Received: 14 June 2022 | Accepted: 14 July 2022

DOI: 10.1002/lio2.879

ORIGINAL RESEARCH

Laryngoscope Investigative Otolaryngology

Comparison of endoscopic underlay and over-under tympanoplasty techniques for type I tympanoplasty

James W. Bao MSCI | Kevin Y. Zhan MD | Cameron C. Wick MD

Department of Otolaryngology—Head and Neck Surgery, Washington University School of Medicine, St. Louis, Missouri, USA

Correspondence
Cameron C. Wick, Washington University School of Medicine, Department of Otolaryngology–Head and Neck Surgery, 660 S. Euclid Ave., Campus Box 8115, St. Louis, MO 63110, USA.
Email: cameron.wick@wustl.edu

Funding information
National Institute of Deafness and Other Communication Disorders, Grant/Award Number: T32DC000022

Abstract

Objective: To compare the indications and efficacy of endoscopic over-under tympanoplasty versus endoscopic underlay tympanoplasty.

Methods: Retrospective cohort study of patients undergoing type I endoscopic tympanoplasty via either an underlay or over-under technique by a single surgeon from 2017 to 2021. Patients were excluded if they had a concurrent mastoidectomy, ossiculoplasty, or advanced cholesteatoma defined by involvement of multiple subsites. Patient demographics, perforation size and location, middle ear status, preoperative and postoperative audiograms, and perforation closure were reviewed. Middle ear status was represented using the Ossiculoplasty Outcome Parameter Score (OOPS). The primary outcome was perforation closure at most recent follow-up and secondary outcomes were change in postoperative pure-tone average (PTA) and air-bone gap (ABG).

Results: Of 48 patients, 27 underwent endoscopic underlay tympanoplasty and 21 underwent endoscopic over-under tympanoplasty. Tragal cartilage-perichondrium graft was used in 90% of procedures. Distribution of OOPS scores was not significantly different between groups. Over- under technique addressed significantly larger perforations (mean size of 54% vs. 31%, $p < .001$) and a higher rate of anterior extension (95% vs. 22%, $p < .001$) than underlay technique. Perforation closure rate was not different between groups (95% vs. 96%). Patients experienced significant improvement in PTA and ABG in both groups.

Conclusion: The endoscopic over-under tympanoplasty is comparable to endoscopic underlay tympanoplasty in terms of graft take and audiologic improvement. The over-under technique is effective for repairing larger perforations or those with anterior extension.

Level of evidence: IV

KEYWORDS
cartilage graft, endoscopic ear, over-under, tympanoplasty

This study was presented as an oral presentation at the Triological Society 124th Annual Meeting at COSM (Dallas, TX, USA; April 30, 2022).

1 | INTRODUCTION

Type I tympanoplasty is a well-established surgery for the repair of perforated tympanic membrane (TM) and can be performed via microscopic or endoscopic approaches. Due to the limited field of view of the microscope for certain parts of the middle ear and eardrum, postauricular access is sometimes required.[1] A transcanal endoscopic approach for ear surgery has gained popularity in recent years due to its minimally invasive nature and improved visualization of the TM and structures poorly visualized during microscopic surgery.[2–5] Various tympanoplasty and ossiculoplasty techniques have been converted to an endoscopic approach with comparable results to that of a microscopic approach.[4,6–9]

Tympanoplasty techniques are traditionally separated into two categories: underlay and overlay.[10–12] In general, both techniques demonstrate favorable success rates for achieving an intact TM and hearing improvement. However, their utilization differs depending on surgeon experience and perforation characteristics.[13,14] Underlay tympanoplasty is simple and effective with graft placement medial to the TM and malleus. Limited space and access to the anterior mesotympanum results in lower success rates for larger and anteriorly located perforations using the underlay technique.[15] Overlay tympanoplasty places the graft lateral to the tympanic annulus and malleus after all squamous epithelium is removed. Overlay tympanoplasty results in high success rates for all perforation sizes and locations, but requires more complex surgical maneuvers and is associated with an increased risk of complications and prolonged healing.[16]

Due to the limitations of underlay tympanoplasty and potential risks of overlay tympanoplasty, otologic surgeons have developed a technique called the over-under tympanoplasty.[17] The over-under technique involves complete separation of the remnant TM from the malleus manubrium and umbo allowing the TM to be elevated higher for better exposure of the anterior mesotympanum and protympanum. This extra elevation allows the graft to be placed "over" the malleus and "under" the anterior TM remnant.[18] Studies using a microscopic over-under technique have demonstrated excellent perforation closure rates with minimal complications for technically challenging anterior or large perforations.[17–19]

A few studies have compared endoscopic over-under tympanoplasty to endoscopic underlay tympanoplasty showing similar success rates and hearing improvement, but vary in use of graft material and disease characteristics described.[20,21] Due to the increased popularity of endoscopic tympanoplasty techniques, this study compares the perforation closure rate of the endoscopic over-under technique to the endoscopic underlay technique to further validate this TM reconstruction method and to critically assess its outcomes by accounting for perforation characteristics and middle ear disease burden.

2 | MATERIALS AND METHODS

2.1 | Subjects

After institutional review board approval (IRB #202108201), the Washington University electronic medical record was queried for patients who underwent a type I endoscopic tympanoplasty via either an underlay or over-under technique by a single surgeon between January 1, 2017 and December 31, 2021. Patients were excluded if they had advanced cholesteatoma defined as present in two or more middle ear subsites, required concurrent mastoidectomy, or ossiculoplasty. Patients were also excluded if they did not return after surgery for at least a 3-month post-operative evaluation.

2.2 | Data collection and definition of variables

Demographic information, otologic treatment history, perforation size, presence of anterior perforation extension, middle ear status, surgical details, pre-operative and post-operative audiograms, and perforation status at most recent follow-up were reviewed. Perforation size was recorded as a percentage of the TM and classified as small (<25%), medium (25–50%), or large (>50%). Anterior extension was defined as any involvement anterior to the plane of the malleus. Patients were assessed for otorrhea and intraoperative status of mucosa and ossicles to characterize middle ear status. The Ossiculoplasty Outcome Parameter Staging (OOPS) index was used to classify middle ear disease burden. OOPS is a validated measure of middle ear risk for predicting ossiculoplasty outcomes by incorporating factors of drainage, mucosal inflammation, status of the ossicular chain, type of surgery performed, and whether it is a revision surgery.[22] Scores less than three are generally considered low risk and scores higher than seven are considered high risk when predicting hearing outcomes after ossiculoplasty.[23,24] The primary outcome measure was perforation closure status at most recent follow-up. Successful closure rate was determined by the percentage of patients who had complete take of the graft with resolution of the TM perforation at most recent follow-up. Any recurrent perforations or atelectasis were considered a graft failure and described within the results. The secondary outcome measure was hearing improvement as defined by change in mean pure-tone average (PTA) or air-bone gap (ABG). PTA was calculated from air-conduction thresholds at 500, 1000, 2000, and 3000 Hz. ABG was calculated from the average difference between air and bone conduction at 500, 1000, 2000, and 3000 Hz.

2.3 | Over-under surgical procedure

A 0°, 3-mm diameter, 14-cm length endoscope was inserted into the ear canal and the TM pathology was visualized and characterized (Figure 1). The perforation was rimmed with a 5910 Beaver blade or Rosen needle. Canal incisions were made at 12 o'clock and 6 o'clock and connected with a round knife. A tympanomeatal flap was elevated, the annulus was identified and the middle ear was entered. The TM was elevated until the lateral process of the malleus was identified. The cartilage cap from the lateral process was removed, the malleus manubrium was scored with a 5910 Beaver blade, and the TM was stripped from the malleus. Care was taken to ensure all squamous elements were removed from the malleus and its umbo (Figure 2). All manipulation of

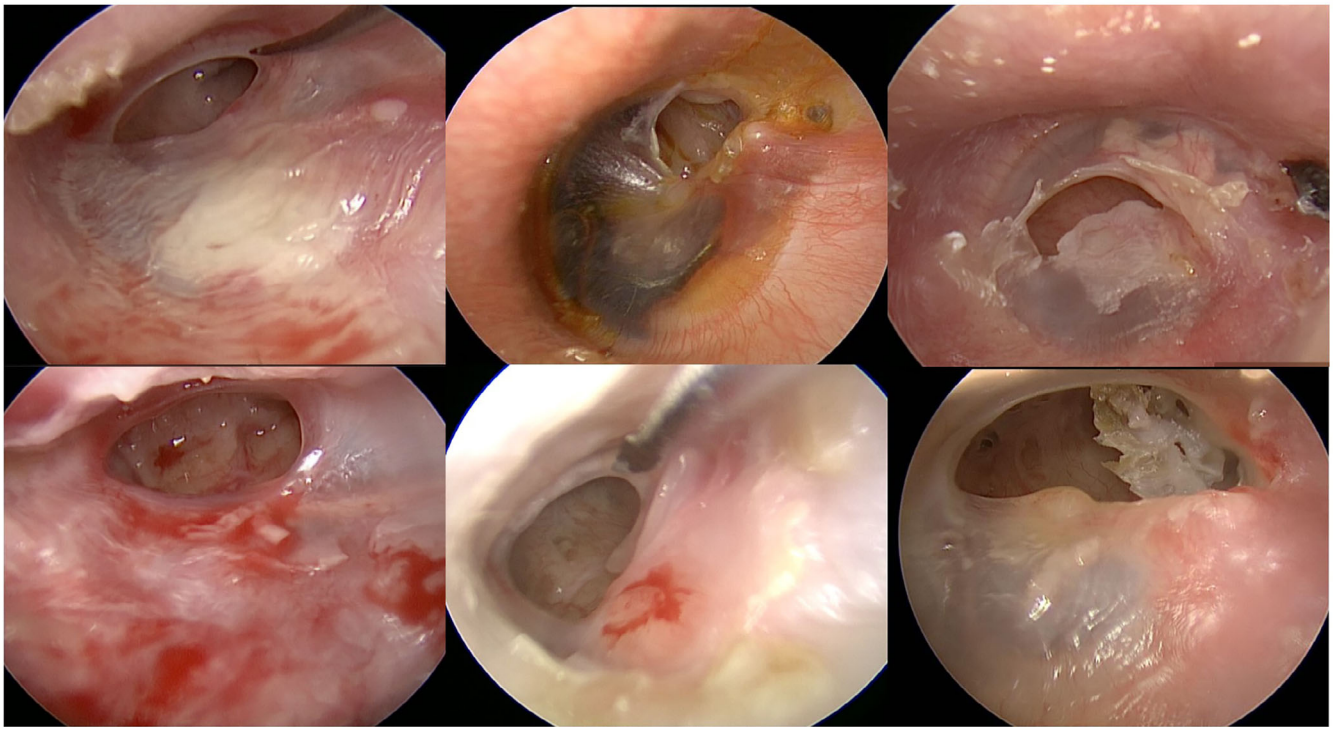

FIGURE 1 Six left tympanic membrane perforations representative of challenging perforations addressed via an endoscopic type 1 over-under tympanoplasty.

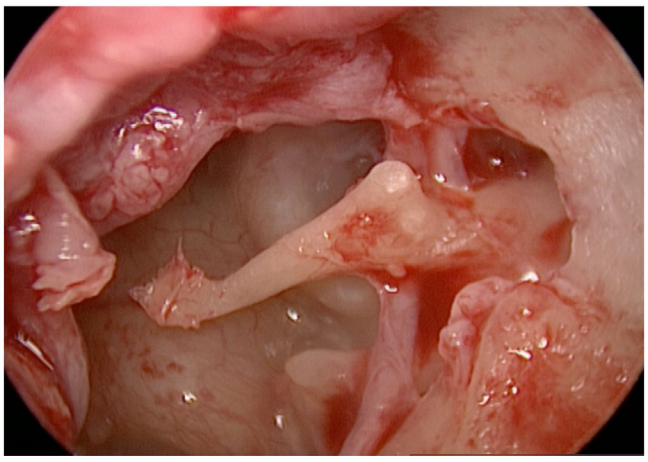

FIGURE 2 Tympanic membrane removal off the malleus increases anterior mesotympanum and protympanum visualization.

the TM on the malleus was performed in the plane of the malleus manubrium in order to limit torque on the ossicular chain. The ossicular chain was palpated and confirmed to have normal mobility.

Using a 15-blade scalpel, a separate incision was made on the posterior tragal skin. A tragal cartilage and perichondrium graft was harvested. The cartilage graft size was estimated with a 7 mm otologic speculum and cut to appropriate size. A 1-mm slit in the cartilage was created accommodate the malleus manubrium. The perichondrium in this slit was marked to help align graft placement on the malleus (Figure 3).

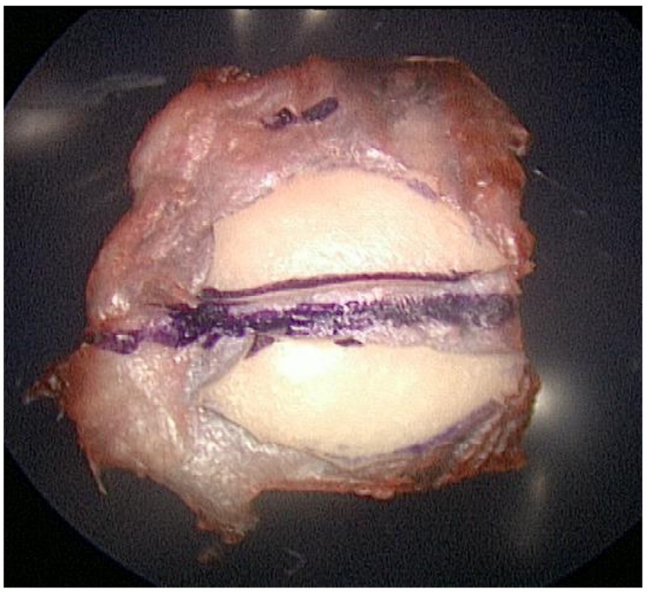

FIGURE 3 Tragal cartilage-perichondrium graft with central cartilage strip removed to accommodate the malleus manubrium.

Gelfoam was placed in the protympanum and anterior mesotympanum. The cartilage-perichondrium graft was placed lateral to the malleus but medial to the anterior TM remnant. Additional gelfoam was placed in the posterior mesotympanum. The tympanomeatal flap was draped over the graft. The edges of the perforation were assessed and minor adjustments made to confirm full coverage of the

entire TM defect (Figure 4). The tympanomeatal flap was secured in its anatomic position with additional gel foam. A cotton ball coated with antibiotic ointment was placed in the external ear canal.

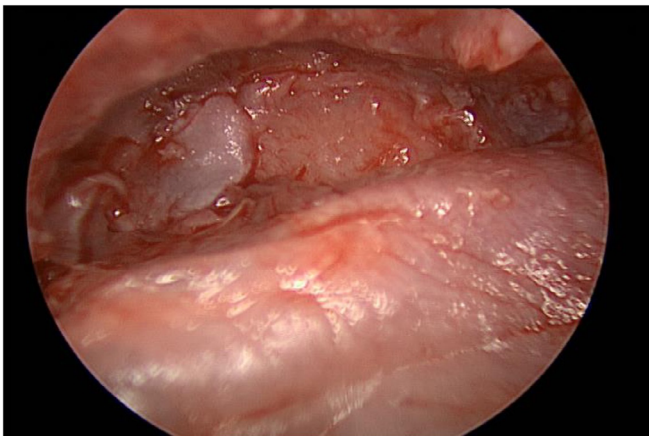

FIGURE 4 Left ear view of an anterior tympanic membrane reconstruction after tragal cartilage-perichondrium graft placement.

2.4 | Statistical analysis

All statistical analyses were performed using IBM SPSS v28 (IBM SPSS Inc., Chicago, IL). Continuous data was assessed for normality using histograms and Shapiro–Wilk test and presented as mean with standard deviation or median with min-max. Independent t-test or Mann–Whitney U test was used to compare means between tympanoplasty groups where appropriate. Chi-square test or Fischer's exact test were used for categorical variables. Wilcoxon signed-rank test was used to compare pre-operative and post-operative hearing data. A *p*-value <.05 was considered statistically significant.

3 | RESULTS

The 48 patients met inclusion criteria for this study, with 27 undergoing endoscopic underlay tympanoplasty and 21 undergoing endoscopic over-under tympanoplasty. Demographic, baseline, and surgical characteristics of these patients are shown in Table 1. Age, sex, BMI, smoking status, and diabetes status did not differ significantly

TABLE 1 Patient demographics, baseline, and surgical characteristics

Characteristic	Underlay ($n = 27$) Mean ± SD or *n* (%)	Over-under ($n = 21$) Mean ± SD or *n* (%)	*p* value
Age (years)	45 ± 19	51 ± 19	.250
Sex (female)	14 (52)	15 (71)	.169
BMI (kg/m^2)	29.3 ± 7.9	29.2 ± 6.8	.958
Smoking status			.891
Never	15 (56)	13 (62)	
Former	7 (26)	5 (24)	
Current	5 (18)	3 (14)	
Diabetes	2 (7)	3 (14)	.599
Cholesteatoma	5 (19)	4 (19)	.987
Revision surgery	4 (15)	6 (27)	.244
Perforation size (%)	31 ± 16	54 ± 23	<.001
Perforation size Group			.010
Small (<25%)	8 (30)	1 (5)	
Medium (25%–50%)	17 (63)	12 (57)	
Large (>50%)	2 (7)	8 (38)	
Anterior extension	6 (22)	20 (95)	<.001
OOPS index			.054
0	14 (52)	4 (19)	
1	3 (11)	2 (10)	
2	2 (7)	8 (38)	
3	6 (22)	7 (33)	
4	1 (4)	0 (0)	
5	1 (4)	0 (0)	
Tragal cartilage-perichondrium graft	23 (85)	20 (95)	.258
Perforation closure	26 (96)	20 (95)	.856
Duration of follow-up (months)	14.3 ± 12.2	14.7 ± 12.5	.917

between tympanoplasty groups. Cholesteatoma confined to the mesotympanum was concurrently addressed in five patients in the underlay group and four patients in the over-under group. Four procedures in the underlay group and six procedures in the over-under group were revision surgeries. A tragal cartilage and perichondrium graft was used in 90% of the tympanoplasties, with a perichondrium only graft used in the remaining 10%.

The perforation sizes addressed by each technique were significantly different, with a mean size of 31% ± 16% in the underlay group and 54% ± 23% in the over-under group (mean difference: 23%; 95% CI: 12%–34%). The over-under technique was also used to address more perforations with anterior extension than the underlay technique (95% vs. 22%; $p < .001$). Median OOPS score was not significantly different between groups, but the underlay technique was used for more ears with OOPS score of 0 than the over-under technique (Δ%: 33%; 95% CI: 8%–58%).

The mean duration of follow-up was about 14 months in each group with 56% of patients examined at least 1 year after surgery. One graft failure was observed with each technique resulting in overall graft success rates of 96% in the underlay group and 95% in the over-under group. The authors did not perform additional analyses to correlate perforation closure with other variables such as size, anterior extension, or OOPS index given the rare occurrences. The failure in the underlay group occurred for a small perforation with a relatively high OOPS index

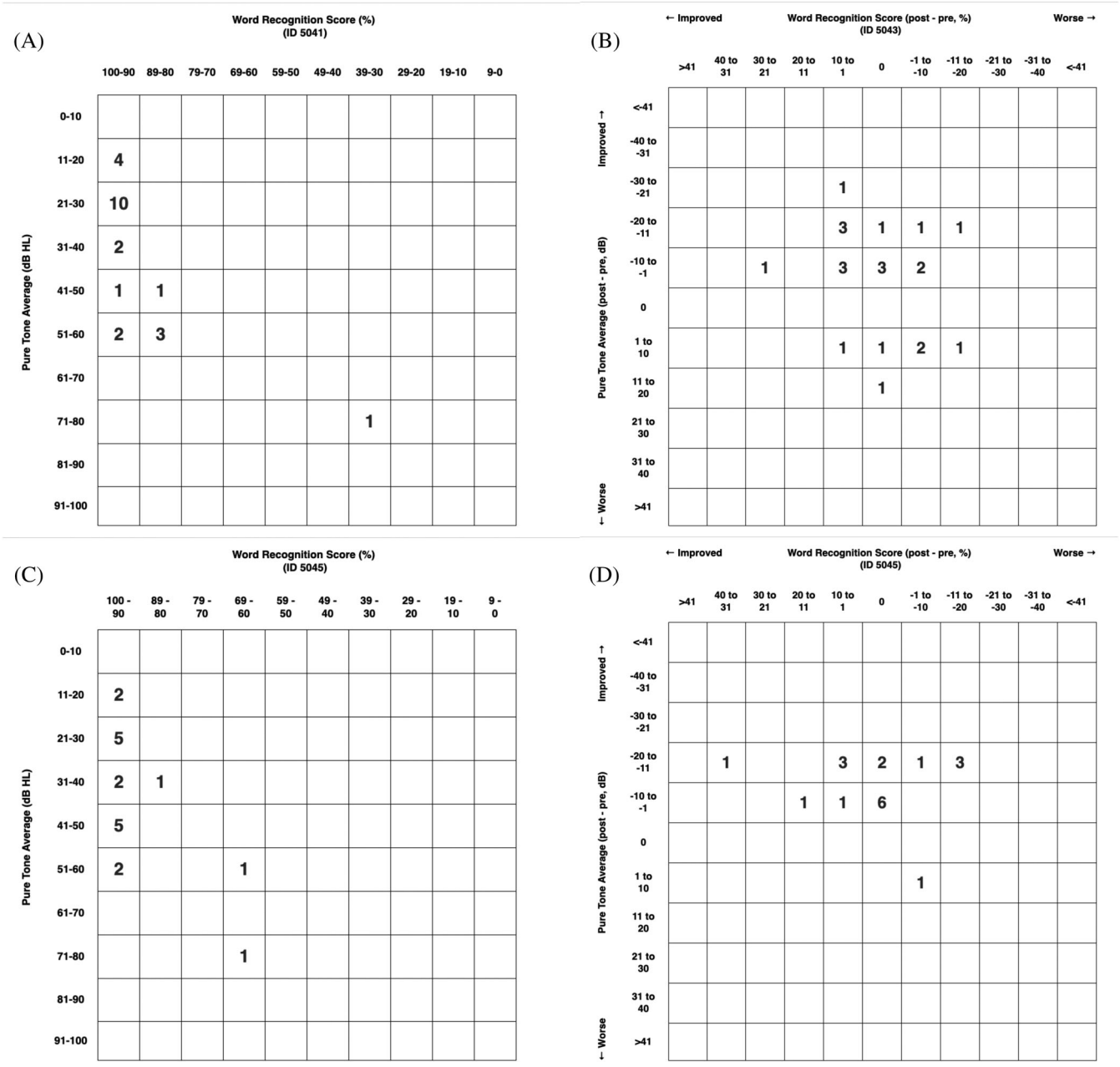

FIGURE 5 Scattergrams of preoperative and change in pure-tone average (PTA) and word recognition score (WRS) after tympanoplasty. (A) Preoperative PTA; underlay (B) ΔPTA and ΔWRS; underlay (C) Preoperative PTA; over-under (D) ΔPTA and ΔWRS; over-under

TABLE 2 Audiometric changes after tympanoplasty

Characteristic	Underlay ($n = 27$) Median (range)	Over-under ($n = 21$) Median (range)	
Preop air PTA (dB)	28 (11–110)	41 (16–84)	
Preop ABG (dB)	14 (1–39)	17 (1–31)	
Postop air PTA (dB)	22 (9–110)	30 (10–69)	
Postop ABG (dB)	9 (−2–35)	9 (−1–17)	
	Median (95% CI)	**Median (95% CI)**	**Difference (95% CI)**
ΔAir PTA (dB)	6 (3–10)	10 (7–13)	4 (−1–8)
ΔABG (dB)	6 (2–10)	10 (7–12)	4 (−1–10)

of 5. This was a revision surgery for an anterior perforation that left a persistent posterior perforation. Significant middle ear inflammation and drainage was noted, as well as remnant cartilage from the previous tympanoplasty on the incudostapedeal joint. Three months after surgery, the perforation and large air bone gap persisted. A revision tympanomastoidectomy was performed to remove the remnant cartilage on the incus and repair the perforation, which at 2 years follow-up has remained closed. The failure in the over-under group occurred for a medium anteriorly extended perforation with extensive infection and granulation of the middle ear. Of note, this patient had vascular risk factors including insulin-dependent diabetes and active smoking through surgery. At 4 months follow-up, a small anterior perforation was noted and covered with a paper patch. The perforation persisted with no signs of infection so revision surgery was deferred. One keratin pearl was identified in both groups and was managed by in-office debridement.

Both underlay and over-under cohorts experienced significant improvements in PTA and ABG after tympanoplasty (Figure 5). Table 2 shows the preoperative values and changes in PTA and ABG. Median preoperative PTAs and ABGs for the underlay group were 28 dB (range, 11–110) and 14 dB (range, 1–39). Median preoperative PTAs and ABGs for the over-under group were 41 dB (range, 16–84) and 17 dB (range, 1–31). The median improvement in air PTA was 6 dB (95% CI: 3–10 dB) for the underlay group and 10 dB (95% CI: 7–13 dB) for the over-under group. The median improvement in ABG was 6 dB (95% CI: 2–10 dB) for the underlay group and 10 dB (95% CI: 7–12 dB) for the over-under group. Improvement in PTA and ABG did not differ significantly between groups.

4 | DISCUSSION

The over-under technique was initially described as a modification of the underlay technique to address perforations that posed difficulty for the underlay method.[17] By separating the TM from the malleus, the entire mesotympanum is exposed and the graft can rest in a more favorable position for perforations with an anterior extension or larger perforations with a limited anterior TM remnant. Graft placement in the over-under technique benefits from improved medial support, both by the malleus as well as direct visualization of anterior gelfoam packing. The overlay technique shares these medial support advantages, which is why some surgeons prefer it for difficult anterior perforations. The medial placement of the graft under the anterior drum remnant helps to prevent blunting and lateralization. During the over-under technique, in the case of a very small or absent anterior remnant the anterior annulus can be elevated from its sulcus and the graft secured underneath it to still achieve this lateral support.

The microscopic overlay technique achieves improved anterior visualization only after removal of the anterior canal skin and a wide canalplasty. These extra surgical steps take time, de-vascularize the TM reconstruction, and create potential for circumferential mid-canal scarring. The minimally invasive endoscopic over-under technique does not require disruption of the anterior canal skin. The wider endoscopic field of view also facilitates improved visualization of the protympanum and pathologies that can block secondary ventilation pathways like a complete tensor fold. For the otologic surgeon already performing endoscopic underlay tympanoplasties, the over-under technique is a natural extension of that skill set and adds something to their armamentarium for challenging perforations.

This study shows similarly high-graft success rates between endoscopic over-under and underlay tympanoplasty techniques, supporting the findings of previous comparative studies.[19–21] The success rate of 1-year follow-ups shows that the over-under technique results in a durable repair. We did not correlate success rate with perforation size, location, or OOPS index due to the rare failure occurrence. We used the OOPS index to distinguish the degree of difficulty for each tympanoplasty. The OOPS index was developed to predict prognosis of patients undergoing ossiculoplasty but also provides an objective scale for the status of the middle ear.[22] OOPS index in this study ranged from 0 to 5 while the maximum score is 7, signifying a relatively low to intermediate disease burden in our cohorts. This was expected by excluding patients with advanced cholesteatomas and patients who underwent concurrent ossiculoplasties and mastoidectomies. The one recurrent perforation of the underlay group occurred with an OOPS index of 5, suggesting that the more advanced disease could have been the cause of the graft failure. The only complications that occurred were two superficial keratin pearls. No graft lateralization, atelectasis, or recurrent cholesteatomas were noted. The over-under cohort will require long-term follow-up and the potential for iatrogenic cholesteatoma does exist if the TM is not cleanly and completely removed from the malleus.

Audiologic improvement was also similar between tympanoplasty techniques. Changes in PTA and ABG were statistically and clinically significant in both cohorts. The extra manipulation of the ossicular chain during with the over-under technique does present concerns for sensorineural hearing loss if force is delivered to the inner ear or added conductive hearing loss if the incudomalleolar joint is disrupted.[25] This study shows no evidence of either type of trauma. Working along a favorable vector for each ossicle can prevent these types of trauma. Relevant for the over-under technique is stripping the TM remnant from the malleus which is done in the plane of the malleus manubrium while avoiding torque in the anterior or posterior directions.

In terms of graft material, tragal cartilage was used for most cases in our cohort. Traditionally, temporalis fascia was the most common graft material, but cartilage has gained popularity due to greater stability, resistance to retraction, and long-term viability compared to fascia.[26,27] Although cartilage is thicker and more rigid than fascia or perichondrium, previous studies have shown no differences in hearing outcomes between graft materials.[27] We have also found that graft success rates are not significantly different between graft materials, though there is a preference towards cartilage in our cohort.

Despite comparable outcomes between endoscopic over-under and underlay techniques, the different indications for each must be discussed. As stated previously, the over-under technique tends to be used for perforations that may be deemed difficult to repair using the underlay technique. Examining our cohort, we found that the over-under technique was used significantly more for large and anteriorly extended perforations. Although the distribution of OOPS index was not significantly different between techniques, more patients with a score of 0 tended to get repaired with an underlay tympanoplasty. This suggests a preference for the underlay technique when perforations are smaller, posteriorly located, and accompanied by less complicated middle ear disease. While attempting to stratify by size, location, and OOPS index, certain conditions contained very few cases and the choice of technique introduces selection bias. The decision on when to employ an advanced technique, like the over-under tympanoplasty, is a subjective one and the differences in these cohorts represent the bias of the senior surgeon. Future studies for comparison of tympanoplasty techniques should be done with more cases, multiple surgeons, and matched controls to mitigate the potential for bias.

This study has limitations secondary to its retrospective nature, single-surgeon decision, relatively short follow-up duration, and small sample size. The study was not powered or meant to show superiority of one particular tympanoplasty technique, but rather to demonstrate how an advanced endoscopic tympanoplasty technique can be incorporated into a surgeons' armamentarium for challenging perforations. Differing levels of comfort with the transcanal endoscopic ear surgery approach may result in different outcomes. Also, the overlay technique remains a valid approach for difficult perforations, both microscopically and endoscopically. The overlay technique was not directly compared in this study.

5 | CONCLUSION

While the choice of tympanoplasty technique clearly depends on differing indications and surgeon preferences, the endoscopic over-under technique is comparable to endoscopic underlay technique in terms of graft take and audiologic improvement with minimal complications. The over-under group had a comparable graft success rate to the underlay group. Audiologic improvement was also comparable between groups without evidence of hearing impairment due to manipulation of the malleus with the over-under technique.

ACKNOWLEDGEMENTS

Research reported in this publication was supported by the National Institute of Deafness and Other Communication Disorders within the National Institutes of Health, through the "Development of Clinician/Researchers in Academic ENT" training grant, award number T32DC000022. The content is solely the responsibility of the authors and does not necessarily represent the official views of the National Institutes of Health.

CONFLICT OF INTEREST

James W. Bao–None; Kevin Y. Zhan–None; Cameron C. Wick–Consultant for Stryker and Cochlear Ltd.

ORCID

James W. Bao https://orcid.org/0000-0002-0316-3628
Kevin Y. Zhan https://orcid.org/0000-0001-7180-0767
Cameron C. Wick https://orcid.org/0000-0003-1779-2385

REFERENCES

1. Kessler A, Potsic WP, Marsh RR. Type 1 Tympanoplasty in children. *Arch Otolaryngol Head Neck Surg*. 1994;120:487-490.
2. Kozin ED, Gulati S, Kaplan AB, et al. Systematic review of outcomes following observational and operative endoscopic middle ear surgery. *Laryngoscope*. 2015;125:1205-1214.
3. Tarabichi M. Endoscopic middle ear surgery. *Ann Otol Rhinol Laryngol*. 1999;108:39-46.
4. Dündar R, Kulduk E, Soy FK, et al. Endoscopic versus microscopic approach to type 1 tympanoplasty in children. *Int J Pediatr Otorhinolaryngol*. 2014;78:1084-1089.
5. Bennett ML, Zhang D, Labadie RF, Noble JH. Comparison of middle ear visualization with endoscopy and microscopy. *Otol Neurotol*. 2016;37:362-366.
6. Anzola JF, Nogueira JF. Endoscopic techniques in Tympanoplasty. *Otolaryngol Clin North Am*. 2016;49:1253-1264.
7. Wick CC, Arnaoutakis D, Kaul VF, Isaacson B. Endoscopic lateral cartilage graft Tympanoplasty. *Otolaryngol Head Neck Surg*. 2017;157:683-689.
8. Hunter JB, Zuniga MG, Leite J, et al. Surgical and audiologic outcomes in endoscopic stapes surgery across 4 institutions. *Otolaryngol Head Neck Surg*. 2016;154:1093-1098.
9. Yawn RJ, Hunter JB, O'Connell BP, et al. Audiometric outcomes following endoscopic ossicular chain reconstruction. *Otol Neurotol*. 2017;38:1296-1300.
10. House H, House W, Tabb H, Wullstein H, Zollner F. Panel on myringoplasty methods. *Arch Otolaryngol*. 1963;78:296-304.
11. Sheehy JL, Glasscock ME. Tympanic membrane grafting with temporalis fascia. *Arch Otolaryngol Head Neck Surg*. 1965;86:391-402.
12. Rizer FM. Overlay versus underlay tympanoplasty. Part I: historical review of the literature. *Laryngoscope*. 1997;107:1-25.
13. Glasscock ME 3rd. Tympanic membrane grafting with fascia: overlay vs. undersurface technique. *Laryngoscope*. 1973;83:754-770.
14. Sergi B, Galli J, de Corso E, Parrilla C, Paludetti G. Overlay versus underlay myringoplasty: report of outcomes considering closure of perforation and hearing function. *Acta Otorhinolaryngol Ital*. 2011;31:366-371.
15. Gerlinger I, Ráth G, Szanyi I, Pytel J. Myringoplasty for anterior and subtotal perforations using KTP-532 laser. *Eur Arch Otorhinolaryngol*. 2006;263:816-819.
16. Angeli SI, Kulak JL, Guzmán J. Lateral tympanoplasty for total or near-total perforation: prognostic factors. *Laryngoscope*. 2006;116:1594-1599.
17. Kartush JM, Michaelides EM, Becvarovski Z, LaRouere MJ. Over-under Tympanoplasty. *Laryngoscope*. 2002;112:802-807.

18. Yawn RJ, Carlson ML, Haynes DS, Rivas A. Lateral-to-malleus underlay Tympanoplasty: surgical technique and outcomes. *Otol Neurotol*. 2014;35:1809-1812.
19. Babu S, Luryi AL, Schutt CA. Over–under versus medial tympanoplasty: comparison of benefit, success, and hearing results. *Laryngoscope*. 2019;129:1206-1210.
20. Choi SW, Kim H, Na HS, et al. Comparison of medial underlay and lateral underlay endoscopic type I Tympanoplasty for anterior perforations of the tympanic membrane. *Otol Neurotol*. 2021;42:1177-1183.
21. Erbele ID, Fink MR, Mankekar G, Son LS, Arriaga MA, Mehta R. Endoscopic over under cartilage tympanoplasty is not inferior to underlay cartilage tympanoplasty. *Otol Neurotol Open*. 2021;1:e005.
22. Dornhoffer JL, Gardner E. Prognostic factors in ossiculoplasty: a statistical staging system. *Otol Neurotol*. 2001;22:299-304.
23. Jung DJ, Lee HJ, Hong JS, et al. Prediction of hearing outcomes in chronic otitis media patients underwent tympanoplasty using ossiculoplasty outcome parameter staging or middle ear risk indices. *PLoS One*. 2021;16:e0252812.
24. Kotzias SA, Seerig MM, et al. Ossicular chain reconstruction in chronic otitis media: hearing results and analysis of prognostic factors. *Braz J Otorhinolaryngol*. 2020;86:49-55.
25. Kazikdas KC, Onal K, Yildirim N. Sensorineural hearing loss after ossicular manipulation and drill-generated acoustic trauma in type I tympanoplasty with and without mastoidectomy: a series of 51 cases. *Ear Nose Throat J*. 2015;94:378-398.
26. Dornhoffer J. Cartilage tympanoplasty: indications, techniques, and outcomes in a 1,000-patient series. *Laryngoscope*. 2003;113:1844-1856.
27. Bayram A, Bayar Muluk N, Cingi C, Bafaqeeh SA. Success rates for various graft materials in tympanoplasty - a review. *J Otol*. 2020;15:107-111.

How to cite this article: Bao JW, Zhan KY, Wick CC. Comparison of endoscopic underlay and over-under tympanoplasty techniques for type I tympanoplasty. *Laryngoscope Investigative Otolaryngology*. 2022;7(4):1186-1193. doi:10.1002/lio2.879