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Endoscopic type I tympanoplasty is as effective as microscopic type I tympanoplasty but less invasive—A meta-analysis

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Abstract

Background: Endoscopic type I tympanoplasty was originally introduced in the 1990s, and the extensive spread of this practice can be easily observed. The conventional technique performed involves the repair of a tympanic membrane perforation, and is defined as microscopic type I tympanoplasty.

Objective of Review: The aim of this study was the comparison of postoperative outcomes of both the endoscopic and the microscopic type I tympanoplasty.

Type of Review: We conducted a meta-analysis in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-analysis (PRISMA) guidelines.

Search Strategy: A systematic literature search was performed in the databases of PubMed, Embase, Cochrane Library, Clarivate Analytics-Web of Science, ClinicalTrials.gov, World Health Organization Library, and Scopus by inserting, 'myringoplasty OR (tympanoplasty AND perforation)' into the search query. We applied only a 'human' filter. We excluded non-English studies. Additional records were identified by checking the references of relevant studies.

Evaluation Method: Comparative studies were included in our analysis. We calculated the pooled odds ratio (OR) with 95% confidence interval (CI) for dichotomous outcomes and weighted mean difference (WMD) with a 95% CI for continuous outcomes. Additionally, we assessed the risk of bias and estimated the quality of evidence for each outcome.

Results: Our systematic search yielded 16 studies (involving 1179 interventions), eligible for analysis. The pooled graft uptake rate (OR: 1.21, CI: 0.82-1.77; $I^2 = 0.0\%$), the postoperative hearing results (WMD = -1.13 ; 95% CI: -2.72 - 0.45 ; $I^2 = 78.1\%$) and the operation time (WMD = -21.11 ; 95% CI: -42.60 - 0.38 ; $I^2 = 99.3\%$), were all comparable amongst the two techniques. In contrast, the endoscopic type I tympanoplasty outperforms when regarding the pooled canaloplasty rate (OR = 7.96; 95% CI: 4.30-14.76; $I^2 = 0.0\%$, $P = 1.000$) and features an increase in desirable cosmetic results (OR = 19.29; 95% CI: 11.37-32.73; $I^2 = 0.0\%$, $P = 0.839$), when compared with the microscopic approach.

István Pap and István Tóth Shared first authorship.

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Conclusions: Based on our meta-analysis, the surgical outcomes of endoscopic type I tympanoplasty in terms of graft uptake rate, postoperative hearing results and operation time were comparable to the microscopic type I tympanoplasty. In regards to cosmetics, an increase in desirable results was achieved in the endoscopic group, particularly the incidence of canaloplasty which proved to be significantly lower.

1 | INTRODUCTION

The increased proportion amongst subjects suffering from chronic tympanic membrane perforations and, interestingly, do not want to be operated on, suggests there is a considerable need for novel therapeutic procedures.¹ An additional systematic review analysing the burden of disease caused by otitis media, in which chronic suppurative otitis media incidence rate was 4.76‰ or at or about 31 million cases, concluded that 22.6% of cases occurring annually were patients under five years old. Otitis media-related hearing impairment has a prevalence of 30.82 per ten-thousand. Annually, 21 000 individuals succumb due to complications of otitis media.² A study found the prevalence of chronic tympanic membrane perforation amongst adults 0.9%, eight out of nine subjects refused tympanoplasty for various reasons.¹ The microscopic tympanoplasty has been the standard procedure regarding the effective reconstruction of a perforated tympanic membrane, dating back to the middle of the 20th century. This approach has many disadvantages including poor cosmetic results, caused by a retroauricular incision and the necessity in performing canaloplasty primarily in cases of anterior perforation.³ Since endoscopic ear surgery was first performed in the 1990s,⁴ it represents the ever-increasing, minimally invasive branch of otologic surgery. An endoscope is an ideal tool, enabling the surgeon to perform transcanal endoscopic ear surgery in its entirety while the classical microscopic approach will most likely require an additional external incision, or a mastoidectomy.³

In regards to the endoscope, the external incision, soft tissue dissection and bone removal can effectively be avoided. In addition, the consumption of medical resources can also be diminished and partly reflecting a shorter rate of hospitalisation.⁵ This approach also provides a wider perspective in reference to enabling access into 'hidden spaces' deep within the middle ear cavity.⁶

1.1 | Objectives

In 2016, a superbly written meta-analysis was published which collected evidence regarding both endoscopic and microscopic type I tympanoplasty.⁷ Since this topic is of particularly high interest, several new studies, including high-quality randomised controlled trials (RCTs), have been recently published. The large body of evidence accumulated proved inspirational, resulting in our intensive review of the plethora of recently published literature. All relevant papers comparing the safety and efficacy of endoscopic type I tympanoplasty to that of microscopic type I tympanoplasty were

Keypoints

- Endoscopic type I tympanoplasty is as effective as microscopic type I tympanoplasty but less invasive.
- The surgical outcomes of endoscopic type I tympanoplasty in terms of graft uptake rate, postoperative hearing results, and operation time were comparable to the microscopic type I tympanoplasty.
- In regards to cosmetics, an increase in desirable results was achieved in the endoscopic group, particularly the incidence of canaloplasty which proved to be significantly lower.

collated. Our paper aims to determine which method proves more effective in and applicable to the treatment of tympanic membrane perforation.

2 | MATERIALS AND METHODS

The Preferred Reporting Items for Systematic Reviews and Meta-analysis (PRISMA) guidelines were used to report our results.⁸ The protocol of this study was registered with PROSPERO (registration number: CRD42018095616; www.crd.york.ac.uk/PROSPERO).

2.1 | Ethical considerations

There were no ethical considerations.

2.2 | Eligibility criteria

Following the PICO framework, eligible studies examined patients (P) at various age, suffering from dry, central tympanic membrane perforation and, who underwent type I tympanoplasty, carried out with either the endoscope (I) or the microscope (C), and discussed strategic, postoperative outcomes (O). Patients with sensorineural or mixed hearing loss, discharging ear, cholesteatoma, ossicular chain abnormality or combating an active ENT infection were excluded.

Randomised and non-randomised studies (nRCT), including conference abstracts, were all included. Case reports, case series, review articles, letters, editorials and comments were excluded.

2.3 | Outcome measures

The graft uptake rate served as our primary outcome. Regarding inclusion, at least a six-month follow-up was required. Our secondary outcomes included postoperative audiological outcomes, the need for canaloplasty, average operation time and cosmetic results. Seven studies^{6,9-14} compared the postoperative hearing outcomes based on the average air-bone gap (ABG); hence, we used the ABG means in support of our analysis. However, four of the included studies¹⁵⁻¹⁸ reported the postoperative ABG, in accordance with the Committee on Hearing and Equilibrium of the American Academy of Otolaryngology, Head and Neck Surgery.¹⁹ In this event, we determined the postoperative hearing results amongst three groups. Group 1 shows the ABG ranging from 0 to 10 dB, Group 2 contains outcomes with ABG ranging from 11 to 20 dB, while in Group 3, the ABG range was 21-30 dB. The necessity of canaloplasty and the duration of the surgery were determined in the review of the surgical reports. The preferred method for reporting cosmetic results was discrepant across the studies, which may influence the precision of the evaluation of cosmetic results. To evaluate the postoperative cosmetic outcome, we collated data creating two groups: good cosmetic results and poor cosmetic results, respectively (Appendix S1.).

2.4 | Search and selection

We performed a systematic search in the databases of PubMed, Embase, Cochrane Library, Clarivate Analytics-Web of Science, ClinicalTrials.gov, World Health Organization Library, and Scopus, dating from inception up through 31 May 2018. The search query included, 'myringoplasty OR (tympanoplasty AND perforation)'. Filters of 'Humans' and 'English language' were applied to the search. Additional records were identified by examining the reference lists of relevant studies.

The yield of search was imported using a reference manager software (EndNote X7.4, Thomson Reuters) with the intent of the removal of duplicate records. Two authors (IP and IT) independently screened the remaining studies, selecting them by title, abstract and full-text. If an agreement could not be reached, the dispute was settled with the aid of a third investigator (I.Sz.).

2.5 | Data extraction and management

The two authors (IP and IT) independently imputed the extracted data onto a previously edited Excel table. We collected general information including the name of the first author and the year of publication, study design, initial population, the total number of interventions, in reference to the accomplished type I tympanoplasty upon one ear and the length of the follow-up. The investigation of outcomes consisted of the graft uptake rate, postoperative audiological results, the need for performing canaloplasty, assessing cosmetic results and average operating time. Discrepancies were resolved by consulting a third investigator (I.Sz.).

2.6 | Risk of bias (ROB) assessment

RoB in the individual studies was independently assessed by two authors (IP and IT) (Appendix S1). Randomised controlled trials were assessed using the Cochrane Risk of Bias Tool, in compliance with the following domains: random sequence generation, allocation concealment, blinding of participants, personnel, and outcome assessment, incomplete outcome data, selective reporting and other bias.²⁰ In the case of nRCTs, we used the topic-tailored version of Newcastle-Ottawa Scale (NOS) regarding three domains: selection, comparability and outcome assessment.²¹ If an agreement could not be reached, a third-party arbitration was adopted to settle the dispute (I.Sz.).

2.7 | Statistical analysis

Statistical analysis was performed in the use of the Stata 11 SE (StataCorp). For dichotomous outcomes (graft uptake rate, canaloplasty rate, cosmetics and hearing outcomes, in accordance with the Committee on Hearing and Equilibrium of the American Academy of Otolaryngology, Head and Neck Surgery), we calculated pooled odds ratios (ORs) with 95% confidence intervals (CIs). In some cases, we applied the Peto method,²⁰ due to the potential, occasional rare event. Weighted mean difference (WMD) with 95% CIs was calculated for continuous outcomes (operation time and ABG means).

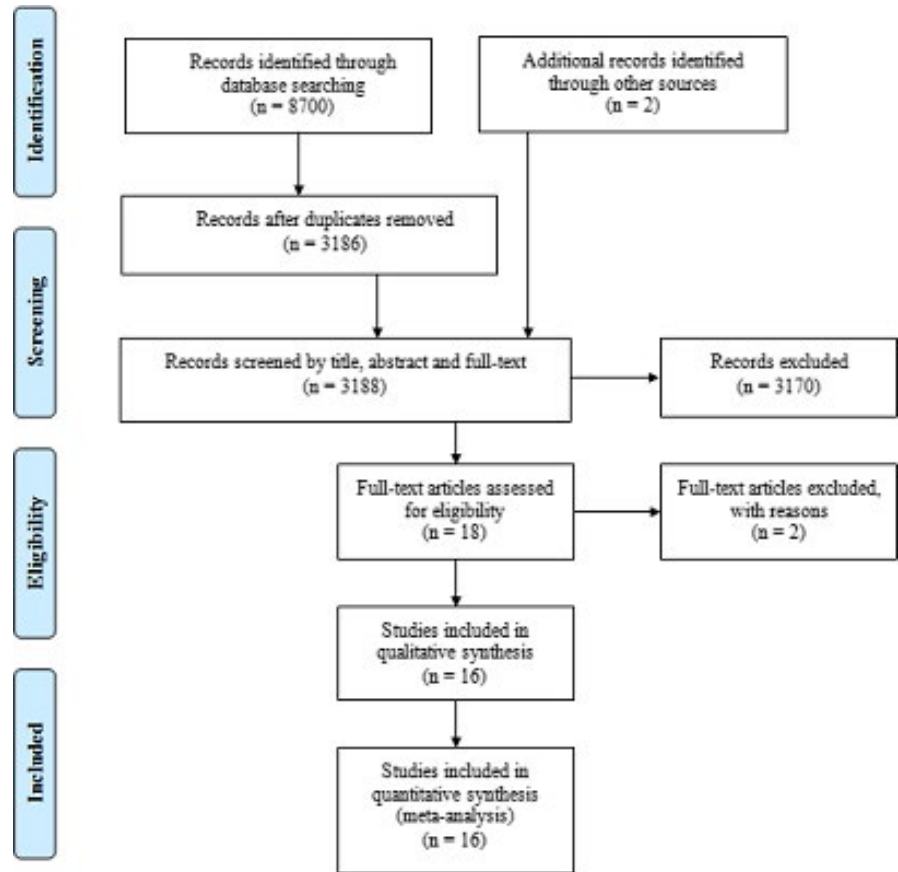
Subgroup analyses were applied in accordance with the study design and included (RCT vs nRCT), if, at least three RCTs were available (graft uptake rate, canaloplasty rate, cosmetics and operation time). We applied the random effect model with DerSimonian-Laird estimation. I^2 and χ^2 tests were used to quantify statistical heterogeneity and gain probability-values, respectively; $P < 0.1$ indicated a significant heterogeneity. To check for publication bias, a visual inspection of funnel plots and Egger's test were performed.²⁰ Sensitivity analysis was performed by omitting studies (individually) from the analyses and recalculating to investigate the impact of the individual studies upon the summary estimate.

The trial sequential analysis (TSA) was conducted regarding the graft uptake rate to observe the futility threshold. Notably, TSA is a methodology which combines an information size calculation (cumulated sample sizes of all included trials) for a meta-analysis with the threshold of statistical significance. In the operational use of this tool, we can quantify the statistical reliability of data in the cumulative meta-analysis adjusting significance levels for sparse data and repetitive testing on accumulating data.²²

2.8 | The GRADE approach

The Grading of Recommendations Assessment, Development and Evaluation (GRADE) was used for assessing the quality of evidence of critical and important outcomes assessed.²³ The grade of evidence was assessed in support of subgroups of RCTs, if possible.

FIGURE 1 Depicts the study flow chart. Our primary search yielded 1737 records in PubMed, 1920 in Embase, 133 in Cochrane Library, in Clarivate Analytics-Web of Science, 7 in ClinicalTrials.gov, 1612 in World Health Organization Library and 2238 in Scopus



3 | RESULTS

3.1 | Search and selection

Figure 1 represents the study flow chart. Our primary search yielded a total of 8700 records. In the screening of the records by title, abstract and full-text, we found 18 articles which met the eligibility criteria.^{6,9-18,24-30} We found two publications with identical cohorts of patients; therefore, we excluded the recently published one.²⁵ Another study was excluded due to insufficient data.²⁸ Inevitably, 16 articles were included in the meta-analysis. Characteristics of the included articles are shown in Table 1. The quality of evidence for each outcome is represented in Table 2.

3.2 | Meta-analysis

3.2.1 | Graft uptake: endoscopic type I tympanoplasty performs as well as microscopic type I tympanoplasty (high grade of evidence)

Sixteen studies including 1179 interventions were deemed eligible for inclusion.^{6,9-18,24,26,27,29,30} Accrued results, in which endoscopic type I tympanoplasty was as effective as microscopic type I tympanoplasty in a homogenous dataset, indicated a 90.5% graft uptake rate in the endoscopic and 88.3% success rate in the microscopic group (OR: 1.21, CI: 0.82-1.77; $I^2 = 0.0\%$, $P = 0.910$) (Figure 2). The direction of association did not change if we included only five

RCTs in the analysis (OR: 0.81, CI: 0.43-1.53; $I^2 = 0.0\%$, $P = 0.989$). Performing trial sequential analysis, we concluded additional trials will prove to be potentially futile (Appendix S1).

Based on the Egger's test, the small study effect is unlikely to occur ($P = 0.727$) (Appendix S1). We performed a sensitivity analysis which demonstrated if any study is excluded from the analysis, the overall results are not affected nor altered. To overcome the potential risk of poor peer review caused by the inclusion of conference abstracts, we performed sensitivity analysis by omitting abstracts from the relating analysis which confirmed that the inclusion of these publications did not change the direction of the main association (Appendix S1).

3.2.2 | Postoperative hearing results: endoscopic type I tympanoplasty performs and microscopic type I tympanoplasty (very low grade of evidence)

Fifteen authors published data regarding audiological outcomes.^{6,9-18,24,27,29,30} We excluded four studies, due to no or insufficient data provided.^{24,27,29,30} In the analysis of the postoperative mean ABGs, no statistically significant difference was found (WMD = -1.13; 95% CI: -2.72-0.45; $I^2 = 78.1\%$, $P < 0.001$) however, a tendency favouring the endoscopic approach could be observed (Appendix S1). Regarding ABG categories, endoscopy proved to outperform microscopy amongst the ratio of patients achieving 0-10 dB ABG (Appendix S1). Our sensitivity analysis showed, if and when any of the participating studies are excluded from the analysis, the overall results are not affected nor altered.

TABLE 1 Summarises the characteristics of the papers considered in our study

| Author, year | Study design | Country/No. of centres | No. of interventions (Endoscopic) | No. of interventions (Microscopic) | Outcomes assessed | Follow-up time (months) |
|------------------------------|-----------------------------------|------------------------|-----------------------------------|------------------------------------|--|-------------------------|
| Harugop, 2008 ¹⁵ | RCT | India/1 | 50 | 50 | Graft uptake, canaloplasty needed, operation time, cosmetic results, hearing results | 6 |
| Jyothi, 2017 ²⁶ | RCT | India/1 | 60 | 60 | Graft uptake, canaloplasty needed, operation time, hearing results | 12 |
| Kaya, 2017 ¹¹ | RCT | Turkey/ | 13 | 13 | Graft uptake, operation time, hearing results | 6 |
| Kumar, 2015 ¹⁶ | RCT | India/1 | 30 | 30 | Graft uptake, canaloplasty needed, operation time, cosmetic results, hearing results | 6 |
| Lade, 2013 ¹² | RCT | India/1 | 30 | 30 | Graft uptake, canaloplasty needed, cosmetic results, hearing results | 6 |
| Choi, 2017 ⁶ | Retrospective comparative study | Korea/1 | 25 | 48 | Graft uptake, canaloplasty needed, operation time, hearing results | 3 |
| Dündar, 2014 ⁹ | Retrospective cohort study | Turkey/2 | 32 | 29 | Graft uptake, operation time, hearing results | 12 |
| Fina, 2016 ²³ | Retrospective cohort study | USA/1 | 29 | 30 | Graft uptake, operation time, hearing results | N/A |
| Huang, 2016 ¹⁰ | Retrospective comparative study | Taiwan/4 | 50 | 50 | Graft uptake, operation time, hearing results | 6 |
| James, 2017 ²⁵ | Prospective comparative study | Canada/1 | 13 | 15 | Graft uptake | 12 |
| Lakpathi, 2015 ¹⁷ | Prospective comparative study | India/1 | 30 | 30 | Graft uptake, operation time, cosmetic results, hearing results | 6 |
| Nassif, 2015 ²⁸ | Observational retrospective study | Italy/2 | 22 | 23 | Graft uptake, operation time, hearing results | 6 |
| Plodpai, 2017 ¹³ | Retrospective comparative study | Thailand/1 | 90 | 91 | Graft uptake, canaloplasty needed, operation time, hearing results | 6 |
| Raj, 2001 ¹⁸ | Comparative study | India/1 | 20 | 20 | Graft uptake, hearing results | 10 |
| Shoeb, 2016 ¹⁴ | Prospective comparative study | India/1 | 30 | 30 | Graft uptake, hearing results | 6 |
| Tay, 2017 ²⁹ | Retrospective study | Singapore/1 | 32 | 74 | Graft uptake, operation time | N/A |

3.2.3 | Canaloplasty rate: endoscopic type I tympanoplasty performs better compared with microscopic type I tympanoplasty (high grade of evidence)

Six studies analysed the canaloplasty rate, including a total of 594 interventions.^{6,12,13,15,16,27} The rate of canaloplasty proved eight times higher in the use of the microscope when compared to that of the endoscope (15% vs 0%; OR = 7.96; 95% CI: 4.30-14.76; $I^2 = 0.0\%$, $P = 1.000$) (Figure 3). In the performance of a sensitivity analysis, if and when any study was excluded from the analysis, the overall results are not affected nor altered.

3.2.4 | Cosmetic results: endoscopic type I tympanoplasty performs better than microscopic type I tympanoplasty (moderate grade of evidence)

Cosmetic results were reported in four articles including 279 interventions.^{12,15-17} Microscopic type I tympanoplasty was reportedly

19 times more likely to result in a poor cosmetic outcome when compared to the endoscopic approach (58.3% vs 0%; OR = 19.29; 95% CI: 11.37-32.73; $I^2 = 0.0\%$, $P = 0.839$) (Figure 4). We performed a sensitivity analysis, based on, if and when any study is excluded from the analysis, the overall results are not affected nor altered.

3.2.5 | Operation time: endoscopic type I tympanoplasty performs and microscopic type I tympanoplasty (low grade of evidence)

Twelve studies evaluated data regarding operation time^{6,9-11,13,15-17,24,27,29,30}; however, three of these were excluded, due to incomplete reporting.^{24,27,30} Of these nine studies, six were nRCTs,^{6,9,10,13,17,29} and an additional three others were RCTs.^{11,15,16} Based on the pooled data analysis, there was no statistically significant difference between the two approaches (WMD = -21.11; 95% CI: -42.60 to 0.38; $I^2 = 99.3\%$, $P < 0.001$) (Appendix S1). Egger's test confirmed there is no small study effect ($P = 0.902$) (Appendix S1). Performing subgroup analysis, based on nRCTs endoscopic Type I Tympanoplasty, requires shorter time,

TABLE 2 Represents the certainty assessment and summary of findings in support of the referenced studies

| Endoscopic approach compared to microscopic approach for type i tympanoplasty | | | | | | | | | | | |
|---|--------------|-------------------------------|-----------------------|--------------|-------------|------------------|------------------------------|--------------------------|---------------------------|--------------------------------|--|
| Certainty assessment | | | Summary of findings | | | | | | | | |
| No. of participants (studies) Follow-up | Risk of bias | Overall certainty of evidence | Study event rates (%) | | | | Anticipated absolute effects | | | | |
| | | | Inconsistency | Indirectness | Imprecision | Publication bias | With microscopic approach | With endoscopic approach | Relative effect (95% CI) | Risk with microscopic approach | Risk difference with endoscopic approach |
| Graft uptake rate (follow-up: mean 6 mo; assessed with: otoscopy)—Critical outcome | | | | | | | | | | | |
| 366 (5 RCTs) | Not serious | +++ High | Not serious | Not serious | Not serious | None | 163/183 (89.1%) | 159/183 (86.9%) | OR 0.81 (0.43 to 1.53) | 89 per 100 | 2 fewer per 100 (11 fewer to 4 more) |
| Postoperative mean ABG (follow-up: mean 6 months; assessed with: clinical records)—Critical outcome | | | | | | | | | | | |
| 561 (2 RCTs, 5 nRCTs) | Serious | + | Very serious | Not serious | Not serious | None | 291 | 270 | | | WMD 1.13 lower (2.72 lower to 0.45 higher) |
| Canaloplasty rate (assessed with: clinical records)—Important outcome | | | | | | | | | | | |
| 340 (4 RCTs) | Not serious | +++ High | Not serious | Not serious | Not serious | Uncertain | 27/170 (15.9%) | 0/170 (0.0%) | OR 8.61 (3.94 to 18.84) | 16 per 100 | 46 more per 100 (27 more to 62 more) |
| Cosmetic results (follow-up: mean 6 months; assessed with: physical examination, patient reports)—Important outcome | | | | | | | | | | | |
| 219 (3 RCTs) | Not serious | +++ Moderate | Not serious | Not serious | Serious | Uncertain | 60/109 (55.0%) | 0/110 (0.0%) | OR 18.86 (10.23 to 34.77) | 55 per 100 | 41 more per 100 (38 more to 43 more) |
| Operation time (assessed with: clinical records)—Important outcome | | | | | | | | | | | |
| 186 (3 RCTs) | Not serious | ++ Low | Very serious | Not serious | Not serious | uncertain | 93 | 93 | | | WMD 0.3 higher (32.18 lower to 32.79 higher) |

Notes: Regarding the risk of bias, in the postoperative mean ABG, we assessed it poses a serious risk due to the number of non-randomised trials, which were higher in number. Undeniably, a serious inconsistency was evaluated in the event of high heterogeneity at the following two outcomes: Postoperative mean ABG ($I^2 = 78.1\%$) and, the duration of the operation ($I^2 = 98.0\%$). The evaluation of indirectness yielded irrelevant results, due to the entirety of the included studies featured a clear PICO, which corresponded to our PICO. Regarding the cosmetic results, imprecision was determined as relevant, since the assessment of cosmetic results was not performed using a standardised questionnaire. The optimal duration of operation was not precisely defined. In consideration of the balance of the outcomes, imprecision was not as serious amongst the outcomes based on RR. Publication bias was not detected amongst critical outcomes. Regarding the remaining three important outcomes, publication bias could not be evaluated, due to the decreased number of included studies.

Abbreviations: ABG, Air-Bone Gap; CI, Confidence Interval; nRCT, non-Randomised Controlled Trial; OR, Odds Ratio; RCT, Randomised Controlled Trial; RR, Risk Ratio; WMD, Weighted Mean Difference.

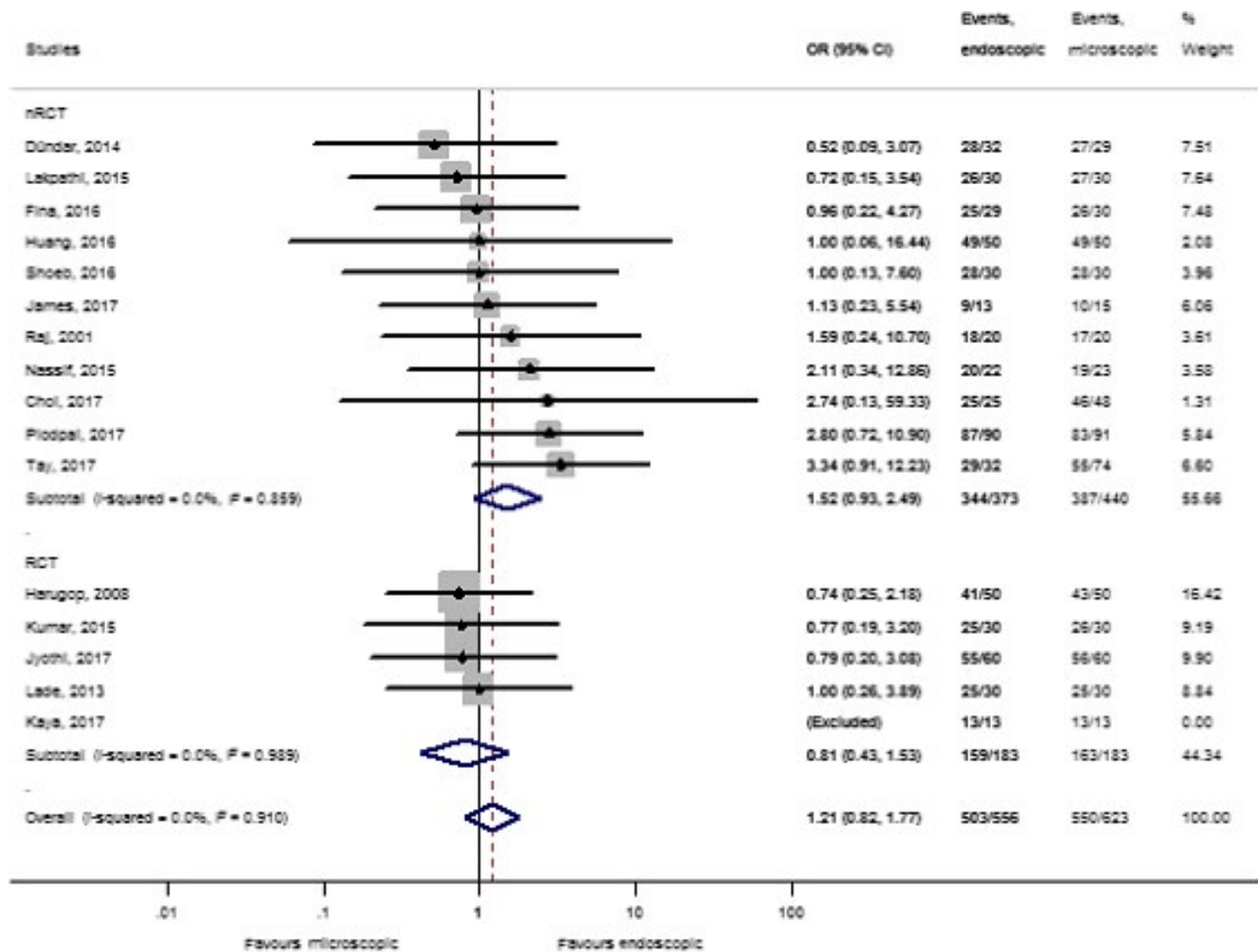


FIGURE 2 Represents the forest plot of our primary outcome, referred to as the graft uptake rate

including an average of 31 minutes (WMD = -31.83 ; 95% CI: -56.72 to -6.94 ; $I^2 = 99.3\%$, $P < 0.001$). The analysis including RCTs offered no statistically significant difference amongst the two groups regarding operation time (WMD = 0.30 ; 95% CI: -32.18 to 32.79 ; $I^2 = 98.0\%$, $P < 0.001$). Performing the sensitivity analysis, we observed that by excluding Harugop's or Kumar's studies the results yielded in favour of endoscopic type I tympanoplasty.

3.2.6 | Postoperative pain, quality of life and perioperative complications

Three studies reported data on postoperative pain,^{6,11,27} all used subjective methods for pain assessment. The studies did not detect a significant difference in the level of postoperative pain between the endoscopic and microscopic techniques.

Only one study investigated quality of life.¹¹ According to their findings, after endoscopic type I tympanoplasty, the patient's quality of life improved significantly.

Nine of the included studies reported data on the incidence and severity of perioperative complications.^{10-13,15,16,18,26,27} Altogether the endoscopic approach proved to be much safer.

Since the discrepant reporting of the findings, these outcomes proved to be ineligible for meta-analysis.

4 | DISCUSSION

Endoscopic ear surgery represents the ever-increasing, minimally invasive branch of otologic surgery. New results culminating in the past recent years warranted an updated meta-analysis to resolve debates concerning the two approaches. Our results indicate that the endoscopic approach competitively achieved graft uptake and hearing restoration equally and the microscopic method, yet it resulted in an increase in the preferred cosmetic results and a lower canaloplasty rate (ie less invasive) (Table 2). These findings support the fact that the endoscope is an ideal tool in the management of chronic suppurative otitis media.

With regards to the primary outcome in association with the graft uptake, both approaches performed well. During endoscopic ear surgery, one-handed dissection is performed. Thus, one might assume that the thickness and manoeuvrability of the materials used for the reconstruction of the tympanic membrane can

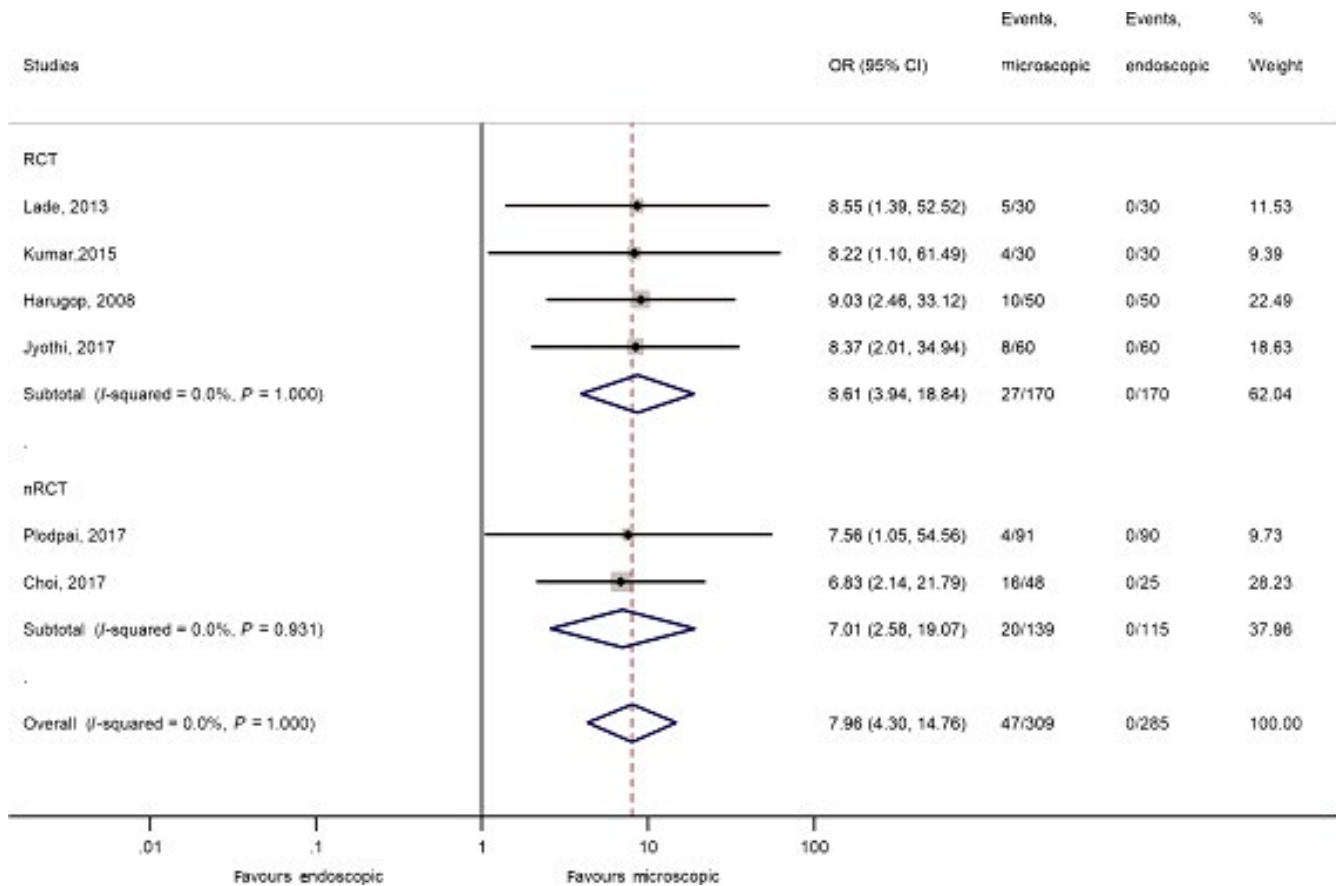


FIGURE 3 Represents the forest plot of our third outcome, commonly referred to as the canaloplasty rate

influence the primary outcome. Although technical differences across studies (eg reconstruction of the membrane with fascia, perichondrium or cartilage) elevated reasonable concern in reference to clinical heterogeneity (Table 3), it did not manifest itself in statistical heterogeneity ($I^2 = 0.0\%$, see Figure 2). The potential selection bias is a persistent worry surrounding surgical studies, however, results on efficacy were also consistent in the subgroup of RCTs (Figure 2). Similarly, the number of interventions proved to be generally satisfactory towards excluding beta-type errors (Appendix S1).

Audiological outcomes reflect graft uptake.³¹ Not surprisingly, the postoperative ABGs showed no difference amongst both groups. However, using ABG as a categorical variable, yielded results favouring endoscopy. Here, we believe the difference observed may be biased due to the potential differences in hearing at the baseline. Factually, this hypothesis in which we failed to detect any difference regarding the graft uptake rate, determines the recovery in hearing.

One of the primary advantages regarding endoscopic type I tympanoplasty is that there is no necessity for performing a canaloplasty. Non-invasiveness was proven both in the subgroup of RCTs and nRCTs (Figure 3): no canaloplasty was required in the endoscopic group. In contrast with the microscopic approach: 47 of 309 interventions (15%) required canaloplasty, resulting in

drilling-out the medial part of the anterior external auditory canal wall. The immense difference amongst both techniques can be explained in which the lens of the endoscope can be approximated one centimetre to the operational field, bypassing the narrowest part of the external ear canal, whereas the microscope lens is lateral to this, restricting the surgical view.

Characteristically, yet another significant advantage regarding the endoscopic technique reflects upon the non-invasiveness aspects. Retroauricular incision is completely avoidable regarding endoscopy, yet a visible scar is nearly inevitable when utilising the use of the microscope. Additionally, the lack of invasiveness reduces the incidence of postoperative auricular deformity, numbness and pain. Based on the three RCTs and one nRCT, the meta-analysis showed endoscopy is definitely preferred concerning cosmetic results (Figure 4). However, the assessment of cosmetic results varies: patients' opinion (subjective) or the presence or absence of a visible scar (objective) was both applied across the vast field of studies.

The duration of the operation can be influenced by various factors. In this study, based upon nRCTs, it can be concluded in which endoscopic type I tympanoplasty requires, on average, 31 minutes less surgical time. This difference may be the result of selection bias (Appendix S1), meaning the surgical time is influenced by the surgeon's experience and the learning curve. However, these articles did not provide any information about these factors. Regarding the

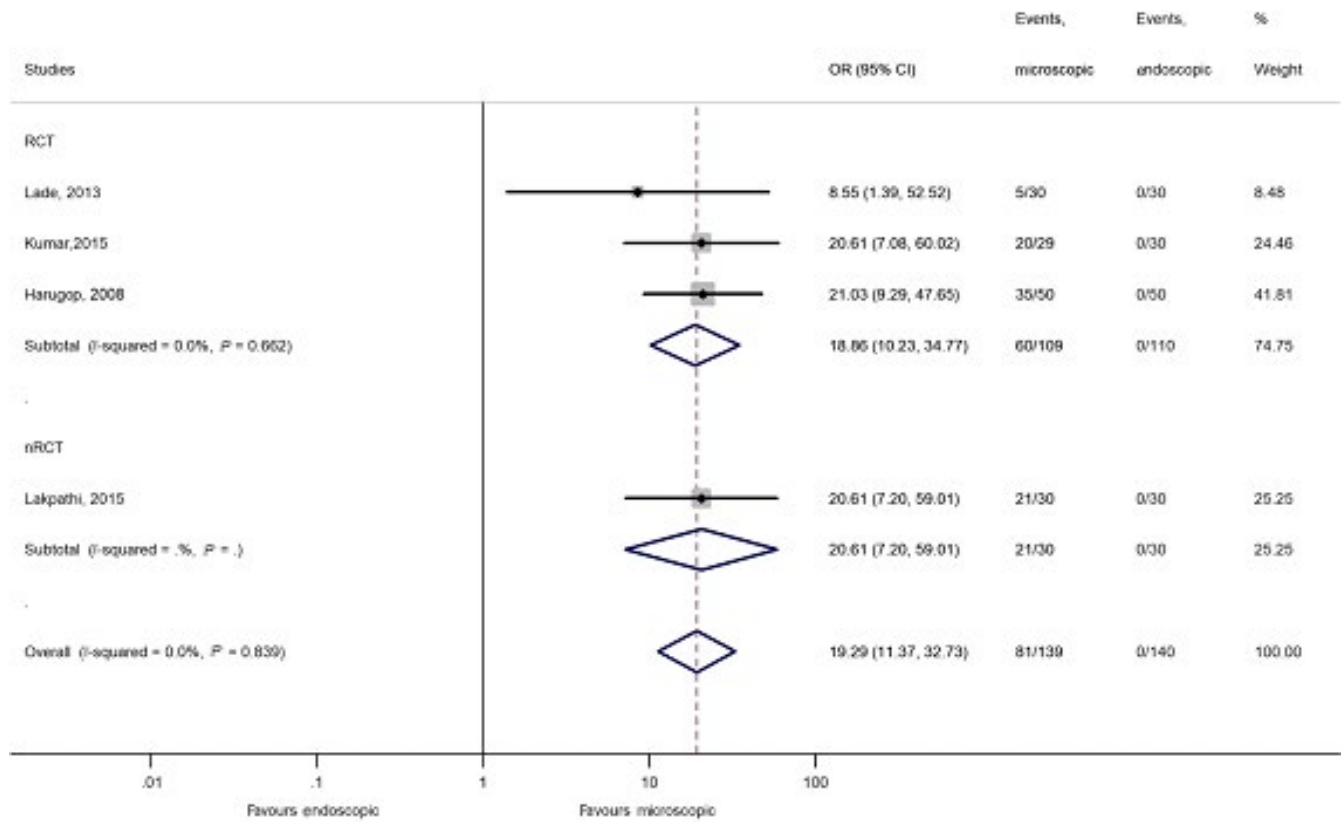


FIGURE 4 Features the forest plot of our fourth outcome, referred to as the cosmetic results

duration of the operation, in consideration of the inclusion of the three RCTs, there is no significant difference amongst the two techniques. The sensitivity analysis demonstrated, with the exclusion of two RCTs, the pooled result becomes statistically significant in favour of the endoscopic approach.^{15,16} Since these articles did not offer enough data regarding the exact anatomical situations, intraoperative complication rates or the surgeon's experience, in the assessment and addressing, specifically, why the endoscopic approach required additionally more time regarding both these studies, ultimately, could not be performed. The analysis suffers from significant heterogeneity, which may reflect clinical and/or methodological differences of the RCTs (Appendix S1). The lack of an additional surgical incision may explain the shorter time required in support of endoscopy.

In the use of an endoscope, one can better visualise the middle ear's structures and concealed anatomical regions, which can be beneficial, not only during myringoplasty, and, additionally, in other middle ear pathologies, such as seen in cholesteatoma or stapes fixation.

4.1 | Strengths and limitations

Our meta-analysis possesses several strengths. A thorough systematic search and RoB assessment was performed using the Cochrane Risk of Bias Tool and NOS. Our findings were similar to those presented in the previously published meta-analysis. In contrast to the former publication, specifically regarding this topic,⁷

the present search yielded an additional three more randomised controlled trials^{11,16,27} which allowed us to arrange subgroups of RCTs. To rate the evidence of every statement, the GRADE approach was used (Table 2). Following the completion of the subgroup analysis, only RCTs were included to grade the evidence of the statements. While performing the TSA, it can be inferred, in which, regarding the graft uptake rate, there was no difference of effect amongst endoscopic type I tympanoplasty and microscopic type I tympanoplasty.

Admittedly, amongst our strengths, our meta-analysis has several limitations. Two papers were conference abstracts, which potentially carry the risk, due to a less than ideal peer review process. Moreover, we were unable to perform subgroup analysis of RCTs separated from nRCTs, due to the diminished number of eligible studies regarding postoperative audiological outcomes. The variance observed in the location and size of the tympanic membrane perforation raised concerns about clinical heterogeneity, especially in the observational studies as demonstrated with the RoB assessment (Appendix S1). Regarding postoperative hearing outcomes, uncertainty is detected in the examination of the categorical audiological results, in accordance with the Committee on Hearing and Equilibrium of the American Academy of Otolaryngology, Head and Neck Surgery. Additionally, a limitation of the measurement regarding our critical outcomes was the use of various materials reconstructing the continuity of the tympanic membrane. A wide spectrum of follow-up periods could be observed which influenced

TABLE 3 summarises the characteristics of perforation, graft material, and the surgical technique across the included studies

| Author, year | Perforation size | Perforation location | Annulus involvement | Graft material | Surgical technique |
|------------------------------|--|---|---------------------|---|--------------------|
| Harugop, 2008 ¹⁵ | Medium to subtotal (according to the number of quadrants involved) | Central (marginal or attic perforations were excluded) | Not reported | Temporal fascia | Underlay |
| Jyothi, 2017 ²⁶ | Not reported | Central | Not reported | Temporal fascia | Underlay |
| Kava, 2017 ¹¹ | <25%, 25%-50%, 50%-75% 75%< | Anterior, posterior, central, subtotal | Not reported | Cartilage | Underlay |
| Kumar, 2015 ¹⁶ | <5 mm | Central | Not reported | Temporal fascia | Underlay |
| Lade, 2013 ¹² | Any (apart from small or moderate sized posterior perforations) | Any (apart from small or moderate sized posterior perforations) | Not reported | Fascia | Underlay |
| Choi, 2017 ⁶ | Percentage of the entire TM area (mean 21.9% ± 12) | Not reported | Not reported | Perichondrium, temporal fascia | Underlay |
| Dündar, 2014 ⁹ | <50%, 50%< | Central, marginal | Not reported | Chondroperichondrial graft | Underlay |
| Fina, 2016 ^{23*} | Not reported | Not reported | Not reported | Not reported | Underlay |
| Huang, 2016 ¹⁰ | Not reported | Central, peripheral | Not reported | Temporal fascia (microscopic group) perichondrium (endoscopic group) | Underlay |
| James, 2017 ²⁵ | Not reported | Not reported | Not reported | Fascia, areolar tissue/perichondrium, non-autogenous grafts | underlay |
| Lakpathi, 2015 ¹⁷ | Small, medium, large | Central | Not reported | Temporal fascia | Underlay |
| Nassif, 2015 ²⁸ | Not reported | Not reported | Not reported | Temporal fascia or perichondrium (microscopic group) perichondrium (endoscopic group) | Underlay |
| Plodpai, 2017 ¹³ | Small, medium, large | Not reported | Not reported | Temporal fascia | Overlay |
| Raj, 2001 ¹⁸ | Not reported | Central | Not reported | Perichondrium | Underlay |
| Shoeb, 2016 ¹⁴ | Large | Anterior, subtotal | Not reported | Temporal fascia | Underlay |
| Tay, 2017 ^{29*} | Not reported | Not reported | Not reported | Not reported | Not reported |

Abbreviation: TM, tympanic membrane.

* Data were collected from conference abstracts.

us towards applying a high RoB (Appendix S1), if and when, a minimum period of six months was not achieved.

5 | CONCLUSION

5.1 | Implications for research

Our meta-analysis provides a high level of evidence towards justifying the introduction of endoscopic type I tympanoplasty. Distinctly, based upon the TSA performed on graft uptake rates amongst the two methods (endoscopic vs microscopic), it can be stated, in which there is no need to perform additional, randomised controlled trials debating this outcome. However, the potential modifying effect of the location of tympanic membrane perforation and the learning curve in surgical practice should be further investigated. Due to the discrepant reporting of the cosmetic results, the importance of developing standardised questionnaires for quality of life evaluation should be emphasised.

5.2 | Implications for clinical practice

Our results imply how endoscopy, if and when accessible, is preferred when compared with microscopy throughout the routine practice. Hence, the implementation of endoscopic type I tympanoplasty regarding the treatment guidelines of chronic suppurative otitis media is strongly recommended.

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CONFLICT OF INTEREST

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SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section at the end of the article.

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