Endoscopic tympanoplasty type I with composite perichondrium-cartilage graft in children: surgical and audiologic outcomes from an Italian cohort

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Abstract
Endoscopic Type I tympanoplasty (TPL I) represent a minimally invasive surgery to treat tympanic membrane perforation. Its role in the pediatric population remains under-evaluated. A retrospective study was conducted on 46 pediatric patients undergoing exclusive endoscopic TPL I with a full-thickness tragal cartilage-perichondrium graft between 2021 and 2024. Surgical outcomes, audiological improvements, and complication rates were assessed at a tertiary Italian center. Anatomical success was achieved in 89.1% of cases, with no major intraoperative and postoperative complications. The mean postoperative air-bone gap significantly improved from 18.0 dB to 10.18 dB. Functional success (ABG ≤20 dB) was recorded in 87% of patients. Failures were more frequent among patients operated on by junior surgeons and in anterior and marginal perforations. Endoscopic TPL I with a composite cartilage-perichondrium graft is a safe and effective option in pediatric patients, providing excellent anatomical and functional outcomes with minimal complications.

Keywords: Endoscopic ear surgery; endoscopic tympanoplasty; children; tympanic perforation; tragal cartilage; perichondrium; surgical and audiologic outcomes

Introduction

Surgical repair of chronic tympanic membrane (TM) perforations—commonly referred to as type I tympanoplasty (TPL I)—is a key otologic procedure aimed at restoring membrane integrity and improving auditory function.

The success of such procedure in the pediatric population is critical to prevent recurrent middle ear infections, reduce the risk of secondary cholesteatoma, ensures proper development of speech and language skills, and improve children's quality of life (Schwam et al., 2021; Haci et al., 2023).

Nevertheless, due to anatomical and physiological differences compared to adults, type I tympanoplasty (TPL I) poses unique challenges in the pediatric population. First, this procedure is associated with a higher rate of reperforation, mainly due to immature Eustachian tube function. Age at surgery and choice of graft material have been matters of debate as influencing factor for optimizing surgical outcomes. While some surgeons advocate postponing surgery until eight years of age, others perform it more precociously, even under six years of age (Abood et al., 2020). Tragal cartilage - often combined with perichondrium- is increasingly preferred in pediatric cases due to its superior structural

stability, although results remain conflicting (Awad et al., 2015; Lou et al., 2020).

Second, the narrower external auditory canal in children has historically made the retroauricolar microscopic approach the gold standard. This limitation has been overcome by the introduction of the endoscopic technique, which offers enhanced and closer visualization of the surgical field through the external meatus in a minimally invasive fashion. Despite a growing body of literature showing that endoscopic TPL I is a highly effective and safe procedure even in the pediatric population, challenges such as the one-handed technique, a steep learning curve, and the lack of clearly superior outcomes compared to the microscopic technique, have so far prevented endoscopy from becoming the standard of care for pediatric TM perforations (Crotty et al., 2023; Alicandri-Ciufelli et al., 2018).

Moreover, although several studies on endoscopic TPL I have explored different grafting materials and technical variations, such as inlay versus underlay approaches, most have been limited by small sample sizes, heterogeneous patient populations, and methodological biases, often mixing different surgical techniques within the same cohort (Bartel et al., 2019; Lou, 2020; Nassif et al., 2022; Sen & Özdamar, 2019). As a result, there remains a lack of high-quality, standardized data specifically focused on outcomes of exclusive endoscopic TPL I in the pediatric population. To address this gap, our study aims to provide a comprehensive evaluation of surgical and audiological outcomes following endoscopic TPL I using a standardized composite perichondrium-cartilage graft in a large cohort of Italian pediatric patients.

Materials and methods

Study design

A retrospective study was conducted on primary cases of totally endoscopic TPL I performed between January 2021 and December 2024 at the IRCCS Azienda Ospedaliero-Universitaria di Bologna, Policlinico di Sant'Orsola (Bologna, Italy), a tertiary referral center for endoscopic ear surgery (EES).

Patients were eligible for inclusion if they met the following criteria: age younger than 17 years at the time of surgery; diagnosis of chronic otitis media with perforated TM, without cholesteatoma; and an intact ossicular chain. Patients were excluded if they had undergone previous tympanoplasty (revision cases), and if intraoperative findings necessitated concomitant ossiculoplasty.

The diagnosis of chronic otitis media was based on clinical history, in-office otoendoscopic examination and evidence of conductive hearing loss. Temporal bone computed tomography imaging was not routinely performed.

Written informed consent was obtained from the patient's parents following a detailed explanation of the procedure and its risks. The study was conducted in accordance with the ethical standards of the institutional and national research committees, as well as the ethical standards stated in the 'Declaration of Helsinki'.

Surgical technique

All procedures were carried out under general anesthesia by surgeons with varying levels of experience in EES: two senior surgeons with more than 10 years of experience and two junior surgeons with less than 5 years.

A 0°, 14-cm long, 3-mm diameter endoscope (Karl Storz, Tuttlingen, Germany) was used to guide the surgery via the external auditory canal (EAC).

Preliminary steps included refreshing of the perforation margins with a hook and/or the sickle knife (**Figure 1, A**), trimming of the EAC hairs, and local infiltration of a vasoconstrictor combined with a local anesthetic in the posterior wall of the EAC. The tympanomeatal flap was elevated by making an incision along the posterior EAC skin, approximately 5-7 mm lateral to the annulus, extended anteriorly and inferiorly according to the size and location of the perforation. Middle ear access was achieved in a subannular plane, and the ossicular chain was inspected and tested with gentle palpation to confirm normal mobility. The remnant tympanic membrane overlying the manubrium of the malleus was carefully elevated in all cases until the umbo (**Figure 1, B**) and cut using micro-scissors. The chorda tympany nerve was identified and preserved in all cases.

A composite graft of tragal cartilage and perichondrium was harvested from a 1-cm incision behind the margin of the tragus skin, leaving the external tip of the tragal cartilage to maintain the normal shape of the tragus. The perichondrium of the convex side of the cartilage was removed, and the cartilage edges were progressively cut with the round knife to create an island of cartilage tailored to the size and shape of the TM perforation. In all cases the cartilage was used full thickness (**Figure 1, C**). In only two cases, the composite graft of tragal cartilage and perichondrium was reinforced with a xenograft derived from porcine small intestinal submucosa (ENT-SRG BIODESIGN, Cook Medical, Bloomington, Indiana, USA).

Some wet pledgets of resorbable sponge were placed into the middle ear cavity to support the graft, which was positioned using the over-under technique (placed over the malleus and under the annulus), at the site of perforation. Eventually, the TMF was repositioned (**Figure 1, D**) and the EAC filled with resorbable sponge without antibiotic.

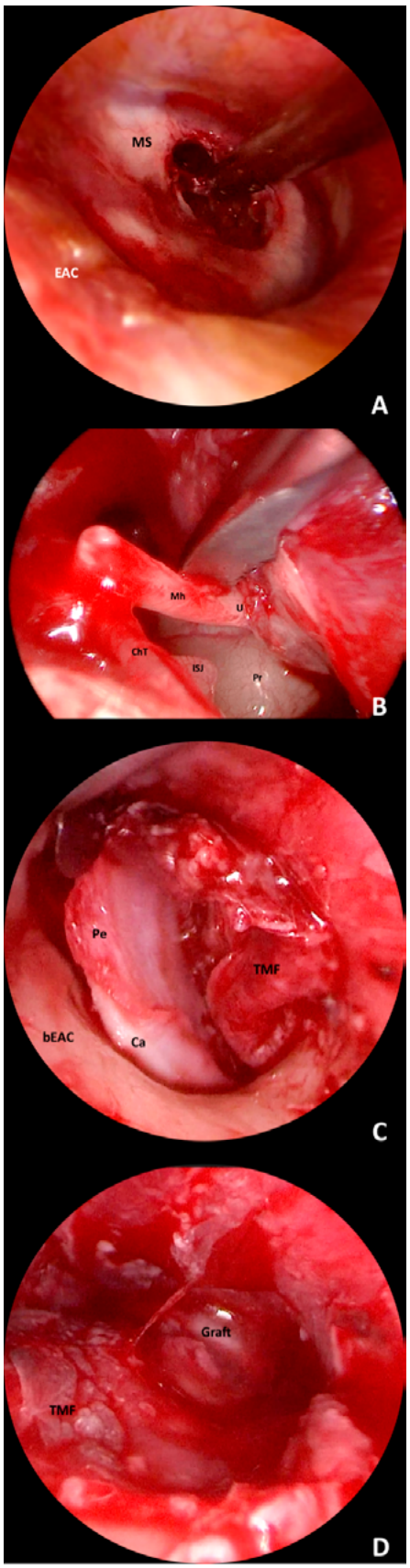
A: Refreshing of the perforation margins with sickle knife; MS myringosclerosis, EAC external auditory canal; B: Detachment of the remnant of the tympanic membrane from the mallues handle. Mh: malleus handle, U: umbo, ChT: chorda tympani, Pr: promontorium, ISJ: incudo-stapedial joint; C: Positioning of the cartilage-perichondrium graft over the malleus handle and under the annulus, c: cartilage, p: perichondrium, TMF: tympano-meatal flap, bEAC: bony external auditory canal. D: Final view after tympano-meatal flap (TMF) repositioning.

Data extraction

Demographic and clinical data - including age, sex, perforation type (central or marginal), location, and preoperative and postoperative audiometric thresholds- were retrieved from the patients charts and follow-up visits.

Details of the surgical procedure and total duration of the operation were extracted from the surgical report. Postoperative complications were categorized as early and late, depending on whether they occurred before or after 2 months post-surgery (Marchioni et al., 2018).

Figure 1. Surgical steps of right endoscopic type I tympanoplasty.



All patients underwent preoperative and postoperative audiological evaluations. According to the American Academy of Otolaryngology–Head and Neck Surgery guidelines, the bone- conduction (BC) and air-conduction (AC) thresholds were calculated as the average for 0.5, 1, 2, and 3 kHz frequencies. The air-bone gap (ABG) was defined as the difference between the four-tone pure-tone average (PTA) for AC and BC.

BC PTA measurements were performed the day after surgery, following institutional protocol, to rule out any immediate inner ear damage.

Follow-up

All the patients received local antibiotic drops (ciprofloxacin) for an average of 10 days postoperatively, and were instructed to avoid blowing of the nose, sneezing and sport activities for 1 month. The first follow-up visit was planned after 8-10 days to check the tragal suture and rule out infection of the surgical site. The EAC was not unpacked in any case.

The second follow up was planned around 6 weeks postoperatively, with otoendoscopy and pure tone audiometry. Anatomical success was defined as the presence of an intact reconstructed TM, without lateralization (as shown in **Figure 2**), and as a postoperative ABG below to 20 dB at second follow-up visit.

The following visits were planned based on the surgical outcome. If regular healing with normalization of the hearing was achieved at the second follow-up, a 6-month follow-up was scheduled, after which the patient was evaluated annually. In cases of delayed healing, bi-weekly follow-ups were arranged until stable outcomes were observed and pure tone audiometry could be performed reliably.

Results

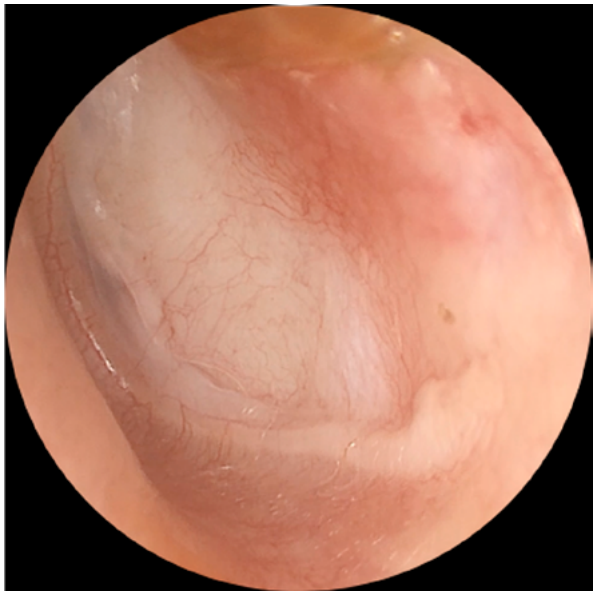
Forty-six patients were included, with an even distribution of males and females, and right and left ears (1:1). The mean age at surgery was 10 years (range 5-17, SD 2.6).

Nine patients presented relevant comorbidities: DiGeorge syndrome (n=1), cleft lip and palate (n=2), cystic fibrosis (n=1), scaphocephaly (n=1), KBG syndrome and growth hormone deficiency (n=1), hypoplasia of the cerebellar vermis (n=1), West syndrome (n=1), congenital hypothyroidism (n=1), double outlet right ventricle (n=1). Three of these patients underwent previous corrective surgery for cleft lip and palate and scaphocephaly. Moreover, 9 patients (19.5%) underwent adenoidectomy and 4 patients (8.7%) same-side myringotomy, prior to tympanoplasty. Pre-operative temporal bone CT scan was performed in 6 cases (12.5%) only.

A marginal perforation of the tympanic membrane was found in 22 patients (47.9%), while a central defect was found in 24 patients (52.1%). Distribution of the subsites of the perforations is shown in **Figure 3.**

The mean duration of surgery was 90 minutes (range 32-169 minutes, SD 30.3), while mean duration of hospitalization was 1.1 day (range 1-2 days, SD 0.3).

Figure 2. Example of 6-month follow-up otoendoscopy showing regular reconstruction and healing of left tympanic membrane, after endoscopic type I tympanoplasty with cartilage-perichondrium graft.



Surgical outcomes

The mean follow-up duration was 8.5 months (range 1-19, SD 9.5).

No intraoperative complications were reported. Regarding the early and late postoperative period, otorrhea from the operated

ear was observed in 2 patients, while vertigo, facial palsy, dysgeusia did not occur.

Anatomical success was achieved in 41 patients (89.1%). Among the 5 cases who had persistent perforation, all had been operated by junior surgeons and were male. Most of them (4/5, 80%) had not undergone adenoidectomy, and had been treated for a marginal perforation (4/5, 80%), involving at least one of the anterior quadrants (4/5, 80%).

A retraction pocket in the reconstructed TM and atelectasis of the whole neo-membrane was found in 1 patient, respectively (2/46, 4.3%). In one patient (1/46, 2.2%) reperforation occurred after 5 months.

Hearing outcomes

No patient experienced a significant postoperative decrease in BC thresholds, indicating preservation of inner ear function. Mean PTA-AC showed a significant improvement from 26.4 (± 10.2) dB to 17.9 (± 12.4) dB after surgery, with a parallel ABG reduction from 18.0 (± 7.3) dB to 10.18 (± 9.6 dB) (**Table 1**).

Forty patients (87%) were considered functionally successful (ABG ≤20 dB). In one patient, revision surgery was proposed due to persistent ABG of 30 dB associated with significant tympanosclerosis at postoperative CT scan, which passed overlooked during primary surgery.

Figure 3 – Distribution of the site of the perforations on a schematic drawing of a right ear. AS= antero-superior quadrant; AI = antero-inferior quadrant; PS: postero-superior quadrant; PI: postero-inferior quadrant; subtotal= perforation involving all the quadrants of the tympanic membrane. No perforation limited to the postero-superior quadrant was found in the cohort.

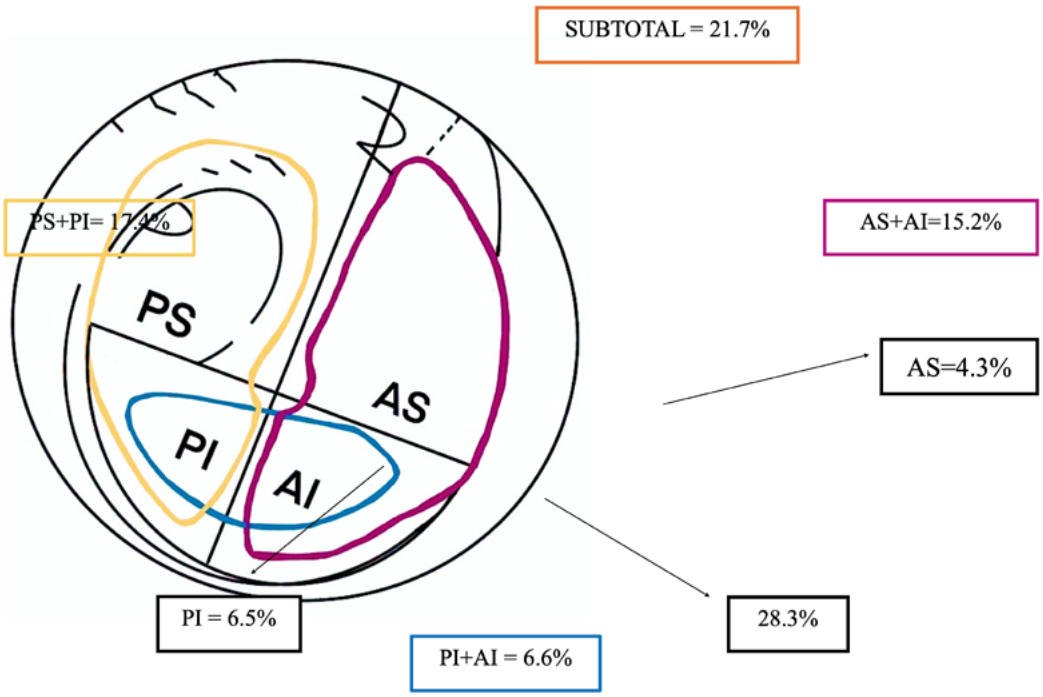


Table 1 – Comparison of audiological data before and after endoscopic type I tympanoplasty with composite cartilage-perichondrium graft

	Preoperative Mean ± SD	Postoperative Mean ± SD	Delta preoperative vs postoperative
PTA BC (dB)	8.67 ± 5.43	7.72 ± 3.76	0.98 ± 4
PTA AC (dB)	26.43 ± 10.2	17.91 ± 12.4	9 ± 9
ABG (dB)	18.0 ± 7.3	10.18 ± 9.6	8 ± 9

Discussion

This study evaluated the surgical and audiological outcomes of endoscopic TPL I using a standardized full-thickness perichondrium-cartilage graft in a pediatric cohort. Our results confirm that the endoscopic technique is both safe and effective, with anatomical and functional outcomes comparable to those reported in the existing literature.

The overall graft success rate of 89.1% aligns well with published pediatric series of endoscopic TPL I, where success rates generally range between 85% and 95% (Schwam et al., 2021; Lou, 2020; Maran et al., 2019; Foulon et al., 2022; Nocini et al., 2025). The reasons for surgical failure should be sought among the several factors that influence graft uptake in children, including frequent upper respiratory infections, the location and size of the perforation, the condition of the contralateral ear. Most surgeons delay surgery because of the frequent viral infections in children, and the possible effect of shorter and more horizontal Eustachian tube (Foulon et al., 2022). In our experience the age limit for considering surgery for a TM perforation is relatively early, at 5 years old.

Over-under reconstruction with full-thickness cartilage-perichondrium graft

The underlay technique, which is commonly used in the endoscopic approach, has been reported to carry a higher risk of graft failure, especially when treating marginal perforations, due to a lack of graft support (Sugimoto et al., 2024; Albazee et al., 2024). Although this may have contributed to our rate of persistent perforations — which occurred mostly in perforations involving the anterior quadrants — the use of a cartilage-perichondrium graft may have facilitated the healing of anterior perforations by providing a rigid and stable surface, less likely to become atrophic over time or to "fall down" compared to fascia or perichondrium alone. It has been recently reported that the endoscopic over-under technique, with umbo detachment, had no impact on the postoperative hearing results and did not increase rate of complications, in a mixed (pediatric and adult) cohort of 97 patients. Indeed, the over–under technique with elevation of the TM from the umbo showed significantly improved TM closure rates than the underlay technique: 94.4%, and 80.6%, respectively (Lotto et al., 2024).

In the endoscopic approach, the overlay technique is extremely demanding, as the one-hand dissection of the skin layer of the TM is challenging (Mahawerawat et al., 2022). It should also be borne in mind that the overlay reconstruction of the TM increases the risk of blunting and lateralization, outcomes that did not occur in any of our patients.

The choice of graft material also plays a crucial role in surgical success. A variety of grafts have been used to repair perforations, such as adipose tissue, perichondrium, cartilage, fascia temporalis or allograft materials. In the literature, these grafts have been associated with different outcomes, although direct comparisons are often limited by heterogeneity among patient cohorts; generally, the decision is based on surgeon preference (Bartel et al., 2019; Lou, 2020; Nassif et al., 2022; Sen & Özdamar, 2019). Traditionally, temporalis fascia has been the most widely used graft material due to its ease of harvest and good acoustic properties (Lajdam et al., 2023; Chen & Zhao, 2022). However, especially in the pediatric population, fascia grafts are associated with higher rates of reperforation and retraction over time, largely due to persistent Eustachian tube dysfunction and the increased mechanical stress on the reconstructed membrane. A few studies have directly compared graft types in the context of the endoscopic approach. According to Sen and Özdamar (2019), perichondrium and fascia grafts were both found acceptable for pediatric endoscopic TPL, with no statistically significant difference in anatomical success rates, though functional outcomes were better in the fascia group. Another study by Awad and Hamid (2015) on a large pediatric cohort showed that the use of partial thickness tragal cartilage resulted in successful anatomical and functional outcomes comparable to other techniques, but with a shorter operative duration. Age, auditory tube dysfunction, and previous adenotonsillectomy were not prognostic factors in their cohort, suggesting that the physical characteristics of cartilage may offer protective advantages against reperforation (Awad & Hamid, 2015).

Our study is the first to report the results from a large cohort of pediatric patients on the use of full-thickness cartilage and perichondrium graft, which likely contributed to the high anatomical success rate, even in the presence of challenging anatomical conditions, such as marginal and anterior perforations. In our experience, the use of such a composite graft offers distinct advantages, including greater structural stability, resistance to negative middle ear pressure, and reduced risk of long-term retraction or graft failure. Furthermore, concerns regarding the potential detrimental impact of cartilage on hearing outcomes were not corroborated in our cohort, where functional success was achieved in 87% of patients. This finding is in line with previous studies showing that cartilage grafts do not significantly impair sound conduction compared to fascia (Awad & Hamid, 2015; Bartel et al., 2019; Dursun et al., 2020). Moreover, it may suggest that time spent thinning the cartilage could be spared without significant impairment of hearing function (Sabaa et al., 2023; Reynders et al., 2025). Indeed, the improvement in mean AC thresholds and the reduction of the ABG observed in our cohort reinforce the efficacy of the procedure in restoring hearing function.

Advantages and limitations of the endoscopic approach in treating pediatric TM perforations

Our study supports previous findings that endoscopic tympanoplasty offers advantages in the pediatric population, where the narrow external auditory canal may limit visualization through the microscope. By providing a close-up and wide-angle view of the surgical field through the natural external auditory canal, the endoscopic approach obviates the need for postauricular incisions and canalplasty, reducing surgical time, and possibly promoting faster recovery. In our study a mean duration of 90.2 minutes was found, consistent with literature data. When evaluating the wide range of surgical time (32–169 minutes), it should be taken into account that most surgeries (approximately 74%) were performed by junior surgeons with less than five years of experience in EES. They may have required longer operative times to manage the technical challenges of one-handed surgery, including frequent lens fogging and difficulties in hemostasis control (Alicandri-Ciufelli et al., 2018; Alicandri-Ciufelli et al., 2020; Amorosa et al., 2021). Despite this, overall outcomes remained favorable, suggesting that the endoscopic technique, when applied within a standardized protocol, can be safely and effectively adopted even by less experienced operators. Nevertheless, the few cases of reperforation we observed were exclusively among patients operated on by junior surgeons, underlining the importance of the learning curve and the need for appropriate training and supervision.

Consistent with the minimally invasive nature of the endoscopic technique, hospital stays were limited to one night in most cases. Nassif et al. reported that in their pediatric endoscopic TPL I group, 77% of patients were discharged on postoperative day one, compared to only 13% in the microscopic TPL I group (Nassif et al., 2022).

Another important finding was the low rate of complications associated with the endoscopic procedure. In our cohort, neither intraoperative nor immediate postoperative complications were observed, in line with other reports of both endoscopic and microscopic pediatric tympanoplasty (Hardman et al., 2015; Marchioni et al., 2018).

Study limitations

Several limitations of our study must be acknowledged. The follow-up period was relatively short, with a mean duration of 8.5 months, which may have prevented the detection of late complications such as graft atrophy, delayed reperforation, or the development of retraction pockets. Another limitation is the lack of a control group operated on with different types of grafts. Nevertheless, our sample size is among the largest pediatric cohorts reported for endoscopic tympanoplasty using tragal cartilage selected according to strict inclusion and exclusion criteria. Future studies with longer follow-up and larger multi-institutional series are warranted to confirm the long-term stability of these outcomes.

Conclusion

Our results support that endoscopic TPL I is a feasible and safe surgery even in the pediatric population. The use of composite

full-thickness cartilage and perichondrium graft showed comparable success rates not only to microscopic approach, but also to other grafts utilized in other endoscopic cohorts, with the advantage of saving the time from cartilage thinning. Successful anatomical and functional outcomes were achievable even if the large majority of patients were operated on by junior EES surgeons. Future research with extended follow-up is warranted to fully assess the durability of the results over time.

Acknowledgement

None.

Conflicts of Interest

None of the authors have conflicts of interests to declare.

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