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Microscopic versus endoscopic stapes surgery: systematic review and meta-analysis

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Review Article

Prof J Hajiioannou takes responsibility for the integrity of the content of the paper

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Abstract

Objective. To compare the efficacy and safety characteristics of endoscopic and microscopic stapes surgery based on current evidence.

Methods. A systematic literature search was conducted of three medical databases, focusing on randomised, controlled studies or observational studies. Data related to the efficacy and safety of each technique were extracted. Outcome data were summarised using the pooled mean differences or pooled odds ratios, along with their 95 per cent confidence intervals.

Results. Thirteen studies were included in the meta-analysis. Success rate was evaluated by estimating air–bone gap improvement; this revealed comparable outcomes for the two techniques (mean difference = −0.20; 95 per cent confidence interval = −0.53, 0.14). No statistically significant difference was detected concerning post-operative complications, except for dysgeusia (odds ratio = −1.12; 95 per cent confidence interval = −1.97, −0.28) and pain (odds ratio = −2.00; 95 per cent confidence interval = −2.97, −1.04), which favoured the endoscopic approach.

Conclusion. Though both techniques result in commensurate outcomes concerning success rate, post-operative pain and dysgeusia favour the endoscopic approach. Further high-quality studies are needed to adequately compare the two methods.

Introduction

Binocular vision utilising a microscope for improved visualisation while performing otological surgery, first developed in 1952, offers a plethora of advantages, such as ambidextrous hand mobility and a clear view of the middle-ear anatomy except for the retrotympanic space.[1] Since its initial employment, the microscope has been established as a powerful instrument for treating the majority of middle-ear lesions. Alternatively, endoscopic ear surgery, first described by Ohnsorge in 1977, offers a more transparent view of the middle-ear cavity, while bearing the disadvantages of single-hand surgical manoeuvres and a two-dimensional view.[2] During the last half-century, endoscopic approaches for middle-ear pathologies have shifted from diagnostic-only to operative procedures, including tympanoplasties, cholesteatoma removal and stapes surgery.[3–5]

A plethora of studies has been conducted regarding the comparability of the microscopic versus the endoscopic technique, the learning curve, otological outcomes and complication rates. In addition to quality, ample evidence is needed, which cannot be drawn from individual studies and trials. Thus, we feel that a systematic review and meta-analysis of the aforementioned parameters of each approach is of great importance, allowing sturdy conclusions apropos the best technique for the patients' benefit.

Materials and methods

We prospectively designed search methods, eligibility criteria and a data extraction process. No patient informed consent or institutional review board or ethics committee approval were required because of the nature of the study, which was based on published records. This meta-analysis was conducted in accordance with the Preferred Reporting Items for Systematic Review and Meta-Analysis ('PRISMA') statement.[6]

Search strategy

Two review authors performed an electronic literature search to identify published studies comparing microscopic with endoscopic stapedectomy (EG and KTD). The electronic search involved three medical databases: PubMed, Cochrane Library and Scopus. We used the following medical subject heading (MeSH) terms and Boolean operators in the search: 'otosclerosis', AND 'endoscopic stapedectomy' OR 'endoscopic stapedotomy' OR 'endoscopic stapes surgery', AND 'microscopic stapedectomy' OR 'microscopic stapedotomy' OR 'microscopic stapes surgery', AND 'success rate' OR 'complication' OR 'length of hospitalization' OR 'cost'. The search process was limited to English-language literature, and the search period extended from 1964 until July 2020 (Table 1). The literature was last

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Table 1. Current meta-analysis search strategy according to the PICOT format

Frame	MeSH terms	Search	Inclusion criteria	Exclusion criteria	Sources
P (patients, participants, population)	#1. "Otosclerosis"	#1 AND #2 AND #3 AND #4	Articles focusing on outcomes of stapes surgery (endoscopic or microscopic) for treatment of otosclerosis	– Irrelevant title or abstract – Irrelevant full text – Non-English – Editorial, review, meta-analysis – Studies with <5 subjects – Experimental or non-human studies – Interventions other than stapes surgery – Indications other than otosclerosis – Total number of patients in sample not obvious – Studies on revision cases	– Databases (PubMed, Cochrane Library, ClinicalTrials.gov & Scopus) – Reference lists
I (intervention)	#2. "Endoscopic stapedectomy" OR "endoscopic stapedotomy" OR "endoscopic stapes surgery"				
C (reference test)	#3. "Microscopic stapedectomy" OR "microscopic stapedotomy" OR "microscopic stapes surgery"				
O (outcome)	#4. "Success rate" OR "complication" OR "length of hospitalization" OR "cost"				
T (time)	Search period: 1964 until July 2020; last search: January 2021				

PICOT = patient, intervention, comparator, outcome and timing; MeSH = medical subject heading

accessed in January 2021. Additional records were traced in the reference lists of the gathered studies.

Eligibility criteria

We focused primarily on randomised, controlled studies and secondarily on observational studies comparing endoscopic with microscopic stapes surgery in terms of success rate, complications, hospitalisation duration and cost-effectiveness. We discarded case series, case reports, editorials, reviews and systematic reviews, and studies without data suitable for quantitative analysis. We also excluded studies reporting on surgical interventions other than stapes surgery.

Data extraction

Each study was identified by the name of the first author and the year of publication. The following data were collected: (1) the size of the endoscopic stapes surgery group; (2) the size of the microscopic stapes surgery group; (3) the success rate measured as mean and standard deviation (SD) in each group; (4) the counts of individual complications in the endoscopic and microsurgery groups; (5) the length of hospitalisation in the endoscopic and microsurgery groups; and (6) the costs of the endoscopic and microsurgery groups.

Quality appraisal

Quality appraisal for individual studies, as well as assessment of the overall quality of evidence in the current analysis, was conducted by two independent review authors (KTD and EG). Individual quality appraisal for each included study was conducted using the ROBINS-I[7] tool for non-randomised studies and the RoB 2[8] tool for randomised, controlled trials (RCTs). The ROBINS-I and RoB 2 tools assess studies in seven and four domains, respectively. Both individual RCTs and non-RCTs were considered, bearing a 'high', 'moderate' or 'low' risk of bias, based on the evaluation. The overall quality of the gathered evidence was assessed according to the Grading of Recommendations Assessment, Development and Evaluation ('GRADE') Working Group recommendations,[9] and categorised as 'high' (grade 4), 'medium' (grade 3), 'low' (grade 2) or 'very low' (grade 1) quality of evidence. In cases of disagreement, the two authors reached a consensus after consultation with the senior author (JH).

Data synthesis

The comparison of the two treatment options was conducted through a meta-analysis for every parameter under study. The outcomes of continuous measurements were pooled in terms of mean differences and 95 per cent confidence intervals (CI), whereas the outcomes of count measures were summarised in terms of odds ratios along with 95 per cent CIs through a paired meta-analysis. In addition, a proportion meta-analysis was performed to estimate the incidence of the complication in each arm independently. Inter-study heterogeneity was evaluated using the significance of the Cochran's Q-metric (pQ) and quantified by the Higgins I^2 statistics. Significance was set at $p < 0.05$, and we used continuity correction equal to 0.5 for metrics associated with zero events. The pooled estimate was assessed using the random effects model in the presence of inter-study heterogeneity ($I^2 > 50$ per cent) or with the fixed effects model. A sensitivity analysis

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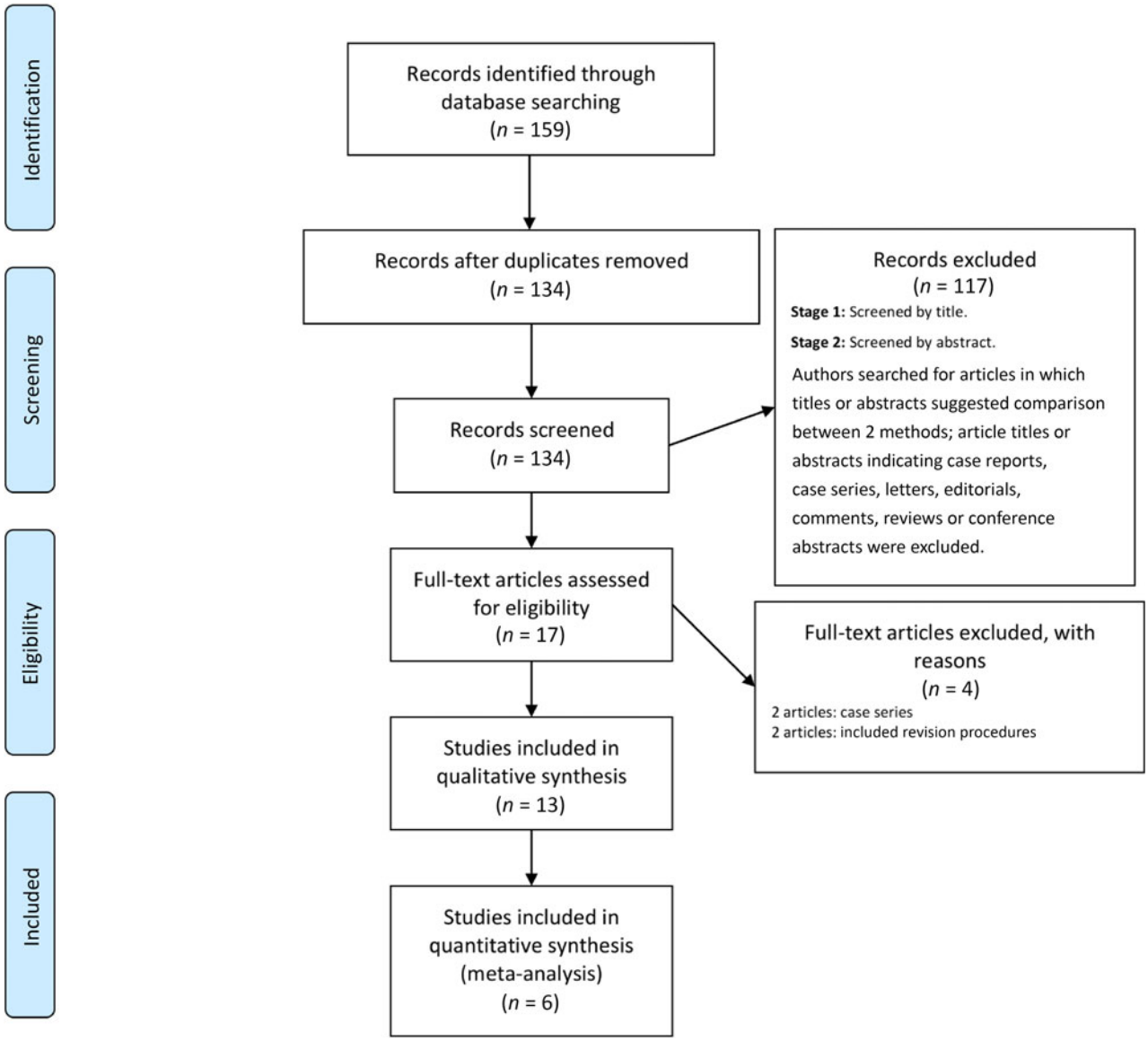


Fig. 1. Preferred Reporting Items for Systematic Reviews and Meta-Analyses ('PRISMA') flowchart.

would be considered only in the case of co-existence of significant statistical heterogeneity and more than three studies per stratum. Publication bias was eyeballed by funnel plots and assessed using the fail-safe N analysis, also known as 'file-drawer analysis'. All statistical analyses were executed using the Jamovi project for the R-statistical environment.[10,11]

Results

Study selection and characteristics

In total, 159 articles were identified through database searching, of which 25 were excluded because of duplication. After the title and abstract evaluation, a further 117 articles were removed. Subsequently, the full text of the remaining 17 articles was reviewed and 4 more articles were excluded. Finally, 13 articles were considered eligible and were included in the quality assessment, while only 9 of them were included in the quantitative synthesis because of the paucity of statistics (Figure 1). Quantitative characteristics for these nine studies are presented in Table 2.[12–20]

The selected articles included a total of 705 patients (711 ears) who underwent endoscopic or microscopic stapes surgery. All articles were written in English language, and were published between 2014 and 2021. One was a randomised, controlled study, while the remaining were observational non-randomised cohort studies. The evidence regarding stapes surgery complications and success is summarised in Tables 3 and 4.

Quality assessment

Regarding the observational studies, all 12 (100 per cent) were considered to have a 'moderate' risk of bias. With regard to the randomised, controlled study, a 'low' risk of bias was ascertained in all domains. Evaluation findings for the observational studies[12–19,21–24] are presented in Table 5, and those for the randomised, controlled trial[20] are shown in Table 6. The overall quality of evidence was found to be 'very low' for three outcomes evaluated (pain, dysgeusia and dizziness) and 'low' for one outcome (success rate). Quality of evidence was downgraded largely because of the presence of risk of bias, indirectness and inconsistency issues (Table 7).

Success rate

Based on five studies,[13,16–18,20] the pooled air–bone gap after endoscopic and microscopic stapes surgery was 9.08 dB

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Table 2. Summary of eligible studies

Study (year)	Study design	Age group	Patients (female/male) (*n*)	Ears (endoscopic/microscopic) (*n*)	Outcomes	Follow-up time (endoscopic/microscopic)	Anaesthesia
Kojima *et al.*[12] (2014)	Retrospective cohort	Paediatric + adult	50 (32/18)	56 (15/41)	Post-operative ABG, dysgeusia, dizziness, pain, facial paralysis, corda tympani injury	6–12 mth / 9 mth – 10 years	General
Gulsen & Karatas[13] (2019)	Retrospective cohort	Adult	61 (34/27)	61 (32/29)	Post-operative ABG, dysgeusia, dizziness, pain, tympanic membrane perforation, corda tympani injury	8–12 mth / 9–15 mth	Local
Daneshi & Jahandideh[14] (2016)	Retrospective cohort	Adult	34 (24/10)	34 (19/15)	Post-operative ABG, dizziness, facial nerve paralysis, corda tympani injury	1–15 mth / 1–15 mth	General
Iannella & Magliulo[15] (2016)	Retrospective cohort	Adult	40 (25/15)	40 (20/20)	Post-operative ABG, dysgeusia, dizziness, pain, tympanic membrane perforation, facial nerve paralysis, tinnitus, corda tympani injury	6–15 mth / 6–15 mth	General
Surmelioglu *et al.*[16] (2017)	Retrospective cohort	Adult	46 (17/29)	46 (22/24)	Post-operative ABG, dysgeusia, dizziness	12–28 mth / 12–48 mth	Local
Ardiç *et al.*[17] (2018)	Retrospective cohort	Adult	94 (37/57)	94 (37/57)	Post-operative ABG	3rd, 12th mth / 3rd, 12th mth	General
Bhardwaj *et al.*[18] (2018)	Retrospective cohort	Adult	40 (17/23)	40 (20/20)	Post-operative ABG, dysgeusia, dizziness, pain, tympanic membrane perforation, corda tympani injury	1st, 3rd, 12th, 24th wk / 1st, 3rd, 12th, 24th wk	Local
Moneir *et al.*[19] (2018)	Retrospective cohort	Adult	42 (?/?)	42 (14/28)	Post-operative ABG, dysgeusia, dizziness, tympanic membrane perforation, SNHL	4–6 wk / 4–6 wk	Local
Das *et al.*[20] (2021)	RCT	Adult	64 (60/4)	64 (32/32)	Post-operative ABG dysgeusia	1st wk / 1st wk	Local
Total			471 (246+?/183+?)	477 (211/266)			

Data for quantitative statistical analysis were drawn from 9 of the 13 eligible studies. ABG = air–bone gap; mth = month(s); wk = week(s); SNHL = sensorineural hearing loss; RCT = randomised, controlled trial

Table 3. Summary of evidence regarding complications of stapes surgery

Complications	Included studies (*n*)	Events/patients – endoscopic (*n*)	Events/patients – microscopic (*n*)	Incidence – endoscopic (95% CI) (%)	Incidence – microscopic (95% CI) (%)	Pooled analysis OR (95% CI)	Heterogeneity (I^2)	Publication bias (*p*-value)
Post-op pain	4 studies [12,13,15,18]	6/87	30/110	4 (0, 8)	28 (6, 50)	−2 (−2.97, −1.04)	0%	<0.001
Post-op dizziness	6 studies [12–15,18,19]	47/120	70/153	41 (5, 77)	45 (12, 79)	−0.46 (−1.31, 0.38)	0%	0.192
Post-op dysgeusia	8 studies [12,13,15,18–21,24]	29/211	66/249	6 (3, 10)	22 (6, 39)	−1.12 (−1.97, −0.28)	34.39%	<0.001

Results from the proportion and the paired meta-analyses with regard to post-operative complications of the two modalities. CI = confidence interval; OR = odds ratio; post-op = post-operative

(95 per cent CI = 7.06, 11.10) and 10.79 dB (95 per cent CI = 7.82, 13.75), respectively. In the absence of statistical heterogeneity (I^2 = 51.57 per cent, pQ = 0.08), there was no difference in terms of success rate between the two treatments (pooled mean difference = −0.20; 95 per cent CI = −0.53, 0.14) (Figure 2). In addition, the regression test for funnel plot asymmetry failed to detect publication bias (p = 9.79).

Complications

The available data permitted the pooling of evidence regarding the three post-operative complications associated with stapes surgery: pain, dizziness and dysgeusia (Figures 3–5). Dizziness was the most frequent post-operative complication, with estimated pooled incidence rates as high as 41 per cent (95 per cent CI = 5–77 per cent) for endoscopic procedures and 45 per cent (95 per cent CI = 12–79 per cent) for microscopic procedures. There was no statistically significant difference between the two modalities (odds ratio = −0.46 (95 per cent CI = −1.31, 0.38)). Conversely, the difference between the two modalities regarding dysgeusia was in favour of the endoscopic surgery (odds ratio = −1.12; 95 per cent CI = −1.97, −0.28). In fact, dysgeusia occurred with an estimated pooled incidence rate as high as 6 per cent (95 per cent CI = 3–10 per cent) after endoscopic surgery and 22 per cent (95 per cent CI = 6–39 per cent) after microscopic stapes surgery. Likewise, post-procedural pain was more frequent (odds ratio = −2.00; 95 per cent CI = −2.97, −1.04) after microscopic (28 per cent; 95 per cent CI = 6, 50) than endoscopic (4 per cent; 95 per cent CI = 0, 8) stapes surgery.

Operation time

Operation time ranged from 45 minutes (SD = 8.4 minutes) to 128 minutes (SD = 27 minutes) for endoscopic procedures, and from 36.5 minutes (SD = 8.2 minutes) to 132 minutes (SD = 38.7 minutes) for microscopic procedures. Based on four studies, there was no significant difference between the two techniques regarding operation time (mean difference = −1.92; 95 per cent CI = −5.88, 2.03; I^2 = 99.22 per cent).

Discussion

Otosclerosis is a multifactorial and complex disorder affecting hearing ability, caused by pathological bone resorption and deposition of the otic capsule.[25] Stapes surgery is a widely accepted method and the 'gold standard' technique for treatment of this disease. While the microscopic approach has traditionally been the preferable modality, remarkable progress has been achieved utilising specially designed endoscopes, providing a powerful asset to otorhinolaryngologists aiming to improve any inadequacy associated with the microscopic approach.[26,27]

Offering excellent visualisation of the middle-ear cavity, the endoscopic technique permits a multi-angle view of every 'corner', combined with improved accessibility to fine structures. Furthermore, the endo-aural approach is feasible through endoscopes, even for narrow or curved external auditory canals, allowing minimally invasive operations. Thus, hearing improvement accomplished by endoscopic stapedectomy is considered comparable to its microscopic counterpart. This conclusion is supported by the results of the current study, and those of previous meta-analyses encountered in the literature, particularly research by Hall *et al.*, Nikolaos *et al.* and

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Table 4. Summary of evidence regarding stapes surgery success

Primary outcome	Included studies (*n*)	Mean ABG difference (95% CI)	Heterogeneity (I^2)	Publication bias (*p*-value)
Success rate	5 studies [13,16–18,20]	−0.20 (−0.53, 0.14)	51.75%	0.044

'Success' reflects post-operative air–bone gap of less than 20 dB. Results from the pooled meta-analysis with regard to post-operative air–bone gap considered successful. ABG = air–bone gap; CI = confidence interval

Table 5. ROBINS-I tool findings: individual observational study risk of bias evaluation

Study (year)	Domain 1	Domain 2	Domain 3	Domain 4	Domain 5	Domain 6	Domain 7	Overall
Sproat *et al.*[21] (2017)	–	+	+	+	+	–	+	–
Kojima *et al.*[12] (2014)	+	+	+	+	+	–	+	–
Cornejo-Suarez *et al.*[22] (2019)	–	+	+	+	+	–	+	–
Gulsen & Karatas[13] (2019)	+	+	+	+	+	–	+	–
Daneshi & Jahandideh[14] (2016)	+	+	+	+	+	–	+	–
Iannella & Magliulo[15] (2016)	–	+	+	+	+	–	+	–
Plodpai *et al.*[23] (2017)	–	+	+	+	+	–	+	–
Surmelioglu *et al.*[16] (2017)	–	+	+	+	+	–	+	–
Ardiç *et al.*[17] (2018)	–	+	+	+	+	–	+	–
Bhardwaj *et al.*[18] (2018)	–	+	+	+	+	–	+	–
Kuo & Wu[24] (2018)	+	+	+	+	+	–	+	–
Moneir *et al.*[19] (2018)	+	+	+	+	+	–	+	–

Domain 1 – bias because of confounding; domain 2 – bias because of participant selection; domain 3 – bias in classification of intervention; domain 4 – bias because of deviations from intended interventions; domain 5 – bias because of missing data; domain 6 – bias in measurement of outcomes; and domain 7 – bias in selection of the reported result. '–' = moderate risk of bias; '+' = low risk of bias

Table 6. RoB 2 tool findings: individual RCT study risk of bias evaluation

Study (year)	Domain 1	Domain 2	Domain 3	Domain 4	Domain 5	Overall
Das *et al.*[20] (2021)	+	+	+	+	+	+

Domain 1 – bias arising from the randomisation process; domain 2 – bias because of deviation from intended intervention; domain 3 – bias because of missing outcome data; domain 4 – bias in measurement of the outcome; and domain 5 – bias in selection of the reported result. '+' = low risk of bias. RCT = randomised, controlled trial

Koukkoullis *et al.*[28–30] Exceptionally, Fang *et al.* observed a statistically significant difference in favour of the endoscopic technique, demonstrating its superiority.[31]

Moreover, the improved visualisation of the surgical field provided by the endoscope enables less bony auditory canal drilling, and, consequently, limited manipulation or injury of the chorda tympani, leading to better rates regarding post-operative dysgeusia.[32] This is in compliance with the outcomes of recent meta-analyses, as their results are relevant to those of the current study.[29–31] Furthermore, less or no scutum curetting, alongside minimal incisions, offers the advantage of minimal post-operative pain.[30,31] This accords with the outcomes of the present study, where post-operative pain was less frequent for the endoscopic approach. On the contrary, Koukkoullis *et al.* reported no statistically significant difference between the two treatment modalities in terms of pain (odds ratio = 0.84; 95 per cent CI = 0.36, 1.96; I^2 = 64.2 per cent, p = 0.039), regardless of the slightest external auditory canal injury.[30] Nonetheless, dizziness was the most frequent complication to be observed in the present study. However, no significant difference was reported between the two approaches (odds ratio = −0.46; 95 per cent CI = −1.31, 0.38; I^2 = 0 per cent, p = 0.192), even if dizziness was also lower with the endoscopic technique.

As far as the operation time is concerned, no statistical analysis could be executed because of the lack of measurable data. Hence, there was insufficient evidence in the present analysis that the endoscopic was inferior to the microscopic technique in this regard. Nonetheless, Das *et al.* reported a statistically significant difference in favour of the endoscopic technique; its operation time was 31 minutes shorter compared with the microscopic method ($p < 0.05$).[20] Additionally, both Gulsen and Karatas, and Plodpai *et al.*, recorded that endoscopic stapedectomy was faster than microscopic stapedectomy, yet no statistical significance was observed ($p > 0.05$ and $p = 0.72$, respectively).[13,23] Moreover, Iannella and Magliulo mentioned that, in the absence of a statistical difference between the two approaches regarding operation time, during their last study period, the surgical execution time of endoscopic stapedectomy appeared to be significantly improved when comparing the first 10 with the last 10 patients.[15]

Apart from its efficacy in ear surgery results, the endoscopic approach appears to be somewhat beneficial concerning middle-ear anatomy teaching and ear surgery skills acquisition. With the endoscopic technique, both the surgeon and their assistants have an unimpeded view of the surgical field and the procedure through the uniformly used monitor, resulting in better education for the observers of the operation.[32,33] Nevertheless, like any other newly introduced technology, this innovative approach has a learning curve for every surgeon not acquainted with endoscopic otology.[16,18–20,23,34] In line with this view, Iannella and Magliulo reported that operative duration seemed to decrease with greater experience.[15]

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Table 7. Quality assessment of overall evidence according to GRADE recommendations[9]

Outcomes	Starting grade	Risk of bias	Imprecision	Indirectness	Inconsistency	Publication bias	Large effect	Dose response	Confounding factors	Final grade	Quality of evidence
Success rate	4	−1	0	0	−1	0	0	0	0	2	Low
Pain	2	−1	0	−1	0	0	0	0	0	0	Very low
Dysgeusia	4	−1	0	−1	−1	0	0	0	0	1	Very low
Dizziness	2	−1	0	−1	0	0	0	0	0	0	Very low

Data represent grades unless indicated otherwise. Starting grade was 4 in outcomes where a randomised, controlled trial was included in the studies. Starting grade was 2 for outcomes where only observational studies where included. GRADE = Grading of Recommendations Assessment, Development and Evaluation working group

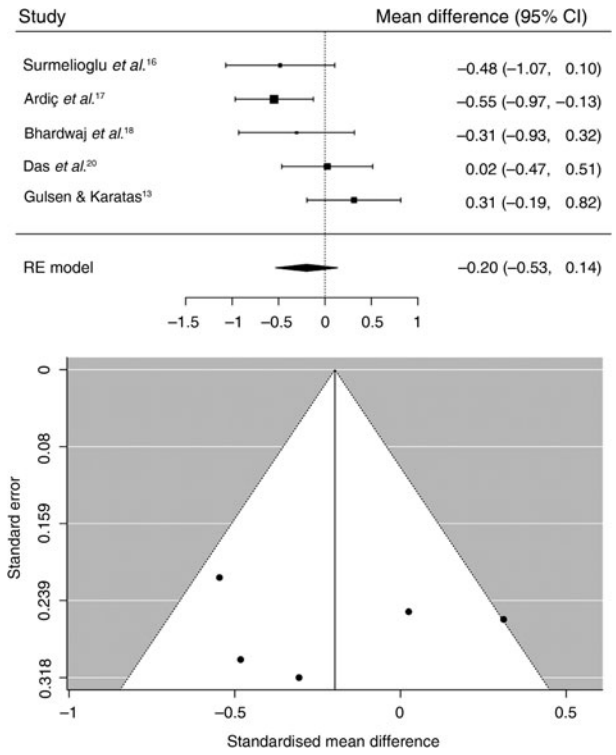


Fig. 2. Forest plot for success of stapes surgery. CI = confidence interval; RE = random effects

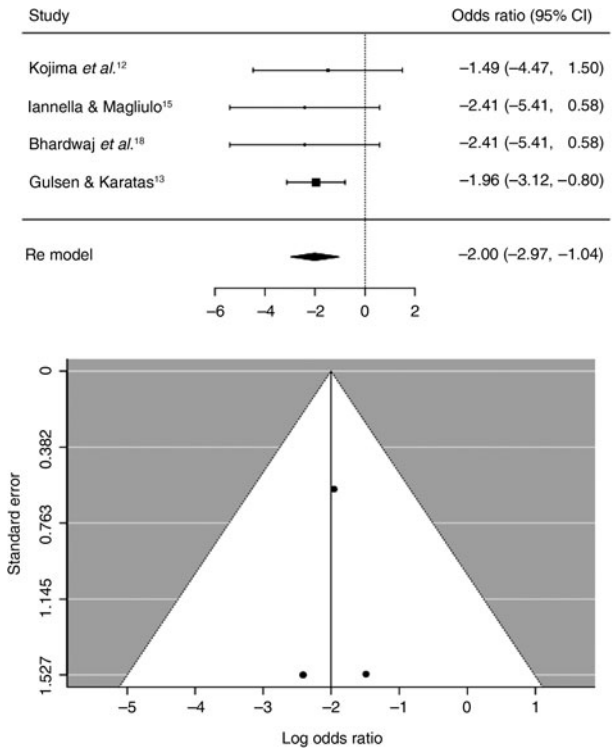


Fig. 3. Forest plot for post-operative pain. CI = confidence interval; RE = random effects

However, as the microscopic technique is of great importance and cannot be entirely substituted, ENT trainees should be enrolled in augmented learning curricula, combining microscopic and endoscopic ear surgery teaching, allowing optimal performance in otological surgery.[32]

As health professionals aim to achieve the highest possible satisfaction and comfort with their services, endoscopic stapes

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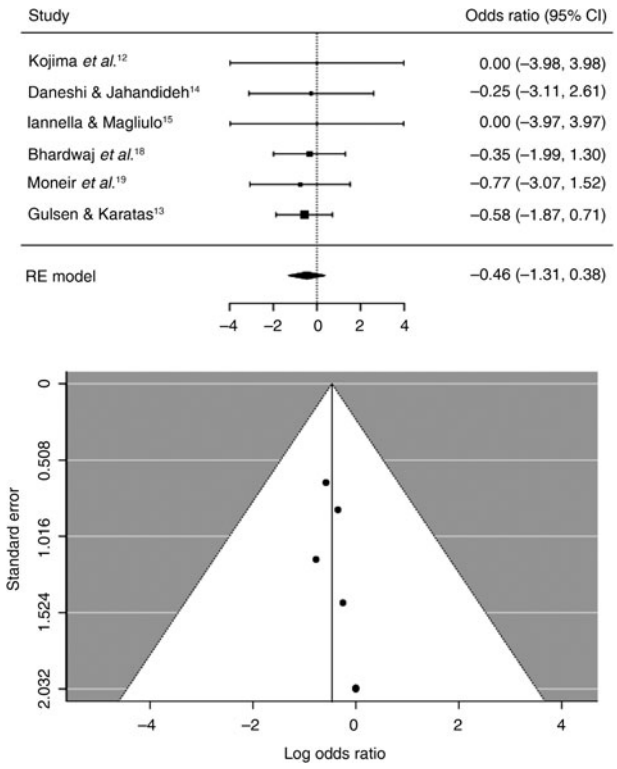


Fig. 4. Forest plot for post-operative dizziness. CI = confidence interval; RE = random effects

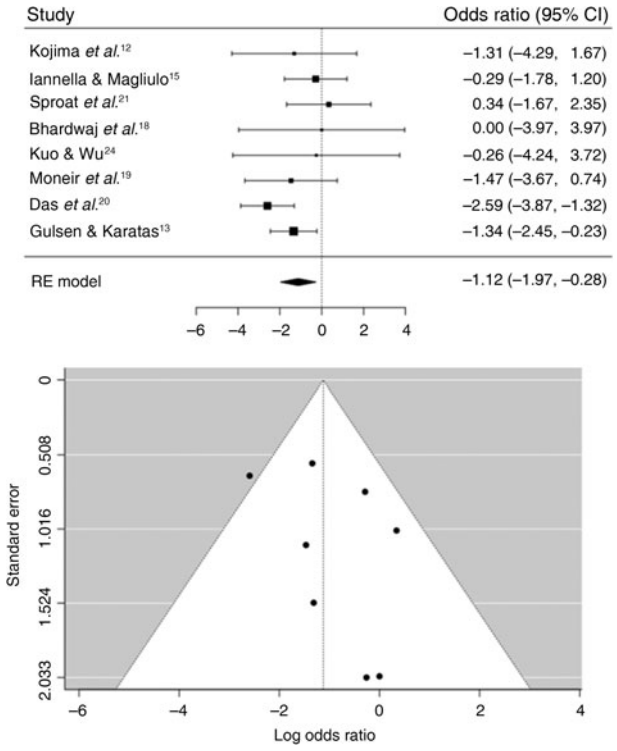


Fig. 5. Forest plot for post-operative dysgeusia. CI = confidence interval; RE = random effects

procedures undoubtedly belong in the everyday clinical practice of otological surgery. Given its proven predominance so far in terms of two-dimensional vision, cosmetic result, post-operative pain and safety, combined with a comparable success rate, endoscopic surgery seems to be the frontrunner, and may replace microscopes in most common otological cases in the near future.[30,31] Furthermore, digitally developed surgical instruments (downsized endoscopes or less heat-emissive cold light sources), as well as the anticipated widespread use of robots in ear surgery, are expected to improve three-dimensional visualisation and overcome the aforementioned drawbacks of the endoscopic technique.[35,36] Undoubtedly, microscopes will still be available for advanced and more complex cases, such as reoperation or when the surgical view is obstructed by extensive bleeding.

Study limitations

The current study is characterised by some important limitations, affecting its power to arrive at extensively applicable conclusions. Most importantly, only one randomised, controlled trial was included in the current analysis. Moreover, clinical heterogeneity and inconsistency in numerous factors contributed to the downgrade of risk of bias scores, including: revision surgery, the number and experience of the operating surgeon(s), follow-up periods, methods and diagnostic tools of complication evaluation and assessment, sample size, and the retrospective nature of data collection. Furthermore, a lack of systematic complication assessment and evaluation methods limited the number of studies included in the final statistical analysis. Additionally, data regarding length of hospitalisation and cost were insufficient; thus, pertinent results in regard to these parameters could not be achieved. These factors should be addressed appropriately in future studies.

Conclusion

Endoscopic stapes surgery is a promising innovative alternative to the microscopic technique, resulting in commensurate outcomes regarding hearing improvement. In terms of post-operative complications, pain and dysgeusia appear to be less frequent using the endoscopic approach. Further studies need to be conducted, including wider sample sizes, in order to draw widely applicable conclusions concerning operation time, the learning curve and the acquisition of otology surgical skills.

Competing interests. None declared

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