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Cartilage versus Temporalis Fascia in Type 1 Tympanoplasty: A Systematic Review and Meta-Analysis of Anatomical and Hearing Outcomes

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Abstract

Background.

Whether cartilage or temporalis fascia is the superior graft material for type 1 tympanoplasty remains debated. Recent comparative studies have not been systematically synthesised, and no prior meta-analysis has formally tested for subgroup differences by age or perforation risk.

Methods.

PRISMA 2020-compliant systematic review and random-effects meta-analysis (PROSPERO CRD420261382008) of PubMed, MEDLINE, Scopus, and ScienceDirect from January 2005 to March 2026, comparing cartilage versus temporalis fascia in primary type 1 tympanoplasty. Two reviewers independently screened, extracted, and assessed risk of bias (Cochrane RoB 2 for RCTs; Newcastle-Ottawa Scale for non-randomised studies). The primary outcome was anatomical graft success; secondary outcomes were postoperative air-bone gap (ABG) and within-arm ABG improvement. Pre-specified subgroup analyses by age (pediatric vs adult) and perforation risk (low- vs high-risk ear) were formally tested between groups; certainty was assessed using GRADE.

Results.

Thirty studies (2,392 ears; 9 RCTs, 21 non-randomised cohorts) contributed to the primary analysis. Cartilage achieved a higher graft success rate than temporalis fascia (pooled RR 1.10, 95% CI 1.07–1.14; $p < 0.0001$; $I^2=35\%$), confirmed at ≥ 12-month follow-up (RR 1.13, 95% CI 1.05–1.22; $p = 0.001$). The advantage was numerically largest in pediatric patients (RR 1.18, $I^2=0\%$) and low-risk ears (RR 1.13, $I^2=0\%$), but formal between-subgroup tests were non-significant (population $p = 0.119$; risk $p = 0.787$). Postoperative ABG did not differ (MD − 0.48 dB, 95% CI − 1.78 to 0.82; $p = 0.469$; $I^2=88\%$), nor did ABG improvement (MD 0.35 dB; $p = 0.731$; $I^2=93\%$). Egger's test indicated small-study effects on the primary outcome ($p < 0.0001$). GRADE certainty was Low for graft success and Very Low for both audiometric outcomes.

Conclusions.

Cartilage grafting confers a small but consistent advantage in anatomical graft success over temporalis fascia in type 1 tympanoplasty, with no penalty in audiometric outcomes — most reliably in pediatric patients and uncomplicated perforations. Certainty ranges from Low to Very Low, reflecting small-study effects and inter-study heterogeneity; standardised outcome definitions are needed for future synthesis.

Introduction

Tympanoplasty is performed to reconstruct a perforated tympanic membrane, most commonly a sequela of chronic otitis media, with the dual aims of preventing recurrent infection and restoring conductive hearing. Many graft materials have been used since the procedure was first described, including fat, temporalis fascia, perichondrium, vein, dura mater, and cartilage.[1]

Temporalis fascia has historically been the most commonly used material, with reported tympanic-membrane closure rates of 93–97%.[2] Despite this, its elastic and fibrous composition predisposes to shrinkage and atrophy over time and to relatively high failure rates in subtotal perforations, wet ears, and other unfavourable conditions.[3] Cartilage grafts, typically harvested from the tragus or concha, offer greater mechanical stability and rigidity, with reported advantages in revision surgery and in challenging clinical scenarios such as total or subtotal perforation, atelectatic middle ear, Eustachian-tube dysfunction, and bilateral disease.[1,4] Concerns persist, however, that their greater stiffness and thickness might compromise audiometric performance compared with the more compliant fascia.

Prior systematic reviews and meta-analyses have addressed this comparison, but the most recent comprehensive syntheses pre-date the substantial body of comparative studies — including randomised trials and endoscopic-era series — published between 2020 and 2026. Existing reviews have also paid limited attention to whether the cartilage advantage is modified by patient age (pediatric vs adult) or by perforation risk profile (low- vs high-risk ear), and none has formally tested for between-subgroup differences. The present review compares anatomical graft success and hearing outcomes between cartilage and temporalis fascia in primary type 1 tympanoplasty, with prospective subgroup analyses by age and perforation risk profile and formal between-group testing.

Methods

Protocol and guidelines

This systematic review and meta-analysis was conducted and reported in accordance with the PRISMA 2020 statement and prospectively registered with PROSPERO (CRD420261382008).

Eligibility criteria

Studies were eligible if they (i) enrolled human patients of any age with a tympanic-membrane perforation due to chronic otitis media and an intact, mobile ossicular chain; (ii) compared a cartilage graft (any form — tragal, conchal, palisade, island, full- or partial-thickness, or chondro-perichondrial composite) with a temporalis-fascia graft in primary type 1 tympanoplasty; (iii) reported extractable comparative data for at least one pre-specified outcome; and (iv) were published in English between 1 January 2005 and 31 March 2026. Eligible designs were randomised controlled trials (RCTs) and prospective or retrospective comparative cohort, case-control, or other directly comparative observational studies.

We excluded non-comparative single-arm studies, animal or cadaveric work, case series with fewer than 10 participants, narrative or systematic reviews, conference abstracts without full text, revision tympanoplasty, cholesteatoma, ossiculoplasty (types 2–4), mixed cartilage-and-fascia graft techniques, and studies with a non-fascia comparator.

Outcomes

The primary outcome was anatomical graft success, defined as an intact, well-healed tympanic membrane without re-perforation, using each study's longest reported follow-up. Secondary outcomes were postoperative air-bone gap (ABG, in decibels) and within-arm change in ABG (pre minus post).

Search strategy

PubMed, MEDLINE, Scopus, and ScienceDirect were searched for studies published between 1 January 2005 and 31 March 2026, combining controlled vocabulary (MeSH) and free-text terms relating to tympanoplasty, myringoplasty, cartilage graft, temporalis fascia, hearing outcomes, graft success, and air-bone gap with Boolean operators. Reference lists of included articles and of relevant prior reviews were hand-searched. Scopus was added to the three databases pre-specified in the protocol (PubMed, MEDLINE, ScienceDirect) to broaden European otolaryngology coverage; this minor protocol deviation is noted here for transparency. The full search strategy is provided in the Supplementary Material.

Study selection, Extraction, Risk of bias assessment

Two reviewers independently screened titles, abstracts, and full texts, and independently extracted study identifiers, design, sample sizes, population and perforation characteristics, cartilage technique, surgical approach, follow-up, outcome definitions, and outcome data using a standardised form. Disagreements at any stage were resolved by discussion, with a third reviewer adjudicating if necessary. To verify accuracy, 10 of the 31 originally screened studies (32%) were independently re-extracted from source PDFs; numerical outcome data matched in all verified studies, but two classification corrections resulted: Jain et al. (2018) was reclassified from a prospective comparative cohort to an RCT and from low- to high-risk ear, and Khare et al. (2026) was excluded for a mixed cartilage-under-fascia technique violating the protocol.

Risk of bias was assessed independently by two reviewers using the Cochrane Risk of Bias 2 (RoB 2) tool for RCTs (five domains; overall rating low, some concerns, or high) and the Newcastle-Ottawa Scale (NOS) for non-randomised comparative studies (≥ 7 stars = high quality, 4–6 = fair, < 4 = poor). Selective outcome reporting was evaluated at the study level. At the meta-analytic level, small-study effects on the primary outcome were assessed by funnel-plot inspection and Egger's linear-regression test, provided that at least 10 studies contributed.

Certainty of evidence (GRADE)

Overall certainty for each pre-specified outcome was assessed using the GRADE framework, with downgrading considered for risk of bias, inconsistency, indirectness, imprecision, and publication bias.

Statistical analysis

All analyses were performed in R version 4.6.0 with the meta (v8.3-0) and metafor packages, using random-effects DerSimonian-Laird models with inverse-variance weighting. For graft success, pooled risk ratios (RR) with 95% confidence intervals were calculated (continuity correction of 0.5 for zero cells); for the continuous secondary outcomes, pooled mean differences (MD) in decibels were calculated. For the ABG-improvement analysis, the within-subject pre-post correlation was not reported in any included study; following Cochrane Handbook guidance we assumed r = 0.5, with sensitivity analyses at r = 0.4 and r = 0.6. Heterogeneity was quantified using Cochran's Q, τ^2, and I^2 (I^2 values of approximately 25%, 50%, and 75% taken as low, moderate, and high). Two pre-specified subgroup analyses on the primary outcome — by patient age (pediatric vs adult) and by perforation risk profile (low- vs high-risk ear, defined a priori) — were formally tested using the random-effects between-group Q test. Sensitivity analyses included restriction to studies with follow-up ≥ 12 months and a leave-one-out analysis. A two-sided p-value of < 0.05 was considered significant.

Low-risk ear was defined a priori as a dry ear with a small-to-moderate perforation and no major associated middle-ear pathology.

High-risk ear was defined as any of: subtotal or total perforation; wet ear or active mucopurulent discharge at the time of surgery; sclerotic mastoid or poor mastoid pneumatisation; or documented Eustachian-tube dysfunction.

Results

Study selection

The PRISMA flow is summarised in Table 1. After de-duplication across PubMed, MEDLINE, Scopus, and ScienceDirect, 48 unique comparative studies were identified; 30 (2,392 ears: 1,172 cartilage, 1,220 fascia; 2,117 grafts intact at final follow-up) contributed to the primary graft-success analysis. Twenty-six studies (2,362 ears) reported postoperative ABG in both arms and 23 reported complete pre- and post-operative ABG. The remaining 18 records were excluded for non-extractable comparative data, mixed cartilage subgroups without recoverable per-arm denominators, inaccessible full text, transcription-error pre/post values, or — following the data-extraction spot-check — protocol-eligibility violation. Per-outcome inclusion is summarised in Table 2.

Table 1. *PRISMA 2020 flow diagram (summary form). The published manuscript should include a graphical PRISMA flow diagram in addition to this table.*

PRISMA stage	Number of records
Records identified through database searching	PubMed = 18; MEDLINE = 12; Scopus = 9; ScienceDirect = 9 (total = 48 after de-duplication by DOI)
Records identified through other sources (reference list / citation tracking)	0
Records after duplicates removed	48 unique records
Records screened (title/abstract)	48
Records excluded at title/abstract	0 (all 48 passed to full-text review)
Full-text articles assessed for eligibility	48
Full-text articles excluded (with reasons)	18 — non-extractable data, mixed cartilage subgroups, inaccessible full text, transcription-error pre-post values, or (following data-extraction spot-check) one study using a mixed cartilage-under-fascia graft technique
Studies included in qualitative synthesis	30
Studies included in primary quantitative synthesis (graft success)	30 (2,392 ears)
Studies in postoperative ABG analysis	26 (2,362 ears)
Studies in ABG-improvement analysis	23

Table 2. *Summary of study selection for each planned outcome.*

Outcome	Studies (k)	Reasons / notes
Total unique records identified	48	Across PubMed, MEDLINE, Scopus, and ScienceDirect, after de-duplication by DOI.
Eligible for graft-success meta-analysis	30	Reported event counts and group sample sizes for both arms (2,392 ears; 2,117 successful grafts).
Eligible for postoperative ABG meta-analysis	26	Reported postoperative ABG mean and SD for both arms (2,362 ears).
Eligible for ABG-improvement meta-analysis	23	Reported pre- and post-operative ABG mean and SD for both arms (within-subject correlation r = 0.5 assumed).
Excluded from any quantitative analysis	18	No extractable comparative outcome data, mixed cartilage subgroups without recoverable denominators, full text inaccessible, inconsistent/duplicated pre-post values suggesting transcription error, or (following the data-extraction spot-check) protocol-eligibility violation (one study using a mixed cartilage-under-fascia graft technique that violated the protocol exclusion criterion for mixed-technique grafts).

Study characteristics

The 30 included studies were published between 2007 and 2025 and comprised 9 RCTs and 21 non-randomised comparative cohorts. Sample sizes ranged from 35 to 390 patients per study and reported follow-up from 3 months to 5 years (median ≈ 12 months). Cartilage techniques included tragal, conchal, palisade, island, full-thickness, partial-thickness, and chondroperichondrial composite grafts; the comparator was a temporalis-fascia graft in every study. Study-level characteristics are listed in Appendix Table A1.

Risk of bias of included studies

Of the 9 RCTs, 2 (22%) were rated at high overall risk on RoB 2 and 7 (78%) at some concerns; none were at low risk. Recurring sources of concern were inadequately described randomisation (Domain 1), the structural inability to blind the operator in surgical trials (Domain 2; all 9 trials), unblinded outcome assessment (Domain 4; only 1 trial described blinded assessment), and absent pre-registration against which to verify outcomes (Domain 5; 8 trials). Per-study judgements are given in Table 5; the traffic-light plot is provided as Supplementary Figure S1.

The 21 non-randomised comparative studies achieved a median NOS score of 6/9 (range 4–9): 9 (43%) were rated high quality (≥7 stars), 12 (57%) fair (4–6), and none poor. Star loss most often occurred in

the Comparability domain — reflecting absent adjustment or matching for confounders such as patient age, perforation size, ear status, and mastoid pneumatisation — and to a lesser extent in the Outcome domain (follow-up < 12 months) and the Selection domain (single-centre retrospective designs without documented consecutive enrolment). Per-study NOS scores are in Appendix Table A2.

Table 5. *Per-study RoB 2 judgements for the 9 randomised controlled trials. D1, randomisation process; D2, deviations from intended interventions; D3, missing outcome data; D4, measurement of the outcome; D5, selection of the reported result.*

Study	D1	D2	D3	D4	D5	Overall
Shah 2025 (endoscopic cartilage vs fascia)	Low	Some concerns	Some concerns	Low	Some concerns	Some concerns
Nagar 2024 (Eur Arch ORL — endoscopic, CSOM inactive)	High	Some concerns	Some concerns	Low	Some concerns	High
Wang 2024 (over-under myringoplasty)	Low	Some concerns	Low	Low	Some concerns	Some concerns
Dhoke 2023 (paediatric, full-thickness tragal)	High	Some concerns	Some concerns	Low	Some concerns	High
Chaudhary 2023 (paediatric, tragal vs fascia)	Low	Some concerns	Low	Low	Some concerns	Some concerns
Yang 2022 (Tragus perichondrium-cartilage island)	Some concerns	Some concerns	Low	Low	Low	Some concerns
Akhtar 2020 (half-thickness tragal cartilage)	Some concerns	Some concerns	Low	Low	Some concerns	Some concerns
Ciger 2018 (WsCCG vs fascia)	Some concerns	Some concerns	Some concerns	Some concerns	Some concerns	Some concerns
Jain 2018 (island cartilage vs fascia)	Some concerns	Some concerns	Low	Low	Some concerns	Some concerns

Certainty of evidence (GRADE)

The Summary of Findings is given in Table 3. Graft success was rated Low certainty (downgraded one level each for risk of bias and for publication bias). Postoperative ABG was rated Very Low certainty (downgraded for risk of bias, serious inconsistency, and imprecision). ABG improvement was rated Very Low certainty (downgraded for risk of bias, very serious inconsistency, imprecision, and indirectness arising from the assumed within-subject correlation).

Table 3. *Summary of Findings (GRADE).*

Outcome	k (n)	Effect (95% CI)	Heterogeneity	Downgrade factors	Certainty (GRADE)
Graft success	30 (2,392 ears)	RR 1.10 (1.07–1.14)	I^2 = 35%	Risk of bias (−1; 2/9 RCTs at high risk, 12/21 NRS only fair quality); Publication bias (−1; Egger p<0.001)	**LOW**
Postoperative ABG	26 (2,362 ears)	MD −0.48 dB (−1.78 to 0.82)	I^2 = 88%	Risk of bias (−1); Serious inconsistency (−2); Imprecision (−1; CI crosses zero)	**VERY LOW**
ABG improvement (pre–post)	23	MD 0.35 dB (−1.65 to 2.35)	I^2 = 93%	Risk of bias (−1); Very serious inconsistency (−2); Imprecision (−1); Indirectness (−1; assumed r=0.5)	**VERY LOW**

Primary outcome — graft success

Across all 30 studies (2,392 ears; 2,117 successful grafts), cartilage was associated with a significantly higher probability of an intact tympanic membrane at final follow-up: pooled RR = 1.103 (95% CI 1.066 to 1.142; z = 5.55; p < 0.0001), corresponding to approximately a 10% relative increase in graft take. Heterogeneity was moderate (I^2 = 35.4%, 95% CI 0.0% to 58.6%; τ^2 = 0.0029; Cochran Q = 44.91 on 29 df, p = 0.030); 28 of 30 study point estimates lay above unity (Figure 1).

Sensitivity analysis

Restriction to the 10 studies with follow-up ≥ 12 months yielded a slightly larger pooled effect (RR = 1.133, 95% CI 1.050 to 1.224; p = 0.001; n = 804 ears; I^2 = 58.2%; τ^2 = 0.0078). The leave-one-out analysis was stable: removing any single study moved the pooled RR only between 1.096 and 1.109 and the result remained significant in every iteration.

Subgroup analyses

Pre-specified subgroup results are summarised in Table 4. By population, the cartilage advantage was numerically largest in pediatric patients (k = 9; RR 1.184, 95% CI 1.103 to 1.272; p < 0.0001; I^2 = 0%) and was also significant in adults (k = 11; RR 1.096, 95% CI 1.037 to 1.157; p = 0.001; I^2 = 40.7%) and in mixed-population studies (k = 3; RR 1.114, 95% CI 1.019 to 1.218; p = 0.017; I^2 = 0%); the population-unclear subgroup (k = 7) did not reach significance. The formal subgroup-difference test was Q = 5.85 on 3 df, p = 0.119. By perforation risk, low-risk ears (k = 5) showed RR 1.132 (95% CI 1.063 to 1.206; p < 0.001; I^2 = 0%) and high-risk ears (k = 9) RR 1.098 (95% CI 1.025 to 1.177; p = 0.008; I^2 = 46.9%); the

subgroup-difference test was non-significant (Q = 0.48 on 2 df, p = 0.787). Subgroup-specific forest plots are shown in Figures 2–5.

Secondary outcome — postoperative air-bone gap

In the 26 studies (2,362 ears: 1,192 cartilage; 1,170 fascia) reporting postoperative ABG in both arms, the pooled mean difference (cartilage − fascia) was −0.48 dB (95% CI −1.78 to 0.82; z = −0.72; p = 0.469), with very high heterogeneity (I^2 = 88.2%, 95% CI 84.0% to 91.4%; τ^2 = 8.12; Q = 212.61 on 25 df, p < 0.0001). The 0.48-dB mean difference is well below the test-retest variability of pure-tone audiometry (~5 dB) and below any threshold of clinical perceptibility. The forest plot is shown in Figure 6. The leave-one-out analysis was confirmatory: the pooled MD remained between −0.70 dB and −0.02 dB across all iterations and was non-significant throughout.

Secondary outcome — change in air-bone gap (pre vs post)

For the 23 studies in which within-group ABG improvement could be computed (r = 0.5 assumed), the pooled mean difference (cartilage − fascia) was 0.35 dB (95% CI −1.65 to 2.35; p = 0.731; I^2 = 92.7%; τ^2 = 19.91). Sensitivity analyses at r = 0.4 (MD 0.36 dB; p = 0.723) and r = 0.6 (MD 0.34 dB; p = 0.739) produced essentially identical pooled estimates, confirming that the result is not driven by the assumed correlation.

Heterogeneity and publication bias

The funnel plot for the primary outcome (Figure 7) is asymmetric: smaller studies (those with larger standard errors) tended to lie to the right of the pooled estimate, more often reporting a benefit for cartilage. Egger's regression test confirmed this impression (intercept 2.446, SE 0.390; t = 6.27 on 28 df; p < 0.0001), indicating significant small-study effects that may include publication bias, selective reporting in single-centre series, or genuine differences between small and large studies. By contrast, the funnel plot for postoperative ABG was symmetric (Egger's intercept 0.75, t = 0.81 on 24 df, p = 0.425).

Summary of pooled effect estimates

Table 4. *Pooled effect estimates for all primary, secondary, subgroup, and sensitivity analyses. Random-effects DerSimonian-Laird estimator. All numerical results were independently verified using the R meta package (v8.3-0).*

Outcome / subgroup	k	Effect (95% CI)	p-value	I^2 (%)	τ^2
Graft success (RR, cartilage / fascia)					
Overall	30	1.103 (1.066 to 1.142)	<0.0001	35.4	0.003
Pediatric	9	1.184 (1.103 to 1.272)	<0.0001	0.0	0.000
Adult	11	1.096 (1.037 to 1.157)	0.001	40.7	0.003
Mixed population	3	1.114 (1.019 to 1.218)	0.017	0.0	0.000
Unclear (population)	7	1.056 (0.993 to 1.123)	0.082	38.0	0.003
Subgroup-diff test (population)	—	Q = 5.85, df = 3	0.119	—	—
High-risk ear	9	1.098 (1.025 to 1.177)	0.008	46.9	0.004
Low-risk ear	5	1.132 (1.063 to 1.206)	<0.001	0.0	0.000
Unclear (risk)	15	1.106 (1.046 to 1.168)	<0.001	44.5	0.005
Mixed/Unclear (risk)	1	1.125 (0.894 to 1.415)	0.314	—	—
Subgroup-diff test (risk)	—	Q = 0.48, df = 2	0.787	—	—
Sensitivity (FU ≥ 12 mo)	10	1.133 (1.050 to 1.224)	0.001	58.2	0.008
Postoperative ABG (MD, dB; cartilage − fascia)					
Overall	26	−0.48 (−1.78 to 0.82)	0.469	88.2	8.12
ABG improvement (MD, dB; cartilage − fascia, r = 0.5)					
Overall	23	0.35 (−1.65 to 2.35)	0.731	92.7	19.91
Sensitivity (r = 0.4)	23	0.36 (−1.64 to 2.37)	0.723	91.3	19.43
Sensitivity (r = 0.6)	23	0.34 (−1.66 to 2.34)	0.739	94.1	20.47

Discussion

The present meta-analysis shows that cartilage grafts confer a modest but consistent advantage over temporalis fascia in anatomical graft success in type 1 tympanoplasty, while producing clinically indistinguishable hearing outcomes. The cartilage advantage corresponds to approximately a 10% relative increase in graft take and was preserved when the analysis was restricted to studies with ≥ 12-month follow-up (RR 1.13).

The mechanical superiority of cartilage is plausible. Its greater thickness and rigidity confer resistance to resorption and retraction.[5] Temporalis fascia, by contrast, is abundant, transparent, and easily harvested but lacks elasticity and is more susceptible to pressure-related complications that increase the risk of re-perforation, retraction-pocket formation, and thinning over time.[5,6] Cartilage therefore appears to provide better anatomical outcomes in hostile middle-ear environments such as Eustachian-tube dysfunction, recurrent infection, and chronic inflammation.

Despite the structural difference between the two graft materials, both produced equivalent audiometric outcomes. The pooled postoperative ABG mean difference (− 0.48 dB) fell well below the test-retest variability of pure-tone audiometry and well below any threshold of clinical perceptibility. This finding addresses a long-standing concern that cartilage's greater thickness and stiffness might compromise sound transmission; the present results, consistent with previous syntheses,[7,8] indicate that these structural qualities do not impair audiometric function. Subgroup analyses by age and by perforation risk did not reach statistical significance for differential effects on either graft success or hearing outcomes — although the cartilage advantage was numerically largest in pediatric patients (RR 1.18; $I^2 = 0\%$) and in low-risk ears (RR 1.13; $I^2 = 0\%$). The absence of formal subgroup-difference significance should not be read as evidence of no differential effect; stratification reduces sample size and widens confidence intervals, and larger subgroup studies may be needed to confirm or refute a true modifying effect.

Heterogeneity was moderate for graft success ($I^2 = 35\%$) and high for the audiometric outcomes ($I^2 = 88–93\%$). Although stratification by age and risk addressed two pre-specified drivers, residual variability is likely from unmeasured factors including perforation characteristics, the specific cartilage technique used, and follow-up duration. Cartilage sub-types differ by donor site, preparation, thickness, and shaping technique — palisade, island, full-thickness, partial-thickness, and composite chondroperichondrial grafts were pooled together in the present analysis as a single "cartilage" arm, in line with prior published meta-analyses. Chen and Zhao[9] have reported statistically significant differences in graft success between palisade and island cartilage techniques, and Lajdam et al.[16] have reported that full-thickness cartilage may produce slightly better audiometric outcomes than partial-thickness preparations. Heterogeneous definitions of graft success — including intact eardrum,[11] absence of perforation recurrence with hearing improvement,[12] absence of retraction with a dry ear,[13] and the composite "no perforation, medialization, or lateralization"[14] — further contribute to between-study variability, as does the wide range of follow-up durations (3 months to 5 years).

Our findings are consistent with previous meta-analyses[9,15,16] and with the conclusions of Iacovou et al.[17] regarding the higher anatomical success of cartilage compared with temporalis fascia. Yang et al.[10] and the systematic reviews of Mohamad et al.[11] and Jeffery et al.[18] report comparable outcomes. In contrast, Lyons et al.[19] found no superiority for one-piece composite cartilage-perichondrium grafts over temporalis fascia, which may reflect their cohort of predominantly low-risk patients (in whom the cartilage advantage is smaller in absolute terms) and the specific composite graft technique used. With respect to hearing outcomes, our finding of no statistically significant difference is consistent with most prior syntheses,[10,11,16,18] although Jalali et al. and Chen and Zhao[9,15] have reported slightly better postoperative ABG with temporalis fascia in some sub-analyses — a discrepancy that may reflect different included-study populations, varying cartilage sub-type composition, or differences in audiometric reporting.

Egger's regression test was significant for the primary outcome ($p < 0.0001$), indicating small-study effects. Smaller studies tended to report larger cartilage advantages; this asymmetry may reflect publication bias, selective reporting in single-centre case series, or genuine clinical differences between small specialised cohorts and larger pragmatic series. The pooled estimate of cartilage's advantage in graft success may therefore be modestly inflated. However, the consistency of the effect across subgroup, sensitivity, and leave-one-out analyses — and the absence of asymmetry on the audiometric funnel plot — argue that the qualitative conclusion (cartilage superior anatomically, equivalent audiometrically) is robust even if its magnitude is slightly overestimated.

These findings must be interpreted in the context of the methodological quality of the included studies. None of the 9 RCTs was rated at overall low risk of bias on RoB 2: 7 were rated some concerns and 2 at high risk, principally driven by inadequate description of the randomisation process, the structural impossibility of operator blinding in surgical trials, infrequent description of blinded outcome assessment, and the absence of trial-registry entries against which to verify pre-specification of outcomes. The 21 non-randomised studies achieved a median NOS score of 6 out of 9, with most studies losing stars in the Comparability domain because they did not adjust for or match on patient age, perforation size, ear status, or mastoid status. The overall body of evidence supporting the cartilage advantage in graft success is therefore of Low certainty on GRADE, downgraded for risk of bias and for publication bias. The audiometric outcomes are of Very Low certainty, downgraded additionally for serious or very serious inconsistency and imprecision. The cartilage advantage in graft success therefore reflects Low-certainty evidence and should inform rather than dictate clinical practice; larger, multi-centre, registered randomised trials with blinded outcome assessment, standardised outcome definitions, and minimum 12-month follow-up are needed to provide higher-certainty evidence.

Limitations

Several limitations warrant explicit acknowledgement. First, included studies varied in follow-up duration, ranging from 3 months to 5 years; only 10 studies explicitly reported follow-up of at least 12 months, and although the sensitivity analysis restricted to these studies reproduced the primary finding (RR 1.13), the

reduction in k limits the precision of that estimate. Second, the definition of "graft success" was heterogeneous across included studies, contributing to the moderate heterogeneity observed in the primary analysis. Third, our "cartilage" arm pooled palisade, island, full-thickness, partial-thickness, and chondroperichondrial composite techniques, which may have obscured technique-specific differences. Fourth, the significant Egger's test ($p < 0.0001$) indicates substantial small-study effects on the primary outcome, suggesting that the true cartilage advantage in graft success may be somewhat smaller than the pooled point estimate. Fifth, no included study reported the within-subject correlation between pre- and postoperative ABG, requiring an assumed value of $r = 0.5$ for the change-score analysis (sensitivity analyses at $r = 0.4$ and $r = 0.6$ confirmed robustness). Sixth, audiometric outcomes were variably reported as either three- or four-frequency pure-tone averages, contributing to the very high heterogeneity ($I^2 = 88–93\%$) for those outcomes. Seventh, none of the 9 RCTs was rated at overall low risk of bias on RoB 2 and the majority of non-randomised studies were of only fair quality, which translated to a Low or Very Low GRADE certainty rating across the three outcomes. Finally, only studies published in English were included; this may have excluded relevant evidence from non-English-language otolaryngology literature.

Conclusions

In this meta-analysis of 30 contemporary comparative studies (2,392 ears) of cartilage versus temporalis fascia in primary type 1 tympanoplasty, cartilage produced a small but consistent advantage in anatomical graft success (RR 1.10, 95% CI 1.07–1.14; $p < 0.0001$) without any compromise in audiometric outcomes. The benefit was numerically largest in pediatric patients and in low-risk perforations, although the formal between-subgroup tests were not statistically significant. Significant small-study effects on the primary outcome suggest the magnitude of the cartilage advantage may be modestly inflated by publication bias, and the overall certainty of evidence is Low for graft success and Very Low for the audiometric outcomes. Clinically, these findings support the use of cartilage grafting in type 1 tympanoplasty, particularly in pediatric and low-risk cases, while reassuring practitioners that the choice does not entail an audiometric penalty. Larger, multicentre, registered randomised trials with blinded outcome assessment, standardised outcome definitions, and ≥ 12-month follow-up are needed to refine subgroup-specific recommendations and to provide higher-certainty evidence.

Declarations

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Author Contribution

S.A. and N.A.R. performed the literature screening and study selection, extracted the data, drafted the Results and Discussion sections, and edited the manuscript. R.S. wrote the Methods and Results sections, and assisted with the figures and tables. E.M. wrote the Introduction. P.S. assisted with data extraction and contributed to the Discussion section. H.G. supervised the study and critically revised and edited the manuscript. All authors reviewed and approved the final manuscript.

Data Availability

The datasets generated and/or analyzed during the current study are available in the supplementary material of this published article. Additional extracted study-level data are available from the corresponding author upon reasonable request.

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Figures

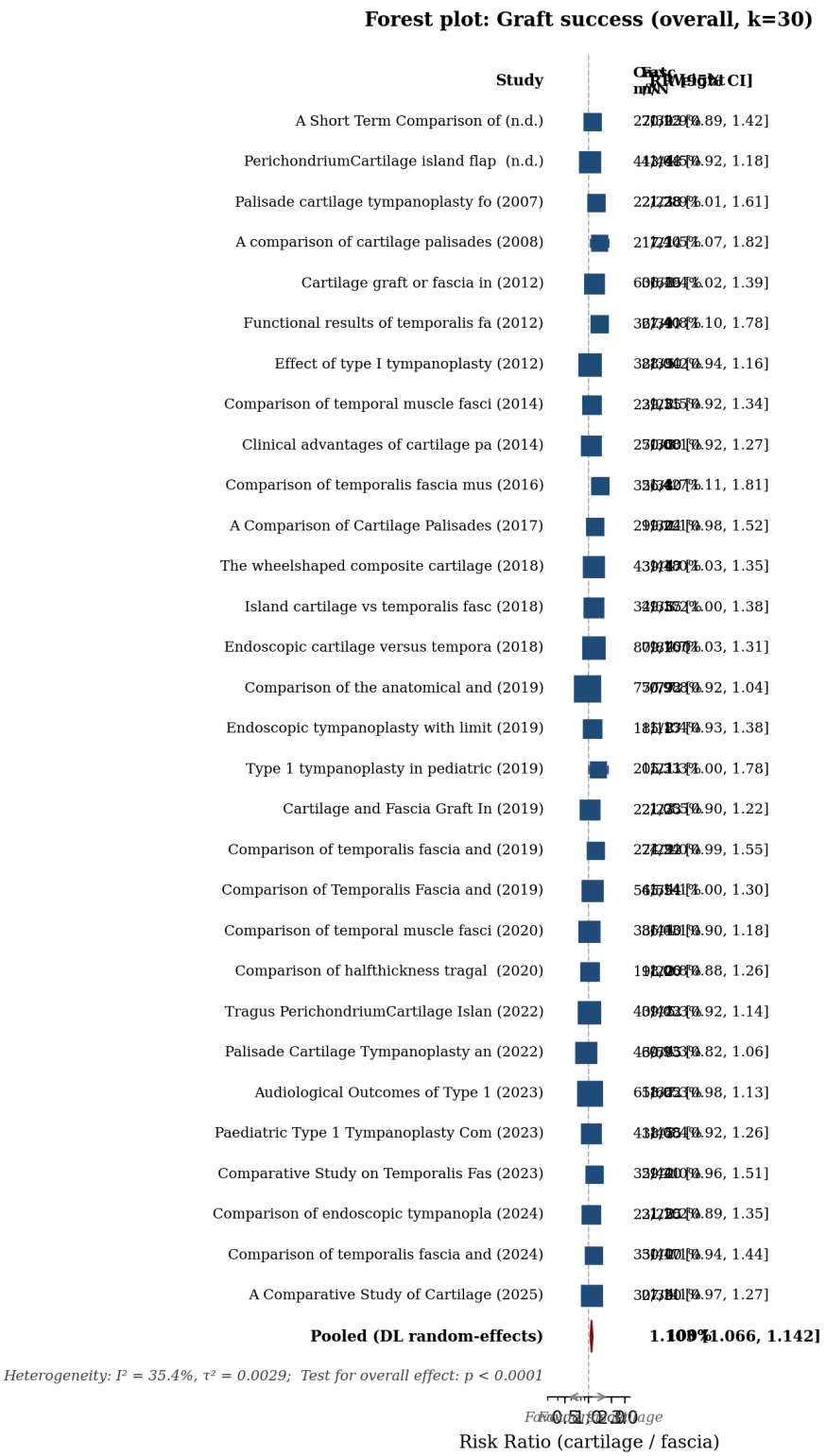


Figure 1

Forest plot for the primary outcome (graft success). Squares represent study-specific risk ratios sized by random-effects weight; horizontal lines are 95% confidence intervals; the red diamond is the pooled DerSimonian-Laird estimate. RR > 1 favours cartilage.

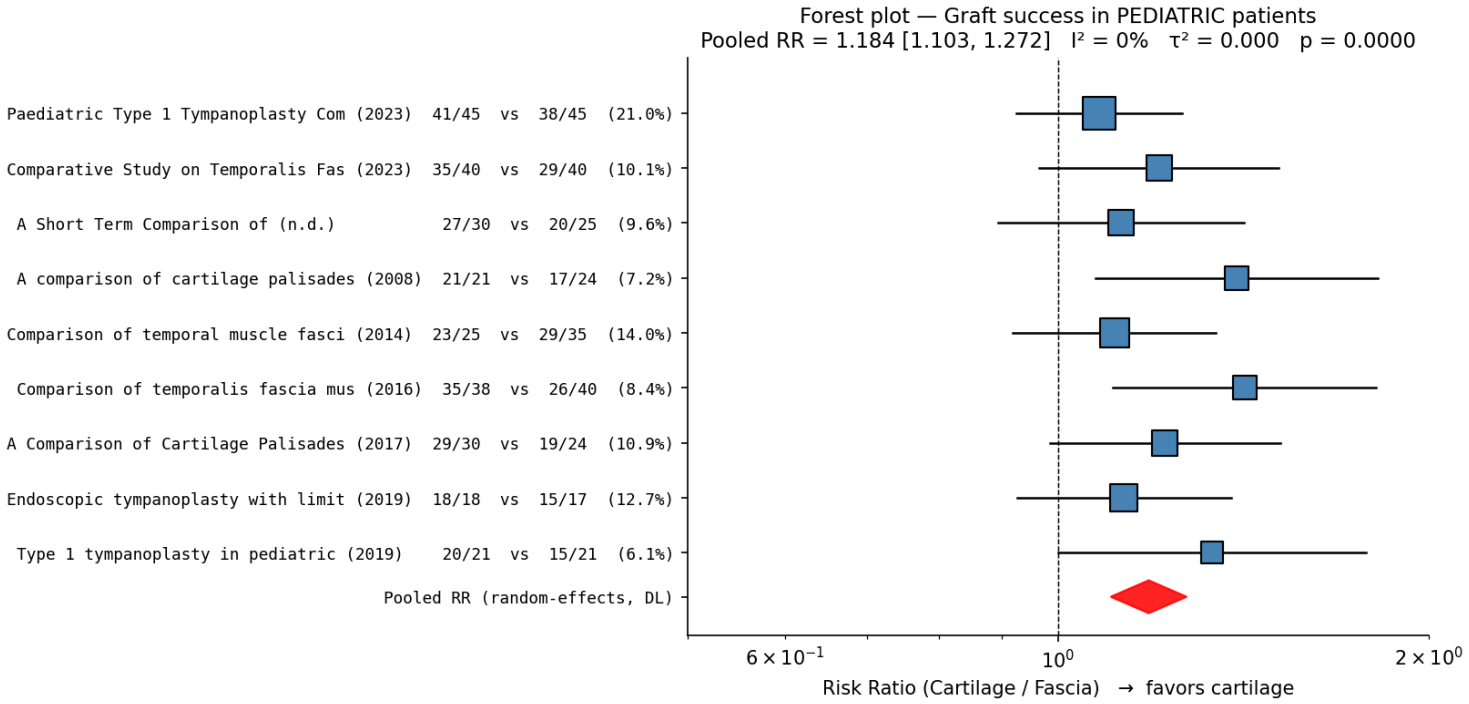


Figure 2

Forest plot for graft success in pediatric patients (k = 9, I² = 0%).

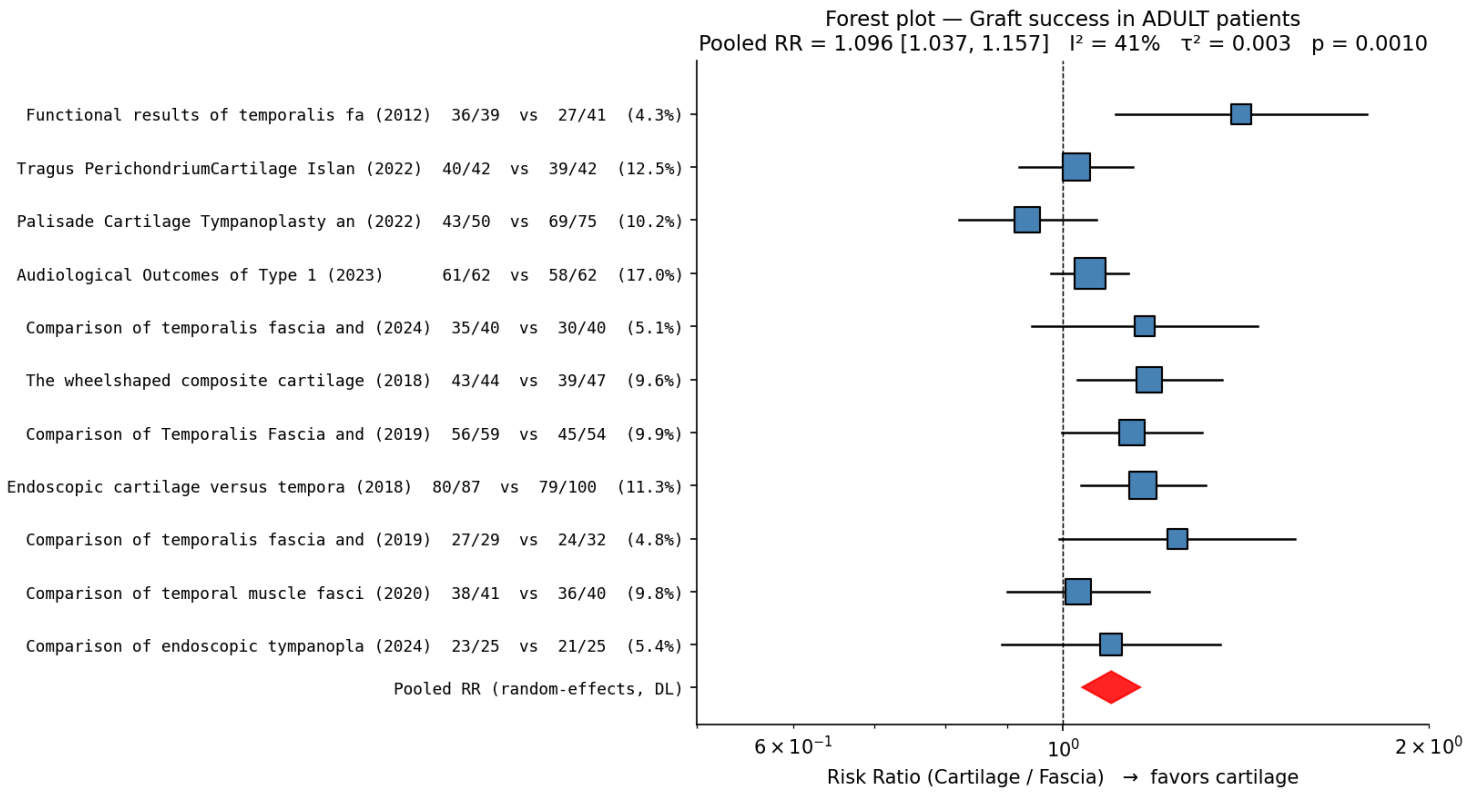


Figure 3

Forest plot for graft success in adult patients (k = 11, I² = 40.7%).

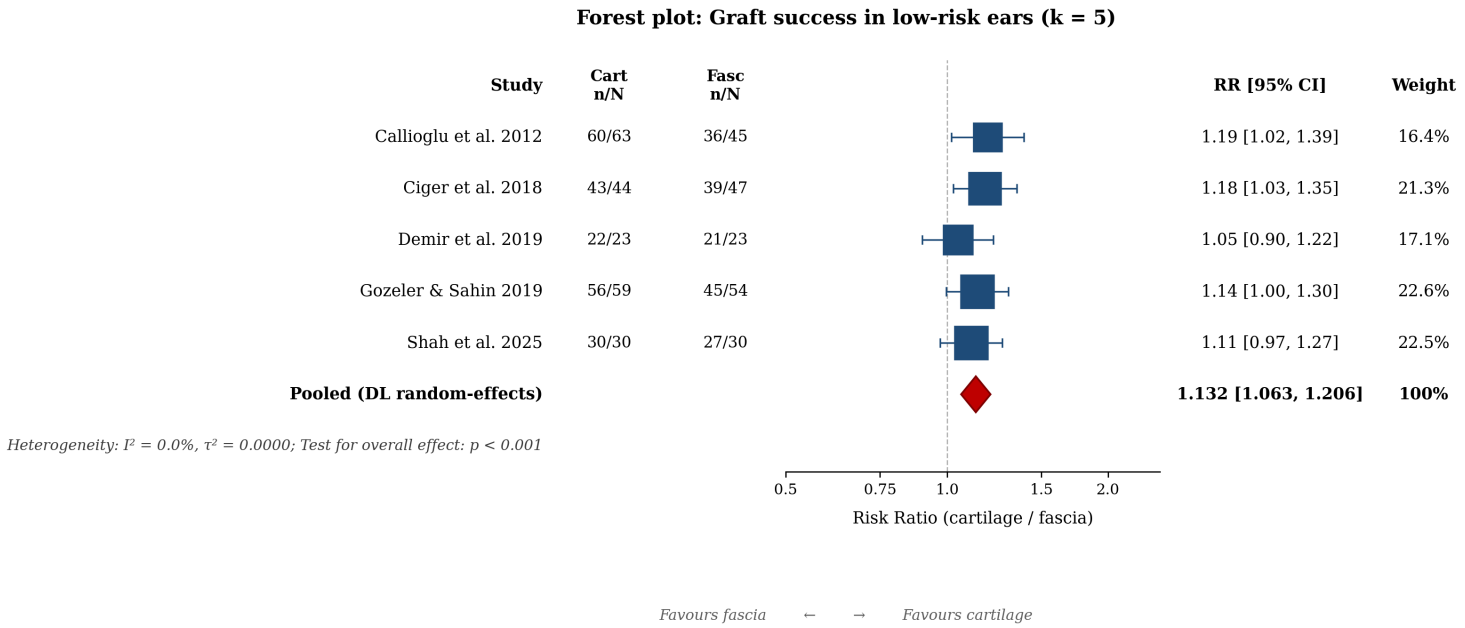


Figure 4

Forest plot for graft success in low-risk ears (k = 5, I² = 0%).

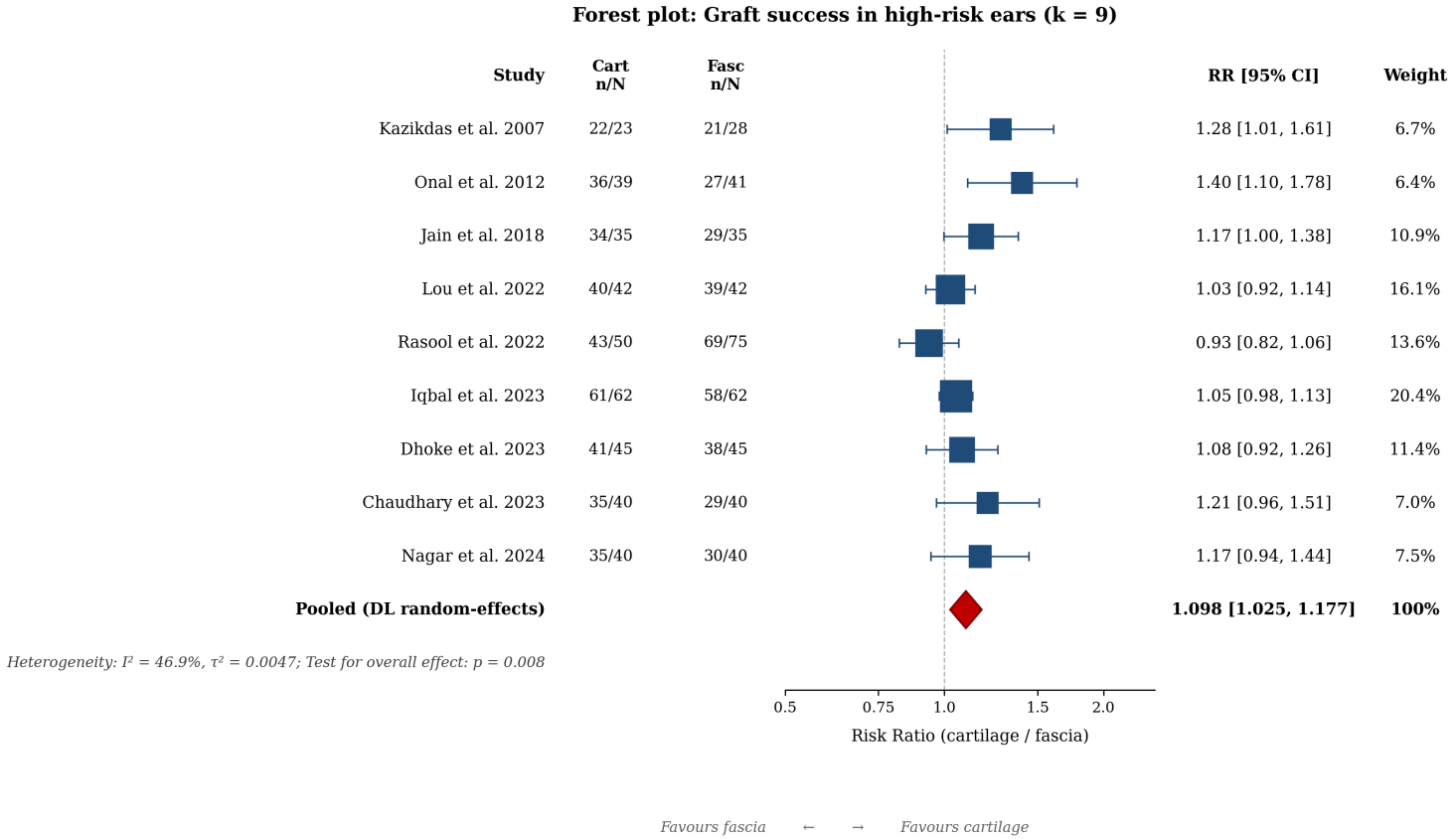


Figure 5

Forest plot for graft success in high-risk ears (k = 9, I² = 46.9%).

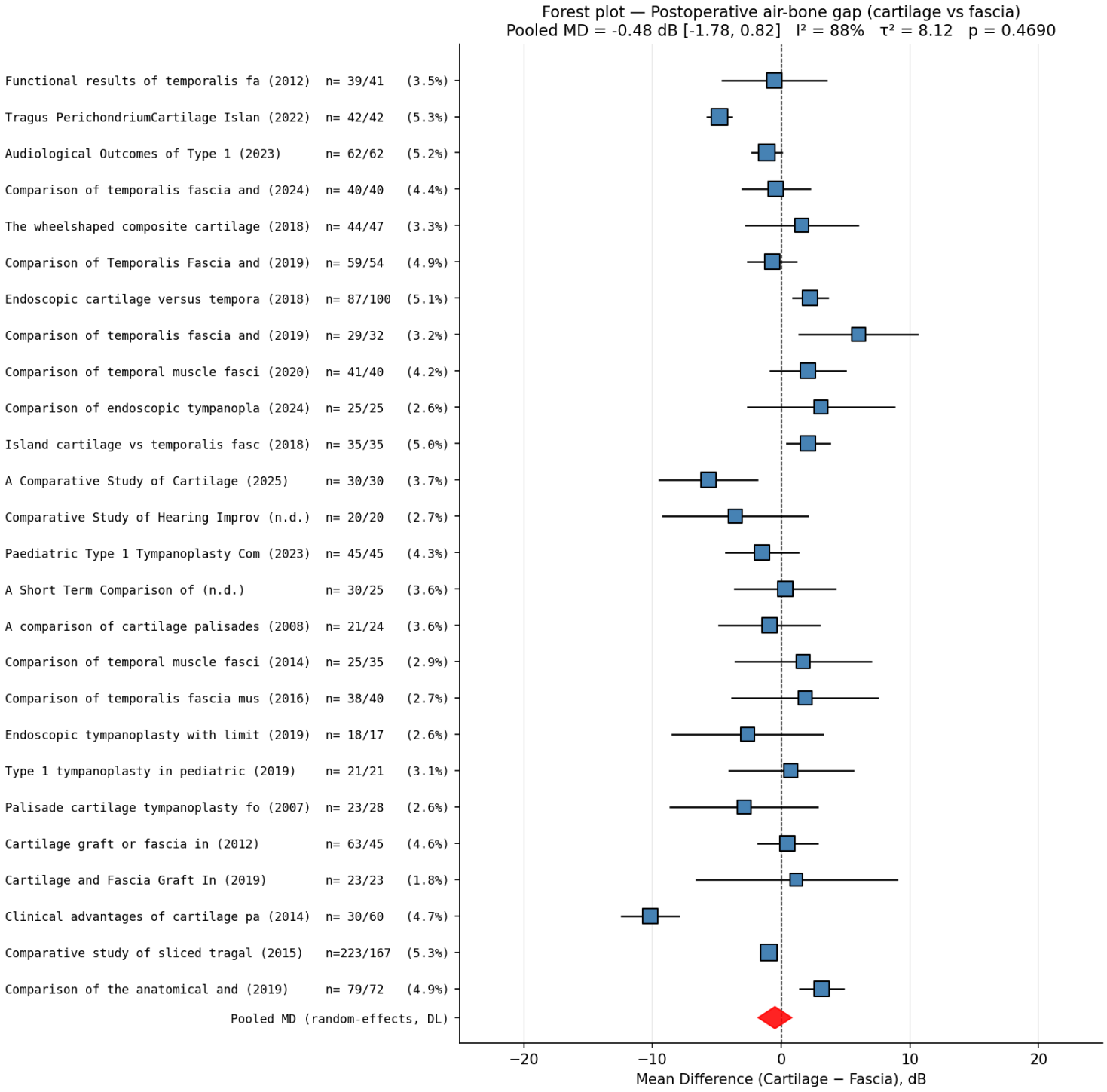


Figure 6

Forest plot for postoperative air-bone gap (mean difference, cartilage − fascia). Negative values favour cartilage. The wide spread of individual estimates (−10.2 dB to +6.0 dB) drives the high I² value.

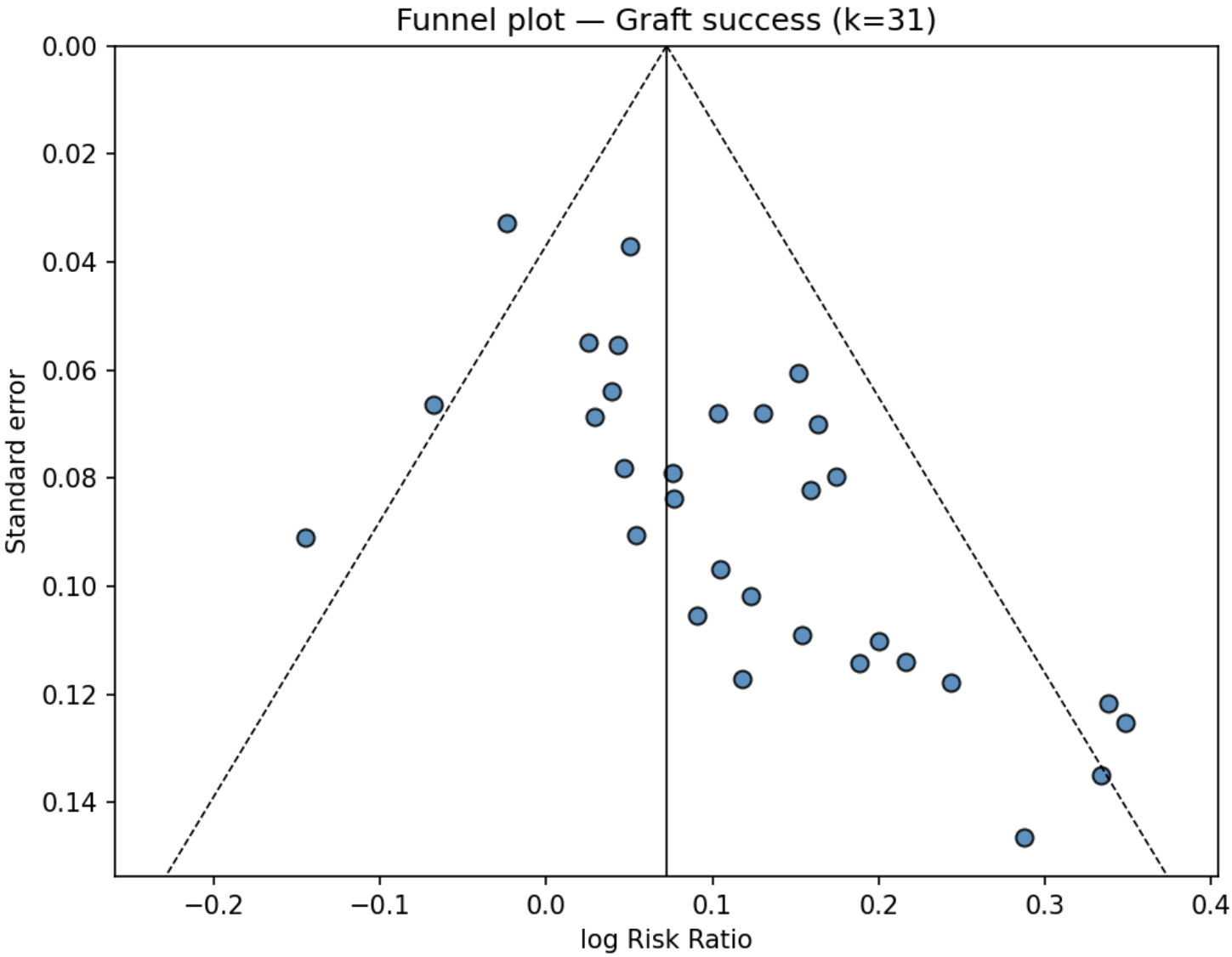


Figure 7

Funnel plot for graft success (k = 30). The vertical line is the pooled log RR; dashed lines represent the pseudo-95% confidence funnel. Visible asymmetry (more small-study points on the right) corresponds to Egger's test p < 0.0001.

Supplementary Files

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- SupplementaryMaterial.docx