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Endoscopic partial and total ossicular chain reconstruction in children: A multicentric study

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A B S T R A C T

Objective: To evaluate the surgical techniques and audiological outcomes from a cohort of pediatric endoscopic ossiculoplasty (OPL) procedures across three European tertiary referral centers.

Methods: A retrospective, multicentric study was conducted on pediatric patients undergoing endoscopic OPL. Audiological assessments conducted before and after surgery were compared, with postoperative evaluations performed at three months post-operatively and, when available, at the last follow-up (FU) visit.

Results: A total of 77 patients with a mean age of 11.36 years (range 4–17) were included, with the most frequent indication for OPL being cholesteatoma (62 %). 21 % required a combined approach with canal wall-up mastoidectomy, while OPL was performed endoscopically in all cases (Cohen 2b). Partial ossicular replacement prosthesis (PORP) was used in 48 cases, with significant improvement in air-bone gap (ABG) from 29.52 ± 13.11 dB preoperatively to 18.48 ± 11.18 dB at last FU ($p < 0.01$). No significant difference in ABG improvement was observed among different PORP materials and techniques ($p = 0.70$). Total ossicular replacement prosthesis (TORP) was employed in 29 cases, with a non-significant ABG improvement ($p = 0.12$). However, titanium TORP yielded significantly better outcomes compared to bone and semi-synthetic materials ($p < 0.01$ and $p = 0.03$, respectively). At last FU (mean 30.78 ± 24.44 months), ears with a healthy neotympanum (74 %) showed significantly better hearing outcomes than those with disease recurrence ($p = 0.04$).

Conclusion: This study supports the use of transcanal endoscopic ossiculoplasty (OPL) as a safe and effective technique for improving hearing in pediatric patients with conductive or mixed hearing loss due to middle ear disease. The preference for autologous materials in partial reconstruction reflects their biocompatibility and established performance. TORP outcomes varied significantly by material, with titanium prostheses providing the best hearing improvement. Disease recurrence significantly affects hearing outcomes, emphasizing the challenge of achieving a stable and ventilated middle ear to guarantee optimal OPL results.

1. Introduction

Hearing loss (HL) in the pediatric population presents a significant challenge, with potential long-term consequences on speech and language development, academic performance, cognitive outcomes, and social well-being. According to the World Health Organization, chronic otitis media (COM) accounts for over half of the global burden of hearing impairment. The estimated annual incidence in children is around 4.76 cases per 1000 individuals, equating to approximately 31 million cases each year, with more than 22 % occurring in children under 5 years of age [1]. Reconstructive middle ear surgery with restauration of the tympanic membrane (TM) and the ossicular chain are key surgical strategies to reduce the burden of conductive or mixed hearing loss in patients with middle ear disease. Especially ossiculoplasty (OPL) is a

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challenging surgical intervention requiring a high degree of precision in order to restore sound conduction [2].

Across decades, a variety of technical options and prostheses have been adopted to reconstruct the ossicular chain. Depending on the presence or absence of the stapes suprastructure, a partial ossicular replacement prosthesis (PORP) or a total ossicular replacement prosthesis (TORP) may be required. Autologous materials, such as incus, malleus head or cartilage, are fully biocompatible but require longer operative time for modelling and may be unavailable due to the patient's ear conditions. Synthetic PORP and TORP, such as titanium-based prostheses, are ready to use and to position, as their distal end can be visualized during surgery. However, costs and risk of extrusion represent possible drawbacks of these solutions [3].

Traditionally performed through a microscopic approach, OPL could now benefit from the minimally invasive alternative of transcanal endoscopic ear surgery (EES), which offers improved visualization of the middle ear anatomy, without need for extensive canalplasty or postauricular incisions [3–5]. Despite the anatomical challenges posed by narrower external auditory canals (EAC) in children, EES has gained popularity among pediatric otologists as a less invasive technique, with cosmetic advantages and satisfactory functional outcomes. Indeed, the reduced length and relative straightness of the EAC in children could offset the diameter limitation, allowing for easier insertion and angular maneuvering of endoscopes and instruments, as reported by previous studies [6,7].

A growing number of academic publications in pediatric otologic surgery have shown that endoscopic approaches yield results comparable to, or better than, microscope-guided techniques for closing TM perforations and removing cholesteatoma [5,8–12]. However, few studies have specifically focused on endoscopic OPL outcomes in children [13–17]. This multicentric retrospective study aims to evaluate the surgical techniques and audiological outcomes from a large cohort of pediatric endoscopic OPL procedures across three European tertiary referral centers.

2. Patients and methods

2.1. Study design and participants

This is a retrospective study on pediatric patients who underwent OPL via an endoscopic transcanal approach at three University Hospitals – Bern (Switzerland), Bologna and Modena (Italy) - between 2017 and 2024.

Cholesteatoma cases requiring mastoidectomy due to disease extension were included if OPL was performed endoscopically, according to Cohen Class 2b classification [18]. Procedures categorized as Cohen Class 2a or lower, patients lacking follow-up (FU) data, and canal-wall down surgeries were excluded from the analysis.

According to these criteria, after reviewing the consecutive cases of endoscopic OPL performed on patients younger than 17 years, 77 patients were retrieved. Of these, 55 had been previously included in a larger retrospective cohort comprising both adult and pediatric cases, recently published by the present authors [3]. For this present study, twenty-two new pediatric cases were added. FU was extended from a mean of 20.7 months (±15.53) in the previously published cohort to 30.78 months (±24.44) in this exclusively pediatric subgroup analysis. This updated study population was assembled to allow for a dedicated analysis of outcomes in children and to strengthen the statistical power by increasing the number of cases.

Surgical procedures conformed to the ethical standards established by the national research committees and the World Medical Association Declaration of Helsinki (2002). Ethical approval for this study was obtained from the institutional and regional review boards (Kantonale Ethikkomission, KEK-BE 2019-00555 and CE-AVEN: 0000872/22).

2.2. Data collection

Patient records and FU visits were reviewed to collect data on preoperative and postoperative hearing function, surgical details, including type of middle ear disease, ossicular chain status, and type of OPL. Where necessary, the surgical videos were reviewed. Cholesteatoma cases were stratified according to ChOLE classification [19]. Audiological assessments conducted before and after surgery were compared, with postoperative evaluations performed at a minimum of three months and, when available, at the last FU visit. These assessments included otoendoscopy and pure-tone audiometry, with bone conduction (BC) and air conduction (AC) pure-tone averages (PTA) calculated from threshold measurements at 0.25, 0.5, 1, 2, and 4 kHz. The mean air–bone gap (ABG) was defined as the difference between AC-PTA and BC-PTA. Improvement in ABG was quantified as the difference between the mean preoperative and postoperative ABG values, with a positive value indicating auditory function enhancement.

2.3. Surgical technique

All procedures were performed under general anesthesia using a transcanal endoscopic approach with a 3-mm diameter, 14-cm length, 0° rigid endoscope. Light intensity was set at 50 % of maximum power, in accordance with standard protocols for endoscopic ear surgery (EES) across all centers. In cases of additional CWU mastoidectomy due to disease extension into the mastoid, OPL was still performed under endoscopic view.

The selection between PORP and TORP was determined intraoperatively based on the presence or absence of the stapes suprastructure, respectively. The availability of autologous materials and the surgeon's preference accounted for the choice of the reconstructive strategy. For heterologous reconstruction, titanium-based prostheses were used, and were in all cases covered with cartilage on their lateral surface to minimize the risk of extrusion. Prosthesis length was adjusted according to intraoperative measurements, and all prostheses were stabilized using resorbable pledgets. The semi-synthetic TORP prosthesis was constructed using a combination of platinum/polytetrafluoroethylene (PTFE) and cartilage. Following repositioning of the tympano-meatal flap, the external auditory canal was packed with resorbable material, based on the surgeon's habits.

2.4. Statistical analysis

All statistical analyses were performed using GraphPad Prism (version 10.0). Continuous variables are reported as mean ± standard deviation (SD), along with median and range. Categorical variables are summarized as counts and percentages. Comparisons of audiological outcomes across different prosthesis material groups (PORP and TORP) were conducted using one-way analysis of variance (ANOVA) for comparisons involving more than two groups. When ANOVA revealed significant differences, post-hoc pairwise t-tests were used to identify specific group differences. For comparisons between two groups independent t-tests were applied. Statistical significance was defined as $p < 0.05$.

To evaluate whether within-group hearing improvements were statistically significant, one-sample *t*-tests were conducted. Effect sizes (Cohen's *f*) were calculated for ANOVA results to quantify the magnitude of group differences. Statistical power was estimated based on observed effect sizes and sample sizes to assess the adequacy of the data in detecting clinically meaningful effects.

3. Results

3.1. Cohort characteristics

A total of 77 pediatric patients were included in the study, with a

mean age of 11.36 years (SD ± 3.56; range 4–17 years). Right-sided procedures accounted for 53 % of the cases (n = 41), and 19 patients (25 %) underwent revision surgery. Regarding surgical indications, 48 patients (62 %) were diagnosed with COM with cholesteatoma, 20 patients (26 %) had COM without cholesteatoma, and 9 patients (12 %) were treated for trauma or malformations. Primary acquired cholesteatoma was the most common condition, observed in 21 patients (44 %), followed by congenital and secondary acquired forms, 10 patients (21 %) each. Residual and recurrent cholesteatoma were less common, accounting for 2 (4 %) and 5 (10 %) cases, respectively. According to the CHOLE classification, 22 patients (46 %) were classified as stage I and 26 patients (54 %) as stage II. The majority of surgeries (79 %) were performed in exclusive EES. Table 1 provides a comprehensive summary of patient demographics and surgical details, including PORP and TORP techniques employed.

3.2. Audiological outcomes

The overall mean pre-operative ABG was 31.51 dB (±13.04), which improved significantly to 22.60 dB (±13.30) at last FU ($p < 0.01$), as indicated in Table 2. AC PTA improved from 41.76 dB (±16.08) pre-operatively to 32.89 dB (±17.19) at last FU. BC PTA remained stable, with a pre-operative value of 10.25 dB (±6.85) and 10.29 dB (±7.65) at last FU. Among patients who received PORP, the mean ABG improved significantly from 29.52 dB (±13.11) pre-operatively to 18.48 dB (±11.18) at last FU ($p < 0.01$), with a mean hearing improvement of 11.0 dB (±13.5). Material subgroups included bone (n = 26), cartilage (n = 13), titanium (n = 6), and cement (n = 3). Despite numerical differences, no statistically significant variation in ABG improvement was observed across different PORP materials (ANOVA: $F = 0.47$, $p = 0.70$).

Patients receiving TORP had a mean pre-operative ABG of 34.97 dB (±12.39) and an ABG of 29.43 dB (±13.90) at last FU, representing a non-significant mean improvement of 5.5 dB (±14.3; $p = 0.12$). However, significant differences were found between TORP materials (ANOVA: $F = 11.75$, $p < 0.01$). Titanium TORP (n = 11) showed the greatest improvement, with a mean hearing gain of 21.1 dB (±12.9). In contrast, semi-synthetic TORP (n = 6) and bone TORP (n = 12) resulted in mean changes of 2.8 dB (±18.7) and −7.4 dB (±12.8), respectively. Post-hoc analysis confirmed that titanium TORP outperformed both bone ($p < 0.01$) and semisynthetic ($p = 0.03$) materials, while the difference between bone and semisynthetic TORP was not significant ($p = 0.19$). The effect size was large (Cohen's $f = 3.43$), indicating a clinically meaningful difference. Fig. 1 provides detailed insights into the specific techniques utilized and their respective pre- and postoperative ABG values.

Table 1
Demographics and surgical data.

	n = 77
Sex	
Female	24
Male	53
Ear (right)	41
Revision surgery	19
Indication	
COM without cholesteatoma	20
COM with cholesteatoma	48
Other	9
Surgical Technique	
EES exclusive	61
Combined CWU (EES, microscope assisted)	16
PORP	**48**
Bone	26
Cartilage	13
Titanium	6
Cement*	3
TORP	**29**
Bone	12
Semi-synthetic°	6
Titanium	11

Abbreviations: COM = chronic otitis media; CWU = canal wall up; EES = endoscopic ear surgery; PORP = partial ossicular replacement prosthesis; TORP = total ossicular replacement prosthesis; *: reconstruction of minor erosion of long process of incus; °cartilage and modified stapes piston [2].

Table 2
Type of ossiculoplasty and audiological outcomes.

Material	N	Pre-operative ABG Mean (±SD)	Last FU ABG Mean (±SD)	P
PORP Total	**48**	**29.52 (±13.11)**	**18.48 (±11.18)**	**<0.01**
Bone	26	28.90 (±15.14)	18.65 (±13.08)	
Cartilage	13	27.96(±10.16)	18.31 (±8.15)	
Titanium	6	34.17 (±10.50)	20.67 (±11.41)	
Cement	3	32.33 (±13.61)	13.33 (±4.16)	
TORP Total	**29**	**34.97 (±12.39)**	**29.43 (±13.90)**	**0.12**
Bone	12	29.06 (±11.14)	36.47 (±14.37)	
Semi-synthetic	6	38.71 (±13.99)	35.92 (±11.78)	
Titanium	11	39.36 (±11.14)	18.27 (±4.90)	
Total	**77**	**31.51 (±13.04)**	**22.60 (±13.30)**	**<0.01**

Abbreviations: ABG = air bone gap; FU = follow-up; PORP = partial ossicular replacement prosthesis; SD = standard deviation; TORP = total ossicular replacement prosthesis.

3.3. Effects of revision surgery and disease recurrence on hearing results

Among the 77 cases included in this study, 19 ears underwent revision surgery, while 58 were primary surgeries. At baseline, the revision group demonstrated a higher mean ABG PTA (34.7 ± 9.7 dB) than the non-revision group (30.5 ± 13.9 dB), a trend that continued post-operatively at 3 months (22.7 ± 11.1 dB vs. 20.8 ± 9.9 dB) and final FU (26.1 ± 11.5 dB vs. 21.5 ± 13.8 dB). However, independent t-tests indicated that these differences were not statistically significant at any time point (all $p > 0.05$). Within-group comparisons using paired t-tests revealed significant improvement in ABG PTA from preoperative to last FU in both the revision ($p < 0.01$) and non-revision groups ($p < 0.01$). At last FU, auditory success (ABG <20 dB) was achieved in 56.9 % of primary procedures and 26.3 % of revision procedures, representing a statistically significant difference (Fisher's exact test, $p = 0.03$)

At final FU (30.78 months ±24.44), 57 ears (74 %) showed an intact and healthy neotympanum, while 20 ears (26 %) exhibited any degree of disease recurrence, including 5 perforations, 1 atelectasis, 9 retraction pockets or cholesteatoma recurrences, and 5 residual cholesteatomas. Ears with an intact TM had significantly better hearing outcomes ($p = 0.04$), with a mean ABG of 20.6 dB (±12.5) compared to 28.4 dB (±14.2) in those with recurrent disease, as illustrated in Fig. 2. No dislocations or extrusions of prostheses were observed. Four patients (5 %) experienced postoperative infections.

4. Discussion

This multicenter study provides insights into surgical strategies, material selection, and audiological outcomes from one of the largest pediatric cohorts undergoing endoscopic OPL reported to date. The overall significant improvement in ABG from 31.51 dB to 22.60 dB ($p < 0.01$) supports the potential of endoscopic OPL to effectively restore sound conduction in children affected by conductive or mixed hearing loss due different middle ear conditions. The stability of the BC PTA before and after surgery further confirms the safety of the endoscopic technique in this context. It is well known that presence of cholesteatoma negatively impacts the results of OPL, both for the possible more extensive involvement of the middle ear and for the challenge of restoring a ventilated ear cavity [20]. However, the feasibility and

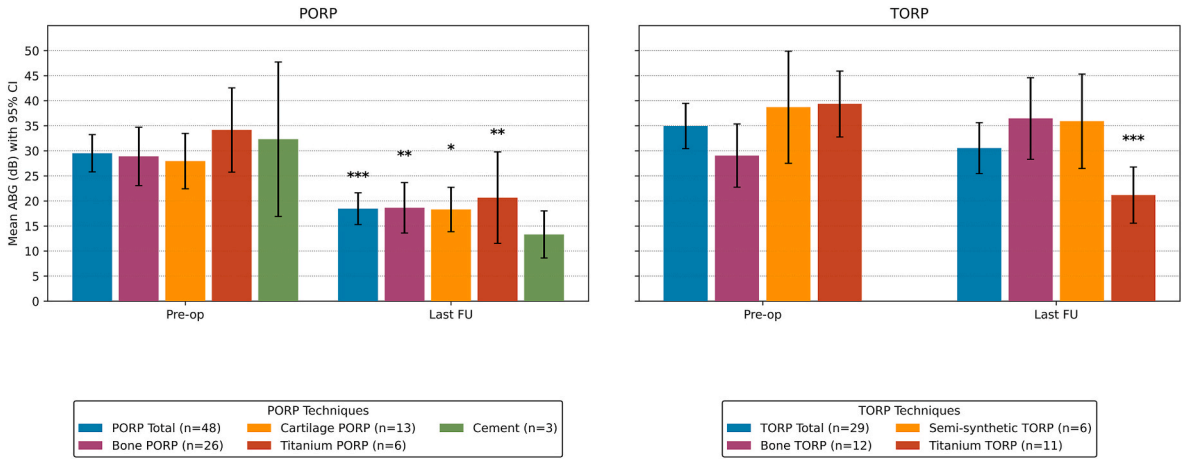

Fig. 1. Hearing results for PORP and TORP between preoperative (Pre-op) and last follow-up (FU).
Abbreviations: ABG = Air-bone gap; CI = Confidence interval; PORP = Partial ossicular replacement prosthesis; TORP = Total ossicular replacement prosthesis; statistical significance indicated as *** for $p < 0.001$, ** for $p < 0.01$, * for $p < 0.05$.

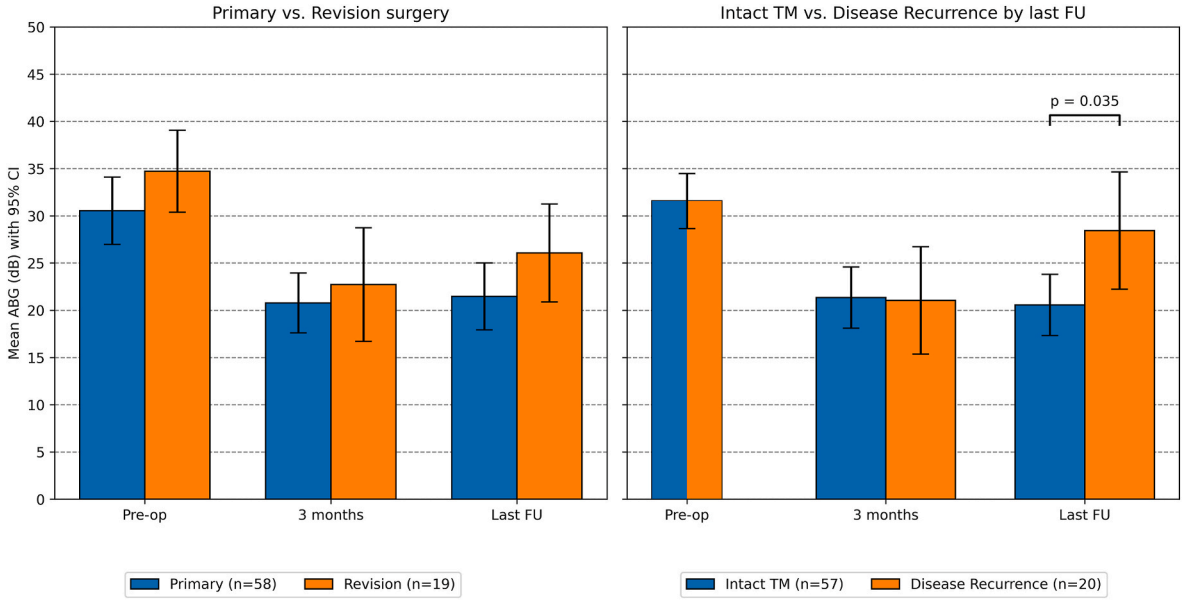

Fig. 2. Impact of revision surgery and TM status at last FU on audiological outcomes.
Left: ABG improvement following primary versus revision OPL; **Right:** ABG stratified by TM status at last FU, comparing ears with an intact TM to those with recurrent disease
Abbreviations: ABG = Air-bone gap; CI = Confidence interval; FU = follow-up; pre-op = preoperative; OPL = ossiculoplasty; TM = tympanic membrane.

efficacy of the endoscopic ossicular chain reconstruction appeared not significantly compromised by the high proportion of cholesteatoma cases (62 %) included in this study. Indeed, we observed that disease recurrence negatively impacts audiological results of endoscopic OPL.

In the PORP group, the significant ABG improvement (mean improvement of 11.0 dB) supports the effectiveness of both autologous and heterologous materials in reconstructing the ossicular chain when the stapes suprastructure is present, with no statistically significant difference between bone, cartilage, titanium, or cement materials in this subgroup. A clear preference for autologous materials emerged across the three centers, with 81.3 % of PORP were made of bone or cartilage. This finding aligns with recent literature on endoscopic OPL in adults and pediatric patients, where bony PORP has been favored due to its biocompatibility and favorable coupling characteristics within the middle ear environment [3]. Similarly, Soloperto et al. performed 74 endoscopic OPL using only autologous materials: incus interposition (61 %), mastoid cortical bone (20 %), tragal or conchal cartilage (15 %), and remodeled malleus head (3, 4 %). Among the 43 PORP in their cohort, the ABG improved from 25.90 (±10.25) to 15.85 (±7.61), however no statistical significance was reached ($p > 0.05$) [4]. Further comparison with other authors suffers from to the preference of most pediatric ear surgeons to perform OPL reconstruction with heterologous materials [14–16,21].

Hearing outcomes for TORP procedures were more variable in our cohort, consistent with existing literature on OPL in general, and pediatric OPL more specifically. A recent multi-institutional analysis of 1679 OPL surgeries identified younger age and absent stapes superstructure as independent predictors of suboptimal hearing outcomes [22], justifying the less satisfactory results of TORP reconstructions in children.

While the overall ABG improvement in the TORP group did not reach statistical significance in our cohort ($p = 0.12$), subgroup analysis revealed that titanium TORPs were associated with significantly better audiological results compared to both bone and semi-synthetic constructs. Notably, bone TORPs showed a negative mean change in ABG,

suggesting that autologous materials may be less suitable for total ossicular replacement in pediatric patients, possibly due to suboptimal coupling to the footplate or ankylosis of the prosthesis to the malleus or oval window niche.

The superior performance of titanium TORPs aligns with previous studies emphasizing their favorable biocompatibility, stability, and adjustability during surgery [2]. Based on their experience with microscopic titanium-based TORPs, Quesnel et al. reported an extrusion rate of less than 3 % in children, and a very low rate of sensorineural hearing loss (1.3 %), indicating the high safety of such prosthesis [21].

Interestingly, among the four studies comparing microscopic and endoscopic OPL in the pediatric papulation, two focused on total ossicular replacement prosthesis (TORP) ossiculoplasty: Kwinter et al. compared post-operative hearing outcomes and morbidity after pediatric TORP OPL in EES versus a post-auricular microscope-guided approach, in a cohort of 41 patients. They found similar hearing outcomes but decreased post-operative pain in the EES group [5]. Baazil et al. reported on short- and long-term outcomes after transcanal endoscope-assisted vs microscope-assisted ossiculoplasty using a single type of TORP (Fisch titanium total prosthesis), concluding that endoscope-assisted TORP has comparable results to the microscopic counterpart [23]. In 2020 a comparative cohort study from two tertiary care centers, including 200 pediatric cases (100 per group), confirmed that endoscopic OPL had equivalent audiometric outcomes with significantly fewer post-auricular approaches and no increase in complications compared to the microscopic group [16]. More recently, Fink et al. conducted a retrospective case–control study on 70 tympanoplasty cases comparing endoscopic and microscopic techniques in children. They reported comparable audiological outcomes and graft intake rates, while the endoscopic group demonstrated shorter operative times and significantly lower rates of residual disease and postoperative complications [24].

Both primary and revision OPL cases showed statistically significant hearing improvement from preoperative assessment to the final FU. Although revision cases presented with worse baseline hearing and less favorable short-term outcomes, within-group comparisons confirmed a significant ABG reduction in both groups ($p < 0.01$). This underscores the potential benefit of endoscopic revision ossiculoplasty even in challenging surgical fields. In line with previous studies, auditory success (ABG $\leq$20 dB) was achieved in a significant higher percentage of cases in the primary OPL subgroup compared to the revision group (56.9 % vs 26.3 %, p = 0.03). Dumont reported that auditory success was significantly greater for primary surgeries than for revisions, both at short-term (71.4 % and 30 % - P = 0.01 in 44 children) and long-term (63.6 % for primary versus 26.3 % for revision surgery - P = 0.05 in 30 children) [17]. According to the large series of Gluth et al., the most impactful risk factor for hearing outcome was multiple revision surgeries [22]. Thus, a cautious counseling with pediatric patients and parents regarding the expected audiological outcomes is needed before revision surgery.

Given that most patients in this study underwent surgery for cholesteatoma, achieving a stable middle ear environment and an intact TM proved crucial to successful long-term outcomes. Recurrence of chronic middle ear disease was not uncommon, with 26 % (20/77 ears) experiencing unfavorable outcome including TM perforation, atelectasis, retraction pockets, recurrent cholesteatoma, or residual disease. Importantly, ears with an intact TM at last FU demonstrated significantly better hearing outcomes (mean ABG 20.6 dB $\pm$ 12.5) compared to those with recurrent pathology (mean ABG 28.4 dB $\pm$ 14.2, $p = 0.04$). These findings emphasize the importance of both functional and disease-related surgical goals, reinforcing the need for long-term surveillance and complete disease eradication.

In a previous publication, we reported outcomes from a cohort of 292 patients, which included 55 pediatric cases analyzed together with 237 adults [3]. In the present study, these 55 pediatric cases were supplemented by 22 additional children, allowing for a focused analysis of pediatric outcomes. When compared with the previously published adult cohort, children presented with significantly higher preoperative ABG values (31.51 $\pm$ 13.04 dB vs. 26.54 $\pm$ 12.52 dB; $p < 0.01$). At last FU, postoperative hearing outcomes were comparable between groups. Although the mean improvement was slightly greater in children, this difference did not reach statistical significance, indicating that hearing restoration after endoscopic OPL yields similar results across age groups.

Regarding postoperative outcome, tympanic membrane perforations occurred in 12 adult cases (5.1 %) and in 5 pediatric cases (6.5 %). In addition, 2 prosthesis extrusions and 3 dislocations were observed in the adult group, whereas no such events occurred among children.

Some limitations of this study should be acknowledged. The retrospective design introduces potential selection bias, and the wide variability in FU and small sample sizes in subgroup analyses may limit comparability and conclusions on long-term stability of prostheses and should therefore be interpreted with caution. This reflects the inherent difficulty of maintaining extended FU in pediatric otology, particularly when outcomes are satisfactory, and patients remain asymptomatic. The paucity of some reconstruction strategies, such as titanium PORP, cement and semi-synthetic TORP, may have influenced the significance of the results. Minor variability in prosthesis selection due to material availability and surgeon preference may have occurred. Most importantly, 79 % of the cases were managed with a purely endoscopic approach, which reflects a predominance of patients with limited cholesteatoma extension or confined middle ear disease included in the present study. Further investigations encompassing a wider range of cholesteatoma stages, along with a systematic stratification of various middle ear pathologies, are warranted to more precisely elucidate the role of endoscopic ossicular chain reconstruction across the full spectrum of pediatric middle ear disease.

5. Conclusion

This study supports the use of transcanal endoscopic ossiculoplasty (OPL) as a safe and effective technique for improving hearing in pediatric patients with conductive or mixed hearing loss due to middle ear disease. The preference for autologous materials in partial reconstruction reflects their biocompatibility and established performance. TORP outcomes varied significantly by material, with titanium prostheses providing the best hearing improvement. Disease recurrence significantly affects hearing outcomes, emphasizing the challenge of achieving a stable and ventilated middle ear to guarantee optimal OPL results.

CRediT authorship contribution statement

Giulia Molinari: Writing – review & editing, Writing – original draft, Methodology, Data curation, Conceptualization. **Raffael Fink:** Writing – review & editing, Writing – original draft, Methodology, Investigation, Formal analysis, Data curation. **Nicola Bisi:** Writing – review & editing, Investigation, Data curation, Conceptualization. **Sven Beckmann:** Writing – review & editing, Investigation, Data curation. **Arianna Burato:** Writing – review & editing, Investigation, Formal analysis, Data curation. **Daniele Marchioni:** Writing – review & editing, Supervision, Methodology, Investigation, Conceptualization. **Livio Presutti:** Writing – review & editing, Supervision, Methodology, Investigation, Conceptualization. **Ignacio Javier Fernandez:** Writing – review & editing, Methodology, Investigation, Conceptualization. **Lukas Anschuetz:** Writing – review & editing, Writing – original draft, Supervision, Methodology, Investigation, Formal analysis, Data curation, Conceptualization.

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Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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