The Journal of Laryngology & Otology

cambridge.org/jlo

Ossicular chain reconstruction: endoscopic or microscopic?

E A Guneri and A Cakir Cetin

Department of Otorhinolaryngology, Dokuz Eylul University Medical School, Izmir, Turkey

Main Article

Dr S Cakir Cetin takes responsibility for the integrity of the content of the paper

Cite this article: Guneri EA, Cakir Cetin A. Ossicular chain reconstruction: endoscopic or microscopic? *J Laryngol Otol* 2020;**134**: 1108–1114. https://doi.org/10.1017/S0022215120002728

Accepted: 9 September 2020
First published online: 7 January 2021

Key words:
Conductive Hearing Loss; Ear Ossicles; Endoscope; Tympanoplasty

Author for correspondence:
Dr Asli Cakır Cetın,
Department of Otorhinolaryngology,
Dokuz Eylul University Medical School,
Balcova, Izmir 35340, Turkey
E-mail: aslicakir84@hotmail.com
Fax: +90 232 4123269

Abstract

Objective. To compare the results of endoscopic and microscopic ossicular chain reconstruction surgery.

Methods. Patients undergoing ossicular chain reconstruction surgery via an endoscopic ($n = 31$) or microscopic ($n = 34$) technique were analysed for age, gender, Middle Ear Risk Index, ossicular chain defect, incision type, ossicular chain reconstruction surgery material, mean air conduction threshold, air–bone gap, air–bone gap gain, word recognition score, mean operation duration and mean post-operative follow up.

Results. Post-operative air conduction, air–bone gap and word recognition score improved significantly in both groups (within-subject $p < 0.001$ for air conduction and air–bone gap, and 0.026 for word recognition score); differences between groups were not significant (between-subject $p = 0.192$ for air conduction, 0.102 for air–bone gap, and 0.709 for word recognition score). Other parameters were similar between groups, except for incision type. However, endoscopic ossicular chain reconstruction surgery was associated with a significantly shorter operation duration ($p < 0.001$).

Conclusion. Endoscopic ossicular chain reconstruction surgery can achieve comparable surgical and audiological outcomes to those of microscopic ossicular chain reconstruction surgery in a shorter time.

Introduction

Background and rationale

The efficacy of endoscopic ear surgery has been validated in an increasing number of studies within the past 10 years.[1] Endoscopes offer minimally invasive approaches for various procedures, including tympanoplasty, stapedotomy, cochlear implantation and skull base surgery; similar or even better surgical outcomes have been reported with such endoscopic techniques.[1–8]

Endoscopic ossicular chain reconstruction has recently become a topic of interest as well.[1,7,9,10] Because endoscopes can better visualise the middle-ear structures,[11] it can be hypothesised that endoscopic ear surgery may improve the post-operative outcomes of patients with conductive hearing loss due to ossicular chain disruption.[1]

Objective

This study aimed to compare the outcomes of endoscopic and microscopic ossicular chain reconstruction.

Materials and methods

Study design

This was a retrospective case–control study.

Setting and ethical considerations

After approval by the institutional review board (protocol number: GOA-3552), a retrospective chart review was conducted of patients who underwent ossicular chain reconstruction between January 2012 and June 2017 in the Department of Otorhinolaryngology, Dokuz Eylul University Medical School.

Participants and eligibility criteria

Patients with ossicular chain disruption due to chronic otitis media only were included. Cases with a minimum of two years' follow up were selected, considering their most recent post-operative audiometric data. Patients with any of the following were excluded from the analyses: age of less than 18 years; cholesteatoma; history of head trauma; revision and/or staged surgical procedures and/or mastoidectomy; surgically confirmed

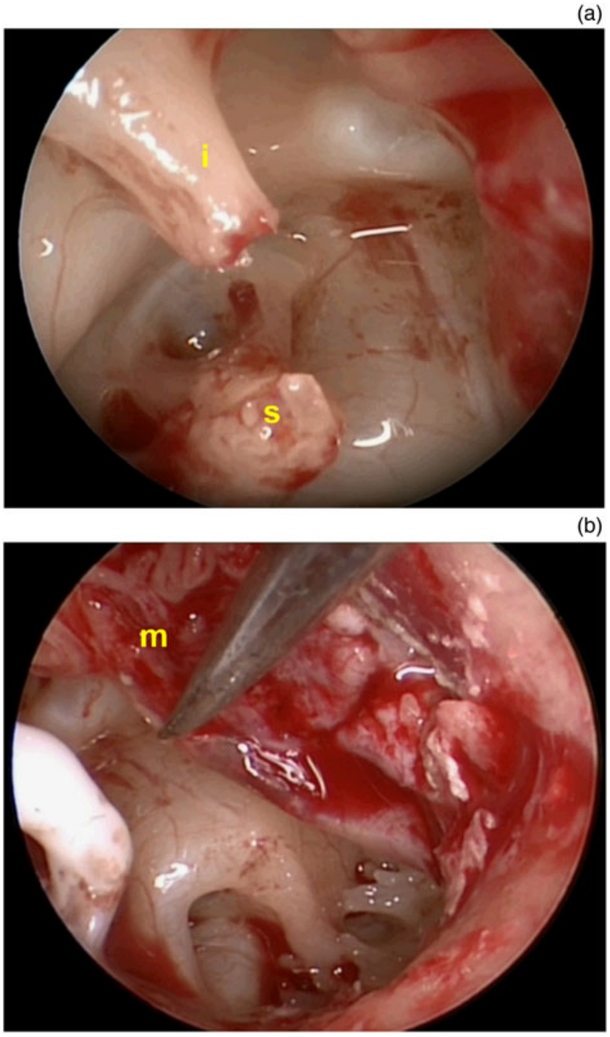

Fig. 1. (a) Peri-operative endoscopic view of the discontinuity between the incus ('i') and stapes ('s'). (b) Touching the malleus ('m') to confirm the integrity and mobility after the application of bone cement between the incus and stapes.

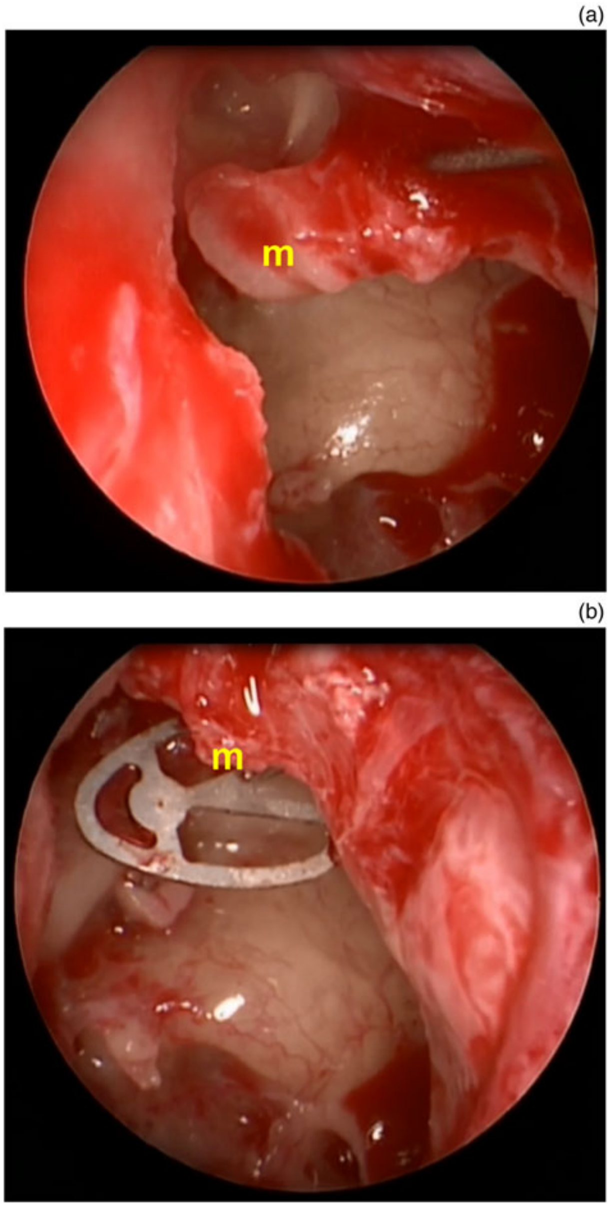

Fig. 2. (a) Peri-operative endoscopic view of the posteriorly relocated malleus ('m'). (b) Repair using a titanium total ossicular replacement prosthesis (Grace Medical) with a cartilage footplate shoe.

otosclerosis; and congenital aural atresia. Patients who underwent a transcanal approach were not included. Moreover, patients who had undergone surgical procedures that started endoscopically but finished microscopically were also excluded.

Sample size, variables and data sources

A total of 65 patients were included, comprising 31 endoscopic and 34 microscopic ossicular chain reconstructions. All surgical procedures were performed under general anaesthesia by the senior author (EAG) (Figures 1–4) using retroauricular and/or endaural approaches; no special instruments were used for the endoscopic surgical procedures. Microscopic ossicular chain reconstruction was generally performed via a retroauricular incision, in contrast to endoscopic ossicular chain reconstruction which was mostly performed with an endaural incision.

The study was designed to compare endoscopic and microscopic ossicular chain reconstruction techniques by evaluating variables such as: the age and sex of the patients; otorrhoea status; presence and location of the tympanic membrane perforation; smoking status; presence of middle-ear granulations or effusion; ossicular chain defect type (based on the Austin–Kartush classification);[12,13] presence of the malleus handle and stapes superstructure; Middle Ear Risk Index;[14] incision type; tympanic membrane grafting material; ossicular chain reconstruction material (bone cement to repair the discontinuity between the incus and stapes); use of a titanium total ossicular replacement prosthesis (Grace Medical, Memphis, Tennessee, USA) with a cartilage footplate shoe, titanium partial ossicular replacement prosthesis (Grace Medical) or autologous ossicle graft; pre- and post-operative second-year pure tone audiogram results[15] (obtained using a Madsen Astera2 audiometer; GN Otometrics, Taastrup, Denmark), including mean air conduction thresholds, air–bone gap, air–bone gap gain and word recognition score; mean operation duration; and mean post-operative follow-up duration.

Bias

To prevent any potential bias, data collection and statistical analysis were cross-checked by a colleague who was not an author of this study and who was blinded to the procedure.

https://doi.org/10.1017/S0022215120002728 Published online by Cambridge University Press

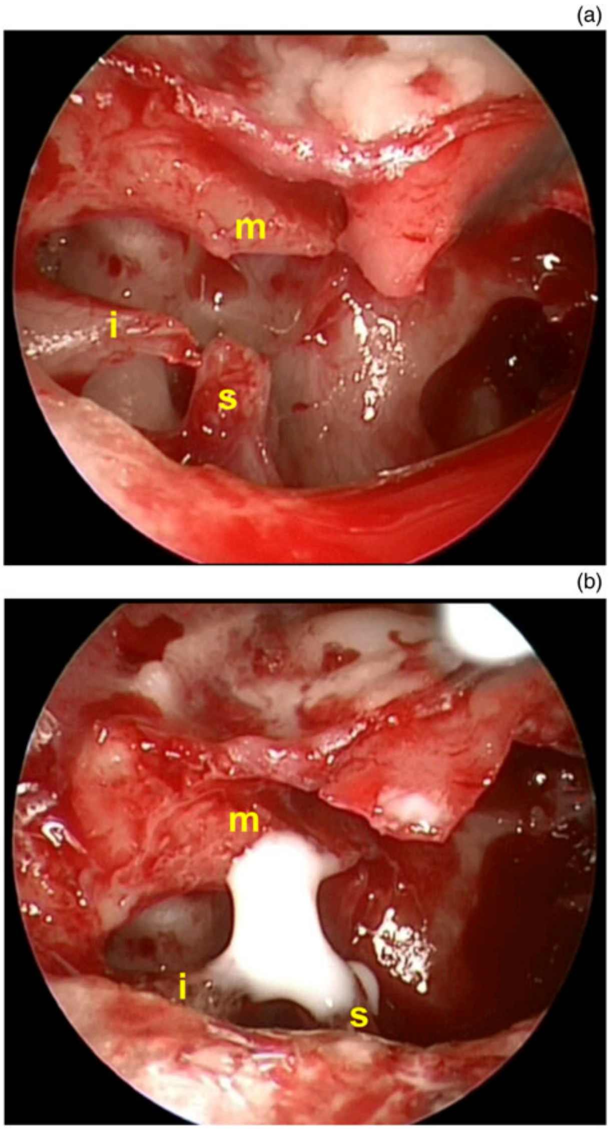

Fig. 3. (a) Peri-operative endoscopic view of the discontinuity between the incus ('i') and stapes ('s'). (b) Bone cement was applied between the incus, stapes and malleus ('m').

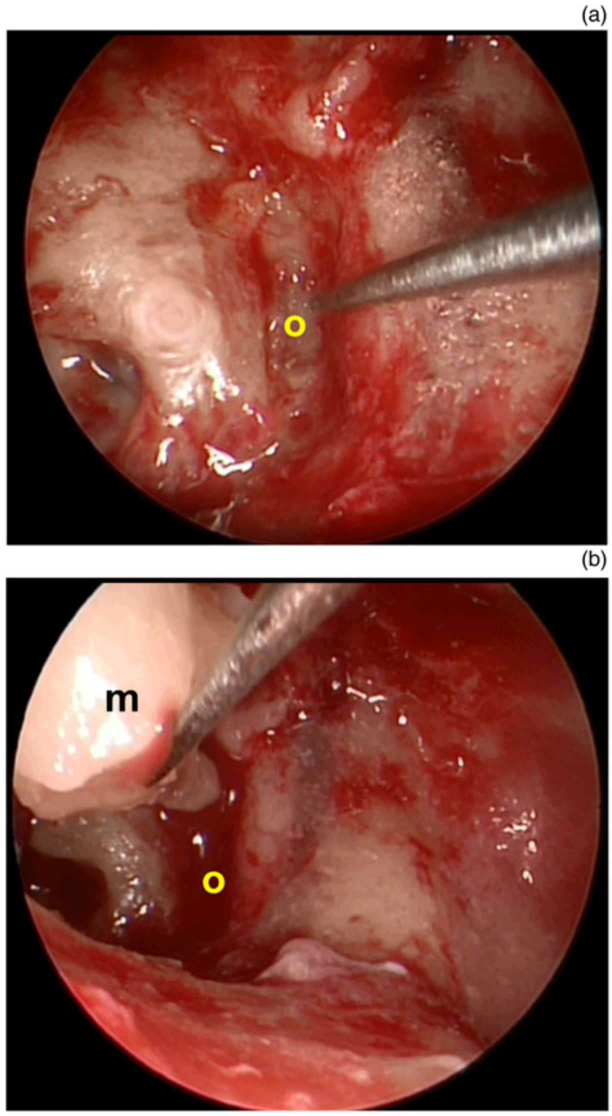

Fig. 4. (a) Peri-operative endoscopic view of the absence of stapes in the oval window ('o'). (b) Placement of autologous malleus graft ('m') onto the oval window.

Statistical analysis

Statistical analyses were performed using SPSS software (version 15.0; IBM, Armonk, New York). Results were expressed as numbers and percentages for categorical variables, mean ± standard deviation for parametric variables, and median and range (minimum, maximum) for non-parametric quantitative variables. The assumption of normality was assessed using the Kolmogorov–Smirnov test for the endoscopic and microscopic ossicular chain reconstruction groups. The independent-samples *t*-test was used to assess the normally distributed quantitative variables, whereas the Mann–Whitney U test was used for non-parametric quantitative variables. Pearson's chi-square and Fisher's exact tests were used to compare the categorical data. Hearing status before and after surgery was compared using the general linear model of repeated-measures analysis of variance to control for within and between subject effects. The 'within-subject effect' refers to the difference between pre- and post-operative measurements, whereas the 'between-subject effect' represents the difference between the two groups. A *p*-value of less than 0.05 was considered statistically significant.

Results and analysis

Participants and descriptive data

The two groups were similar in all aspects except for incision type, which was found to be significantly different (Table 1). Both groups were also similar regarding pre-operative air conduction, air–bone gap, air–bone gap gain and word recognition score data (Table 2).

Outcome data

Audiological outcome

At the two-year follow-up assessment, post-operative air conduction, air–bone gap and word recognition score had improved significantly in both groups (within-subject $p < 0.001$ for both air conduction and air–bone gap, and 0.026 for word recognition score, in both groups), and no significant differences were found between them (between-subject $p = 0.192$ for air conduction, 0.102 for air–bone gap and 0.709 for word recognition score) (Table 3). When the covariates, such as age, sex, Middle Ear Risk Index category, and ossicular chain reconstruction material, were controlled, air conduction and air–bone gap results were also not significantly different

https://doi.org/10.1017/S0022215120002728 Published online by Cambridge University Press

Table 1. Patient characteristics and clinical data

Parameter	Endoscopic group*	Microscopic group†	*P*-value
Age (mean ± SD; years)	41.3 ± 12.8	41.9 ± 12.3	0.867‡
Sex (females/males; *n*)	14/17	16/18	0.878**
Otorrhoea status (*n*)			
– Dry	19	21	0.969**
– Occasionally wet	9	12	0.590**
– Persistently wet	3	1	0.272§
Presence of tympanic membrane perforation (*n*)	16	21	0.409**
Location of tympanic membrane perforation (*n*)			
– Large marginal	6	5	
– Central	4	11	
– Posterior	2	3	
– Anterior	3	1	
– Small central	1	0	
– Subtotal	0	1	
Smoker (*n*)	10	15	0.326**
Presence of middle-ear granulations or effusion (*n*)	17	13	0.180**
Ossicular chain defect type (Austin–Kartush classification) (*n*)			
– Type A	17	15	0.388**
– Type B	2	2	0.658§
– Type C	2	7	0.098§
– Type D	5	2	0.177§
– Type E	5	8	0.456**
Presence of malleus handle (*n*)	19	17	0.360**
Presence of stapes superstructure (*n*)	24	29	0.245**
MERI category (*n*)			
– Normal	1	1	
– Mild risk	11	12	
– Moderate risk	11	13	
– Severe risk	8	8	
MERI score group (<4/≥4; *n*)	12/19	13/21	0.969**
Incision type (*n*)			
– Endaural	31	18	<0.001§ (significant)
– Retroauricular	0	16	<0.001§ (significant)
Tympanic membrane grafting material (*n*)			
– Temporal muscle fascia	3	4	
– Tragal cartilage	7	8	
– Conchal cartilage	0	2	
– Tragal perichondrium	2	0	
– Tragal cartilage + tragal perichondrium	0	2	
– Temporal muscle fascia + conchal cartilage	0	3	
– Temporal muscle fascia + tragal cartilage	5	2	
Ossicular chain reconstruction material (*n*)			
– Bone cement	17	12	0.113**
– Titanium TORP	7	5	0.414**
– Titanium PORP	1	6	0.068§
– Autologous ossicle graft	6	11	0.234**

*n = 31; †n = 34. ‡Independent-samples t-test; **Pearson chi-square test; §Fisher's exact test. SD = standard deviation; MERI = Middle Ear Risk Index; TORP = total ossicular replacement prosthesis; PORP = partial ossicular replacement prosthesis

https://doi.org/10.1017/S0022215120002728 Published online by Cambridge University Press

Table 2. Pre-operative air conduction threshold, ABG and WRS, for both groups

Parameter	Endoscopic group*	Microscopic group†	*P*-value‡
Pre-op air conduction threshold (mean ± SD; dB)	40 ± 13.3	41 ± 13.7	0.774
Pre-op ABG (mean ± SD; dB)	25.7 ± 8.6	27.4 ± 10.8	0.473
Pre-op WRS (mean ± SD; %)	94.4 ± 6.7	94.3 ± 7.9	0.985

*$n = 31$; †$n = 34$. ‡Independent-samples *t*-test. ABG = air–bone gap; WRS = word recognition score; pre-op = pre-operative; SD = standard deviation

(between-subject $p > 0.05$, and within-subject $p < 0.001$). There were no differences in follow-up duration or air–bone gap gain between the groups. In addition, the rate of unfavourable hearing outcome, which was considered to be an air–bone gap gain of less than 10 dB, was also similar between the groups (Table 4).

Other analyses

The mean operation duration was significantly shorter for the endoscopic ossicular chain reconstruction group ($p < 0.05$), and incision type was found to be significantly different between the endoscopic and microscopic groups ($p < 0.05$) (Tables 1 and 4). The mean operation duration was further examined by considering the type of incision among the endoscopic endaural, microscopic endaural and microscopic retroauricular cases. It was found that the mean duration both for microscopic retroauricular and microscopic endaural surgical procedures was significantly longer than for endoscopic endaural cases ($p < 0.05$) (Table 5).

Discussion

Key results

In this study, air conduction threshold, air–bone gap and word recognition score were significantly improved after surgery in both the endoscopic and microscopic ossicular chain reconstruction groups. The general linear model revealed no differences between the two groups regarding air conduction, air–bone gap and word recognition score outcomes (Table 3). The general linear model was also used to determine the effect of covariates such as age, sex, Middle Ear Risk Index category and ossicular chain reconstruction material on the outcomes; the results showed significant post-operative improvements in both groups, with an insignificant difference between them. The rate of an unfavourable post-operative hearing outcome was also similar between the two groups (Table 4). However, the mean operation duration was significantly shorter in the endoscopic group (Tables 4 and 5).

Interpretation and generalisability

Previous studies have shown similar audiological outcomes after endoscopic and microscopic ossicular chain reconstruction.[4,9,16–19] However, the representation of post-operative audiometric data was heterogeneous,[20] and some studies have reported only the gain in the air conduction thresholds or closure of the air–bone gap.[3,9] In our study, we used the general linear model of repeated-measures analysis of variance to independently assess the effects of two different ossicular chain reconstruction techniques (Table 3).

A previous study reported that the post-operative hearing outcomes were better in the endoscopic ossicular chain reconstruction group than in the microscopic ossicular chain reconstruction group; however, this result was attributed to the better pre-operative hearing levels of the endoscopic ossicular chain reconstruction cases.[1] In order to eliminate such confounding factors, we compared the pre-operative hearing characteristics of patients who underwent endoscopic and microscopic ossicular chain reconstruction, and did not find any differences between the groups (Table 2). Because post-operative hearing outcomes after ossicular chain reconstruction may be influenced by the type of the ossicular chain reconstruction material or technique,[21] as well as the status of the middle-ear mucosa and Middle Ear Risk Index category,[22] we attempted to exclude the potential effects of these factors on post-operative hearing results by ensuring that the endoscopic and microscopic groups were matched in terms of their peri-operative features (Table 1).

Endoscopic ear surgery provides a greater field of view and ease of access to hidden areas, which may increase the detection rate of the underlying cause of ossicular chain disruption.[2,3,18,23] However, the endoscopic technique may be challenging because of the lack of depth perception and inability to use both hands during surgery.[23,24] In addition, basic principles should be followed to avoid potential thermal risks.[10,25] A recent study reported that endoscopic ear surgery was associated with better ossicular chain reconstruction outcomes,[1] but we did not find a similar result in our cohort. However, we think that better visualisation, inherent in the endoscopic technique, may help in performing less invasive surgical procedures with endaural or transcanal approaches instead of retroauricular incisions (Table 1).

- This study compared the results of endoscopic and microscopic ossicular chain reconstruction surgery
- It investigated parameters that could affect post-operative outcomes, including demographic data, middle-ear characteristics and pre-operative audiological status
- Results revealed that the endoscopic and microscopic groups were similar in terms of these parameters
- Statistical analysis of pre- and post-operative hearing status in a single model avoided potential biases
- A minimum follow-up duration of two years contributed to the results' reliability
- Endoscopic ossicular chain reconstruction surgery may be performed faster and with similar post-operative outcomes to the microscopic technique

A systematic review comparing endoscopic and microscopic tympanoplasty techniques reported similar rates of tympanic membrane closure; however, the duration of surgery and length of hospitalisation were shorter, and cosmetic results were more favourable, in the endoscopic group.[26] A recent paper has also shown that the cost-effectiveness of endoscopic and microscopic surgical procedures for chronic otitis media is comparable.[27] A smaller incision,[4] less post-operative pain,[16,19] reduced medical expenditure[4] and shorter operation duration[17–19] may be considered as the advantages of all kinds of endoscopic ear surgery.

Table 3. General linear model of repeated-measures ANOVA

Parameter	Endoscopic group*	Microscopic group†	*P*-values: ANOVA (full model)	Within-subject‡	Between-subject**
Air conduction threshold (mean ± SD; dB)			<0.001 (significant)	<0.001 (significant)	0.192
– Pre-op	40 ± 13.3	41 ± 13.7			
– 2nd year post-op	19.2 ± 11.2	26.1 ± 13.0			
ABG (mean ± SD; dB)			<0.001 (significant)	<0.001 (significant)	0.102
– Pre-op	25.7 ± 8.6	27.4 ± 10.8			
– 2nd year post-op	8.4 ± 6.3	12.8 ± 9.9			
WRS (mean ± SD; %)			0.026 (significant)	0.026 (significant)	0.709
– Pre-op	94.4 ± 6.7	94.3 ± 7.9			
– 2nd year post-op	96.5 ± 5.4	95.3 ± 7.3			

Controlled for between- and within-subject effects regarding pre- and second-year post-operative air conduction threshold, air–bone gap and word recognition score results. *$n = 31$; †$n = 34$. ‡Effect between pre- and post-operative repeated measurements; **effect between endoscopic and microscopic groups. ANOVA = analysis of variance; SD = standard deviation; pre-op = pre-operative; post-op = post-operative; ABG = air–bone gap; WRS = word recognition score

Table 4. ABG gain, ABG closure, and operation and follow-up duration, for both groups

Parameter	Endoscopic group*	Microscopic group†	*P*-value
ABG gain (mean ± SD; dB)	17.3 ± 7.9	14.6 ± 12.3	0.301‡
Patients with ABG gain of ≤10 dB (*n*)	4	9	0.146**
Operation duration (mean ± SD; minutes)	65.9 ± 22.0	88.7 ± 25.4	0.002§ (significant)
Follow-up duration (years)			0.104‡
– Mean ± SD	3.2 ± 1.5	3.6 ± 1.2	
– Median (range)	3 (2–6)	4 (2–7)	

*$n = 31$; †$n = 34$. ‡Mann–Whitney U test; **Fisher's exact test; §independent-samples *t*-test. ABG = air–bone gap; SD = standard deviation

Table 5. Operation duration according to incision type

Incision type	Operation duration (mean ± SD; minutes)	*P*-value	Pairwise comparison	Post-hoc *p*-value
Endoscopic endaural (EE)*	65.9 ± 22.0	0.001** (significant)	EE–ME	0.038§ (significant)
Microscopic endaural (ME)†	83.9 ± 23.7		EE–MR	0.001§ (significant)
Microscopic retroauricular (MR)‡	94.1 ± 26.9		ME–MR	0.642§

*$n = 31$; †$n = 18$; ‡$n = 16$. **One-way analysis of variance test; §post-hoc Bonferroni test. SD = standard deviation

According to our results, the mean operation duration was significantly shorter in endoscopic ossicular chain reconstruction cases (Table 4), and an endaural incision was more likely to be used (Table 1). The shorter operation duration was probably a result of the reduced need for curettage and/or drilling of the posterior superior wall of the external auditory canal, and the lack of microscope positioning during surgery. However, we believe that an additional issue could have affected the operation duration, because both groups were similar except for the incision type (Table 1). Therefore, we further analysed the type of incision for each case. Post-hoc analyses showed that the operation duration was significantly shorter for endoscopic endaural surgical procedures than for matched microscopic procedures. However, there was no significant difference in the duration of microscopic endaural and microscopic retroauricular surgical procedures (Table 5). We postulate that a shorter operation duration in the endoscopic group may not be solely an effect of the incision type; the heterogeneity of the endoscopic endaural, microscopic endaural and microscopic retroauricular subgroups with regard to the reconstructive materials used may also have had an influence.

In conclusion, we suggest that endoscopic ossicular chain reconstruction may be performed in a significantly shorter time and that it provides post-operative audiometric outcomes that are similar to those of the microscopic technique.

Limitations

The limitations of our study are: the retrospective design and thus the lack of randomisation, the relatively small sample size, and the heterogeneity of the incision types.

Acknowledgements. The authors would like to acknowledge Professor Pembe Keskinoğlu, an esteemed academic member of the Department of Biostatistics and Medical Information, Dokuz Eylul University Medical School, for her professional contribution to the statistical analysis. The authors would also like to thank Enago (www.enago.com) for the English language review.

https://doi.org/10.1017/S0022215120002728 Published online by Cambridge University Press

Competing interests. None declared

References

1 Yawn RJ, Hunter JB, O'Connell BP, Wanna GB, Killeen DE, Wick CC *et al.* Audiometric outcomes following endoscopic ossicular chain reconstruction. *Otol Neurotol* 2017;**38**:1296–300
2 Kozin ED, Gulati S, Kaplan AB, Lehmann AE, Remenschneider AK, Landegger LD *et al.* Systematic review of outcomes following observational and operative endoscopic middle ear surgery. *Laryngoscope* 2015;**125**:1205–14
3 Zhu VF, Kou YF, Lee KH, Kutz JW Jr, Isaacson B. Transcanal endoscopic ear surgery for the management of congenital ossicular fixation. *Otol Neurotol* 2016;**37**:1071–6
4 Kuo CH, Wu HM. Comparison of endoscopic and microscopic tympanoplasty. *Eur Arch Otorhinolaryngol* 2017;**274**:2727–32
5 Guneri EA, Olgun Y. Endoscope-assisted cochlear implantation. *Clin Exp Otorhinolaryngol* 2018;**11**:89–95
6 Guneri EA, Olgun Y. Endoscopic stapedotomy: our clinical experience. *B-ENT* 2018;**14**:161–7
7 Cox MD, Page JC, Trinidade A, Dornhoffer JL. Long-term complications and surgical failures after ossiculoplasty. *Otol Neurotol* 2017;**38**:1450–5
8 Hsu YC, Kuo CL, Huang TC. A retrospective comparative study of endoscopic and microscopic tympanoplasty. *J Otolaryngol Head Neck Surg* 2018;**47**:44
9 Wu CC, Chen YH, Yang TH, Lin KN, Lee SY, Liu TC *et al.* Endoscopic versus microscopic management of congenital ossicular chain anomalies: our experiences with 29 patients. *Clin Otolaryngol* 2017;**42**:944–50
10 Fisher E, Youngs R, Hussain M, Fishman J. Training for emergencies, endoscopic ear surgery and post-tonsillectomy complications: beware 'scary' otolaryngology. *J Laryngol Otol* 2017;**131**:95
11 Bennett ML, Zhang D, Labadie RF, Noble JH. Comparison of middle ear visualization with endoscopy and microscopy. *Otol Neurotol* 2016;**37**:362–6
12 Austin DF. Ossicular reconstruction. *Otolaryngol Clin North Am* 1972;**5**:145–60
13 Kartush JM. Ossicular chain reconstruction. Capitulum to malleus. *Otolaryngol Clin North Am* 1994;**27**:689–715
14 Dornhoffer JL, Gardner E. Prognostic factors in ossiculoplasty: a statistical staging system. *Otol Neurotol* 2001;**22**:299–304
15 Gurgel RK, Jackler RK, Dobie RA, Popelka GR. A new standardized format for reporting hearing outcome in clinical trials. *Otolaryngol Head Neck Surg* 2012;**147**:803–7
16 Choi N, Noh Y, Park W, Lee JJ, Yook S, Choi JE *et al.* Comparison of endoscopic tympanoplasty to microscopic tympanoplasty. *Clin Exp Otorhinolaryngol* 2017;**10**:44–9
17 Dundar R, Kulduk E, Soy FK, Aslan M, Hanci D, Muluk NB *et al.* Endoscopic versus microscopic approach to type 1 tympanoplasty in children. *Int J Pediatr Otorhinolaryngol* 2014;**78**:1084–9
18 Huang TY, Ho KY, Wang LF, Chien CY, Wang HM. A comparative study of endoscopic and microscopic approach type 1 tympanoplasty for simple chronic otitis media. *J Int Adv Otol* 2016;**12**:28–31
19 Kaya I, Sezgin B, Sergin D, Ozturk A, Eraslan S, Gode S *et al.* Endoscopic versus microscopic type 1 tympanoplasty in the same patients: a prospective randomized controlled trial. *Eur Arch Otorhinolaryngol* 2017;**274**:3343–9
20 Lailach S, Zahnert T, Neudert M. Data and reporting quality in tympanoplasty and ossiculoplasty studies. *Otolaryngol Head Neck Surg* 2017;**157**:281–8
21 Govil N, Kaffenberger TM, Shaffer AD, Chi DH. Factors influencing hearing outcomes in pediatric patients undergoing ossicular chain reconstruction. *Int J Pediatr Otorhinolaryngol* 2017;**99**:60–5
22 Demir UL, Karaca S, Ozmen OA, Kasapoglu F, Coskun HH, Basut O. Is it the middle ear disease or the reconstruction material that determines the functional outcome in ossicular chain reconstruction? *Otol Neurotol* 2012;**33**:580–5
23 Tarabichi M, Ayache S, Nogueira JF, Al Qahtani M, Pothier DD. Endoscopic management of chronic otitis media and tympanoplasty. *Otolaryngol Clin North Am* 2013;**46**:155–63
24 Marchioni D, Mattioli F, Alicandri-Ciufelli M, Presutti L. Endoscopic approach to tensor fold in patients with attic cholesteatoma. *Acta Otolaryngol* 2009;**129**:946–54
25 Mitchell S, Coulson C. Endoscopic ear surgery: a hot topic? *J Laryngol Otol* 2017;**131**:117–22
26 Tseng CC, Lai MT, Wu CC, Yuan SP, Ding YF. Comparison of the efficacy of endoscopic tympanoplasty and microscopic tympanoplasty: a systematic review and meta-analysis. *Laryngoscope* 2017;**127**:1890–6
27 Tseng CC, Lai MT, Wu CC, Yuan SP, Ding YF. Cost-effectiveness analysis of endoscopic tympanoplasty versus microscopic tympanoplasty for chronic otitis media in Taiwan. *J Chin Med Assoc* 2018;**81**:284–90