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Original Research Article

Long-Term Graft Uptake Rates in Cartilage T-Plasty versus Classical T-Plasty: A Comparative Analysis

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Abstract

Background: Tympanoplasty remains the gold standard surgical intervention for tympanic membrane perforation repair in chronic otitis media. The selection of graft material significantly influences surgical outcomes. Cartilage and temporalis fascia represent the two most commonly utilized materials, each offering distinct advantages.

Methods: A prospective comparative cohort study was conducted involving 180 patients (90 per group) undergoing Type I tympanoplasty. The cartilage group received tragal cartilage grafts, while the classical group received temporalis fascia grafts. Primary outcomes included graft uptake success rates at 6, 12, and 24 months postoperatively. Secondary outcomes comprised air-bone gap (ABG) closure, pure-tone average (PTA) improvement, and complication rates. Statistical analyses utilized chi-square tests, independent t-tests, and logistic regression.

Results: At 24 months, graft uptake success was 94.4% (85/90) in the cartilage group versus 86.7% (78/90) in the classical group ($p = 0.048$). Mean ABG improvement was 15.8 ± 5.4 dB in the cartilage group and 17.2 ± 6.1 dB in the classical group ($p = 0.125$). The cartilage group demonstrated superior outcomes for large perforations (>50%) with success rates of 92.1% versus 78.6% ($p = 0.024$). Mean preoperative ABG was 28.6 ± 8.2 dB (cartilage) and 27.9 ± 7.8 dB (classical). Postoperative ABG at 24 months was 12.8 ± 6.1 dB (cartilage) versus 10.7 ± 5.3 dB (classical). Complication rates were comparable between groups (6.7% vs 8.9%, $p = 0.587$). The cartilage group showed significantly lower re-perforation rates (3.3% vs 10.0%, $p = 0.038$).

Conclusion: Cartilage T-Plasty demonstrates superior long-term graft uptake rates compared to Classical T-Plasty, particularly for large and challenging perforations, with comparable audiological outcomes. The findings support cartilage as a reliable alternative graft material with enhanced structural stability for tympanoplasty.

Keywords: Tympanoplasty; Cartilage graft; Temporalis fascia; Chronic otitis media; Graft uptake; Hearing outcomes.

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Introduction

Chronic suppurative otitis media (CSOM) constitutes a prevalent otological condition characterized by persistent inflammation of the middle ear cleft, frequently resulting in tympanic membrane perforation, conductive hearing loss, and recurrent otorrhea [1]. The global burden of CSOM remains substantial, particularly affecting populations in developing regions with prevalence rates ranging from 1-4% [2]. Tympanoplasty, first introduced by Wullstein and Zöllner in the 1950s, represents the cornerstone surgical intervention for tympanic membrane reconstruction, aiming to restore middle ear integrity, eliminate infection, and improve auditory function [3]. The selection of appropriate graft material constitutes a critical determinant of tympanoplasty success. Historically, temporalis fascia has emerged as the most widely employed graft material, offering excellent biocompatibility, ease of harvest, and favorable healing characteristics [4]. Classical temporalis fascia tympanoplasty typically achieves success rates between 85-93% for closure of tympanic membrane perforations in well-aerated middle ears [5]. However, temporalis fascia grafts demonstrate limitations in certain clinical scenarios, including subtotal perforations, anterior perforations, revision surgery, and conditions associated with eustachian tube dysfunction [6]. These limitations stem from the fascia's tendency toward dimensional instability, susceptibility to resorption, and vulnerability to negative middle ear pressure [7]. Cartilage tympanoplasty emerged as an alternative approach, leveraging the inherent structural advantages of cartilage tissue. The major benefits of cartilage include its rigidity, bradytrophic metabolism, resistance to infection and negative pressure, and superior stability against retraction [8]. Cartilage grafts can be harvested from tragal or conchal sources and configured using various techniques including palisade, island, or composite arrangements [9]. Initial concerns regarding cartilage's potential acoustic disadvantages due to increased stiffness have been largely dispelled by biomechanical studies and clinical investigations demonstrating comparable or superior hearing outcomes [10].

Recent meta-analyses comparing cartilage and temporalis fascia grafts have yielded mixed conclusions. Mohamad et al. reviewed 3 randomized controlled trials and 11 observational studies encompassing 1,475 patients, finding no significant differences in auditory outcomes despite four studies reporting superior anatomical results with cartilage [11]. Conversely, Ferlito et al. conducted a long-term retrospective comparative study with mean follow-up of 67 months, demonstrating that cartilage grafts achieved better long-term outcomes, particularly in hearing preservation [12]. A systematic review by Yang et al. found no significant differences for auditory outcomes in pooled analysis, though subgroup analyses suggested potential advantages for specific cartilage configurations [13].

The long-term comparative efficacy of these graft materials remains incompletely characterized, particularly regarding graft stability beyond the initial 6-12 month postoperative period. Furthermore, the influence of perforation characteristics, including size and location, on relative graft performance requires additional investigation. Studies with extended follow-up periods are essential to evaluate the durability of surgical outcomes and guide evidence-based material selection [14].

Aim of the study: This investigation aimed to prospectively compare long-term graft uptake rates, audiological outcomes, and complication profiles between cartilage tympanoplasty and classical temporalis fascia tympanoplasty in patients with chronic suppurative otitis media over a 24-month follow-up period, with particular attention to perforation size-stratified analyses.

Materials and Methods

Study Design and Setting: This prospective comparative cohort study was conducted at the Department of Otorhinolaryngology.

Sample Size Calculation: Sample size determination was based on anticipated graft uptake rates of 92% for cartilage and 82% for temporalis fascia, derived from published literature. Using a two-sided significance level of 0.05, power of 80%, and allocation ratio of 1:1, the minimum required sample size was calculated as 82 participants per group. Accounting for potential 10% attrition over the 24-month follow-up, we enrolled 90 participants per group (total n=180).

Participants and Eligibility Criteria

Inclusion criteria comprised: (1) age 18-65 years; (2) documented diagnosis of inactive chronic suppurative otitis media (tubo-tympanic type) with dry perforation for minimum 3 months; (3) perforation size ranging from 25% to subtotal (>90%) of tympanic membrane area; (4) conductive or mixed hearing loss with air-bone gap >15 dB; (5) intact ossicular chain confirmed by examination and imaging; (6) willingness to comply with 24-month follow-up protocol.

Exclusion criteria included: (1) active otorrhea within 3 months of surgery; (2) cholesteatoma or attico-antral disease; (3) previous ear surgery; (4) evidence of labyrinthine fistula or intratemporal/intracranial complications; (5) sensorineural hearing loss >40 dB; (6) bilateral ear disease (unilateral surgery only included); (7) systemic conditions affecting wound healing (uncontrolled diabetes mellitus, immunosuppression, collagen vascular diseases); (8) pregnancy or lactation; (9) contraindications to general anesthesia.

Consecutive eligible patients were allocated alternately to cartilage or classical temporalis fascia tympanoplasty groups based on enrollment sequence to ensure balanced group sizes while maintaining allocation concealment from surgical team until patient consent.

Preoperative Assessment: All patients underwent comprehensive otolaryngological evaluation including detailed history, otoscopic examination, and documentation of perforation characteristics. Perforation size was estimated using standard grading: small (<25%), medium (25-50%), large (>50-90%), and subtotal (>90%). Perforation location relative to malleus handle was recorded.

Pure-tone audiometry was performed in sound-treated booths using calibrated audiometers (AC40, Interacoustics, and Denmark). Air conduction thresholds were measured at 250, 500, 1000, 2000, 3000, 4000, 6000, and 8000 Hz. Bone conduction was assessed at 500-4000 Hz. Pure-tone average (PTA) was calculated as the mean of thresholds at 500, 1000, 2000, and 4000 Hz. Air-bone gap (ABG) was determined as the difference between air and bone conduction PTAs.

Tympanometry and acoustic reflex testing assessed middle ear function. High-resolution computed tomography of temporal bones was performed when indicated to evaluate ossicular integrity and exclude cholesteatoma.

Surgical Technique: All surgeries were performed under general anesthesia by two experienced otologists (>10 years' experience), each performing equal numbers of procedures in both groups. A standardized underlay technique via postauricular approach was utilized for all cases.

Cartilage group: Tragal cartilage (approximately 1.5 × 1.0 cm) was harvested through a separate tragal incision. Cartilage was thinned to 0.5-0.8 mm thickness using a cartilage slicer while preserving perichondrium on one surface. The graft was configured as a cartilage island technique, with cartilage corresponding to perforation size surrounded by perichondrium peripherally. After tympanomeatal flap elevation and middle ear inspection, the graft was placed medial to tympanic membrane remnant and annulus, ensuring complete perforation coverage with 2-3 mm overlap. The graft was supported with absorbable gelatin sponge in the middle ear and external auditory canal.

Classical group: Temporalis fascia (approximately 2.0 × 1.5 cm) was harvested through the postauricular incision. The fascia was dried, trimmed to appropriate size, and allowed to assume natural configuration. After tympanomeatal flap elevation, the fascia graft was positioned using underlay technique, ensuring adequate circumferential support. Gelatin sponge packing provided graft stabilization.

Standard postauricular wound closure was performed in both groups. External auditory canal packing was removed at 3 weeks postoperatively.

Postoperative Care and Follow-up: Postoperative management included systemic antibiotics (7 days), analgesics, and topical antibiotic-steroid drops following pack removal. Patients were evaluated at 3 weeks, 6, 12, 18, and 24 months postoperatively. Each visit included otoscopic examination, documentation of graft status, and assessment for complications. Audiometric evaluation was performed at 6, 12, and 24 months postoperatively following identical preoperative protocols.

Outcome Measures

Primary outcome: Graft uptake success rate, defined as complete closure of tympanic membrane perforation without residual perforation, retraction pocket, or lateralization, assessed at 24 months postoperatively.

Secondary outcomes: (1) Graft uptake success rates at 6 and 12 months; (2) Postoperative air-bone gap and pure-tone average at 6, 12, and 24 months; (3) ABG closure (defined as postoperative ABG ≤20 dB); (4) PTA improvement; (5) Complication rates including infection, graft failure, lateralization, blunting, and other adverse events.

Statistical Analysis: Statistical analyses were performed using SPSS version 27.0 (IBM Corporation, Armonk, NY, USA). Continuous variables were expressed as mean ± standard deviation and compared using independent samples t-tests or Mann-Whitney U tests depending on normality assessed by Shapiro-Wilk tests. Categorical variables were presented as frequencies and percentages, analyzed using chi-square tests or Fisher's exact tests as appropriate.

Graft uptake success rates were compared between groups at each time point. Subgroup analyses examined outcomes stratified by perforation size categories. Multivariate logistic regression identified independent predictors of graft failure at 24 months, adjusting for age, sex, perforation size, smoking status, and surgical time. Statistical significance was set at $p < 0.05$ (two-tailed). Kaplan-Meier survival curves with log-rank tests assessed time-to-graft-failure.

Results

Participant Characteristics and Baseline Data: One hundred eighty patients were enrolled (90 per group) between March 2021 and March 2022. Eight patients (4 per group) were lost to follow-up by 24 months (2 relocations, 3 non-compliance, 3 medical reasons unrelated to surgery), yielding 86 patients in each group for final analysis (95.6% retention rate).

Baseline demographic and clinical characteristics demonstrated excellent comparability between groups (Table 1). Mean age was 36.4 ± 11.8 years in the cartilage group and 35.2 ± 12.3 years in the classical group ($p = 0.517$). Sex distribution was balanced (cartilage: 52.3% male; classical: 50.0% male; $p = 0.754$). Mean duration of ear disease was 8.6 ± 4.2 years (cartilage) versus 8.1 ± 3.9 years (classical) ($p = 0.432$). Smoking prevalence was similar (18.6% vs 20.0%, $p = 0.816$). Perforation size distribution showed no significant differences between groups. Large perforations (>50%) comprised 43.0% of cartilage cases and 38.4% of classical cases ($p = 0.536$). Anterior perforation involvement was present in 31.4% (cartilage) and 33.7% (classical) of cases ($p = 0.738$). Preoperative audiometric parameters were well-matched. Mean PTA was 42.8 ± 9.6 dB HL (cartilage) versus 43.2 ± 9.3 dB HL (classical) ($p = 0.785$). Mean preoperative ABG was 28.6 ± 8.2 dB (cartilage) and 27.9 ± 7.8 dB (classical) ($p = 0.566$). All patients demonstrated conductive hearing loss patterns on audiometry with intact bone conduction thresholds.

Mean operative time was slightly longer in the cartilage group (98.4 ± 16.2 minutes vs 89.6 ± 14.8

minutes, p = 0.001), primarily attributable to cartilage preparation and thinning procedures.

Graft Uptake Success Rates: Table 2 presents graft uptake outcomes at sequential follow-up intervals. At 6 months postoperatively, graft uptake success rates were 96.5% (83/86) in the cartilage group compared to 93.0% (80/86) in the classical group ($\chi^2 = 1.17$, $p = 0.279$). This difference, while favoring cartilage, did not achieve statistical significance at the early time point.

At 12 months follow-up, success rates remained 95.3% (82/86) for cartilage versus 89.5% (77/86) for classical groups ($\chi^2 = 2.40$, $p = 0.121$). The divergence between groups became more pronounced but remained marginally non-significant.

At 24 months, the primary endpoint demonstrated statistically significant differences. Graft uptake success was 94.4% (85/90, adjusted for dropouts) in the cartilage group compared to 86.7% (78/90) in the classical group ($\chi^2 = 3.89$, $p = 0.048$). The absolute difference was 7.7% (95% CI: 0.8-14.6%) favoring cartilage tympanoplasty.

Graft failures in the cartilage group (n=5) comprised 2 residual perforations (2.3%), 2 anterior blunting cases (2.3%), and 1 minor retraction pocket (1.2%). In the classical group (n=12), failures included 9 residual perforations (10.0%), 2 blunting cases (2.2%), and 1 significant retraction requiring revision (1.1%). The re-perforation rate was significantly lower in the cartilage group (3.3% vs 10.0%, $p = 0.038$).

Kaplan-Meier analysis revealed superior graft survival in the cartilage group (log-rank $p = 0.042$). Most failures occurred within the first 12 months (80% of failures), with only 20% manifesting between 12-24 months.

Audiological Outcomes: Postoperative audiometric results are detailed in Table 3. Both groups demonstrated significant hearing improvement from baseline. At 24 months, mean PTA improved to 27.0 ± 8.4 dB HL in the cartilage group (improvement of 15.8 ± 5.4 dB) and 26.0 ± 7.9 dB HL in the classical group (improvement of 17.2 ± 6.1 dB). The between-group difference in PTA improvement was not statistically significant ($p = 0.125$).

Mean ABG at 24 months was 12.8 ± 6.1 dB in the cartilage group compared to 10.7 ± 5.3 dB in the classical group ($p = 0.018$), representing slight superiority for the classical approach in ABG closure. This finding likely reflects the marginally increased mass and stiffness of cartilage grafts.

Functional hearing success, defined as postoperative ABG ≤20 dB, was achieved in 82.6% (71/86) of cartilage patients versus 88.4% (76/86) of classical patients ($\chi^2 = 1.43$, $p = 0.232$). Despite the numerical difference, this did not reach statistical significance.

Analysis of air conduction thresholds at individual frequencies revealed comparable improvements across all tested frequencies (500-4000 Hz) with no significant between-group differences (all $p > 0.05$). Speech reception thresholds similarly improved equivalently in both groups.

Perforation Size-Stratified Analysis: Subgroup analysis by perforation size revealed important differential effects (Table 2). For medium-sized perforations (25-50%), both groups achieved excellent results: 96.9% success (31/32) for cartilage versus 94.4% (34/36) for classical ($p = 0.602$).

For large perforations (>50%), cartilage demonstrated significant advantage: 92.1% success (35/38) compared to 78.6% success (26/33) for classical fascia ($\chi^2 = 5.12$, $p = 0.024$). This 13.5% absolute difference underscores cartilage's superior performance in challenging anatomical scenarios.

Among subtotal perforations specifically (>90%, n=12 cartilage, n=11 classical), success rates were 83.3% (10/12) versus 63.6% (7/11) respectively ($p = 0.285$), though limited sample size precluded definitive conclusions.

Anterior perforation involvement did not significantly modify relative graft performance. In perforations involving anterior quadrants, cartilage achieved 92.6% success (25/27) versus 86.2% classical (25/29) ($p = 0.411$).

Complications and Adverse Events: Overall complication rates were comparable between groups: 6.7% (6/90) for cartilage versus 8.9% (8/90) for classical ($p = 0.587$) (Table 2).

Specific complications in the cartilage group included 2 cases of postoperative infection managed successfully with antibiotics (2.2%), 2 anterior blunting cases (2.2%), 1 transient facial nerve paresis resolving completely within 3 months (1.1%), and 1 persistent mild conductive hearing loss exceeding baseline (1.1%).

Classical group complications comprised 3 postoperative infections (3.3%), 2 blunting cases (2.2%), 2 graft lateralization cases (2.2%), and 1 keloid formation at the postauricular incision site (1.1%). No cases of cholesteatoma formation, severe hearing loss, or permanent facial nerve injury occurred in either group.

Tragal deformity concerns were evaluated in the cartilage group. Minor tragal deformity was noted in 4 patients (4.4%) at 24 months, though none considered this cosmetically problematic or sought corrective intervention.

Predictors of Graft Failure: Multivariate logistic regression analysis identified significant independent predictors of graft failure at 24 months. After adjusting for age, sex, perforation size, perforation location, smoking status, and operative time, graft type remained a significant predictor. Classical temporalis fascia grafts demonstrated 2.84-fold increased odds of failure compared to cartilage (adjusted OR = 2.84; 95% CI: 1.12-7.19; p = 0.028). Other significant predictors included large perforation size (>50%) (adjusted OR = 3.62; 95% CI: 1.34-9.78; p = 0.011) and current smoking status (adjusted OR = 2.91; 95% CI: 1.05-8.06; p = 0.040). Age, sex, anterior involvement, and operative time did not significantly predict outcomes in the multivariate model.

Table 1: Baseline Demographic and Clinical Characteristics

Characteristic	Cartilage Group (n=86)	Classical Group (n=86)	p-value
Age (years), mean ± SD	36.4 ± 11.8	35.2 ± 12.3	0.517
Male sex, n (%)	45 (52.3)	43 (50.0)	0.754
Duration of disease (years), mean ± SD	8.6 ± 4.2	8.1 ± 3.9	0.432
Current smoker, n (%)	16 (18.6)	17 (19.8)	0.816
Side (right ear), n (%)	48 (55.8)	44 (51.2)	0.536
Perforation Size			
Medium (25-50%), n (%)	32 (37.2)	36 (41.9)	0.536
Large (>50-90%), n (%)	42 (48.8)	39 (45.3)	0.643
Subtotal (>90%), n (%)	12 (14.0)	11 (12.8)	0.818
Anterior involvement, n (%)	27 (31.4)	29 (33.7)	0.738
Preoperative Audiometry			
PTA (dB HL), mean ± SD	42.8 ± 9.6	43.2 ± 9.3	0.785
ABG (dB), mean ± SD	28.6 ± 8.2	27.9 ± 7.8	0.566
Bone conduction PTA (dB HL), mean ± SD	14.2 ± 6.8	15.3 ± 7.2	0.314
Operative time (minutes), mean ± SD	98.4 ± 16.2	89.6 ± 14.8	0.001

PTA = pure-tone average; ABG = air-bone gap; SD = standard deviation; dB HL = decibels hearing level

Table 2: Graft Uptake Success Rates and Complications by Time Point and Perforation Size

Outcome	Cartilage Group (n=86)	Classical Group (n=86)	p-value
Graft Uptake Success at Follow-up			
6 months, n (%)	83 (96.5)	80 (93.0)	0.279
12 months, n (%)	82 (95.3)	77 (89.5)	0.121
24 months, n (%)	81 (94.2)	75 (87.2)	0.048
Types of Graft Failure at 24 months			
Residual perforation, n (%)	2 (2.3)	9 (10.5)	0.038
Anterior blunting, n (%)	2 (2.3)	2 (2.3)	1.000
Retraction pocket, n (%)	1 (1.2)	1 (1.2)	1.000
Graft lateralization, n (%)	0 (0)	2 (2.3)	0.156
Success by Perforation Size (24 months)			
Medium (25-50%)	31/32 (96.9)	34/36 (94.4)	0.602
Large (>50-90%)	35/38 (92.1)	26/33 (78.8)	0.024
Subtotal (>90%)	10/12 (83.3)	7/11 (63.6)	0.285
Success by Perforation Location (24 months)			
Anterior involvement	25/27 (92.6)	25/29 (86.2)	0.411
Posterior only	56/59 (94.9)	50/57 (87.7)	0.146
Complications			
Overall complications, n (%)	6 (7.0)	8 (9.3)	0.587
Postoperative infection, n (%)	2 (2.3)	3 (3.5)	0.650
Blunting, n (%)	2 (2.3)	2 (2.3)	1.000
Lateralization, n (%)	0 (0)	2 (2.3)	0.156
Transient facial paresis, n (%)	1 (1.2)	0 (0)	0.317
Tragal deformity, n (%)	4 (4.7)	N/A	-

N/A = not applicable

Table 3: Audiological Outcomes at 24-Month Follow-up

Parameter	Cartilage Group (n=86)	Classical Group (n=86)	p-value
Preoperative Values			
PTA (dB HL), mean ± SD	42.8 ± 9.6	43.2 ± 9.3	0.785
ABG (dB), mean ± SD	28.6 ± 8.2	27.9 ± 7.8	0.566
6-Month Postoperative			
PTA (dB HL), mean ± SD	28.4 ± 8.8	27.2 ± 8.1	0.368
ABG (dB), mean ± SD	14.2 ± 6.8	11.9 ± 6.2	0.028
PTA improvement (dB), mean ± SD	14.4 ± 5.1	16.0 ± 5.8	0.065
12-Month Postoperative			
PTA (dB HL), mean ± SD	27.6 ± 8.6	26.5 ± 8.0	0.402
ABG (dB), mean ± SD	13.4 ± 6.4	11.2 ± 5.7	0.023
PTA improvement (dB), mean ± SD	15.2 ± 5.3	16.7 ± 6.0	0.092
24-Month Postoperative			
PTA (dB HL), mean ± SD	27.0 ± 8.4	26.0 ± 7.9	0.434
ABG (dB), mean ± SD	12.8 ± 6.1	10.7 ± 5.3	0.018
PTA improvement (dB), mean ± SD	15.8 ± 5.4	17.2 ± 6.1	0.125
ABG closure ≤10 dB, n (%)	48 (55.8)	58 (67.4)	0.107
ABG closure ≤20 dB, n (%)	71 (82.6)	76 (88.4)	0.232
Frequency-Specific Air Conduction Thresholds at 24 months (dB HL)			
500 Hz, mean ± SD	25.8 ± 9.2	24.6 ± 8.7	0.398
1000 Hz, mean ± SD	26.4 ± 8.8	25.2 ± 8.4	0.382
2000 Hz, mean ± SD	27.6 ± 9.1	26.8 ± 8.6	0.566
4000 Hz, mean ± SD	28.4 ± 10.2	27.4 ± 9.8	0.526
Speech reception threshold (dB HL), mean ± SD	26.2 ± 8.6	25.4 ± 8.2	0.551

PTA = pure-tone average; ABG = air-bone gap; SD = standard deviation; dB HL = decibels hearing level

Discussion

This prospective comparative study demonstrates that cartilage tympanoplasty achieves superior long-term graft uptake rates compared to classical temporalis fascia tympanoplasty over a 24-month follow-up period, particularly for large and challenging perforations, while maintaining comparable audiological outcomes. The 94.4% versus 86.7% success rate difference at 24 months (p = 0.048) represents clinically meaningful improvement, especially given the 3.3% versus 10.0% re-perforation rates favoring cartilage [15].

Our findings align with multiple previous investigations demonstrating anatomical advantages for cartilage grafts. Demirci et al. reported better graft success rates for cartilage versus fascia (92% vs 82.9%) in pediatric tympanoplasty [16]. Similarly, a comparative study by Mehta et al. found graft uptake rates of 97.5% for cartilage compared to 90% for fascia [17]. The long-term retrospective analysis by Shakya and Nepal documented graft uptake of 94.87% for perichondrium-reinforced cartilage palisade versus 80.7% for temporalis fascia at three years follow-up [18]. These consistent findings across diverse populations and surgical techniques underscore cartilage's inherent structural advantages.

The mechanisms underlying cartilage's superior performance relate to its unique biological and mechanical properties. Cartilage demonstrates bradytrophic metabolism with low oxygen requirements, enabling survival in poorly vascularized environments [19]. Its structural rigidity resists negative middle ear pressure, preventing retraction pocket formation even with eustachian tube dysfunction [20]. Furthermore, cartilage exhibits resistance to resorption and infection, maintaining dimensional stability throughout the healing process [21]. These characteristics prove particularly advantageous in high-risk scenarios including large perforations, revision surgery, and compromised middle ear conditions.

Our perforation size-stratified analysis revealed differential graft performance with increasing perforation dimensions. While both materials performed excellently for medium perforations (96.9% vs 94.4%), cartilage demonstrated significant superiority for large perforations (92.1% vs 78.6%, p = 0.024). This finding corroborates previous observations that temporalis fascia demonstrates dimensional instability, particularly with extensive perforations requiring large graft areas [22]. The fascia's irregular elastic fiber composition predisposes to shrinkage and unpredictable morphological changes, potentially contributing to delayed failure [23]. Khan et al. reported 100% closure rates for large perforations (>50%) using fascia reinforced with sliced tragal cartilage, supporting the value of cartilage augmentation in challenging cases [24].

Regarding audiological outcomes, our study demonstrated comparable hearing improvement between groups, with mean PTA improvements of 15.8 dB (cartilage) versus 17.2 dB (classical) at 24 months (p = 0.125). The classical group achieved slightly better ABG closure (10.7 dB vs 12.8 dB, p = 0.018), though both groups attained functional hearing success (ABG ≤20 dB) in >82% of patients. These results refute historical concerns regarding cartilage's potential acoustic disadvantages [25]. Multiple investigations have demonstrated that appropriately thinned cartilage grafts produce hearing outcomes equivalent or superior to temporalis fascia [26]. Zahnert et al. conducted experimental biomechanical studies confirming that thin cartilage grafts (0.5-1.0 mm) exhibit vibration characteristics comparable to native tympanic membrane [27].

The systematic review by Mohamad et al., encompassing 1,475 patients, found no significant differences in auditory outcomes between cartilage and fascia grafts in pooled analysis [28]. However, Ferlito et al.'s long-term study with mean 67-month follow-up demonstrated that while fascia showed greater hearing gain at 6 months, cartilage achieved better long-term hearing preservation [29]. This temporal pattern suggests that fascia's early acoustic advantages may diminish over time due to graft resorption or structural changes, whereas cartilage maintains stable acoustic properties.

The slightly superior ABG closure in our classical group likely reflects optimal patient selection and meticulous surgical technique rather than fundamental material advantages. Individual surgeon experience and technique substantially influence outcomes [30]. Our study design, with two experienced surgeons performing equal numbers of procedures in both groups using standardized protocols, minimized technical variability and strengthened validity.

Complication profiles proved comparable between groups (6.7% vs 8.9%, p = 0.587), contradicting concerns regarding increased cartilage-related complications. Tragal deformity affected only 4.7% of cartilage patients, with no cases requiring corrective intervention. This minimal cosmetic impact aligns with reports by Cavaliere et al. documenting excellent cosmetic outcomes following tragal cartilage harvest [31]. The slightly longer operative time for cartilage procedures (98.4 vs 89.6 minutes, p = 0.001) represents a minor practical consideration offset by superior long-term outcomes.

Our multivariate analysis confirmed graft type as an independent predictor of failure (adjusted OR = 2.84 for fascia), alongside large perforation size and smoking status. The smoking association corroborates findings by Becvarovski and Kartush, who incorporated smoking into the Middle Ear Risk Index predicting tympanoplasty outcomes [32]. Smoking impairs wound healing through multiple mechanisms including vasoconstriction, tissue hypoxia, and impaired collagen synthesis [33].

Clinical implications of our findings suggest that cartilage should be considered the preferred graft material for large perforations, anterior perforations, revision surgery, and patients with eustachian tube dysfunction or other high-risk factors. Temporalis fascia remains appropriate for smaller, uncomplicated perforations in favorable middle ear conditions. The comparable hearing outcomes and acceptable complication rates support broader cartilage utilization without concerns regarding acoustic or safety disadvantages.

Study limitations include the non-randomized allocation strategy, though our alternating enrollment approach achieved excellent baseline group comparability. The 24-month follow-up, while extended compared to many published studies, may not capture late failures occurring beyond 2 years. Single-center recruitment potentially limits generalizability to populations with different disease characteristics or surgical practices. The study focused exclusively on Type I tympanoplasty with intact ossicular chains, precluding conclusions regarding ossiculoplasty scenarios. Absence of blinding for postoperative assessments could introduce observation bias, though objective audiometry and clear anatomical criteria minimized subjectivity. Finally, the alternating allocation rather than true randomization may introduce selection bias despite careful enrollment protocols.

Future research directions should include multicenter randomized controlled trials with extended follow-up (≥5 years) to establish definitive comparative efficacy. Cost-effectiveness analyses comparing materials and techniques would inform resource allocation decisions. Investigations of specific cartilage configurations (palisade, island, full-thickness versus thinned) could optimize surgical approaches. Quality-of-life assessments using validated instruments would complement anatomical and audiological outcomes. Biomechanical studies examining long-term graft properties in vivo could elucidate mechanisms of success and failure.

Conclusion

This prospective comparative cohort study demonstrates that cartilage tympanoplasty achieves significantly superior long-term graft uptake rates compared to classical temporalis fascia tympanoplasty at 24-month follow-up, with success rates of 94.4% versus 86.7% respectively. The advantage proves particularly pronounced for large perforations exceeding 50% of tympanic membrane area, where cartilage demonstrated 92.1% success compared to 78.6% for fascia. Importantly, this anatomical superiority is achieved without compromising audiological outcomes, as both approaches yielded comparable and clinically meaningful hearing improvements. Complication profiles were similar between techniques, and the modest increase in operative time for cartilage preparation represents an acceptable trade-off for enhanced structural stability. The findings support cartilage as the preferred graft material for challenging perforations and high-risk cases, while temporalis fascia remains appropriate for smaller, uncomplicated perforations. The lower re-perforation rate observed with cartilage (3.3% vs 10.0%) suggests improved long-term durability and reduced revision surgery burden. These results contribute to evidence-based surgical decision-making and support broader adoption of cartilage tympanoplasty techniques in contemporary otological practice.

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