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REVIEW ARTICLE

Is cartilage better than temporalis muscle fascia in type I tympanoplasty? Implications for current surgical practice

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Abstract The aim of this study was to compare the hearing results and graft integration rates in patients undergoing myringoplasty for the reconstruction of the tympanic membrane, with the use of either cartilage or temporalis muscle fascia (TMF). A systematic literature review in Medline and other database sources up to February 2012 was carried out, and the pooled data were meta-analyzed. Twelve studies were systematically analyzed. One represented level I, one level II and ten level III evidence. The total number of treated patients was 1,286. Cartilage reconstruction was used in 536, TMF in 750 cases. Two level III studies showed a significant difference between the pre- and postoperative air-bone gap closure, in favor of cartilage grafting. The mean graft integration rate was 92.4 % in the cartilage group and 84.3 % in the TMF group ($p < 0.05$). The rates of re-perforations were 7.6 and 15.5 %, respectively ($p < 0.05$). Among the other complications of type I tympanoplasty, retraction pockets, otitis media with effusion, anterior blunting, and graft lateralization were usually surgically managed, whereas most of the rest were minor and could be dealt with conservatively. The graft integration rate in myringoplasty is higher after using cartilage, in comparison with fascia reconstructions (grade C strength of recommendation), and the rate of re-perforation is significantly lower. Although cartilage is primarily used as grafting material in cases of Eustachian tube dysfunction, adhesive otitis media, and subtotal perforation in everyday surgical practice, a wider utilization for the reconstruction of the tympanic membrane in myringoplasties can be recommended.

Keywords Tympanoplasty · Myringoplasty · Graft · Cartilage · Fascia · Perforation · Hearing

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Introduction

The repair of an eardrum perforation has been the milestone operation in otology, since the first surgical attempts in the field of ear surgery. The tympanoplasty is a well-described procedure, widely performed all over the world, aiming to reconstruct the eardrum and contribute to a well-aerated, healthy, and hearing middle ear. The myringoplasty (type I tympanoplasty) in particular was first described by Berthold in 1878, and since then numerous surgical techniques have been developed, and various graft materials have been used for repairing the tympanic membrane defect [1]. Indeed, skin, fascia, vein, perichondrium, and dura mater have all been employed in tympanic membrane reconstruction [2–8]; however, temporalis fascia represents the most widely used grafting material [9].

The situation gets more complex, and failure rates are considered higher in cases of Eustachian tube dysfunction, retraction pocket, adhesive otitis media, and subtotal or total perforation. Therefore, graft materials more rigid than fascia (i.e., cartilage), and more resistant to infection, resorption, and retraction have been proposed as more appropriate for tympanic membrane reconstruction [10–13]. However, the increased thickness, stiffness, and mass of cartilage [14] may negatively influence the integration of the graft and the hearing results.

The aim of the present study was to assess the existing evidence in favor of or against cartilage type I tympanoplasty in comparison with temporalis muscle fascia (TMF) myringoplasty, with regard to graft integration rates and hearing results. The respective complications from the use of these grafting materials in type I tympanoplasties will also be explored.

Materials and methods

An extensive search of the literature was performed in Medline, Scopus, EMBASE, and CINAHL up to February 2012, having as primary end-points the comparison of hearing results and graft integration rates in patients who had undergone type I tympanoplasty using either cartilage, or TMF for the reconstruction of the tympanic membrane. The number of studies initially selected was 111.

Using this framework of results, the retrieved studies were critically appraised, according to evidence-based guidelines for the categorization of medical studies (Tables 1, 2, 3) [9, 14–25]. Language restrictions limited the included literature to English-speaking articles. Forty studies continued to meet the defined criteria, and were further analyzed.

During the search the keywords “tympanic”, “membrane”, “perforation”, “graft”, “success”, “hearing”, “gap”, “tympanoplasty”, “myringoplasty”, “cartilage”, and “fascia” were utilized. The keywords “tympanoplasty”, “myringoplasty”, “cartilage”, and “fascia” were considered primary, and were either combined to each of the other keywords individually, or used in groups of three. In addition, reference lists from the retrieved articles were manually searched.

Patients with history of ossicular discontinuity, ossiculoplasty, cholesteatoma, previous ear surgery, or syndromes affecting the status of the middle ear were excluded.

The meta-analysis of data was carried out in the StatsDirect statistical software, and the Random-Effects Model was used to assess the pooled proportion of success and the

Table 1 Levels of evidence regarding the primary research question in studies that investigate the results of a treatment (http://www.cebm.net/index.aspx?o=1025)

Category of evidence	Study design
Level I	High quality randomized trial with statistically significant difference, or no statistically significant difference but narrow confidence intervals
	Systematic review of level I randomized control trials (and study results were homogenous)
Level II	Lesser quality randomized control trial (e.g., <80 % follow-up, no blinding, or improper randomization)
	Prospective comparative study
	Systematic review of level II studies or level I studies with inconsistent results
Level III	Case control study
	Retrospective comparative study
	Systematic review of level III studies
Level IV	Case series
Level V	Expert opinion

Table 2 Strength of recommendation by category of evidence for guideline development [40]

Strength of recommendation	Category of evidence
A	Directly based on category I evidence
B	Directly based on category II evidence or extrapolated recommendation from category I evidence
C	Directly based on category III evidence or extrapolated recommendation from category I or II evidence
D	Directly based on category IV evidence or extrapolated recommendation from category I, II or III evidence

Table 3 Cartilage versus temporalis muscle fascia in type I tympanoplasty

Authors	Study type	Level of evidence	Type of patients	Patients/technique (cartilage group)	Patients/technique (TF group)	Follow-up	Graft outcome/hearing outcome	Remarks
Iacovou et al. [23]	Retrospective comparative	III	Adults[a]	39 chondrotympanoplasties with tragal cartilage	30 underlay myringoplasties	12 months	97.4 % integration rate in the cartilage versus 93.3 % in the TF group ABG closure ≤10 dB in 73.7 % of patients in the cartilage versus 67.9 % in the TF group	(a) The middle ear resonant frequency remained within the normal range in 73.7 % of the cartilage versus 42.9 % of the TF group (b) Cartilage improves the compliance of the repaired TM-ossicular chain system, resulting in smaller impedance, as it eliminates the increased stiffness, by increasing the mass of the system
Tek et al. [21]	Prospective randomized comparative	II	Adults[b]	37 cartilage reinforcement tympanoplasties with cymba cartilage	40 underlay myringoplasties	6 months	86.5 % integration rate in the cartilage versus 67.5 % in the TF group 11.62 ± 7.45 dB mean ABG gain in the cartilage versus 9.44 ± 9.12 dB in the TF group	(a) The graft integration rate is significantly higher in the cartilage compared to the TF group (b) Good functional results (ABG <20 dB) were observed in 87.5 % in the cartilage versus 85.1 % in the TF group
Onal et al. [17]	Retrospective comparative	III	Adults[a]	44 perichondrium-cartilage island graft tympanoplasties with tragal cartilage	48 underlay myringoplasties	≥1 year	93.2 % integration rate in the cartilage versus 89.6 % in the TF group ABG ≤20 dB occurred in 97.7 % in the cartilage versus 93.7 % in the TF group	(a) The mean postoperative air-bone gap is better in the cartilage compared to the TF group (b) Cartilage grafts can be used to reconstruct the TM without fear of impairing hearing
Albirmawy [15]	Retrospective comparative	III	Children	40 ring graft tympanoplasties with tragal cartilage	42 underlay myringoplasties	≥1 year	95 % integration rate in the cartilage versus 76.2 % in the TF group ABG improved 14.67 ± 2.10 dB in the cartilage versus 13.25 ± 9.57 dB in the TF group	(a) The difference in graft acceptance rates between the two groups was statistically significant (b) ABG ≤20 dB occurred in 100 % in the cartilage versus 71.4 % in the TF group
Yetiser and Hidir [9]	Retrospective comparative	III	Adults[c]	47 cartilage shield tympanoplasties with tragal cartilage	66 underlay myringoplasties	≥1 year	95 % integration rate in the cartilage versus 93 % in the fascia group 14.2 ± 7.7 dB mean postoperative ABG in the cartilage versus 19.7 ± 12.0 dB in the TF group	(a) The hearing gain in patients with cartilage grafting is significantly better compared to TF use (b) Thinning of the harvested cartilage graft leads to curling towards the side of the perichondrium, not only making the placement difficult, but also preventing full contact with the TM remnant
Gamra et al. [16]	Retrospective comparative	III	Adults/children	90 cartilage–perichondrium graft myringoplasties with tragal or concha cartilage	290 underlay myringoplasties	3 months to 6 years	97.7 % integration rate in the cartilage versus 96.9 % in the TF group 16 ± 10 dB mean ABG gain in the cartilage versus 18 ± 7 dB in the TF group	(a) ABG closure ≤10 dB occurred in 48.8 % of patients in the cartilage versus 16.2 % in the TF group (b)Good functional results (ABG <20 dB) were observed in 89 % of patients in the cartilage versus 82.8 % in the TF group (c) The authors recommend using cartilage as a 1st choice in tympanoplastic procedures
Ozbek et al. [20]	Retrospective comparative	III	Children	21 over-underlay cartilage palisade tympanoplasties with cymba cartilage	24 over-underlay myringoplasties	1–3 years	100 % integration rate in the cartilage versus 70.8 % in the TF group 14.71 ± 2.47 dB mean ABG gain in the cartilage versus 14.20 ± 9.49 dB in the TF group	(a) Compared to TF, cartilage resistance to frequent infections, and TM retractions secondary to ET dysfunction, are the two main reasons for graft stability in pediatric myringoplasties (b) Precise placement of the cartilage pieces is a prerequisite, which allows the use of full-thickness cartilage strips without fear of impairing hearing

Table 3 continued

Authors	Study type	Level of evidence	Type of patients	Patients/technique (cartilage group)	Patients/technique (TF group)	Follow-up	Graft outcome/hearing outcome	Remarks
Kazikdas et al. [19]	Retrospective comparative	III	Adults/children	23 cartilage palisade tympanoplasties with cymba cartilage	28 over-underlay myringoplasties	3 months to 3 years	95.7 % integration rate in the cartilage versus 75 % in the TF group ABG in cartilage group improved from 25.6 ± 8.6 dB to 17.3 ± 8.8 dB/ABG in TF group improved from 30.7 ± 12.6 to 20.2 ± 12.1 dB	(a) 60.9 % of patients in the cartilage group achieved ABG closure <15 dB (b) 76.2 % of patients in the cartilage group achieved postoperative SRT <30 dB
Couloigner et al. [22]	Retrospective comparative	III	Children	59 inlay butterfly cartilage tympanoplasties with tragal cartilage	29 underlay myringoplasties	26.6 ± 19.9 months (cartilage)/ 21.8 ± 17.1 months (TF)	71 % integration rate in the cartilage versus 83 % in the TF group No significant difference between IBCT and TF hearing thresholds postoperatively	(a) Anatomic results are better when there is at least 2 mm larger diameter of the cartilage graft than the TM perforation (b) IBCT did not improve the mean PTA threshold at 4,000 Hz
Kirazli et al. [18]	Retrospective comparative	III	Adults	15 perichondrium cartilage island graft tympanoplasties with tragal cartilage	10 underlay myringoplasties	4 months to 3 years (cartilage)/6 months to 3 years (TF)	100 % integration rate in the cartilage versus 83.3 % in the TF group 11.8 dB mean ABG gain in the cartilage versus 11.5 dB in the TF group	The overall and frequency specific hearing improvements after cartilage tympanoplasty is comparable to TF grafting
Al lackany and Sarkis [24]	Retrospective comparative	III	Adults/children	90 perichondrium cartilage graft	110 underlay myringoplasties	≥6 months	92.3 % integration rate in the cartilage versus 80 % in the TF group 16.5 ± 2.44 dB mean postoperative ABG in the cartilage versus 21.02 ± 3.9 dB in the TF group	(a) The rate of re-perforation was markedly reduced when perichondrium cartilage graft was used (b) Hearing results were better in central perforations in the TF group, and in subtotal and total perforations in the cartilage group
Mauri et al. [25]	Prospective randomized comparative	I	Adults[d]	31 inlay butterfly cartilage tympanoplasty	33 underlay myringoplasties	7.61 ± 4.1 months (IBCT)/ 7.4 ± 3.6 months (TFT)	85.3 % integration rate in the cartilage versus 83.3 % in the TF group Closure of the ABG to within 10 dB in 64.7 % and to within 20 dB in 94.1 % in the cartilage group versus 75 and 97.2 % in TF group, respectively	(a) Similar primary clinical outcomes were observed between the 2 techniques (b) Postoperative inflammation had an independent effect on the graft integration rate (c) Postoperative pain was more pronounced in the TF group (d) Immediate postoperative hearing was reportedly better in the IBCT group (e) The estimated charge for IBCT was 65 % less expensive than TFT

TF temporalis fascia, *ABG* air-bone gap, *TM* tympanic membrane, *ET* Eustachian tube, *IBCT* inlay butterfly cartilage tympanoplasty, *TFT* temporalis fascia tympanoplasty

[a] Lower cut-off criterion 16 years of age

[b] Lower cut-off criterion 14 years of age

[c] Few children were also included in the cartilage group

[d] Lower cut-off criterion 15 years of age

pooled proportion of re-perforation in the cartilage and fascia groups. Statistical importance was accepted at the level of 0.05.

Results

Among the 40 analyzed studies, four represented prospective randomized studies, two were prospective studies, 14 were retrospective comparative studies, and 15 retrospective studies. There were also two systematic reviews and three books.

Eighteen studies directly compared cartilage and fascia in type I tympanoplasties [9, 14–30]. Among these studies, two were incorporated in a larger patient series by the same principle author, and were not included in the analysis of pooled data to avoid double-counting of the operations [26, 27]. Three more studies also included patients with cholesteatoma [28–30]. In the absence of clear-cut data referring only to patients with type I tympanoplasty without cholesteatoma, these studies were also not used in the analysis of pooled data. Finally, one study exclusively included patients with revision type I tympanoplasties, and was further excluded to avoid sample heterogeneity [14].

From the remaining 12 studies, one represented level I, one level II, and ten level III evidence. The total number of treated patients was 1,286. Cartilage reconstruction was used in 536 type I tympanoplasties, whereas TMF in 750. The mean graft integration rate in the cartilage group was 92.4 % (95 % CI 87.8–96.0) and in the temporalis fascia group 84.3 % (95 % CI 76.9–90.5). The difference proved statistically significant ($p < 0.05$).

With regard to the functional outcomes of the operations, two level III studies showed a significant difference between the pre- and postoperative air-bone gap closure, in favor of the cartilage grafting materials, and an additional level III study improved results in the cartilage group in cases of subtotal and total TM perforation, and better postoperative air-bone gap closure with fascia in cases of central perforation.

The majority of treated patients were followed up for over 1 year. The rates of re-perforations were 7.6 (95 % CI 4.03–12.2) and 15.5 % (95 % CI 8.9–23.6) for cartilage and fascia, respectively ($p < 0.05$). The rest of the reported complications are summarized in Table 4.

Discussion

TMF is widely used for the reconstruction of tympanic membrane perforations, with generally satisfying results. The fascia is flexible and has more or less the same thickness as a tympanic membrane (when properly prepared) [26]. It is also easily accessible, available in

Table 4 Complications of type 1 tympanoplasty

Grafting material	Complications	Type of management
Cartilage	Perforation ($n = 44$)	Conservative ($n = 6$)
		Surgical ($n = 18$)
		n.r. ($n = 20$)
	Retraction pocket ($n = 5$)	Conservative ($n = 2$)
		Surgical ($n = 3$)
	Myringitis ($n = 9$)	Conservative
		n.r. ($n = 60$)
	Granuloma ($n = 2$)	Conservative
	Otorrhea ($n = 6$)	Conservative
	Otitis externa ($n = 1$)	Conservative
	Tragal hematoma/infection ($n = 2$)	Surgical
Fascia	Perforation ($n = 84$)	Conservative ($n = 10$)
		Surgical ($n = 14$)
		n.r. ($n = 60$)
	Retraction pocket ($n = 6$)	Surgical
	Myringitis ($n = 15$)	n.r. ($n = 60$)
	Anterior blunting ($n = 2$)	Surgical
	Lateralization ($n = 1$)	Surgical
	Granuloma ($n = 2$)	Conservative
	Otorrhea ($n = 15$)	Conservative
	Otitis media with effusion ($n = 2$)	Surgical
	Otitis externa ($n = 2$)	Conservative

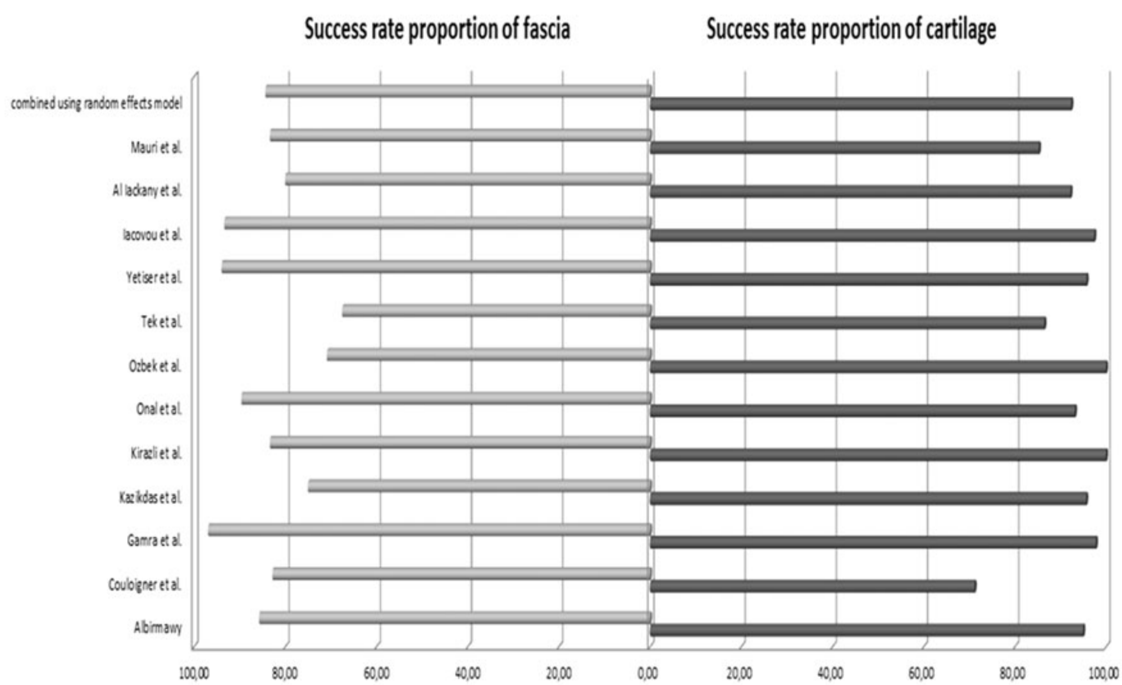
n.r. not reported

sufficient size, and can be trimmed to the desired dimensions. However, TMF is composed of irregularly arranged elastic fibers and fibrous connective tissue. Hence, it may demonstrate radical and unpredictable changes in shape, shrinking, or even thickening postoperatively [31].

Unlike fascia, cartilage demonstrates higher mechanical stability [32], considerable stiffness, and slower metabolism, and can therefore be considered a reliable grafting material [10, 18, 33]. Cartilage has a constant shape, it is firmer than fascia, lacks fibrous tissue [10], but shows high concentration of the highly resistant protein elastin [23]. These features help the postoperative dimensions of the graft to remain the same, and cover large perforations with stability. Moreover, at least in theory, cartilage grafting may prevent retraction pockets [21] and re-perforations, which may follow episodes of acute otitis media. Finally, harvesting cartilage graft is not more difficult than fascia, whether it is taken from the concha or the tragus [34–36].

However, concerns had been previously expressed that the rigid nature of the cartilage may theoretically impede with the sound-conducive properties of the tympanic membrane [14, 23, 37]. Indeed, Zahnert et al. [38] suggested that the ideal acoustic thickness of cartilage should be approximately 0.5 mm, instead of the standard full thickness cartilage graft (0.7–1 mm thick), to achieve optimal hearing results. However, thinning the cartilage makes the reconstruction process more difficult due to the most probable twisting of the cartilage. Hence, precise placement of the cartilage pieces, as well as a reduction in the number of palisades is required to successfully apply this technique [20]. Atef et al. [39] also concluded that slicing the cartilage to half its normal thickness added to the technical difficulties of the procedure without making a significant difference to the hearing gain, after analyzing the effect of cartilage disc thickness on hearing results following perichondrium–cartilage island flap tympanoplasty.

The present study, taking into account the results of over 1,000 patients and applying strict inclusion criteria, demonstrated that the graft integration rate is higher in the cartilage compared with the temporalis fascia group in type I tympanoplasty ($p < 0.05$; Figs. 1, 2). Indeed, 9 out of 12 analyzed studies reported a success rate of over 90 % in the cartilage patient group (Fig. 3). In contrast, most fascia patient groups had lower success rates, and only three fascia groups reported a success rate of over 90 % (Fig. 3). It should be noted that the majority of the analyzed studies were level III, with only one study representing level II, and one study representing level I evidence. The results from the level I study were suggestive of at least non-inferiority of cartilage compared with fascia in type I



	Albirmawy	Couloigner et al.	Gamra et al.	Kazikdas et al.	Kirazli et al.	Onal et al.	Ozbek et al.	Tek et al.	Yetiser et al.	Iacovou et al.	Al lackany et al.	Mauri et al.	combined using random effects model
success fascia proportion	85,71	82,76	96,90	75,00	83,33	89,58	70,83	67,50	93,94	93,33	80,00	83,33	84,32
success cartilage proportion	95,00	71,19	97,78	95,65	100,00	93,18	100,00	86,49	95,74	97,44	92,22	85,29	92,38

Fig. 1 Raw data for the success rate of cartilage versus temporalis fascia grafting in type 1 tympanoplasty (patient series)

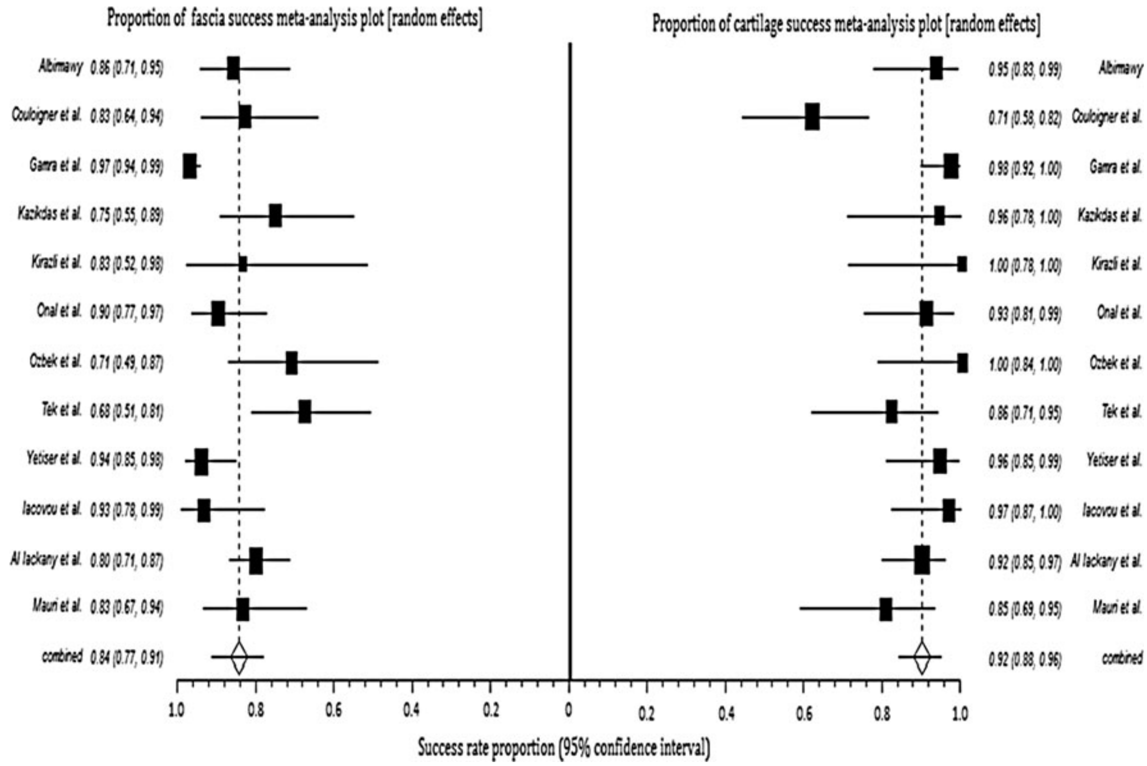
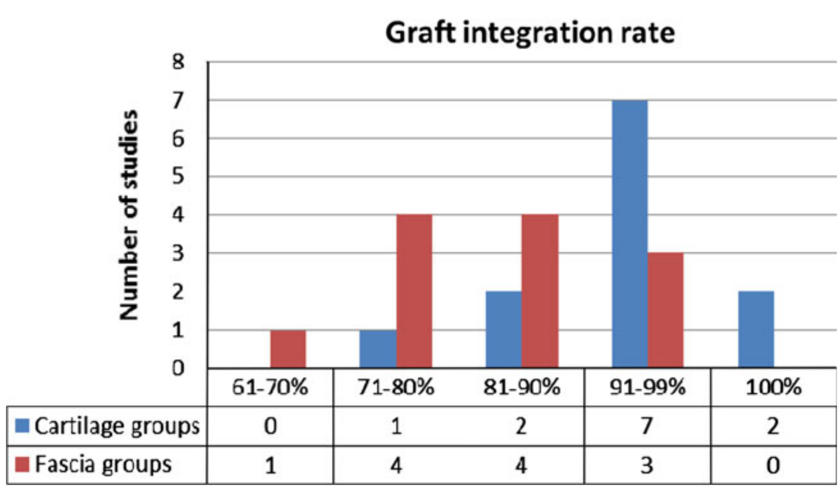


Fig. 2 Proportion meta-analysis plot for the success rate of cartilage versus temporalis fascia grafting in type 1 tympanoplasty (patient series). Temporalis fascia tympanoplasties are depicted on the *right*, and cartilage tympanoplasties on the *left* side of the *graph*

Fig. 3 Success rates in type 1 tympanoplasty by grafting material



tympanoplasties, whereas the quality of evidence from the remaining studies allows us to adopt a grade C strength of recommendation regarding the effectiveness of cartilage versus fascia in type I tympanoplasties (Table 2).

It should also be noted that two level III studies showed a significant difference between the pre- and postoperative air-bone gap closure, in favor of the cartilage grafting materials. Yetiser et al. [9] showed a statistically different postoperative air-bone gap of 14.2 ± 7.7 dB in the cartilage group as compared to 19.7 ± 12 dB in the fascia group ($p = 0.008$). Similar results were reported by Onal et al. [17], who found a mean postoperative air-bone gap of 12.08 ± 6.71 dB for the fascia group, and 9.33 ± 4.74 dB for the cartilage group. The difference was statistically significant ($p = 0.027$), even though the respective air-bone gap between the two graft materials did not differ pre-operatively ($p = 0.572$). However, the better hearing outcomes in these two studies should be weighed against the respective results of nine other studies, which did not report any statistically significant differences between the two

Table 5 Audiometric results in type I tympanoplasty (cartilage vs. temporalis muscle fascia)

Authors	Mean pre-/postoperative ABG (cartilage)	Mean pre-/postoperative ABG (TF)	Mean pre-/postoperative AC thresholds (cartilage)	Mean pre-/postoperative AC thresholds (TF)	Remarks
Iacovou et al. [23]	27.2 ± 6.6/ 9.1 ± 3.6 dB	26.6 ± 7.4/ 8.8 ± 4.5 dB	n.r.	n.r.	(a) 21–30 dB hearing gain in the AC thresholds was obtained in 65.8 % of patients in the cartilage versus 60.7 % of patients in the TF group (b) No statistically significant difference in the pre- and postoperative ABG was found between the two groups
Tek et al. [21]	23.87 ± 7.73/ 12.09 ± 5.9 dB	23.03 ± 8.95/ 13.11 ± 7.13 dB	35.12 ± 11.96/ 23.5 ± 9.54 dB	32.53 ± 10.46/ 23 ± 9.13 dB	(a) 11.62 ± 7.45 dB gain in the AC thresholds was found in the cartilage versus 9.44 ± 9.12 dB in the TF group (b) There is statistically significant difference between pre- and postoperative ABG and AC thresholds within but not between groups
Onal et al. [17]	22.01 ± 8.38/ 9.3 ± 4.74 dB	22.99 ± 8.09/ 12.0 ± 6.71 dB	34.72 ± 9.71/ 20.76 ± 8.63 dB	34.82 ± 10.94/ 21.65 ± 8.77 dB	(a) No statistically significant difference in the pre- and postoperative AC thresholds was found between the cartilage and TF groups (b) There was statistically significant difference between pre- and postoperative AC thresholds within the two groups (c) The ABG difference between the two groups was not statistically significant preoperatively, but proved statistically significant postoperatively
Albirmawy [15]	26.62 ± 1.73/ 10.95 ± 2.12 dB	25.98 ± 2.21/ 23.5 ± 3.3 dB	n.r.	n.r.	(a) There is statistically significant difference between pre- and postoperative ABG gain within, but not between groups (b) There is statistically significant difference between pre- and postoperative SRT gain within, but not between groups
Yetiser and Hidir [9]	12.7 ± 6.2/ 14.2 ± 7.7 dB	27.1 ± 10.4/ 19.7 ± 12 dB	38.6 ± 13.6/ 24 ± 9.8 dB	43.5 ± 13.1/ 14.5 ± 8.3 dB	(a) There is statistically significant difference between pre- and postoperative ABG between the cartilage and TF groups (b) There is statistically significant difference between pre- and postoperative AC thresholds between the cartilage and TF groups
Gamra et al. [16]	30 ± 6/ 16 ± 10 dB	36 ± 6/ 18 ± 7 dB	n.r.	n.r.	(a) The postoperative AC gain was not significantly different between the cartilage and TF groups (b) No statistically significant difference in the postoperative ABG was found between the two groups

Table 5 continued

Authors	Mean pre-/postoperative ABG (cartilage)	Mean pre-/postoperative ABG (TF)	Mean pre-/postoperative AC thresholds (cartilage)	Mean pre-/postoperative AC thresholds (TF)	Remarks
Ozbek et al. [20]	25.04 ± 2.1/ 25.58 ± 1.97 dB	10.33 ± 1.87/ 11.25 ± 9.58 dB	n.r.	n.r.	(a) There is statistically significant difference between pre- and postoperative ABG gain within, but not between groups (b) There is statistically significant difference between pre- and postoperative SRT gain within, but not between groups
Kazikdas et al. [19]	25.6 ± 8.6/ 17.3 ± 8.8 dB	30.7 ± 12.6/ 20.2 ± 12.1 dB	31.4 ± 10.7/ 22.4 ± 12.0 dB	42.2 ± 14.6/ 29.7 ± 17.0 dB	(a) The postoperative AC gain was not significantly different between the cartilage and TF groups (b) No statistically significant difference in the postoperative ABG was found between the two groups
Couloigner et al. [22]	n.r.	n.r.	24 ± 12[a], 21 ± 11[a], 19 ± 9[a], 20 ± 11[a,b]/ 19 ± 14[a], 15 ± 11[a], 14 ± 10[a], 20 ± 13[a,b]	29 ± 12[a], 23 ± 12[a], 20 ± 8[a], 24 ± 10[a]/ 19 ± 10[a], 16 ± 7[a], 13 ± 6[a], 16 ± 10[a]	There is statistically significant difference between pre- and postoperative AC thresholds within, but not between groups[b]
Kirazli et al. [18]	28.1 ± 8.8/ 16.2 ± 6.2 dB	30.4 ± 8.5/ 18.9 ± 5.4 dB	34.3 ± 12.5, 31.3 ± 11.7, 23 ± 8.4, 24 ± 11.8[a]/n.r.	35.5 ± 12.3, 33.5 ± 9.1, 30 ± 7, 26.6 ± 5.2[a]/n.r.	There is statistically significant difference between pre- and postoperative ABG gain within, but not between groups
Al lackany and Sarkis [24]	n.a.[c]	n.a.[c]	n.a.[c]	n.a.[c]	There is statistically significant difference between pre- and postoperative ABG gain between groups, in favor of the cartilage in total and subtotal, and the TF in cases of central perforation
Mauri et al. [25]	n.r.	n.r.	n.r.	n.r.	There is statistically significant difference between pre- and postoperative ABG gain within, but not between groups

ABG air-bone gap, *TF* temporalis fascia, *AC* air conduction, *n.r.* not reported, *SRT* speech recognition threshold, *n.a.* not available

[a] Data referring to the frequencies of 500, 1,000, 2,000, and 4,000 Hz, respectively

[b] No statistically significant difference; 4,000 Hz in the cartilage group is excluded

[c] Uniform results not available

methods of reconstruction, and an additional study, which showed improved results in the cartilage group in cases of subtotal and total tympanic membrane perforation, and better postoperative air-bone gap closure with fascia in cases of central perforation. Furthermore, most studies report statistically significant difference between the pre- and postoperative air conduction thresholds within but not between the cartilage and fascia groups (Table 5). The aforementioned discrepancies preclude us from drawing definite conclusions regarding the strength of the respective recommendations.

Previous studies had also reported a graft integration rate of 90–95 % for the first year after a type I tympanoplasty, and a rate of re-perforation of 10–15 % over the next 3–10 years [17, 18]. However, the results of the present study suggest that the relatively high rates of re-perforation may only apply for fascia myringoplasties (15.5 %), as the respective results in the cartilage group were found significantly lower (7.6 %, $p < 0.05$). Among the other complications of type I tympanoplasty, retraction pockets, otitis media with effusion, anterior blunting, and graft lateralization are usually surgically managed, whereas most of the rest are minor and can be dealt with conservatively (Table 4).

It should be mentioned that despite the calls for a wider use of cartilage in type I tympanoplasties [16, 18, 20], this grafting material is primarily used in cases of Eustachian tube dysfunction, adhesive otitis media, and subtotal perforation. Hence, there can be a selection bias when forming the respective comparison groups. The strict selection criteria in the present study limited the possibility of such bias, because all included patients had been randomly assigned to either grafting material, according to the detailed analysis of the materials and methods section of each included study. Based on the available data, the utilization of cartilage for the reconstruction of the tympanic membrane in type I tympanoplasties can, thus, be recommended.

Conclusion

The use of cartilage in type I tympanoplasty is associated with higher graft integration rates as compared to fascia reconstructions (grade C strength of recommendation). In addition, the obtained audiometric results appear to be at least comparable, and the rate of re-perforation is lower.

Although cartilage is primarily used as grafting material in cases of Eustachian tube dysfunction, adhesive otitis media, and subtotal perforation in everyday surgical practice, a wider utilization for the reconstruction of the tympanic membrane in myringoplasties can be considered.

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References

1. Shambaugh GE (1990) Closure of tympanic membrane perforations. In: Glasscock ME III, Shambaugh GE (eds) Surgery of the ear, 4th edn. W. B. Saunders, Philadelphia, pp 334–348
2. Nissen AJ, Nessen RL, Yonkers AJ (1986) A historical review of the use of bone and cartilage in otologic surgery. Ear Nose Throat J 65:493–496
3. Heermann H (1961) Tympanoplasty with fascial tissue taken from the temporal muscle after straightening the anterior wall of the auditory meatus. HNO 9:136–137
4. Storrs LA (1961) Myringoplasty with the use of fascia grafts. Arch Otolaryngol 74:45–49
5. Shea JJ (1960) Vein graft closure of eardrum perforations. Arch Otolaryngol 72:445–447
6. Tabb HG (1960) Closure of perforations of the tympanic membrane by vein grafts: a preliminary report of twenty cases. Trans Am Laryngol Rhinol Otol Soc 70:191–207
7. Preobrazhenski TB, Rugov AA (1965) The employment of preserved dura mater graft in tympanoplasty. Vestn Otorinolaringol 5:38–42
8. Albrite JP, Leigh BG (1966) Dural homograft (alloplastic) myringoplasty. Laryngoscope 76:1687–1693
9. Yetiser S, Hıdır Y (2009) Temporalis fascia and cartilage-perichondrium composite shield grafts for reconstruction of the tympanic membrane. Ann Otol Rhinol Laryngol 118:570–574
10. Levinson RM (1987) Cartilage–perichondrial composite graft tympanoplasty in the treatment of posterior marginal and attic retraction pockets. Laryngoscope 97:1069–1074
11. Mills RP (1997) Management of chronic suppurative otitis media. In: Booth JB, Kerr AG (eds) Scott-Brown's otolaryngology, 6th edn. Butterworth-Heinemann International Editions, Oxford, pp 3–5
12. Kerr AG, Byrene JET, Smyth GDL (1973) Cartilage homografts in the middle ear: a long term histologic study. J Laryngol Otol 87:1193–1199
13. Buckingham RA (1992) Fascia and perichondrium atrophy in tympanoplasty and recurrent middle ear atelectasis. Ann Otol Rhinol Laryngol 101:755–758
14. Dornhoffer JL (1997) Hearing results with cartilage tympanoplasty. Laryngoscope 107(8):1094–1099
15. Albirmawy OA (2010) Comparison between cartilage–perichondrium composite 'ring' graft and temporalis fascia in type one tympanoplasty in children. J Laryngol Otol 124(9):967–974
16. Gamra OB, Mbarek C, Khammassi K, Methlouthi N et al (2008) Cartilage graft in type 1 tympanoplasty: audiological and ontological outcome. Eur Arch Otorhinolaryngol 265:739–742
17. Onal K, Arslanoglu S, Oncel S, Songu M, Kopar A, Demiray U (2011) Perichondrium/cartilage island flap and temporalis muscle fascia in type I tympanoplasty. J Otolaryngol Head Neck Surg 40(4):295–299
18. Kirazli T, Bilgen C, Midilli R, Ogut F (2005) Hearing results after primary cartilage tympanoplasty with island technique. Otolaryngol Head Neck Surg 132(6):933–937
19. Kazikdas KC, Onal K, Boyraz I, Karabulut E (2007) Palisade cartilage tympanoplasty for management of subtotal perforations: a comparison with the temporalis fascia technique. Eur Arch Otorhinolaryngol 264:985–989
20. Ozbek C, Çiftci OE, Tuna EU, Yazkan O, Ozdem C (2008) A comparison of cartilage palisades and fascia in type 1 tympanoplasty in children: anatomic and functional results. Otol Neurotol 29:679–683
21. Tek A, Karaman M, Uslu C et al (2012) Audiological and graft take results of cartilage reinforcement tympanoplasty (a new technique) versus fascia. Eur Arch Otorhinolaryngol 269(4):1117–1126
22. Couloigner V, Baculard F, El Bakkouri W et al (2005) Inlay butterfly cartilage tympanoplasty in children. Otol Neurotol 26:247–251
23. Iacovou E, Vlastarakos PV, Panagiotakopoulou A et al (2012) Effect of type I tympanoplasty on the resonant frequency of the middle ear: comparison between chondrotympanoplasty and temporalis fascia grafting. J Otolaryngol Head Neck Surg 41(1):14–19
24. Al lackany M, Sarkis NN (2005) Functional results after myringoplasty and type 1 tympanoplasty with the use of different graft materials. J Med Res Inst 26:369–374
25. Mauri M, Lubianca Neto JF, Fuchs SC (2001) Evaluation of inlay butterfly cartilage tympanoplasty: a randomized clinical trial. Laryngoscope 111(8):1479–1485
26. Onal K, Arslanoglu S, Songu M, Demiray U, Demirpehlivan IA (2012) Functional results of temporalis fascia versus cartilage tympanoplasty in patients with bilateral chronic otitis media. J Laryngol Otol 126(1):22–25
27. Demirpehlivan IA, Onal K, Arslanoglu S, Songu M, Ciger E, Can N (2011) Comparison of different tympanic membrane reconstruction techniques in type I tympanoplasty. Eur Arch Otorhinolaryngol 268:471–474
28. Yung M, Vivekanandan S, Smith P (2011) Randomized study comparing fascia and cartilage grafts in myringoplasty. Ann Otol Rhinol Laryngol 120(8):535–541
29. Gerber MJ, Mason JC, Lampert PR (2000) Hearing results after primary cartilage tympanoplasty. Laryngoscope 110(12):1994–1999
30. Cabra J, Monoux A (2010) Efficacy of cartilage palisade tympanoplasty: randomised controlled trial. Otol Neurotol 31:589–595

31. Indorewala S (2002) Dimensional stability of free fascia grafts: an animal experiment. Laryngoscope 112(4):727–730
32. Neumann A, Kevenhoerster K, Gostian AO (2010) Long-term results of palisade cartilage tympanoplasty. Otol Neurotol 31(6):936–939
33. Aidonis I, Robertson TC, Sismanis A (2005) Cartilage shield tympanoplasty: a reliable technique. Otol Neurotol 26(5):838–841
34. Dornhoffer J (2000) Surgical management of atelectatic ear. Am J Otol 21:315–321
35. Dornhoffer J (2004) Cartilage tympanoplasty: indications, techniques and outcomes in a 1,000 patient series. Laryngoscope 113:1844–1856
36. Dornhoffer J (2006) Cartilage tympanoplasty. Otolaryngol Clin N Am 39:1161–1176
37. Puls T (2003) Tympanoplasty using conchal cartilage graft. Acta Otorhinolaryngol Belg 57:187–191
38. Zahnert T, Huttenbrink KB, Murbe D, Bornitz M (2000) Experimental investigations of the use of cartilage in tympanic membrane reconstruction. Am J Otol 21:322–328
39. Atef A, Talaat N, Moseleh M, Safwat S (2007) Effect of the thickness of the cartilage disk on the hearing results after perichondrium/cartilage island flap tympanoplasty. ORL 69:207–211
40. Shekelle PG, Woolf SH, Eccles M et al (1999) Clinical guidelines: developing guidelines. BMJ 318(7183):593–596