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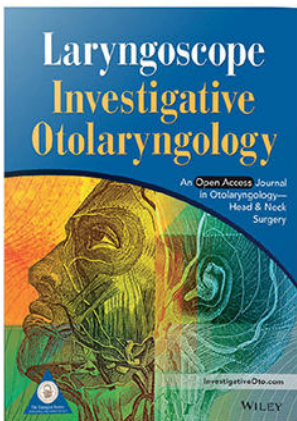


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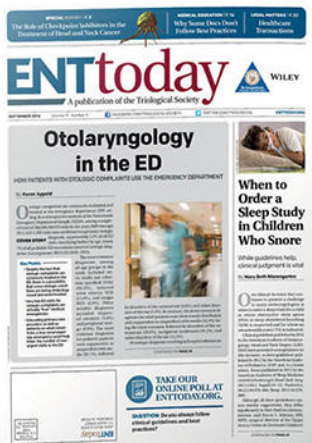
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Endoscopic Versus Microscopic Stapes Surgery Outcomes: A Meta-analysis and Systematic Review

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Objective: Compare intraoperative and postoperative outcomes of endoscopic and microscopic stapes surgery to provide objective evidence on whether the former is a better alternative than the latter.

Methods: We performed a systematic review and meta-analysis for studies that compared endoscopic stapes surgery with microscopic stapes surgery. Only studies that met predetermined criteria were selected and assessed for bias and quality. Primary outcomes were postoperative air–bone gap (ABG) and chorda tympani nerve injury. Secondary outcomes were average operating time, tympanic membrane (TM) perforation, and postoperative taste disturbance, pain, and dizziness. We calculated pooled odds ratios (ORs) with 95% confidence intervals (CIs) for dichotomous outcomes and weighted mean difference (WMD) with 95% CI for continuous outcomes. A confidence interval starting above 1.0 was considered as statistically significant. I^2 and χ^2 tests were used to quantify statistical heterogeneity. We used funnel plots to look for publication bias and performed a sensitivity analysis.

Results: Six nonrandomized cohort studies were eligible. The primary outcomes were ABG < 10 dB: OR = 1.80 (95% CI: 0.96 to 3.38), ABG = 11 dB to 20 dB: OR = 1.49 (95% CI: 0.76 to 2.93), ABG > 20 dB: OR = 2.51 (95% CI: 0.77 to 8.22), and chorda tympani injury: OR = 3.51 (95% CI: 1.55 to 7.93). Secondary outcomes were taste: OR = 2.36 (95% CI: 1.01 to 5.51), average operation time: WMD = 0.14 (95% CI: –11.69 to 11.98), TM perforation: OR = 1.70 (95% CI: 0.44 to 6.58); pain: OR = 0.84 (95% CI: 0.36 to 1.96), and dizziness: OR = 2.15 (95% CI: 0.94 to 4.89).

Conclusions: Endoscopic stapes surgery is a valid alternative to the microscope.

Key Words: Endoscopic, microscopic, stapedotomy, stapedectomy, otosclerosis.

Level of Evidence: 2a

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INTRODUCTION

The microscope is the conventional method used by ear surgeons to view the middle ear structures, allowing for binocular vision and the freedom of both hands. Its main disadvantage is the need for an unobstructed, direct view of the operating area.¹ The endaural incision, drilling of the bony auditory canal, and regular repositioning of the patient and the surgeon are a few examples of how the operation has to adapt to the microscope. Nevertheless, the microscope has proven itself as the tool of choice in stapes surgery with reliable outcomes.²

In contrast, the endoscope has only recently been introduced as an alternative viewing apparatus for middle ear surgery. Since its beginnings more than 50 years ago, it has become the modern way to visualize middle ear structures, gradually making its way into the surgical realm.^{3,4} Initially, its use was limited as an adjuvant tool to improve detection in cholesteatoma surgery and in endoscopically assisted ear surgery.^{5–9} Soon, surgeons realized that it can be used to replace the microscope entirely for certain operations such as stapes surgery, with outcomes comparable to the microscopes.¹⁰ The endoscope can

offer a close-up view of the stapes footplate, with minimal drilling of the external auditory canal and reduced manipulation of the chorda tympani nerve.^{11–13} The magnified, wide-field view and the improved illumination provide a safer manipulation of the stapes superstructure, the footplate, and the chorda tympani. In their study, Bennett et al. concluded that all of the regions of the middle ear have better visualization by the endoscope (0°, 30°, and 45°) compared to the microscope.¹⁴ However, the endoscope is not without its drawbacks, which include the loss of three-dimensional vision and the use of one hand, resulting in surgeons being reluctant to change from the microscope because of a possible long learning curve.^{1,15} It has also been reported anecdotally that heat emanating from the light of the endoscope can also injure the chorda tympani nerve, and the loss depth perception can impact the choice of prosthesis length and thus hearing outcomes. Irrigation is therefore paramount with both techniques.

Recently, there has been a number of publications comparing the two modalities and only one review, but no meta-analysis that attempted to collect all evidence on the field.¹⁶ Therefore, we decided to systematically review the literature for studies that compared endoscopic with microscopic stapes surgery to perform a meta-analysis to test our hypothesis: endoscopy performs better than microscopy.

MATERIALS AND METHODS

This meta-analysis adheres to Preferred Reporting Items for Systematic Reviews and Meta-analysis guidelines and was registered onto the PROSPERO under the registration number CRD42018095617.¹⁷

Search Query

A search was performed in the PubMed, Embase, Cochrane, Web of Science, ClinicalTrials, World Health Organization, and Scopus databases from inception up to June 6, 2018. Our search query was the combination of free text terms and Medical Subject Headings as follows: (endoscop* OR microscop* OR conventional OR traditional) AND (stapedotomy OR stapedectomy OR stapes OR otosclerosis). Cited and citing articles or relevant papers were hand searched to ensure the detection of all available records.

Selection and Eligibility

Yield of search was compiled in reference manager software (EndNote 7.4; Clarivate Analytics, Philadelphia, PA, USA) to remove overlaps between databases and duplicate records. Remaining records were selected by title, abstract, and full text by two authors in duplicate (A.K. and I.T.). If an agreement could not be reached, the dispute was resolved with the help of a third investigator (P.R.). We chose studies whose populations were patients suffering from conductive hearing loss due to stapes fixation and undergoing stapes surgery, which was carried out either with the endoscope or the microscope, and recorded intraoperative and/or postoperative outcomes.¹⁸ Only controlled studies were included. Primary outcomes were the average postoperative air–bone gap (ABG) and injury to the chorda tympani nerve. Secondary outcomes were the average operating times, intraoperative tympanic membrane (TM) perforation, and postoperative complications of taste disturbance, pain, and dizziness. We searched for observational and experimental (randomized and nonrandomized) controlled studies. Case

reports, case series, letters, editorials, comments, and review articles were excluded, as well as conference abstracts.

Data Extraction

Our review team registered the collected data onto a predefined Excel (Microsoft, Redmond, WA) table. Two independent authors collected the data (A.K. and I.T.), and the table was reviewed by a third author (P.R.). We collected data for the primary outcomes and several secondary outcomes but only analyzed those reported by at least three studies.

Study Quality Assessment

The quality of the studies was also independently assessed by two authors (A.K. and I.T.) according to the Newcastle-Ottawa Scale for cohorts, a validated quality assessment instrument for nonrandomized trials, which consists of three domains of quality: selection, comparability, and exposure assessment.¹⁹ Because bias cannot be described with numerical value, we graded each section as having an either high-, low-, or uncertain-level risk of bias. This was because the authors were uncertain of the risk of some of the elements found in each of the study methods. Any discrepancies were resolved through discussion. If an agreement could not be reached, the dispute was settled with the help of a third investigator (P.R.) and the senior statistician.

Statistical Analysis

Statistical analysis was performed by using Stata 11 SE (StataCorp, College Station, TX). We calculated pooled odds ratios (ORs) with 95% confidence intervals (CIs), in some cases by means of the Peto method because of rare events, for dichotomous outcomes and weighted mean difference (WMD) with 95% CI for continuous outcomes.²⁰ A CI starting above 1.0 was considered as statistically significant. The zero events were handled with continuity correction. We only considered results credible if they included three or more studies. We applied the random-effects model with DerSimonian-Laird estimation. I^2 and χ^2 tests were used to quantify statistical heterogeneity and gain probability values, respectively, and were interpreted as per the identifying and measuring heterogeneity section in the Cochrane handbook.²⁰ To check for publication bias, a visual inspection of funnel plots was performed. Sensitivity analysis was performed by omitting studies (one by one) from the analyses and recalculating to investigate the impact of the individual studies on the summary estimate.¹⁹

RESULTS

The search yielded a total of 3,017 articles. After excluding duplicates, we screened the remaining records for eligibility and found six articles for qualitative and quantitative synthesis (Fig. 1).^{15,21–25} Characteristics of the included studies are presented in Table I. All the six articles were nonrandomized cohort studies, with the exposure group being all patients who underwent fully endoscopic stapes surgery, and the control group being all patients who underwent microscopic stapes surgery during the study period. A summary of our analysis results can be seen in Table II.

Primary Outcomes

Average postoperative ABG. All studies evaluated average postoperative ABG, but only five studies^{15,21–23,25}

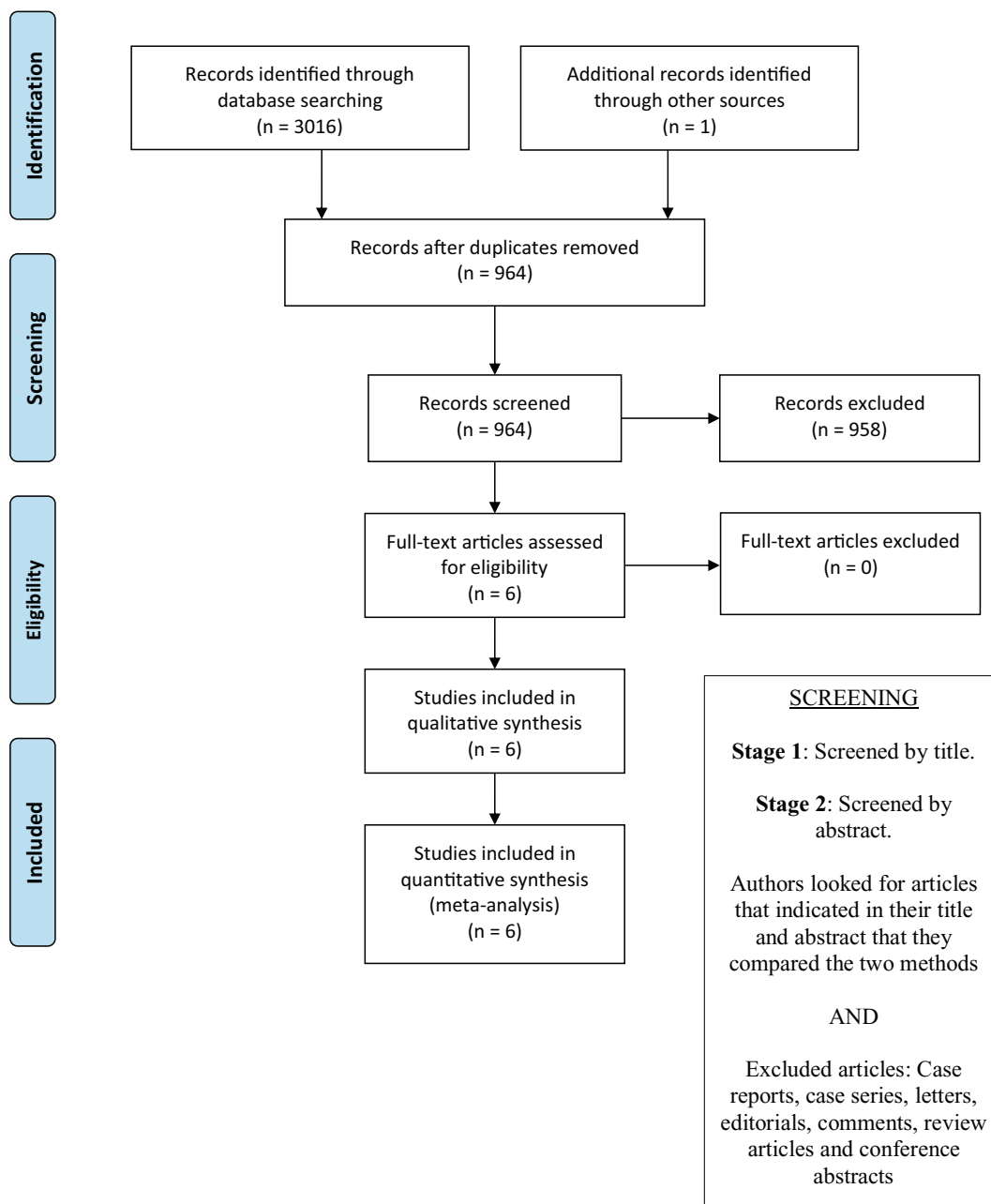


Fig. 1. Flow diagram of the systematic review and meta-analysis. [Color figure can be viewed in the online issue, which is available at www.laryngoscope.com.]

performed the evaluation according to the Committee on Hearing and Equilibrium of the American Academy of Otolaryngology–Head and Neck Surgery.²⁶ We analyzed the ABG in three groups. Group 1 was ABG of 10 dB or less (Fig. 2). There was no significant difference (OR = 1.80 [95% CI: 0.96 to 3.38]), and the I^2 and χ^2 statistical analysis suggested homogeneity ($I^2 = 0.0%$, $P = .529$). When the Sproat et al. study was removed during sensitivity analysis, there was a statistically significant difference in favor of the endoscope.²³ Group 2 was ABG between 11 dB and 20 dB (Fig. 3). There was no significant difference (OR = 1.49 [95% CI: 0.76 to 2.93]), and

the I^2 and χ^2 statistical analysis suggested homogeneity ($I^2 = 0.0%$, $P = .753$). Group 3 was ABG > 20 dB (Fig. 4). Patients were more than two times likely to end up in this group if they were operated on with a microscope (OR = 2.51 [95% CI: 0.77 to 8.22]), but this was not statistically significant, and the I^2 and χ^2 statistical analysis suggested homogeneity ($I^2 = 0.0%$, $P = .673$).

Chorda tympani injury. Injury to the nerve was more than three times likely to happen with microscopic stapes surgery (OR = 3.51 [95% CI: 1.55 to 7.93]) and was statistically significant (Fig. 5). The I^2 and χ^2 statistical analysis suggested homogeneity ($I^2 = 0.0%$, $P = .924$).

TABLE I.
Characteristics of Included Studies.

First Author, Year	Study Design	No. of Ears		Outcomes	Follow-up Time	Anesthesia
		Endoscope	Microscope			
Kojima et al., 2014	Retrospective cohort	15	41	Operation time, postoperative ABG, dizziness, TM perforation, taste	6 to 12 months	General
Iannella and Magliulo, 2016	Retrospective cohort	20	20	Operation time, postoperative ABG, chorda injury	6 to 15 months	General
Daneshi and Jahandideh, 2016	Retrospective cohort	19	15	Postoperative satisfaction, postoperative ABG, operation time, facial nerve paralysis, chorda injury, dizziness, posterior canal removal	1 to 15 months	General
Surmelioglu et al., 2017	Retrospective cohort	22	24	Operation time, postoperative ABG, dizziness, chorda injury, TM perforation	6 months	Local
Plodpai et al., 2017	Retrospective cohort	18	19	Operation time, postoperative ABG, dizziness, chorda injury, TM perforation	6 months	Local
Sproat et al., 2017	Retrospective cohort	34	47	Postoperative ABG, chorda injury, dizziness, TM perforation, taste	Recorded first follow-up only	General
Total no. of ears		128	166	294		

ABG = air-bone gap; TM = tympanic membrane.

During sensitivity analysis, if the Surmelioglu et al. study was excluded, then there was no statistically significant difference.²⁴

Secondary Outcomes

Postoperative taste disturbance. Four studies^{15,21,23,24} evaluated postoperative taste disturbance, which was more than two times as likely to happen with microscopic stapes surgery (OR = 2.36 [95% CI: 1.01 to 5.51]) and was statistically significant. The I^2 and χ^2 statistical analysis suggested mild heterogeneity ($I^2 = 21.2\%$, $P = .283$).

Average operating time. Five studies compared the average operating times.^{15,21,22,24,25} The average operating time for the mean operating times reported with

the endoscope was 64.6 minutes and for the microscope was 69.6 minutes. However, only three studies were included in the meta-analysis due to insufficient published data such as the standard deviation.^{15,24,25} Our results showed no significant difference between the two operations (WMD = 0.14 [95% CI: -11.69 to 11.98]). The results of the I^2 and χ^2 statistics suggested considerable heterogeneity ($I^2 = 82.8\%$, $P = .003$).

Tympanic Membrane (TM) perforation. Four studies^{21,23-25} evaluated TM perforation. TM perforation was not significantly different between the endoscopic and microscopic approach (OR = 1.70 [95% CI: 0.44 to 6.58]). The I^2 and χ^2 statistical analysis suggested homogeneity ($I^2 = 0.0\%$, $P = .983$).

Postoperative pain. Four studies^{15,22,24,25} evaluated postoperative pain, which was the same for microscopic

TABLE II.
Summary of OR Statistical Analysis.

Outcome	No. of Studies Included	No. of Events/Total No. of Cases		Result Analyzed	95% Confidence Interval		I^2	χ^2	Statistically Significant
		Endoscope	Microscope		Lower	Upper			
Primary outcomes									
Group 1: ABG = 0-10 dB	5	83/106	100/142	OR = 1.80	0.96	3.38	0%	0.529	No
Group 2: ABG = 11-20 dB	5	20/106	33/142	OR = 1.49	0.76	2.93	0%	0.753	No
Group 3: ABG = 21-30 dB	5	3/106	9/142	OR = 2.51	0.77	8.22	0%	0.481	No
Chorda tympani injury	6	3/128	20/166	OR = 3.51	1.55	7.93	0%	0.924	Yes
Secondary outcomes									
Average operation time	3	Not applicable	Not applicable	WMD = 0.14	-11.69	11.98	82.8%	0.003	No
Postoperative dizziness	6	35/128	70/166	OR = 2.15	0.94	4.89	0.0%	0.49	No
Postoperative pain	4	63/91	95/132	OR = 0.84	0.36	1.96	64.2%	0.039	No
Postoperative taste disturbance	4	7/91	19/132	OR = 2.36	1.01	5.51	21.2%	0.283	Yes
Tympanic membrane perforation	4	2/89	5/131	OR = 1.70	0.44	6.58	0.0%	0.983	No

ABG = air-bone gap; OR = odds ratio; WMD = weighted mean difference.

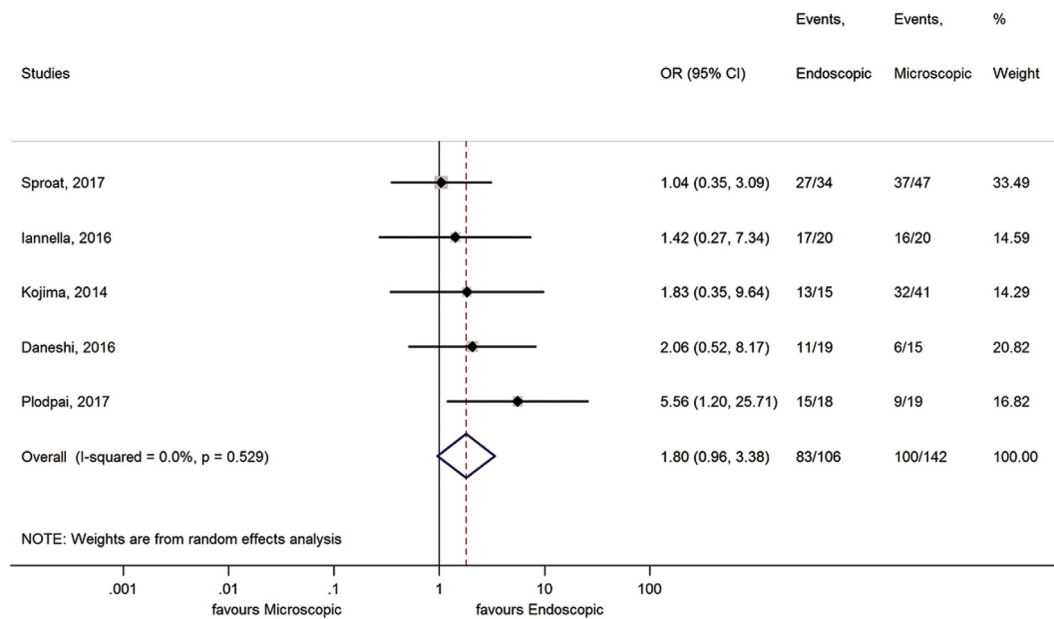


Fig. 2. Forest plot of odds ratio (OR) with a 95% confidence interval (CI) of patients with average postoperative air–bone gap <10 dB. No statistical difference. [Color figure can be viewed in the online issue, which is available at www.laryngoscope.com.]

and endoscopic stapes surgery (OR = 0.84 [95% CI: 0.36 to 1.96]). The I^2 and χ^2 statistical analysis suggested significant heterogeneity ($I^2 = 64.2\%$, $P = .039$).

Postoperative dizziness. All studies evaluated postoperative dizziness, and there was no statistical difference (OR = 2.15 [95% CI: 0.94 to 4.89]). The I^2 and χ^2 statistical analysis suggested mild heterogeneity ($I^2 = 0.0\%$, $P = .49$). Postoperative dizziness is significantly higher with microscopic stapes surgery when the Iannella and Magliulo study is removed for sensitivity analysis.¹⁵

Risk of Bias Analysis

The risk of bias within individual studies is graphically represented in Table III. The Plodpai et al.²⁵ and Surmelioglu et al.²⁴ studies were judged to have a low risk of bias, Iannella and Magliulo¹⁵ and Daneshi and Jahandideh²² moderate risk, and Kojima et al.²¹ and Sproat et al.²³ high risk.

The main reason for studies being assessed as high risk was not explicitly stating their sources and methods (e.g., the randomization process, patient selection, patient records, theater logbooks, audiology database).

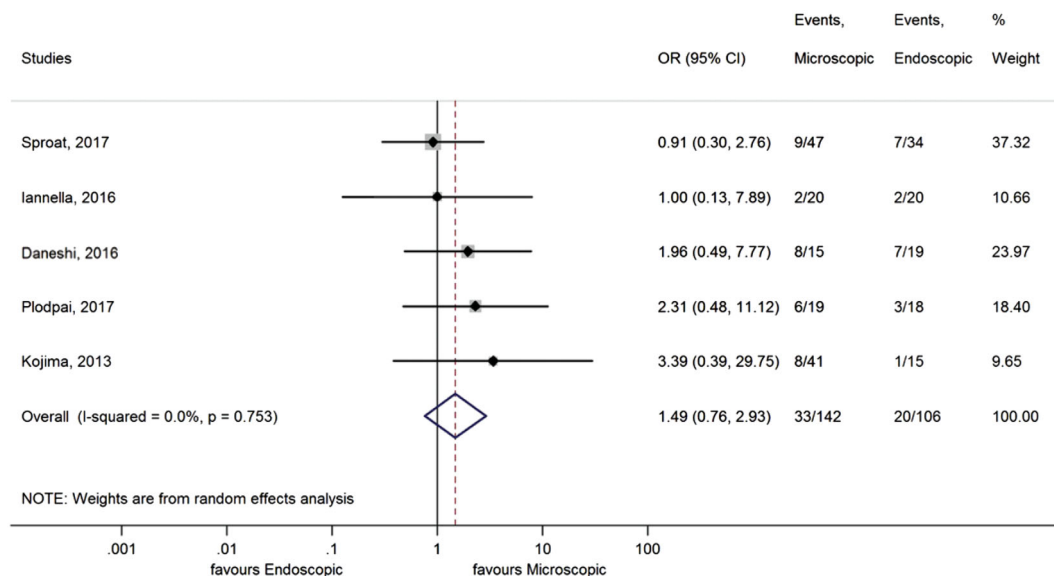


Fig. 3. Forest plot of odds ratio (OR) with a 95% confidence interval (CI) of patients with average postoperative air–bone gap 10 dB to 20 dB. No statistical difference. [Color figure can be viewed in the online issue, which is available at www.laryngoscope.com.]

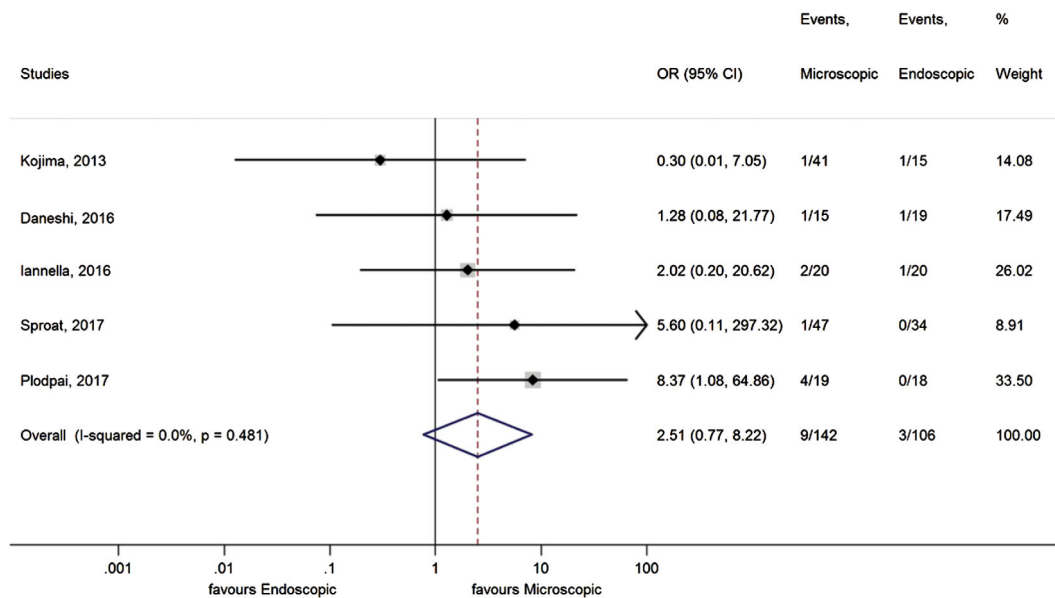


Fig. 4. Forest plot of odds ratio (OR) with a 95% confidence interval (CI) of patients with average postoperative air-bone gap >20 dB. No statistical difference. [Color figure can be viewed in the online issue, which is available at www.laryngoscope.com.]

The selection process was of particular interest as none of the studies were blinded, and surgeons might have chosen patients with ideal ears for the endoscopic procedures, a major confounder, or overestimated their results. Some of the authors tried to mitigate this selection bias by stating there was randomization but did not describe the process.

An uncertain risk of bias in some studies was that patients for each group were selected from different time periods. This was due to the surgeons operating initially with the microscope before they changed to the endoscope, and using the data collected during those two periods for comparison. The difference of the surgeon's skill level between the two techniques could be considered

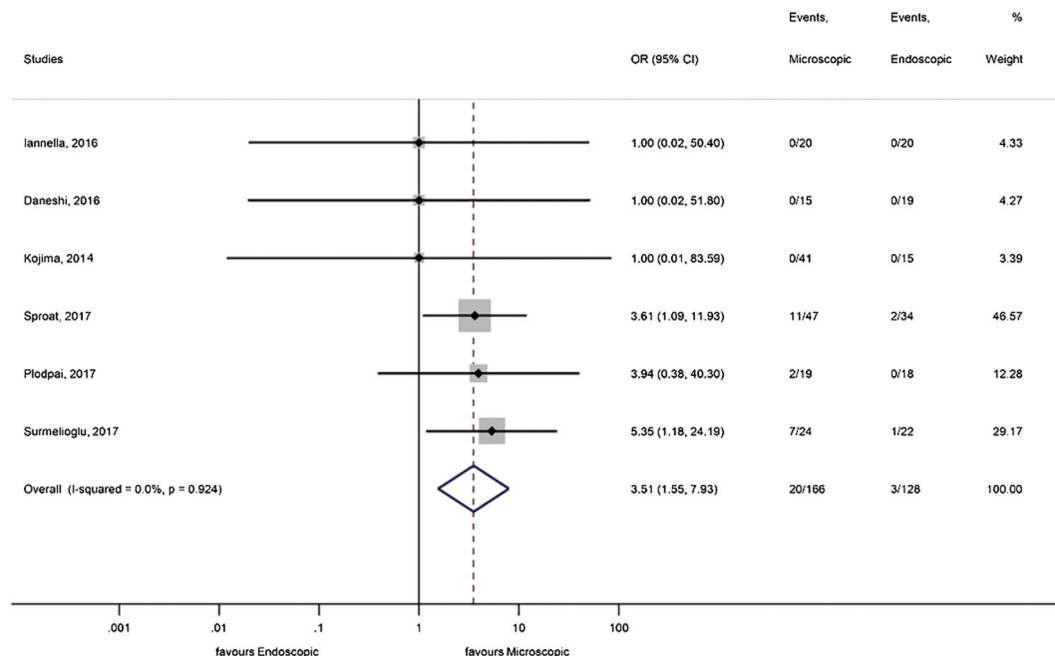


Fig. 5. Forest plot of odds ratio (OR) with a 95% confidence interval (CI) of patients who suffered chorda tympani injury. The zero events were handled with continuity correction. Injury is most likely with (favors) the microscope. [Color figure can be viewed in the online issue, which is available at www.laryngoscope.com.]

TABLE III.
Risk of Bias Analysis.

	Daneshi and Jahandideh, 2016	Kojima et al., 2014	Sproat et al., 2017	Plodpai et al., 2017	Iannella and Magliulo, 2016	Surmelioglu et al., 2017
Representativeness of the study	✓	X	X	✓	✓	✓
Selection of the nonexposed cohort	✓	X	X	✓	?	✓
Ascertainment of exposure	?	?	✓	✓	?	✓
Demonstration that outcome of interest was not present at start of the study	?	X	X	✓	?	✓
Comparability of cohorts on the basis of the design or analysis controlled for confounders	?	?	✓	✓	?	X
Assessment of outcome	X	X	?	?	X	X
Was follow-up long enough for outcomes to occur	X	✓	X	✓	✓	✓
Adequacy of follow-up of cohorts	✓	X	X	✓	✓	✓

✓ = low risk; X = high risk; ? = uncertain risk.

as a confounder that would have influenced the selection process as mentioned earlier. In addition, we judged that to include patients who had been operated on in the past (revision surgeries), patients who were not followed up for a minimum of 6 months, or to exclude patients lost to follow-up due to inadequate data were causes of high risk of bias.

Most importantly, there was no standardized way of reporting outcomes and statistical results, which we judged to carry the highest risk of bias. This was especially true in the case of the chorda tympani injury and postoperative taste disturbance. All studies were able to comment on whether the nerve was injured, but most of them did not grade the injury level, which could range from mild manipulation to severing the nerve. Similarly, there was no clarification on the definition of taste disturbance or how it was measured and for how long. Only two studies mentioned that the disturbance was transient.^{15,24} We recommend that future studies state if the nerve was manipulated or severed and avoid using the term injury. In addition, taste needs to be measured with a validated method, and any changes after surgery need to be reviewed in follow-up, stating if it was transient or permanent. The correlation of nerve injury with taste disturbance also needs to be statistically analyzed, as some of the studies indicated no correlation between the two.

With regard to ABG measurements, previous endoscopic and microscopic stapes surgery case series have demonstrated improvement in hearing by closure of the average ABG rather than just the average postoperative ABG.^{11,12,18} Only Surmelioglu et al. published their results in this manner, which we believe to be a more accurate way to demonstrate surgical effectiveness.²⁴ Hence, we recommend that in the future results are published both ways to assist analysis.

Other than Iannella and Magliulo, no other study clarified how operation time was measured, which made assessment of this parameter extremely difficult.¹⁵ Surgeries done under local anesthesia took longer, which is a confounding factor, and we assume this was due to patient movement during the procedure.^{24,25} All studies compared dizziness, but only two attempted to quantify it with respect to the duration (number of days after surgery).^{15,21} Similarly, only

two out of four studies attempted to quantify pain with respect to severity and the need for medication.^{15,22}

DISCUSSION

The main advantage of the endoscope over the microscope is better visualization of the middle ear structures, requiring less bone removal and chorda tympani nerve manipulation, which is a cause of postoperative taste disturbance.¹⁵ Our study concluded that the hearing outcomes of the endoscopic approach are similar to those of the microscope. However, there would have been a statistical difference for ABG <10 dB favoring the endoscope if we had not included the results of Sproat et al. in our analysis.²³ In that study they compared the outcomes from separate time periods. We stated earlier that the surgeon's skill level with the endoscope might not be the same as with the microscope, which in turn might have affected their outcomes. At the same time, Sproat et al. were the only ones to use an otology audit tool to collect data and provided the largest number of cases for analysis. It could be inferred that the other studies overestimated their results in favor of the endoscope, especially in the absence of blinding.

The chorda tympani can clearly be visualized during the procedure with either intervention, making easy for surgeons to include in their notes if it was injured, and in turn to include it in their study outcomes. However, the level of manipulation is not stated, and thus the term is vague, just as the terms used for postoperative taste disturbance in the absence of a validated tool and follow-up. Although our study has shown statistically significant difference in favor of the endoscope, this result must be taken in context with the significant level of bias calculated in our analysis. In the Surmelioglu et al. study, the microscopic intervention, which was performed by either of two surgeons, had a very high level of chorda tympani injury compared to the endoscope, which was performed only by the more experienced of the two surgeons.²⁴ The surgeon's experience, a confounder, could have influenced the outcomes in this study. We find no statistical difference in the chorda tympani injury when we remove Surmelioglu et al. from our analysis. Furthermore, a

secondary meta-analysis (see Supporting Table I in the online version of this article) of the risk difference (RD) was not statistically significant, which would further support the hypothesis that there is no advantage with the endoscope.

Theoretically, endoscopically operated patients would suffer less with postoperative dizziness because of reduced manipulation of the stapes footplate due to better visualization. Equally, they would have complained less about postoperative pain due to less drilling of the external auricular canal. However, our study has shown that there was no statistical difference with either outcome. In experienced hands, TM perforation numbers will be minimal no matter which approach is used.

The operating time was the most poorly measured and published outcome, and this reflects the retrospective nature of the studies. Although there is no significant difference in our analysis, a significant heterogeneity is seen in our results.

It was mentioned several times in the literature that the endoscope allows views with minimal or even without the need of drilling the bone of the posterior canal. This outcome was only sufficiently recorded by two studies.^{15,22} Future studies should record if the drilling was done and try to quantify it (e.g., minimal, moderate, and extensive). Also, there is anecdotal evidence that depending on the surgeon's dominant hand they would drill one side and not the other due to space constraints.

Learning curve was a particularly recurring theme. The Iannella and Magliulo study was able to plot a learning curve for endoscopic stapes surgery by analyzing the average operating times of a surgeon by groups of cases and by time intervals.¹⁵ In the first 10 cases done with the endoscope, the average operation time was significantly slower than the last 10 cases. However, they found no statistical difference between the average surgical times for endoscopic and microscopic approaches in the last 4-month period of their 1-year study and in the last 10 out of 20 cases. This would suggest that the learning curve for the endoscope is 10 cases. This is much smaller than the 60 to 80 cases for conventional microscopic surgery as published by Yung et al.²⁷ Nonetheless, the learning curve has often been framed as the main cause for surgeons' reluctance to change to the endoscope due to probable longer operation time.^{1,21} Although the evidence is weak and not an outcome of this study, we believe surgeons should not be afraid to operate with the endoscope, as the learning curve is not long and outcomes are similar or better than the microscopes, even at the early stages.

Study Limitations

Our meta-analysis used nonrandomized studies, which were done retrospectively and contained significant bias that reduced its level of evidence. By including only articles that directly compared the two surgeries we have limited our data pool. This has resulted in a theoretical increased risk of publication bias, which could not be assessed using the symmetry of the funnel plot due to the low number of eligible studies (see Supporting Information, Appendix A and B in the online version of this article). The authors contemplated

the use of indirect comparison especially, as these can offer outcomes from a larger number of cases without great inconsistency from a direct comparison.²⁸ However, this would not have decreased the risk of bias as the main risk factors of randomization, selection and publication would still exist, and new confounding factors would creep in.

CONCLUSION

Overall, our study indicates endoscopic and microscopic stapes surgery have similar audiological success, with some data suggesting a lower risk of chorda tympani injury and postoperative taste disturbance with the endoscope. However, we acknowledge the limitations of our study and would like to encourage prospective randomized controlled trials to validate our results.

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