



Endoscopic revision stapes surgery: surgical findings and outcomes

Ignacio Javier Fernandez¹ · Domenico Villari¹ · Cecilia Botti¹  · Livio Presutti¹

Received: 16 September 2018 / Accepted: 2 January 2019 / Published online: 11 January 2019
© Springer-Verlag GmbH Germany, part of Springer Nature 2019

Abstract

Purpose Hearing results in revision stapes surgery are largely dependent on the cause of failure, and an appropriate intraoperative diagnosis is crucial for a good outcome. The endoscope allows a detailed exploration of the middle ear cavity and is particularly suitable for the intraoperative assessment of the cause of failure of previous stapes surgery. The present study analyzes the intraoperative findings and outcomes of patients undergoing revision stapes surgery through the endoscopic transcanal approach.

Methods Surgical videos and charts of patients undergoing endoscopic revision stapes surgery from 2008 to 2017 were reviewed retrospectively. Intraoperative findings, difficulties encountered during the surgery and hearing outcomes were evaluated. The feasibility of each surgical step with the totally endoscopic approach or the need for bimanual manipulation was assessed as well.

Results Thirty-four patients were included in the study. The endoscopic transcanal approach allowed a detailed exploration of the middle ear cavity and an accurate intraoperative diagnosis and management of the different causes of failure of the previous surgery. 89.8% of patients achieved an air-bone gap for the PTA ≤ 20 dBHL and 68.5% a closure of the air-bone gap.

Conclusions The present study showed that totally endoscopic revision stapes surgery is a feasible, safe and effective procedure. The transcanal endoscopic approach allowed an accurate intraoperative diagnosis without the need for an endaural or retroauricular approach, with the possibility to manage all the possible intraoperative scenarios. A larger series with a longer follow-up is needed to validate the results.

Keywords Endoscopic ear surgery · Revision stapes surgery · Revision stapedotomy · Endoscopic stapes surgery · Stapes surgery

Introduction

Primary stapes surgery can be considered successful if an air-bone gap of ≤ 10 dB is achieved [1]. Lack of hearing improvement after previous surgery, hearing deterioration and vertigo are the most frequent reasons for revision stapes surgery [2]. Traditionally, revision stapes surgery is performed with the microscope through a transcanal approach [1, 3]. Previous surgery adds additional challenges, such

as erosion of the long process of the incus or presence of fibrous scar tissue in the tympanic cavity and oval window niche. Furthermore, with the traditional microscopic approach, the evaluation of middle ear is often partial and sometimes the surgical maneuvers can be difficult and “blind”. According to the literature, the surgical outcome after revision stapes surgery is less favorable when compared with primary surgery. Up to 90% of patients can achieve an air-bone gap (ABG) < 20 dB after revision stapes surgery, but the success rate (ABG < 10 dB) is reported between 40 and 80% of the cases [4–12]. In addition, revision stapes surgery carries a higher risk of sensorineural hearing loss and vertigo [4, 6, 9, 10].

The clinical and radiological pre-operative evaluation is very important to detect the causes of hearing failure, to give revision surgery a higher chance of success [9, 10].

The endoscope has been recently introduced as an interesting tool in stapes surgery, which has the advantage of

Electronic supplementary material The online version of this article (<https://doi.org/10.1007/s00405-019-05280-4>) contains supplementary material, which is available to authorized users.

✉ Cecilia Botti
botceci@gmail.com

¹ Department of Otolaryngology, Head and Neck Surgery, University Hospital of Modena, Via del Pozzo, 71, 41100 Modena, Italy

offering a complete exploration of the middle ear spaces, ossicles anatomy, prosthesis position and oval window conditions.

The present study explores the role of an exclusive endoscopic transcanal approach in the management of revision stapes surgery. Advantages and limits encountered in the endoscopic revision stapes surgery are highlighted. To the authors' knowledge, this is the first study focusing on endoscopic revision stapes surgery.

Materials and methods

Patients with previous microscopic surgery for otosclerosis and undergoing totally endoscopic revision stapes surgery between 2008 and 2017 at the Otolaryngology Department of the University Hospital of Modena were enrolled for the study. Inclusion criteria were age > 18 years, follow-up > 6 months and available surgical video. The criteria adopted for revision in our department were: poor audiologic outcome (persistent conductive hearing loss); worsening of the audiologic outcome with the new onset of a conductive hearing loss (ABG > 10 dB) after previous surgery (recurrent conductive hearing loss); vertigo and progressive sensorineural hearing loss after previous stapes surgery (suspicion of perilymph fistula); loose wire syndrome [13]; and recurrent vertigo due to long prosthesis syndrome [14]. Intraoperative surgical findings and audiometric outcomes were analyzed retrospectively from charts of patients and from the otology database of our institution.

Surgical technique

Patients underwent general or local anesthesia plus sedation. The 0° and 45° endoscopes, diameter of 3 mm and 15 cm of length (Karl Storz, Tuttlingen, Germany) were used through the external auditory canal for a transcanal exclusive endoscopic approach (EES). A modified Rosen incision in the posterior wall of the external auditory canal (EAC) from 5 to 12 o'clock was performed to create a tympanomeatal flap limited to expose the OW (oval window) area. The tympanomeatal flap was then elevated to gain the access to the middle ear cavity, preserving the attachment of the tympanic membrane to the malleus. The flap was pulled anteriorly until the posterior border of malleus was visible. Chorda tympani was preserved, if present. To better expose the oval window region, a small atticotomy (bone removal from the scutum ≤ 1 mm) was carried out, if not adequately performed during previous surgeries. Then, we conducted an endoscopic exploration of the anatomy of the middle ear, to check prosthesis position, ossicular chain, window condition and facial nerve course. Further surgery was performed based on intraoperative findings. According

to the status of the ossicular chain, anatomical and functional conditions, the old prosthesis was mobilized from the scar tissue, repositioned or substituted with a new prosthesis. In case of incus erosion, depending on the degree of erosion, an incus reconstruction with bone cement or malleostapedotomy was performed. Cases with ossicular chain fixation were treated according to the underlying cause. At the end of surgery, correct mobility of ossicular chain and prosthesis was checked, Gelfoam was positioned in the oval window niche and in the EAC and finally the tympanomeatal flap was repositioned.

Intraoperative surgical findings

The intraoperative surgical findings were recorded from the surgical videos of the patients included in the study. The following points were evaluated for each patient:

- 1) Visualization of the status of the prosthesis.
- 2) Visualization of the status of the footplate.
- 3) Visualization of the status of the incus.
- 4) Visualization of the incudal-malleolar joint (in case of altered ossicle mobility).
- 5) Visualization of the anterior malleolar ligament (in case of malleus ankylosis).
- 6) Visualization of the intratympanic facial nerve.
- 7) Visualization of the round window niche.
- 8) Visualization of the tip of the drill during the platinotomy and exploration of the new platinotomy hole.
- 9) Control of the adequate positioning of the new prosthesis.
- 10) Complications during surgery and change of the surgical strategy.

The intraoperative findings regarding the condition of the prosthesis were further classified as: (1) prosthesis not anchored, free in the tympanic cavity; (2) prosthesis anchored to the incus, but incorrectly inserted into the oval window; (3) prosthesis not anchored to the ossicular chain, but correctly inserted into the oval window.

For the incus status, the long process of the incus was classified as normal, minimal erosion, and extensive erosion. The position of the incus was observed and classified in normal or dislocated. For the footplate status, the presence and position of previous platinotomy were described, as well as the presence of fibrous scar tissue or anomalous bone regrowth.

Difficulties encountered during surgery were evaluated considering the one-handed condition of the endoscopic approach. The feasibility of each surgical step with the totally endoscopic approach or the need for bimanual manipulation, switching to the microscopic approach, was evaluated as well.

Audiological evaluation

Audiometric outcomes were analyzed in patients with a complete follow-up of at least 6 months from revision surgery. The last post-operative follow-up audiogram was included if fulfilling the AAO-HNS guidelines [15]. Pre-operative and post-operative data were compared. The pre-operative audiometric values were obtained from the most recent audiogram within one month prior to surgery. The bone-conduction (BC) and air-conduction (AC) threshold were calculated as the average for 0.5–1–2 and 3 kHz. The air-bone gap (ABG) was reported as the four-tone pure-tone average (PTA) for AC minus the PTA for BC at 0.5–1–2 and 3 kHz. Additionally, pre-operative minus post-operative pure-tone BC at 1–2 and 4 kHz was calculated for measurement of the overclosure or sensorineural damage. Sensorineural damage was defined as a reduction in BC > 20 dBHL.

The Student's *t* test was used to calculate the statistical significance of the difference between pre-operative and post-operative ABG and BC thresholds. Statistical significance was set < 0.05 with a 95% confidence interval.

Results

Thirty-four patients with a minimum follow-up of 6 months were included in the study. All patients were operated on for hearing improvement. Of those, 2 presented with persistent conductive hearing loss and 32 with recurrent conductive hearing loss. Three patients also complained of associated tinnitus. Four patients experienced multiple revision surgeries before the endoscopic one.

Patients were female in 23 cases and male in 11, with a mean age of 54 years (range 16–69 years). The operated side was left in 16 patients and right in 18 patients.

General considerations

The pre-operative CT scan was available in 18 patients, it was diagnostic for prosthesis dislocation only in 4 cases, of which it showed a displacement out of the oval window in 3 cases and a prosthesis too deep in the vestibule in 1 case. The CT scan did not permit to understand preoperatively the cause of hearing failure in the remaining 14 cases, showing a normal position of the prosthesis. Thirty-two patients underwent general anesthesia, while two patients underwent local anesthesia plus sedation. The mean surgical time was 43 min (range 20'–90').

Endoscopic surgical findings

An optimal visualization of the intraoperative details was achieved for all cases (100%). A plausible cause of persistent

or recurrent hearing loss was detected in all patients. The incudal-malleolar joint was explored only in one case, through minimum scutum removal, due to excessive incus mobility detected upon palpation of the ossicles, that revealed the presence of joint luxation. No cases of round window obliteration were observed. One case of ossification of the anterior malleolar ligament (House's syndrome) was detected after malleus palpation and endoscopic exploration after tympanic membrane detachment from the malleus handle. Intraoperative findings are reported in Table 1.

The old prosthesis was used again in seven cases, while it was substituted by a new one in the remaining cases. Of the latter, three were revision of a previous malleostapedotomy. Bone cement was used to reconstruct the long process of the incus in four cases to have a support to anchor the prosthesis. It was also used to reinforce a dislocated incudal-malleolar joint in one case.

Complications

Four patients had post-operative vertigo and one patient had a slight postural instability. In all cases, symptoms resolved within 24 h. No sensorineural hearing loss or facial palsy was noted. Chorda tympani was present in 33 out of 34 patients and in all of them it was anatomically preserved. Subjective post-operative dysgeusia (of new onset) was not noticed.

Audiological results

Nineteen patients had complete audiometric data and follow-up of at least 6 months after surgery (Table 2). The mean PTA for AC improved from 64 dBHL (range 48–91, SD 18.8) to 37 dBHL (range 15–86, SD 20.2) and the mean ABG from 38 dB (range 14–49, SD 12.3) to 8 dBHL (range 0–39, SD 10.6). The overall mean hearing improvement was statistically significant ($p < 0.001$). Post-operative ABG was ≤ 20 dBHL in 17/19 cases (89.5%) and ≤ 10 dB (ABG closure) in 13/19 cases (68.4%). No cases of sensorineural hearing loss were observed.

Among the 16 patients who showed a post-operative hearing improvement, the mean PTA for AC improved from 64 dBHL (range 48–91, SD 10.6) to 32 dBHL (range 15–57, SD 11.5) and the mean ABG from 38 dBHL (range 17–49, SD 8.8) to 8 dBHL (range 0–19, SD 5.3).

Three patients did not show any significant improvement of the AC threshold during the post-operative follow-up. Those cases were characterized by the following intraoperative findings: lateralized incus (one case); presence of fibrous scar tissue in middle ear cavity reducing the mobility of ossicles and prosthesis (two cases); the old prosthesis was not replaced by a new one, but it was only mobilized and left in place (all three cases).

Table 1 Intraoperative surgical findings in the 34 cases

Intraoperative findings	<i>N</i>	%	Surgical correction
Stapes			
Correct platinotomy	14	41	–
Incorrect platinotomy (anterior)	1	3	New stapedotomy
Re-closed platinotomy	14	41	Reopening of stapedotomy
Fibrous tissue	6	18	Removal
Absent platinotomy	2	6	New stapedotomy
Incus			
Normal	21	62	–
Partial erosion	10	29	3 bone cement 7 proximal attachment
Extensive erosion	1	3	Malleostapedotomy
Fracture	1	3	Bone cement
Luxation	1	3	Bone cement
Malleus			
Normal	33	97	Mobilization (anterior ligament drilling)
Fixed	1	3	
Prosthesis			
Correct position	4	12	–
Short	7	21	New prosthesis
Long/intravestibular	1	3	New prosthesis
Absent	2	6	New prosthesis
Attached to the incus—out of platinotomy	12	35	4 old 8 new prosthesis
Detached from incus—inside platinotomy	1	3	New prosthesis
Detached from incus—out of platinotomy	13	38	New prosthesis

Conditions of stapes, incus, malleus and prosthesis and surgical correction needed are analyzed as reported *N* number of cases

Table 2 Hearing results are reported as mean of 19 cases with audiologic complete follow-up

Variables	Preoperatively	Postoperatively	<i>p</i>
SNHL, %		0% (0/19)	
ABG ≤ 10 dB, %		68.5% (13/19)	
ABG 11–20 dB, %		21% (4/19)	
ABG > 20 dB, %		10.5% (2/19)	
Mean ABG, dB	38.2 (SD 12.3)	7.8 (SD 10.6)	<0.001
Mean BC, dB	26.8 (SD 10.8)	29.5 (SD 11.4)	0.47
Mean AC, dB	64.4 (SD 18.8)	37.3 (SD 20.2)	<0.001
BC at 4 kHz, dB	33.9 (SD 20.9)	38.5 (SD 22.8)	0.29

SNHL sensorineural hearing loss, ABG air-bone gap, BC bone conduction, AC air conduction, SD standard deviation

Discussion

The operating microscope, developed in 1952 [16], provided the surgeon with the adequate magnification for fine ear surgery and allowed the development of stapes surgery since 1956 [17]. Since then, revision stapes surgery has been classically performed with conventional microscopic

procedures. Although there has been an improvement in revision stapes techniques during the last 30 years, with the introduction of the CO₂ laser, the malleostapedotomy technique and the ionomeric bone cement, functional results remain generally still inferior to primary stapes surgery. In the literature, the success rate reported for revision surgery is rather variable, with an ABG < 10 dB HL ranging from 51 to 80% and with an ABG < 20 dB HL from 54 to 92% (Table 3) [4–12]. In addition, the incidence of complications such as vertigo and sensorineural hearing loss is higher in major series of revision stapes surgery [4, 6, 9, 10] compared with primary surgery.

Hearing results in revision stapes surgery are largely dependent on the cause of failure, and an appropriate diagnosis is crucial for a good outcome [9, 10, 18]. Unfortunately, pre-operative diagnosis can be made through the clinical history and HRCT scan only in a few cases, if prosthesis dislocation is identified [12]. Therefore, the intraoperative diagnosis is still an essential step of revision stapes surgery.

Revision stapedotomy is characterized by very variable intraoperative surgical findings [10, 19]. Moreover, anatomic variations can make revision surgery more challenging. The endoscope has improved the knowledge of the complex anatomy of the middle ear in vivo [20–24]. The endoscope

Table 3 Rate (%) of audiological results in revision stapes surgery

References	<i>N</i>	Follow-up	≤ 10 dB	≤ 20 dB	Dead ear
Pedersen [4]	186 (163)	– (2.6 y)	51	75	1.2
Han [5]	74 (73)	6 w (18.2)	45.6	82.4	1.3
Hammer-schlag [6]	308 (250)	6 w –	80	85	0
De la Cruz [7]	356 (331)	3 w (4.6)	60	78	1.4
Lippy [8]	522 (483)	6 m (8.2)	71	86	0.2
Gros [9]	63 (63)	1 m –	52	79.4	1.6
Schmid [10]	201 (172)	6 m (12)	55	84	1.2
Vincent [11]	652 (538)	3 m (25)	63	75	2.9 (SNHL)
Bernard-eschi [12]	102 (85)	6 m (15)	60	85	2
Present study	34 (19)	6 m (10)	68.5	89.5	0

A comparison between this study and what is reported in literature

N number of patients included in the study and () number of patients with hearing results included in the analysis, *Follow-up* minimum follow-up time and () mean follow-up time. *w* weeks, *m* months, *y* years, *SNHL* sensorineural hearing loss (including dead ears)

allows the magnification of the anatomy of the ossicles, their articulation and mobility and observation of the position of the prosthesis, avoiding blind dissection [21, 23]. In our series, we observed that the endoscope allowed an optimal exploration of the middle ear, identifying the correct cause of failure in all cases but three (91.2%).

Prosthesis dislocation is one of the most common causes of failure after primary stapes surgery in large studies [4–12]. In those cases, the endoscope always permitted to detect the possible cause of dislocation. Although the endoscopic vision has not the advantage of a tridimensional image, the depth and the proper penetration of the prosthesis through the platinotomy hole can properly be assessed by moving the endoscope closer, which permits to magnify that detail from a different point of view compared to the microscope (Fig. 1). In our cases, we observed the platinotomy hole to be closed by bone regrowth in 14 cases (41%) and by fibrous tissue in 6 cases (18%). An excellent view of the footplate allowing a safe and proper platinotomy was provided by the endoscope in all those cases. The detail provided by magnification permitted, in the cases with prosthesis dislocation, to remove safely the scar tissue covering the footplate and to explore the old platinotomy area (Fig. 2).

A reduced mobility of the malleus is a further cause of unfavorable results after stapes surgery [9, 11, 12, 25, 26] and its detection not only is difficult to assess by palpation, but it can also be easily overlooked [26]. The endoscopic approach permits to easily explore the anterior malleolar ligament adding a visual information to the tactile one, without the need for an endaural or a retroauricular approach.

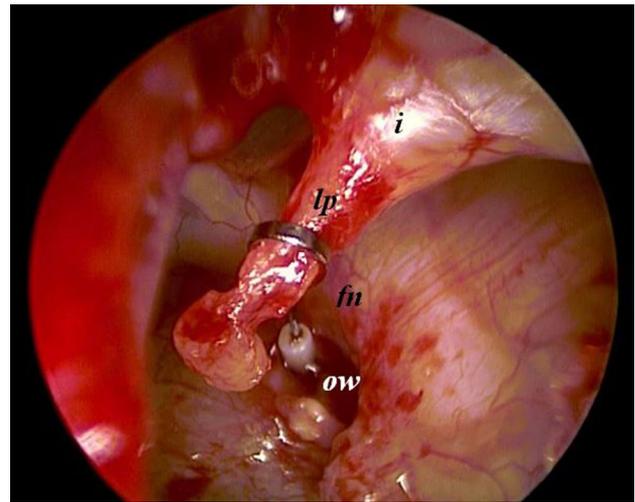


Fig. 1 Left ear. Endoscopic view of a well-positioned prosthesis. *i* incus, *lp* long process of the incus, *ow* round window, *fn* facial nerve

In our series, one case had an anterior malleolar ligament ossification which was treated endoscopically through the trans-canal approach.

Fibrous tissue and adhesions are other common causes of unfavorable functional result after primary stapes surgery. They reduce ossicular chain and prosthesis mobility and may contribute to prosthesis dislocation [9, 10, 27]. However, some authors [14] have reported a poor improvement of hearing in cases with a correctly placed prosthesis and reduced mobility due to adhesions as the sole (identified) cause of failure. They, indeed, observed that replacing the prosthesis in those cases did not result in further hearing gain but sometimes in hearing deterioration [14].

Our failures after endoscopic revision surgery were associated with leaving the old prosthesis in place after removal of adhesions (three out of three cases). In contrast with the observations of Lippy et al. [14], we believe that replacing the prosthesis and a proper cleaning of fibrous tissue covering the oval window, followed by the exploration of the platinotomy hole, may improve hearing. The lesson we learned from those cases, was not only to replace the prosthesis, but to accurately identify an improper perforated or partially re-closed footplate hole. The endoscope provides an optimal vision and magnification of the footplate area, allowing a fine removal of the fibrous tissue. Cases with significant bleeding during fibrous tissue removal may be treated with CO₂ laser, which permits to create an opening without complete removal of fibrous tissue from the oval window, as advocated by other authors [27].

Finally, the ossicular chain abnormalities are frequent and challenging causes of poor hearing outcome after stapes surgery. Of those, the erosion of the long process of the incus is the most common finding [10]. Our observations are in line

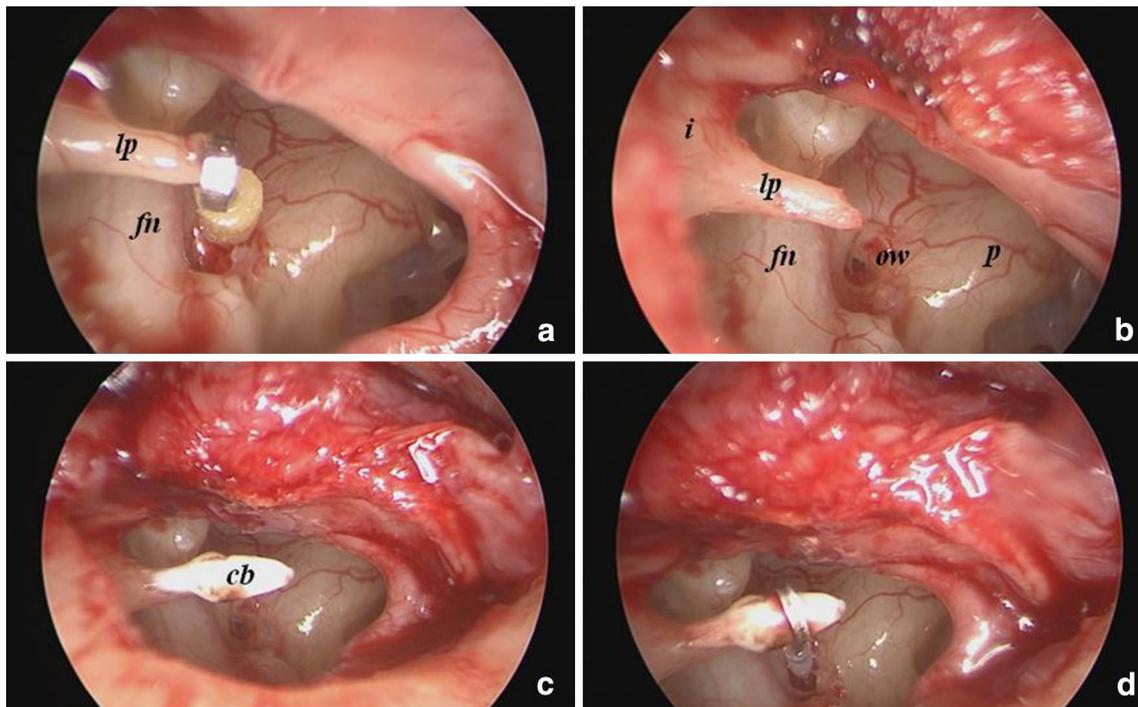


Fig. 2 Right ear. Use of cement bone in revision stapes surgery. **a** Prosthesis is dislocated by long process of the incus; **b** after removal of prosthesis, extensive erosion of the long process of the incus is visualized; **c** cement bone reinforces the long process of the incus;

d a new prosthesis is inserted into the platinotomy and anchored to cement bone. *i* incus, *lp* long process of the incus, *ow* oval window, *fn* facial nerve, *cb* cement bone, *p* promontory

with other authors, having a prevalence of incus erosion of 35.3%. Management of incus erosion was feasible and effective in all cases through the totally endoscopic approach, without the need for bimanual manipulation (Figs. 2, 3). In case of long process erosion, both bone cement and malleostapedotomy techniques were feasible, as required, through a totally endoscopic technique, with a proper visualization of the involved structures during each surgical step (Figs. 2, 3).

One case of incus luxation was found in our series (2.9%), with a prevalence which was consistent with larger series [9, 10]. That case was detected by observation of excessive incus mobility and poor transmission of movements from and to the malleus at palpation, observed with 0° and 45° lenses. It was managed through a trans-canal lateral atticotomy uncovering the incudo-malleolar joint which resulted partially luxated, followed by the assembly of the incus with the malleus with ionomeric bone cement (Fig. 3). Of interest, that surgical solution, which was alternative to incus removal and malleostapedotomy, resulted in a good outcome (closure of the air-bone gap for the PTA), virtually avoiding long-term problems related with the malleostapedotomy technique.

Finally, supporting the utility of the endoscopic approach, we observed a case of bone ridge that fixed the incus to the facial nerve bony canal, which was overlooked during the

primary microscopic surgery and resulted barely visible with the 0° endoscope. It was eventually detected with the 45° endoscope, permitting to solve the diagnostic problem and to avoid removal of the incus and malleostapedotomy.

Auditory outcomes of our series are in line with those of the most recent literature (Table 3), with a success rate of 89.5% \leq 20 dBHL and 68.5% with closure of the air-bone gap (\leq 10 dB). In addition, no cases of sensorineural hearing loss were observed and only the 11% had transitory (< 24 h) vertigo.

The present study has some limits, as it comprises a limited case series, it is a retrospective study, and it does not provide a control group of patients treated with traditional microscopic surgery. However, it analyzes a sample which is representative of the whole spectrum of causes of poor functional outcome after primary stapes surgery (Table 1). Within that variable intraoperative scenario, the endoscopic stapes revision surgery has been proved to be feasible, safe and effective. It permitted to obtain hearing results in line with the best results of larger microscopic series (Table 3). The advantages of a better exploration of the middle ear provided by the endoscope through a transcanal approach, allowed an accurate intraoperative diagnosis and are one of the main strengths of the procedure, which requires, however, a long learning curve and

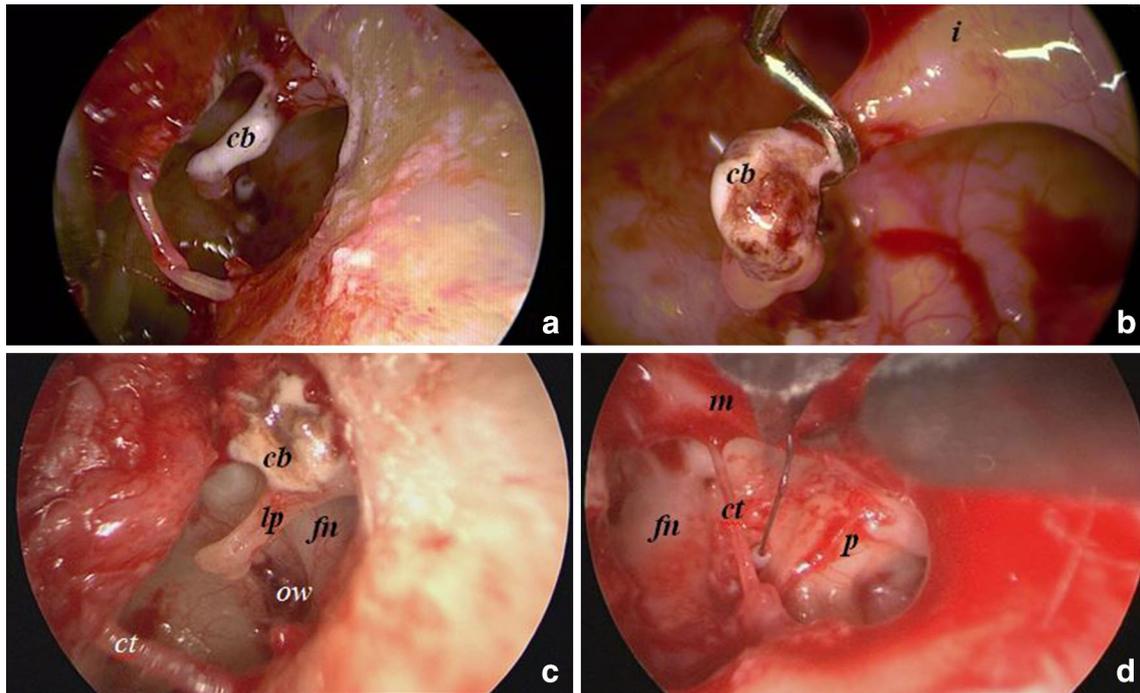


Fig. 3 **a, b** Cement bone is used to reinforce the long process of the incus; **c** incudo-malleolar joint lussation is reinforced with cement bone; **d** malleostapedotomy with prosthesis anchored to the handle of

the malleus. *i* incus, *lp* long process of the incus, *ow* oval window, *fn* facial nerve, *cb* cement bone, *p* promontory, *ct* chorda tympani, *m* handle of the malleus

surgical experience as for the microscopic counterpart. The advantages in terms of depth perception provided by the microscope can be partially balanced by the endoscopic surgical experience. Nonetheless, the 3D system [28, 29] which is currently available for the endoscopic ear surgery, can overcome the bi-dimensionality of the endoscopic view, giving an advantage in terms of depth perception.

Conclusions

The present study showed that totally endoscopic revision stapes surgery is a safe and effective procedure in experienced hands. The great advantage, which the endoscopic approach adds to the classic microscopic approach, is to allow the surgeon an extremely detailed exploration of the whole middle ear cavity through a transcanal approach, without the need for an endaural or retroauricular approach and with the possibility to diagnose and manage all the possible intraoperative scenarios. A larger series with a longer follow-up is needed to validate the results of the present study and to evaluate the possible advantages in terms of hearing outcomes.

Funding None.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

References

- Battista RA, Wiet RJ, Joy J (2006) Revision stapedectomy. *Otolaryngol Clin N Am* 39(4):677–697. **(Review)**
- Durko M, Kaczmarczyk D, Durko T (2007) Revision stapes surgery: retrospective analysis of surgical findings in a series of 21 otosclerosis patients. *Adv Otorhinolaryngol* 65:273–277
- Kanona H, Bhutta MF, Lavy J (2017) Our approach to revision stapes surgery and the outcomes from 49 procedures at a UK tertiary centre. *Clin Otolaryngol* 42(4):931–935
- Pedersen CB (1994) Revision surgery in otosclerosis—operative findings in 186 patients. *Clin Otolaryngol Allied Sci* 19(5):446–450
- Han WW, Incesulu A, McKenna MJ et al (1997) Revision stapedectomy: intraoperative findings, results, and review of the literature. *Laryngoscope* 107(9):1185–1192. **(Review)**
- Hammerschlag PE, Fishman A, Scheer AA (1998). A review of 308 cases of revision stapedectomy. *Laryngoscope* 108(12):1794–1800
- De la Cruz A, Fayad JN (2000) Revision stapedectomy. *Otolaryngology head and neck surgery. Otolaryngol Head Neck Surg* 123(6):728–732
- Lippy WH, Battista RA, Berenholz L et al (2003) Twenty-year review of revision stapedectomy. *Otol Neurotol* 24(4):560–566

9. Gros A, Vatovec J, Zargi M, Jenko K (2005) Success rate in revision stapes surgery for otosclerosis. *Otol Neurotol* 26(6):1143–1148
10. Schmid P, Häusler R (2009) Revision stapedectomy: an analysis of 201 operations. *Otol Neurotol* 30(8):1092–1100. <https://doi.org/10.1097/MAO.0b013e3181b4ecb2>
11. Vincent R, Rovers M, Zingade N, Oates J, Sperling N, Devèze A, Grolman W (2010) Revision stapedotomy: operative findings and hearing results. A prospective study of 652 cases from the otology–neurotology database. *Otol Neurotol* 31(6):875–882
12. Bernardeschi D, Canu G, De Seta D, Russo FY, Ferrary E, Mosnier I, Sterkers O (2018) Revision stapes surgery: a review of 102 cases. *Clin Otolaryngol*. <https://doi.org/10.1111/coa.13181>
13. McGee TM (1981) The loose wire syndrome. *Laryngoscope* 91(9 Pt 1):1478–1483
14. Lippy WH, Berenholz LP (2010) The long prosthesis syndrome. *Otol Neurotol* 31(3):548–549
15. Gurgel RK, Jackler RK, Dobie RA, Popelka GR (2012) A new standardized format for reporting hearing outcome in clinical trials. *Otolaryngol Head Neck Surg* 147(5):803–807
16. Shea JJ (1958) Fenestration of the oval window. *Ann Otol Rhinol Laryngol* 67:932–951
17. Shea JJ, Sanabira F, Smyth GDL (1962) Teflon piston operation for otosclerosis. *Arch Otolaryngol* 76:516–521
18. Wegner I, Vincent R, Derks LSM, Rauh SP, Heymans MW, Stegeman I, Grolman W (2018) An internally validated prognostic model for success in revision stapes surgery for otosclerosis. *Laryngoscope*. <https://doi.org/10.1002/lary.27132>
19. Glasscock ME, Storper IS, Haynes DS et al (1995) Twenty-five years of experience with stapedectomy. *Laryngoscope* 105(9 Pt 1):899–904
20. Marchioni D, Molteni G, Presutti L (2011) Endoscopic anatomy of the middle ear. *Indian J Otolaryngol Head Neck Surg* 63(2):101–113
21. Marchioni D, Soloperto D, Villari D et al (2016) Stapes malformations: the contribute of the endoscopy for diagnosis and surgery. *Eur Arch Otorhinolaryngol* 273(7):1723–1729
22. Nogueira JF, Mattioli F, Presutti L et al (2013) Endoscopic anatomy of the retrotympanum. *Otolaryngol Clin N Am* 46(2):179–188
23. Marchioni D, Piccinini A, Alicandri-Ciuffelli M et al (2013) Endoscopic anatomy and ventilation of the epitympanum. *Otolaryngol Clin N Am* 46(2):165–178
24. Bonali M, Anschuetz L, Fermi M et al (2017 May) The variants of the retro- and hypotympanum: an endoscopic anatomical study. *Eur Arch Otorhinolaryngol* 274(5):2141–2148
25. Fisch U, Acar GO, Huber AM (2001) Malleostapedotomy in revision surgery for otosclerosis. *Otol neurotol* 22:776–785
26. Nandapalan V, Pollan A, Langner A et al (2002) The anterior and superior malleal ligaments in otosclerosis. *Otol Neurotol* 23:854–861
27. Lesisnsky SG (2002) Causes of conductive hearing loss after stapedectomy or stapedotomy: a prospective study of 279 consecutive surgical revisions. *Otol Neurotol* 23(4):281–288
28. Bernardeschi D, Lahlou G, De Seta D et al (2018) O. 3D endoscopic ear surgery: a clinical pilot study. *Eur Arch Otorhinolaryngol* 275(2):379–384
29. Chen CK, Hsieh LC, Hsu TH (2018) Novel three-dimensional image system for endoscopic ear surgery. *Eur Arch Otorhinolaryngol* 275(12):2933–2939