgery is gaining popularity as a minimally invasive surgical technique for middle ear diseases. Its ongoing implementation into clinical routine has consequences regarding teaching of middle-ear anatomy and ear surgery. To improve undergraduate and postgraduate training, we investigated the perception of and preference for endoscopy compared to microscopy at different educational levels.

Study design: Qualitative study using a thematic analysis approach.

Setting: Tertiary academic medical center.

Methods: After running a standardized curriculum of endoscopic and microscopic anatomy and surgical skills education, five focus groups were held. The interviews were conducted, video-recorded, transcribed, and analyzed. Analysis of the data gave rise to 11 themes, which show the participants' perceptions and preferences.

Results: Five medical students, 11 otorhinolaryngology residents, and three staff members participated in this qualitative study. For anatomy teaching, there was a clear preference for the endoscopic technique. The main advantages were the enhanced overview and perception of the anatomical details provided through endoscopy. For skills acquisition, the perceived advantages of the techniques were: the same view of the surgical field for endoscopy, and the two-handed surgical technique for microscopy. However, there was no clear preference between the techniques for skills acquisition.

Conclusion: The endoscopic technique was generally judged more beneficial for teaching anatomy, especially due to the greater visualization of the complex middle-ear anatomy. Given that both techniques will remain important to future surgeons, the relative unique benefits of each must be considered when designing and optimizing curricula for otologic education.

Introduction

Endoscopic ear surgery is gaining popularity as a minimally invasive alternative to the microscopic approach to surgery of the middle ear. Its clinical applicability either as exclusive or as an adjunct, relates to the full spectrum of otology and lateral skull-base surgery.[1-6] The ongoing implementation of this technique in clinical routine has *inter alia* consequences for the teaching of middle-ear anatomy and ear surgery skills to medical students, otorhinolaryngology (ORL) residents, and fellows.

Recently, the endoscopic and microscopic techniques were compared in terms of their impact on teaching middle-ear anatomy.[7] In this study, endoscopy provided significantly improved gains in anatomical knowledge compared to microscopy. In another study, a direct comparison between endoscopic and microscopic techniques for learning basic ear-surgery skills revealed similar operating times for each technique. However, accidental damage to the ossicular chain during the dissection and grasping tasks was significantly less of a problem for the students and residents when using endoscopy.[8]

However, the question of why endoscopy offers these advantages despite its associated limitations, such as the one-handed surgical technique and the lack of depth perception,[9] remains a matter of debate. A qualitative investigation of the features of both of these techniques and their comparisons is still lacking. With a view to improving as best as possible the training regarding anatomy teaching and surgical skills acquisition of medical students, ORL residents, and fellows, we investigated the perception of and preference for endoscopy compared to microscopy, and the reasons behind these.

Methods

Design

Qualitative methods in which participants discuss an issue in small groups facilitated by a moderator, such as focus group studies, are especially suitable to capture participant experiences, and also for addressing important 'why questions'.[10] Interviewing participants in groups rather than individually fosters a safe environment and encourages in-depth discussion. We therefore used focus groups for data generation, which then result in verbatim transcripts. The overall approach we used is constructivist thematic analysis.[11] Thematic analysis is a pragmatic approach to qualitative analysis that involves the search for themes within a database - in this case the transcripts of the focus groups. Thematic analysis can be adapted to the specific requirements of a particular study, as it is theoretically flexible.[11] The constructivist approach implies that the results are interpretations that are created through the interactions and shared experiences of research participants, researchers and data.

The local Ethical Committee (Kantonale Ethikkomission Bern) reviewed the study protocol and granted permission (KEK-BE ID REQ-2018-00310). All participants gave their informed consent to participate in the study, and received no financial incentive.

Setting

At our tertiary academic teaching hospital, a curriculum on middle-ear anatomy teaching and basic surgical skills acquisition was conducted using Peyton's four-step approach[12]. The participants included final year medical students during their clinical ORL training, ORL residents, and members of staff from the ORL Department. They

were randomized into two groups, with the first starting with endoscopy and the second starting with microscopy. After completion of the first technique, the groups were crossed-over and underwent the same curriculum using the other technique. Anatomical knowledge was assessed using a structured questionnaire and anatomy teaching was performed in a one-to one setting on cadaveric whole-head specimens by an experienced tutor following a predefined curriculum. Thereafter, basic ear surgery skills were taught, with the time required to fulfill the grasping and dissection tasks was recorded, along with any damage to the ossicular chain. In this way, all of the participants gained experience of both the endoscopic and microscopic techniques. The detailed protocols used and the quantitative results can be found in the relevant publications.[7,8]

Participants

Following the education curriculum, 19 participants volunteered to participate in these focus group interviews. Five focus groups of 3-4 participants were conducted. Three groups included sixth-year medical students and ORL residents, one included ORL residents only, and one included staff members only. Nine of the participants were women (47%), and the mean age was 33 years (range, 26-43 years).

Data collection

The focus groups were held separately and defined per educational level (students, residents, members of staff), to foster open discussion. The sessions took place on different days, and each was moderated by one of two authors (LA, CiD). Consistency across focus groups was ensured by using a questioning route that contained the main questions and discussion probes (Table 1).[13] Particular emphasis was put on different opinions and views, and on promoting in-depth discussions.

Open-ended questions started the discussion, and the moderator searched for clarification where necessary. Further, the moderator encouraged all of the participants to contribute. We intentionally included different educational levels, as this allows consideration of all educational levels and supports the credibility of the study by data triangulation.[14] We experienced saturation of ideas in the 5th session.

Data analysis

According to the guidelines for thematic analysis, one author (TS) transcribed and initially read all of the transcripts to identify and highlight preliminary themes.[10] Next, all of the authors went through an iterative process together to establish the main themes. This continued until they had reached consensus across the whole research team. They not only paid particular attention to how frequent an opinion was expressed, but also to how extensive it was across the groups. The main focus here was thus to represent the range of views as closely as possible.[13]

Additionally, from the results, the author team developed implications regarding relevant clinical and educational implications.

Results

The initial analysis of the data resulted in 11 themes, which showed the participant perception and preference for endoscopy compared to microscopy as an overall technique. These themes were divided into '*Impact on learning and teaching of anatomy*' (themes A1-A5), and '*Impact on basic surgical skills acquisition*' (themes S1-S6). Representative citations from the interviews for each theme are reported in Tables 2 and 3.

Impact on learning and teaching of anatomy

Five themes were identified, with three related to visualization, one to handling, and one to overall preference. The main results are illustrated in Figure 1.

Theme A1: The 'overview of the middle ear' was central to learning its anatomy, and an advantage of endoscopy

There was strong agreement among the participants from all educational levels that the visualization offered by endoscopy was particularly beneficial to learning about middle-ear anatomy. The main difference was that the trainee could see the whole middle ear in endoscopic wide-angle views, compared to the sectional views offered by microscopy. Moreover, all of the participants perceived that the dynamic endoscopic exploration was superior to the more static microscopic technique, especially in the 'hidden areas' of the middle ear. However, some medical students and residents reported improved orientation using the microscopy set-up.

Theme A2: 'Perception of anatomical details' was perceived as superior with the endoscopic technique

There was strong agreement among the participants regarding the superiority of endoscopy for the anatomical details. Moreover, the resident's groups in particular emphasized that recognizability of the structures was improved using endoscopy.

Theme A3: An advantage in microscopy was the 'depth of field'

The depth of field offered by microscopy was considered superior by many participants, compared to the two-dimensional (2D) vision of endoscopy. However, the medical students and residents perceived that the enhanced endoscopic topography offered comprehensive understanding, which was more important for

learning anatomy than the depth of perception. The discussion in the group of staff members was controversial, with emphasis on the need for training and experience in both of these techniques to be able to correctly judge distances.

Theme A4: The 'handling of the visualization tool' was important for optimal learning performance, especially for beginners, and was easier with the microscope

An association between the handling of the endoscope and the microscope, and the learning performance was observed by the majority of the participants. Residents reported more ease in the handling of the microscope, as they were used to this from clinical practice. The image stability offered by microscopy was perceived positively by the inexperienced students and residents. However, the majority of the students and residents agreed on the improvement of this issue with experience. Accordingly, image stability was not an issue among the staff members. The necessity to frequently change the position of the microscope to see the different regions was perceived as a drawback of this technique.

Theme A5: General 'preference' for the endoscope for learning and teaching anatomy

There was a strong preference of the participants in favor of the endoscopic technique for learning and teaching middle-ear anatomy, mainly because of the possibility for better visualization of the complex anatomy.

Impact on basic surgical skills acquisition

Six themes were identified, where three were related to handling, and three to the same view of the surgical field, the learning curve, and the overall preference. The main results are illustrated in Figure 2.

Theme S1: The 'two-handed surgical technique' was an advantage for the microscopic approach in middle-ear surgical skills acquisition

In contrast to the endoscopic technique, the microscopic approach offered the opportunity to use a two-handed technique, which was perceived as an advantage for surgical skills. There was strong agreement on this topic among the staff members in particular. Similarly, the students and residents largely agreed on this theme; however, they also emphasized the necessity for a learning curve for the two-handed technique.

Theme S2: The visualization tool manipulation was advantageous for microscopy, particularly for the 'impact on safety'

The inexperienced participants reported an increased cognitive load using an endoscope, as the camera had to be guided along a narrow space without touching important structures, such as the ossicular chain. The residents in particular discussed the safety issues due to inappropriate manipulation of the endoscope. The skills of the camera guidance were identified as important issues by the residents. Controversially, there was strong agreement among the staff members (and one resident) regarding the more intuitive handling of the endoscopic technique, and its advantage for the acquisition of surgical skills.

Theme S3: 'Speed of task execution' was not related to the technique

There was strong agreement among all of the participants that the speed of the task execution was not related to the technique used, but to the difficulties inherent to the task and to their previous experience.

Theme S4: The endoscopic technique was clearly superior concerning the 'same view of the surgical field' by the trainee and the teacher

All of the participants agreed that the quality of the view of the surgical field has a central role in the learning of surgical skills. In this context, there was consensus in favor of the endoscopic technique, where the trainee and the teacher have the same view on the monitor. Moreover, the explanations given by the teachers were easier to follow in the endoscopy setting. Similarly, the staff members indicated that the endoscopic technique was ideal for teaching the residents.

Theme S5: The 'learning curve' is similar for both techniques

According to the participants, neither of the two techniques was necessarily learned faster. In the opinion of most of the participants, this issue also depended on previous knowledge and experience, such as of functional endoscopic sinus surgery. The staff members agreed that the learning curve should not been divided between one or the other technique, as both tools might be used for ear surgery. They advocated concomitant learning of both techniques during residency and fellowships.

Theme S6: No general 'preference' for either tool regarding the acquisition of basic ear surgery skills

There was no agreement between the participants concerning a general preference for either tool for acquisition of basic ear surgical skills and for future surgery. While the inexperienced would tend to start ear surgery with the microscope due to safety concerns (e.g., damage to structures, management of bleeding), the experienced residents and staff members emphasized the duality of both techniques for future ear surgery, because each of the two have their strengths and limitations.

Discussion

This study examined participant perception of, and preference for, endoscopy compared to microscopy for middle-ear surgery, and included the reasoning behind these. For anatomy teaching, there was a clear preference for the endoscopic technique. The main advantages were the enhanced overview and perception of the anatomical details provided through endoscopy. For skills acquisition, the perceived advantages of the techniques were: same view of the surgical field for endoscopy, and two-handed surgical technique for microscopy. However, there was no clear preference between the techniques for skills acquisition. Moreover, clinical and educational implications were collected, and are summarized in Table 4.

Learning and teaching anatomy

A relevant advantage of endoscopy compared to microscopy for learning middle ear anatomy is the better overview using wide-angle views (*Theme A1*).[15] This is particularly the case if angled scopes are used, which allow significantly more insight into difficult-to-visualize areas of the middle ear.[16,17] Furthermore, the results show that recognition of anatomical details endoscopically is beneficial for all participants (*Theme A2*). A recent study reported that the main advantage was having a close-up view without losing illumination. [18]

Although microscopy allows a 3D view compared to 2D endoscopy, medical students and ORL residents evaluated the endoscopic technique as advantageous in this respect. The reason was their improved topographical knowledge of middle ear anatomy, which enhanced understanding of the distances between structures (*Theme A3*). Nevertheless, a true 3D view should not be disregarded, especially when it comes to surgery. Indeed, traditional 2D and modern 3D endoscopic techniques have recently been compared for surgeons performing endoscopic ear

surgery.[9,19] Here, 3D endoscopy was shown to be suitable for endoscopic ear surgery and to have advantages, especially for less experienced surgeons. Taken together, the advantages of the endoscopic view and dissection of the middle ear appear to be superior to the microscopic technique (*Theme A5*). These subjective perceptions are in line with the quantitative results, which described significantly higher gain in anatomical knowledge compared to the microscopic technique, independent of the participant educational level.[7] Therefore, the use of endoscopes in the curricula of undergraduate and postgraduate training related to middle-ear anatomy can generally be advocated (Table 4).

Basic surgical skills acquisition

The inexperienced participants in the present study expressed safety concerns in the acquisition of basic-ear surgery skills with the endoscopic tool (*Theme S2*). However, from a clinical side, several recent studies have revealed no safety concerns regarding endoscopic ear surgery.[20-22] Interestingly, among the inexperienced participants in the present study, the safety concerns mentioned above (*Theme S2*) regarding the endoscopic approach do not match the quantitative results of the curriculum.[8] Indeed, there was significant increase in damage to the ossicular chain for the students and residents with the microscopic technique, as compared to endoscopy. This contrast between subjective perception and objective damage might be best explained by the improved view of the structures and the manipulations using endoscopy. During the microscopic dissection, the inexperienced participants in this study might have ignored the damage to the ossicles, as they might not have been aware of it.

Another key finding was that the speed at which these tasks were performed did not depend on the technique used (*Theme S3*). This is in line with a quantitative

assessment that defined similar operative times for each technique, which greatly depended on training status.[8] However, several studies have suggested that the endoscopic technique might be completed more rapidly than the microscopic technique for various operations.[21-23] This might have arisen from several reasons, which will range from the extent of disease to the surgical approach itself (e.g., transcanal vs. retroauricular), and its interpretation might be limited, especially if the kind of pathology requires extensive bone removal.

According to the participants, their view on the steps performed by either the teacher or the trainee has a very important role, and the endoscopic technique was clearly superior (*Theme S4*). As the teacher and the trainees have the same view during the instruction and the consecutive dissection by the trainee, direct implementation of the dissection steps is improved using endoscopy compared to microscopy.[18] Moreover, it has been reported that the learning curves for the two techniques are comparable.[24-27] This was also the opinion of the participants in this study (*Theme S5*), who indicated that the learning curve depends on previous knowledge and experience.

In terms of future training for surgical skills (*Theme S6*), the participants in this study expressed no general preference for either of the two techniques. Interestingly, from the subjective feedback collected directly after the teaching curriculum, there was preference toward the endoscopic approach.[8] This might be related to the need for the microscopic technique during various otologic operations that require bone removal (e.g., mastoidectomy, cochlear implants), and it emphasizes the need for dedicated learning of both of these techniques to cover the full spectrum of otology. Indeed, we can consider that parallel implementation of both techniques into clinical routine might be beneficial, as the thorough understanding of middle-ear anatomy

offered by endoscopy might also improve the learning curve (*Theme S5*) even during microscopic approaches.

The present study has limitations, as it involved participants from one institution, where the endoscopic approach has an important role. To gain an even clearer picture, further studies that include participants from other institutions would thus be helpful. Moreover, the sample size is limited, and with the third session of residents and students we observed saturation of ideas, which indicated good validity for the residents and students' perceptions. However, for the staff members, more participants and groups would have been suitable.

Conclusions

Both the endoscopic and microscopic techniques have advantages for learning and teaching middle-ear anatomy and for basic ear-surgery skills acquisition. The endoscopic technique was judged to be generally more beneficial for teaching anatomy, especially due to the superior visualization of the complex middle-ear anatomy. However, the duality of both techniques is important for future ear surgery, which needs to be considered in the setting-up of efficient curricula for improved education in otology.

Acknowledgements

The authors wish to acknowledge Gianni Pauciello for the professional editing of the figures.

References

1. Dähn J, Anschuetz L, Konishi M, Sayles M, Caversaccio M, Dubach P. Endoscopic ear surgery for external auditory canal. Otol Neurotol. 2017;38(5):e34-e40. doi:10.1097/MAO.0000000000001386
2. Marchioni D, Gazzini L, De Rossi S, et al. The management of tympanic membrane perforation with endoscopic type I tympanoplasty. Otol Neurotol. 2020;41(2):214-221.
3. Presutti L, Anschuetz L, Rubini A, et al. The impact of the transcanal endoscopic approach and mastoid preservation on recurrence of primary acquired attic cholesteatoma. Otol Neurotol. 2018;39(4):445-450.
4. Fernandez IJ, Bonali M, Fermi M, Ghirelli M, Villari D, Presutti L. The role of endoscopic stapes surgery in difficult oval window niche anatomy. Eur Arch Otorhinolaryngol. 2019;276(7):1897-1905.
5. Presutti L, Alicandri-Ciufelli M, Bonali M, et al. Expanded transcanal transpromontorial approach to the internal auditory canal: pilot clinical experience. Laryngoscope. 2017;127(11):2608-2614.
6. Yacoub A, Wimmer W, Molinari G, et al. Transcanal transpromontorial approach to lateral skull base: maximal area of exposure and surgical extensions. World Neurosurg. 2020;135:e181-e186. doi: 10.1016/j.wneu.2019.11.102.
7. Anschuetz L, Huwendiek S, Stricker D, Yacoub A, Wimmer W, Caversaccio M. Assessment of middle ear anatomy teaching methodologies using microscopy versus endoscopy: a randomized comparative study. Anat Sci Educ. 2019;12(5):507-517.
8. Anschuetz L, Stricker D, Yacoub A, Wimmer W, Caversaccio M, Huwendiek S. Acquisition of basic ear surgery skills: a randomized comparison between endoscopic and microscopic techniques. BMC Med Educ. 2019;19(1):357.

9. Anschuetz L, Niederhauser L, Wimmer W, et al. Comparison of 3- vs 2-dimensional endoscopy using eye tracking and assessment of cognitive load among surgeons performing endoscopic ear surgery. JAMA Otolaryngol Head Neck Surg. 2019 Jul 25. doi: 10.1001/jamaoto.2019.1765. [Epub ahead of print]
10. Barbour RS. Making sense of focus groups. Med Educ 2005 Jul;39(7):742-50.
11. Kiger ME, Varpio L. Thematic analysis of qualitative data: AMEE Guide No. 131. Med Teach. 2020 Aug;42(8):846-854.
12. Peyton JWR. Teaching and learning in medical practice. Manticore Europe; 1998.
13. Krueger RA, Casey MA (2014): Focus groups: a practical guide for applied research. 5th ed. London: Sage Publications, Inc.
14. Frambach JM, van der Vleuten CP, Durning SJ. AM last page. Quality criteria in qualitative and quantitative research. Acad Med. 2013 Apr;88(4):552.
15. Bennett ML, Zhang D, Labadie RF, Noble JH. Comparison of middle ear visualization with endoscopy and microscopy. Otol Neurotol. 2016;37(4):362-366. doi:10.1097/MAO.0000000000000988
16. Bonali M, Fermi M, Alicandri-Ciufelli M, et al. Prediction of endoscopic middle ear visibility in relation to the anatomy and the optical angle: implications for endoscopic ear surgery. Otol Neurotol. March 2020 (in press)
17. Furukawa T, Watanabe T, Ito T, Kubota T, Kakehata S. Feasibility and advantages of transcanal endoscopic myringoplasty. Otol Neurotol. 2014;35(4):e140-e145. doi:10.1097/MAO.0000000000000298.
18. Anschuetz L, Presutti L, Marchioni D, et al. Discovering middle ear anatomy by transcanal endoscopic ear surgery: a dissection manual. J Vis Exp. 2018;(131):56390. doi:10.3791/56390

19. Molinari G, Ragonesi T, Hool SL, et al. Surgical implications of 3D vs 2D endoscopic ear surgery: a case-control study. Eur Arch Otorhinolaryngol. 2020. https://doi.org/10.1007/s00405-020-06040-5
20. Botti C, Fermi M, Amorosa L, et al. Cochlear function after type-1 tympanoplasty: endoscopic *versus* microscopic approach, a comparative study. Eur Arch Otorhinolaryngol. 2019;277(2):361-366.
21. Kaya I, Sezgin B, Sergin D, et al. Endoscopic *versus* microscopic type 1 tympanoplasty in the same patients: a prospective randomized controlled trial. Eur Arch Otorhinolaryngol. 2017;274(9):3343-3349.
22. Manna S, Kaul VF, Gray ML, Wanna GB. Endoscopic *versus* microscopic middle ear surgery. Otol Neurotol. 2019;40(8):983-993.
23. Hsu Y-C, Kuo C-L, Huang T-C. A retrospective comparative study of endoscopic and microscopic tympanoplasty. J Otolaryngol - Head Neck Surg. 2018;47(1):44.
24. Doğan S, Bayraktar C. Endoscopic tympanoplasty: learning curve for a surgeon already trained in microscopic tympanoplasty. Eur Arch Otorhinolaryngol. 2016;274(4):1853-1858.
25. Li B, Asche S, Yang R, Yueh B, Fina M. Outcomes of adopting endoscopic tympanoplasty in an academic teaching hospital. Ann Otol Rhinol Laryngol. 2019;128(6):548-555.
26. Liu C-Y, Yu EC-H, Shiao A-S, Wang M-C. Learning curve of tympanoplasty type I. Auris Nasus Larynx. 2009;36(1):26-29.
27. Tseng C-C, Lai M-T, Wu C-C, Yuan S-P, Ding Y-F. Learning curve for endoscopic tympanoplasty: initial experience of 221 procedures. J Chin Med Assoc. 2017;80(8):508-514.

Tables

Table 1. Questioning route used by the moderator in guiding the focus group interviews.

• How did you experience the courses overall?
• How do you rate your knowledge of anatomy? • What is the best way to learn anatomy? • In your opinion, what are the differences in learning anatomy comparing endoscopy/ microscopy, and why? • What are the advantages of the respective techniques? • What should an anatomy course ideally look like? • Which tool would you prefer for learning middle-ear anatomy in the future, and why?
• How is the handling of the endoscope compared to the microscope for performing basic surgical procedures, and why? • Do you see an advantage for teaching in the endoscopic technique? • Which tool would you prefer for ear interventions in the future, and why? • What would be the requirements for you to trust yourself with such an intervention?

Table 2. Exemplary citations from the focus groups on the impacts on learning and teaching anatomy. MS, medical student; OR, ORL resident; OS, ORL staff member. Numbers indicate focus group and participant number.

Theme	Exemplary citations
Theme A1: The overview of the middle ear was central to learning its anatomy, and an advantage of endoscopy	*"I think the main advantage of the endoscope is the panoramic view. That you just have the wide-angle view, in the middle ear."* (OS 5.3) *"You can look around more dynamically. You can't easily look around with a microscope, and therefore better with the endoscope."* (OR 2.1)
Theme A2: Perception of anatomical details was perceived as superior with the endoscopic technique	*"I think, that if you look at the individual structures and have to learn, then I think with the endoscope it was easier for me."* (MS 4.1) *"If you know where you are, what you're looking at, you see a lot more details with an endoscope and you're in it."* (OR 3.3)
Theme A3: An advantage in microscopy was the depth of field	*"With the microscope not everything is equally sharp, but rather with the endoscope and that is of course an incredible advantage."* (OR 4.4) *"I think no matter if you use a microscope or an endoscope, you have to calibrate your arm movements. You have to learn that with the microscope and with the endoscope. How fast can I push my endoscope forward, how far."* (OS 5.1)
Theme A4: The handling of the visualization tool was important for optimal learning performance, especially for beginners, and was easier with the microscope	*"It is like a picture with the microscope, a stable picture. I mean with the endoscopy you have to be practiced, it is also much more dynamic. I think the microscopic picture is then more like a textbook, like a normal picture."* (MS 1.4) *"The microscope was easier right from the start, because I'm more used to it and with the endoscope, that takes practice, that you can see everything exactly."* (OR 4.3)
Theme A5: General preference for the endoscope for learning and teaching anatomy	*"It is more dynamic and I also think that you see more with an endoscope. If you use a microscope, you just keep this view and then you always have to change it. I think the endoscope is better."* (MS 2.3) *"The endoscope can help you a lot, especially in the early stages. I think it is really important for the anatomy teaching."* (OS 5.2) *"I'd say for teaching purposes, I think the endoscope is better. Because simply the whole middle ear is seen. I think it is an enrichment if you have the possibility to show anatomy like that."* (OS 5.2)

Table 3. Exemplary citations from the focus groups on the impacts on basic surgical skills acquisition**.** MS, medical student; OR, ORL resident; OS, ORL staff member. Numbers indicate focus group and participant number

Theme	Exemplary citations
Theme S1: The two-handed surgical technique was an advantage for the microscopic approach in middle-ear surgical skills acquisition	*"The advantage for surgery is if it bleeds, then you are lucky if you have two hands to operate." (OR 1.3)* *"Depending on how difficult the task is, it might take a bit more practice to do it one-handed than two-handed. But it also depends on how it is taught. If it's taught directly endoscopically, you might not recognize anything else. Like in the nose it is the most normal thing in the world and if you've never done it with one hand and always learned two-handed, then it's tedious." (OS 5.1)*
Theme S2: The visualization tool manipulation was advantageous for microscopy, particularly for the impact on safety	*"The disadvantage is to hold the endoscope in your hand. And that's relatively difficult at first. You have to get a little bit of feeling first, and that you only have to move a little bit and always adjust it, back and forth, orientate on the screen. And with the microscope I look straight down." (OR 3.4)* *"I can imagine, if it were a real ear, that the endoscope might be slower. Because if now at the cadaver, if I bump into something, it is not so bad. What I was most afraid of, if I go out and change the instrument, I rush right into the ossicles with the endoscope." (OR 1.2)*
Theme S3: Speed of task execution was not related to the technique	*"With the endoscope it's much faster because it's dynamic. You don't have to reposition the microscope every time."* (OR 3.3) *"With the microscope, because you are more used to it and because you can work with two hands."* (OR 3.1) *"I think it is certainly depending on the task and the level of training."* (OS 5.1)
Theme S4: The endoscopic technique was clearly superior concerning the same view of the surgical field by the trainee and the teacher	*"It is more beautiful endoscopically, if both can look at the picture at the same time. In this way I know exactly which task the teacher means."* (MS 2.4) *"I think it's easier with the screen, especially the interaction with the teacher is much easier with the endoscope."* (OR 4.4) *"The advantage of the endoscope is that everyone sees the same thing. If you sit next to it, as an instructor, then you can perfectly supervise your pupil."* (OS 5.3)

Theme S5: The learning curve is similar for both techniques	*"I think the learning curve with the endoscope is steeper."* (MS 4.2) *"I also think, purely from a technical point of view, I don't think that it matters, if you have the same amount of practice with both."* (OR 4.3)
Theme S6: No general preference for either tool regarding the acquisition of basic ear surgery skills	*"I would of course prefer the endoscope, simply because I see better."* (OS 5.3) *"The microscope is often the plan B, because you have two hands and you can drill. Ear surgery will never be purely endoscopic. I think there will always be both methods, because each has its strengths and limitations."* (OS 5.1)

Table 4: Possible clinical and educational implications regarding middle ear anatomy teaching and basic surgical skills acquisition.

Middle ear anatomy learning and teaching
• Use the endoscope during anatomy curricula during medical school and demonstrations should be performed by an experienced teacher • Use the endoscope during cadaveric dissection courses to demonstrate the anatomy • The assessment of anatomy during difficult cases (e.g. revision surgery, malformation of ossicles) can be facilitated by using an endoscope. • For teaching activities actual depth perception may play a subordinate role. • Combine techniques, where the perception of depth is important to gain experience. • Use endoscopes from the start of postgraduate education (e.g. in outpatient clinics) to facilitate its implication during more complex tasks.
Basic surgical skills acquisition
• Combine endoscopic and microscopic dissection during post-graduate education to cover the full spectrum of otology. • Management of bleeding may be crucial and its management particularly important in the endoscopic technique. • Provide tight supervision for first endoscopic otology cases of residents to ensure patient's safety. • Start with easier tasks, e.g. in the external auditory canal before stepping forward into the middle ear. • Use the endoscope for teaching activities whenever possible, maybe as additional step for demonstration purposes. • Technical versatility allows for best results with regards to the learning curve. • Combine both tools during surgical education.

Figure legends

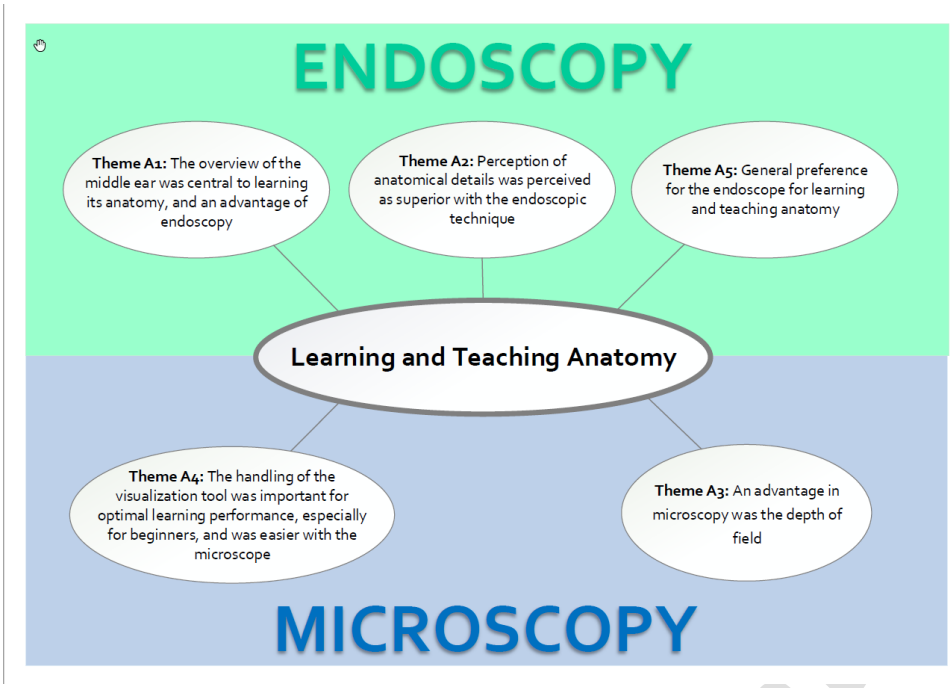

Figure 1

Illustration of the advantages and general preferences for learning and teaching anatomy, according to the five themes (A1-A5). Top: Advantages of endoscopy. Bottom: Advantages of microscopy. Middle: No preference.

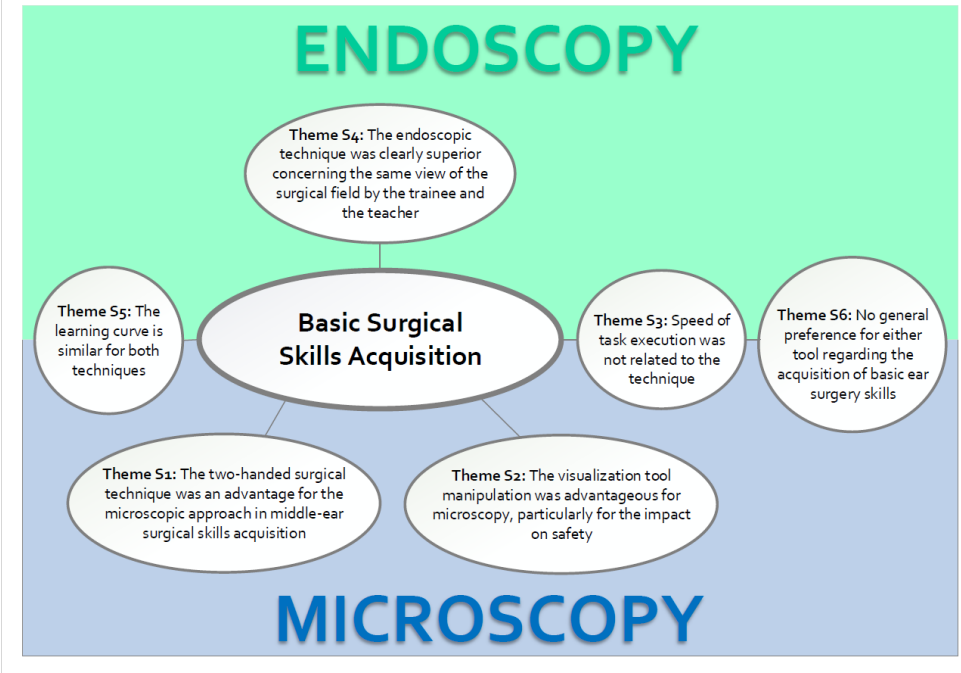

Figure 2

Illustration of the advantages and general preferences for acquiring ear-surgery skills, according to the six themes (S1-S6). Top: Advantages of endoscopy. Bottom: Advantages of microscopy. Middle: No preference.