Long-term results of type I tympanoplasty with perichondrium reinforced cartilage palisade vs temporalis fascia for large perforations: A retrospective study

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A B S T R A C T
Objective: To compare the rate of graft uptake and postoperative hearing outcomes of Type I tympanoplasty with perichondrium reinforced cartilage palisade to temporalis fascia for large tympanic membrane (TM) perforations over 5 years follow-up period.

Materials and methods: This was a retrospective comparative study involving patients with chronic otitis media with large TM perforations. The patients underwent type I tympanoplasty using either perichondrium reinforced cartilage palisade (CP group) or temporalis fascia (TF group) as the graft via a transmeatal approach and under local anesthesia. Morphological and functional results were recorded at three- and five years follow-up. Demographic profiles including age and sex, surgery side, contralateral disease and graft uptake rate, as well as hearing outcomes, were compared between the two groups.

Results: At three years follow-up, graft uptake was 94.87% for perichondrium reinforced cartilage palisade and 80.7% for fascia, respectively, (p = 0.67). At five years follow-up, the uptake rate dropped to 87.17% in the CP group, but to 66.6% in the TF group (p=0.019). Hearing improved after surgery in both groups, and showed no significant difference between the two groups.

Conclusion: Over long-term, perichondrium reinforced palisade showed a statistically significant better outcome regarding graft uptake than temporalis fascia in type I tympanoplasty for large TM perforations with comparable audiometric results.

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1. Introduction

Tympanoplasty is a surgery performed to create an intact, near normal, dry and functional tympanic membrane, with middle ear aeration and mucosalization, as well as a functional ossicular chain (Vashishth et al., 2014a). Graft materials used for tympanoplasty have evolved over time. Initially, epidermal origin grafts such as skin were used. Later it shifted to mesodermal origin grafts such as veins and then to temporalis muscle fascia, perichondrium and composite grafts (Dornhoffer, 2006). For a long time, temporalis fascia has been one of the most frequently used graft material with an uptake rate of 85−100% (Aidonis et al., 2005). It is still being used and considered as the gold standard to compare against other graft materials (Cabra and Motux, 2010). Initial and delayed temporalis fascia graft failures are primarily related to infection, retraction pockets and technical errors (Amedee et al., 1989). Temporalis fascia is also found to undergo atrophy, shrinkage and unpredictable changes due to its irregular elastic and fibrous tissue composition, with potential subsequent failure, which has led to a search for a better option. Cartilage has therefore become a material of choice (Beutner et al., 2010).

Cartilage is resistant to retraction and resorption (Gérad et al., 2003). Currently, it is indicated in revision cases, cases with allergy issues, high-risk cases with bilateral perforations, large perforations, atelectatic middle ear cavity or cholesteatoma. The graft can be harvested either from the concha or tragus, depending on the surgeon’s choice (Puls, 2003).

There are different techniques for tympanoplasty with cartilage grafts described in the literature (Singh et al., 2019). Tos classified cartilage tympanoplasties in six groups. He showed 23 different techniques where tragal or conchal cartilage was used as palisades.
strips, slices, foils, thin or thick plates, cartilage—perichondrium composite island grafts, butterfly and crown corks, placed in an underlay, overlay or under-overlay fashion (Tos, 2008). It was Heermann from Germany who first described the cartilage palisade technique in 1962 (Kazikdas et al., 2007). It is one of the commonest techniques used with reported uptake ranging from 86 to 100% (Yung, 2008; Cabra and Monlux, 2010). In the Heermann technique, six to eight palisades are needed to close the perforation. Tos modified this technique to use only two or three 4–5 mm broad palisades to cover the entire perforation. We further modified the procedure by Tos and Heermann to use three to five palisades to cover the perforation. According to Tos, a gap between palisades is left open (Tos, 2008; Kazikdas et al., 2007). None of the articles has presented any issues regarding the gap. We used the Heerman technique at our center previously, but discontinued using this technique because of persistent presence of gaps between the palisades after the surgery, which became a risk factor for secondary infection. We later modified the technique by covering the palisades with perichondrium laterally in an underlay manner. The main goal was to reduce the gap and minimize the risk of failure due to the gap. There have been a few studies published on temporalis fascia reinforced with cartilage, but they are different from ours. Instead of fascia, we used perichondrium to avoid additional incisions. This is the first time such methods are reported in the literature. In this study, we evaluated the long-term morphological and functional results of perichondrium reinforced cartilage palisades with comparison to temporalis fascia at three- and five-years follow-ups.

2. Materials and methods

We conducted a retrospective comparative study of data from 110 cases that underwent surgery for large perforations from July 2013 to December 2014 in our hospital that met the inclusion criteria, using a trans-meatal approach. All procedures were done by a single surgeon (first author), who also made the decision on choice of graft materials (cartilage or fascia).

Of the 110 cases enrolled in the study, 15 were lost to follow-up during the five years follow-up period. Cases were divided into two groups, i.e. a perichondrium reinforced cartilage palisade (CP) group and a temporalis fascia (TF) group.

Inclusion criteria were chronic otitis media with large perforations (more than 50%) and 13 years of age or older (the minimum age for tympanoplasty under local anesthesia at our hospital). Cases with congenital craniofacial abnormalities (e.g., cleft palate), otorrhea, cholesteatoma, retractions or atelectasis, and revision cases were excluded from the study.

Before the procedure, the patient underwent detailed history taking, physical examination, and ear examination with an otoscope. An examination under the microscope was done before surgery. Temporal bone CT scan was not obtained as the diagnosis was straight forward. The study underwent ethical clearance by the institutional review board (No: 11/2019- 027-CSH). An informed consent for the surgery was received from each participant.

Audiological evaluation was performed seven days before the procedure and at three months post-surgery, with a second post-operative test at 12 months or later. The average pure tone threshold over 500, 1000, 2000 and 3000 Hz, as well as air bone gap (ABG), calculated as the difference between the average air and bone conduction thresholds, were obtained.

2.1. Surgical techniques

All cases were done via a trans-meatal approach under local anesthesia on a day case basis. The tragus was used as the graft donor site in the cartilage group and temporalis muscle fascia in the fascia group.

2.2. Perichondrium reinforced cartilage palisade tympanoplasty

Following initial assessment of the tympanic membrane and its pathology, the tragus was infiltrated with 2% lidocaine with epinephrine (1:200,000). An incision was made about 3 mm posterior to the dome of cartilage. Soft tissue and muscle fibers were dissected from the lateral surface of the cartilage to fully expose the cartilage laterally and medially. The graft site was left open after the composite perichondrium cartilage graft was obtained. The perichondrium attached to the anterior side of the tragal cartilage was removed, whereas perichondrium on the other side was preserved. The perichondrium was trimmed by removing muscle fibers attached to it.

An appropriate size aural speculum was kept in the ear canal. Under an operating microscope, the margin of perforation, as well as the under surface of the remnant tympanic membrane if present, was freshened with a straight needle. A standard tympanomeatal flap was lifted following an incision in the bony posterior canal wall about 5–6 mm lateral to the annulus. The middle ear condition was evaluated, and ossicular chain mobility assessed in all cases.

The middle ear was filled with gel foam. Cartilage palisades of appropriate sizes (usually 3–5 with perichondrium facing laterally) were prepared and placed first at the anterior margin parallel to handle of malleus and under the annulus using the over-underlay technique. This was then covered with perichondrium detached from the anterior side of tragus, which was kept medial to the annulus and handle of malleus using the underlay technique. The flap was laid back to the posterior canal, and pieces of antibiotic soaked gel foam were used to cover the graft and fill the external auditory canal (Fig. 1).

2.3. Temporalis fascia tympanoplasty

An ipsilateral transverse supra-auricular incision was made just above attachment of pinna, and temporalis fascia graft was harvested and any remaining attached muscular and soft tissue fibers were removed bluntly. The graft was dried up and trimmed into an appropriate size. It was then placed medial to the handle of malleus and remnant of the tympanic membrane in an underlay fashion.

2.4. Follow-up

Patients were given oral antibiotics (amoxicillin with clavulanic acid 625 mg TDS) for a week and analgesics ibuprofen 400 mg + paracetamol 500 mg TDS for three days and as needed in the postoperative period. On the sixth postoperative day, sutures for fascia graft and ear canal pack were removed. Follow-up was done on the sixth day, 12 weeks and six months postoperatively, and then yearly for five years. Postoperative audiological testing was done at 12 months follow up and repeated only at patient’s request or if patient reported change in hearing.

2.5. Analysis and statistics

Anatomical and functional outcomes in graft uptake and hearing results were analyzed. Fisher’s exact test, dependent and independent ‘t’ tests were conducted using the SPSS statistical package version 23.0 with the level of significance set at p < 0.05.

3. Results

Of the 110 cases, 8 in the CP group and 6 in the TF group were
lost to followed up over the five years. Thus, only 39 cases in the CP group and 57 cases in the TF group were included for analysis.

Demographic profiles of the groups are shown in Table 1. The mean age was 26.41 ± 7.27 in the CP group and 27.21 ± 10.81 in the TF group (p = 0.66). There were 10 males and 29 females in the CP group, and 24 males and 33 females in the TF group, respectively (p = 0.12). Similarly, the difference between the side of disease was not statistically significant (p = 1.00) between the two groups, although the disease was unilateral in 21 cases in the CP group but in 44 cases in the TF group, and bilateral in 18 cases in the CP group but in only 13 cases in the TF group, respectively, (p = 0.015).

Overall graft uptake in the 96 analyzed patients was 86.5% in the first three years and decreased to 75% for the five-year follow-up period. Uptake was 94.8% in the CP group in the first three years of

| Table 1 | Distribution of enrolled patients. |
|---------|-----------------------------------|
|         | Group CP          | Group TF       |
|         | Perichondrium Reinforced Cartilage Palisade, No. (%) | Temporalis Fascia, No. (%) |
| Enrolled | 47                | 63             |
| Lost to Follow up | 8                | 6             |
| Included | 39                | 57             |
| Age (Years) | Range      | Mean         | Range      | Mean         |
|           | 16–50         | 26.41 ± 7.27 | 13–55      | 27.21 ± 10.81 | p value 0.66 |
| Sex       | Male          | Female        | Male       | Female        |
|           | 10 (25.7%)    | 29 (74.3%)    | 24 (42.1%) | 33 (57.9%)    |
| Ratio     | 0.34          | p value 0.72  | p value 0.12 |
| Site      | Left          | Right         | Left       | Right         |
|           | 22 (59.4%)    | 17 (43.6%)    | 33 (57.9%) | 24 (42.1%)    |
| Ratio     | 1.29          | p value 1.00  | p value 0.12 |
| Disease   | Unilateral    | Bilateral     | Unilateral | Bilateral     |
|           | 21 (53.8%)    | 18 (46.2%)    | 44 (77.2%) | 13 (22.8%)    |
| Ratio     | 1.16          | p value 0.015 | p value 0.015 |
| Graft Status at 3 years | Uptake  | Failure     | Uptake  | Failure     |
|           | 37 (94.9%)    | 2 (5.1%)     | 46 (80.7) | 11 (19.3%)   |
| p value 0.67 |
| Graft Status at 5 years | Uptake  | Failure     | Uptake  | Failure     |
|           | 34 (87.2%)    | 5 (12.8%)    | 38 (66.7) | 19 (33.3%)   |
| p value 0.019 |

"F" Fisher exact test.
follow-up, compared to the 80.7% in the TF group ($p = 0.67$).

By the five-year follow-up, grafts in 3 patients from the CP group with initial uptake failed, reducing the group uptake rate to 87.17%. In comparison, grafts in 8 patients in the TF group with initial uptake failed, reducing group uptake rate to 66.6 ($p = 0.019$), suggesting better long-term outcomes with cartilage than fascia in graft uptake.

Hearing evaluation results are displayed in Table 2. Air conduction threshold was $44.07 \pm 11.82$ dB HL in the CP group and $43.99 \pm 10.75$ dB HL in the TF group, respectively, before surgery, and $30.20 \pm 15.35$ dB HL in the CP group and $28.95 \pm 14.41$ dB HL in the TF group postoperatively. The ossicular chain mobility was intact in all cases. Hearing significantly improved after surgery in both groups and showed no significant difference between the two groups, indicating little effects on hearing results by the type of graft used.

### Table 2

Hearing results.

|                      | Group CP | Group TF | $P$ value between the groups |
|----------------------|----------|----------|-----------------------------|
|                      | Perichondrium Reinforced Cartilage Palisade | Temporalis Fascia |                             |
| Included             | 39       | 57       |                             |
| Preoperative         | 44.07 ± 11.82 | 43.99 ± 10.75 | 0.975                        |
| ACT (dB)             |          |          |                             |
| Postoperative        | 30.20 ± 15.35 | 28.95 ± 14.41 | 0.689                        |
| $P$ value within group$^a$ |          |          |                             |
| Preoperative         | <0.0005  | <0.0005  |                             |
| ACT (dB)             | 24.35 ± 6.31 | 24.93 ± 7.72 | 0.688                        |
| Postoperative        | 13.25 ± 8.38 | 11.54 ± 7.76 | 0.316                        |
| $P$ value within group$^b$ |          |          |                             |
|                      | <0.0005  | <0.0005  |                             |

ACT: Air Conduction Threshold, ABG: Air Bone Gap.

$^a$ Paired 't' test, $^b$ Independent 't' test.

4. Discussion

Chronic otitis media is a long-standing middle ear infection that can lead to ear discharge and permanent changes in the tympanic membrane (Chemmangath et al., 2019). Treatment options include ear toileting, topical or systemic antibiotics, or surgery to eradicate disease and close the perforation (Dornhoffer, 1997). Even though otologists have been performing surgeries to treat this condition for more than five decades, the choice of graft and surgical techniques have always been a controversy. Nevertheless, surgical experience and personal preference of the surgeon plays a paramount role in repair approach selection (Özdamar and Sen, 2019).

Temporalis fascia has been one of the most frequently used graft materials because it is easily accessible, available in sufficient quantity, has a low metabolism, and its thickness resembles the normal tympanic membrane (Dornhoffer, 1997). However, the fascia consists of irregularly arranged elastic fibers and fibrous connective tissue and because of which its dimensions are unpredictable postoperatively (Yegin et al., 2016).

Cartilage grafting and its use in middle ear surgery is not the latest idea, and it has been widely accepted among ENT surgeons for the past few decades (Amdee et al., 1989). Its first use was reported almost more than a half-century ago. The causes of failure of tympanoplasty, especially with fascia as a graft, have been reported to include eustachian tube defect, adhesive otitis media, atelectatic ears, large/subtotal perforations and fibrosis in the middle ear. Large perforations have been a negative prognostic factor for the surgery (Dursun et al., 2020). In these high-risk cases, cartilage offers a better prognosis than fascia due to its escalated mechanical endurance under negative pressure in the tympanic cavity (Mürbe et al., 2002). However, many surgeons are reluctant to use cartilage as graft due to its mass and stiffness effect leading to alteration of acoustic transfer characteristics. Nevertheless, this has now been disproved by various studies. A study done by Zahner et al. recommended that the cartilage plate with a thickness of less than 0.5 mm bestowed the littlest acoustic transfer loss when the normal tympanic membrane was used as a reference (Zahner et al., 2000; Gamra et al., 2008). The greatest disadvantage now lies with its opacity, through which hidden cholesteatoma might not be visualized and might be missed (Spielmann and Mills, 2006).

Postoperative oitis media with effusion might be challenging to diagnose along with the difficulty of inserting a grommet after cartilage tympanoplasty (Dornhoffer, 2000, 2006).

The cartilage palisade technique was described and popularized by Heermann from Germany, and is also known as the Heermann technique. He used full-thickness cartilage strips with preserved perichondrium on the outer surface, deposited parallel to handle of malleus until they covered the middle-ear cavity completely (Heermann et al., 1970). The technique was modified by Tos where he increased the width of palisades from 4–5 mm and used only two to three of them (Kazikdas et al., 2007). However, our technique is a modification of both, in which we made three to five palisades of 3–4 mm in size, kept under the annulus and covered with perichondrium on the lateral side under the annulus and handle of malleus using the underlay technique. Tos left the gap between the palisades open and described that the gap would soon be covered with tissue fluid, over which epithelization would occur. He did not report any consequences regarding the gap. In comparison, we used perichondrium as reinforcement to cover the gaps and to decrease the risk of failure. Before this modification, when we used the traditional technique described by Heermann, the gap remained open and our unpublished records showed significant number of cases with failure and infection due to the gaps. Unfortunately, this has not been mentioned in any studies in the literature as a drawback. To the best of our knowledge, there has not been any study to describe the use of cartilage palisade reinforced with perichondrium in type I tympanoplasty.

Numerous studies have reported their results using the technique described by Heermann with modifications using full-thickness or split-thickness cartilage, but the follow-up was short (six months to one year) in most of the studies. With long-term follow-up, the success rate of tympanoplasty tends to be lower than with short-term follow-up (Yegin et al., 2016). Three studies reported results with follow-ups longer than five years. Velepic et al. (2012) studied 56 patients, including 44 adults and 12 children, with cartilage palisade grafts, and reported an uptake of 71.43% at 11 years follow-up. Cartilage resorption was seen in 25%
of the patients. Thomassen et al. (Cay-Thomassen et al., 2009) compared cartilage palisades and fascia in 32 children with cholesteatomatous chronic otitis media and reported an 87% graft uptake for palisades and 79% uptake for fascia at ten years follow-up. Neumann et al. (2010), on the other hand, claimed a 100% uptake after ten years with cartilage palisades. However, they studied only 29 patients. We showed better outcomes, with 94.9% uptake at three years and 87.2% uptake at five years, than those by Velepic and Thomassen, although our follow-up period was only about half compared to theirs. We need five more years of follow-up to claim robust perichondrium reinforcement outcomes over ten years. Besides, small sample size in our study is also a drawback that could affect the validity of our results, showing the need for a larger sample size study.

There are a few other studies with short follow-ups but without perichondrium reinforcement. Kazidka et al. (Tos, 2008) achieved a graft uptake rate of 95.7% (22/23) with cartilage palisades and 75% (21/28) with temporalis fascia for large perforations in a group of patients (mean age = 27.6 years) over a mean follow-up of 18.7 months, demonstrating a statistically significant difference between the two types of graft (p < 0.05). In a randomized and controlled trial including 64 patients using palisades and 59 using fascia grafts (mean age = 33 years), Vashisth et al. (2010) achieved a 92% graft uptake in those using palisades and 74.6% uptake in those using fascia over follow-ups of six months. The difference was statistically significant (p = 0.009).

The graft uptake rates obtained by Vashisth et al. (Vashishth et al., 2014b) was 83.3% in those using temporalis fascia and 90% in those using cartilage palisades, respectively, at one-year follow-up. Similarly, a prospective study by Pradhan et al. (2017) showed an 80% graft uptake in patients using fascia and 96.7% uptake in those using palisades for large/subtotal perforations at two years follow-up. Arora et al. had an uptake of 93% with fascia and 90% with palisades at six months follow-up in a prospective randomized study (Arora et al., 2017). These studies have higher uptake rates than ours, but over very short follow-up periods. A meta-analysis study was done by Jeffery et al. on cartilage palisades and concluded that they provided excellent graft uptake (Jeffery et al., 2017).

In our study, we found that the uptake rate of fascia grafts decreased as follow-up time increased, as compared to cartilage grafts. At five-year, the difference was statistically significant, which suggests that cartilage is superior to fascia for large perforations. A meta-analysis study was done by Jalali et al. (2017) on cartilage in comparison to fascia and revealed that graft amalgamation rates in tympanoplasty were 92% and 82% for cartilage and fascia, respectively. Of every 11 patients receiving cartilage, graft uptake was seen in one more patient than when fascia was used.

Some studies compared fascia and cartilage reinforced temporals fascia. These studies are similar to ours with regard to reinforcement. However, we combined cartilage reinforcement with perichondrium, instead of fascia. Tek et al. (2012) compared fascia in 37 patients with cartilage reinforced fascia in 40 patients and reported 100% uptake for cartilage reinforcement and 66% for fascia without reinforcement at six months follow-up. Similarly, Oacak et al. (2017) showed a 82.9% uptake in 82 patients with fascia only and 86.5% uptake in 97 patients with cartilage reinforced fascia at six months follow-up. Kouhi et al. (2018) reported an uptake of 93.4% in 346 patients using cartilage reinforced fascia and 91.6% in 320 patients using fascia only at two years follow-up. All these are retrospective studies with a short follow-up period, making their results weak. While our method is similar to the cartilage reinforced fascia technique other than using perichondrium instead of fascia, we think our technique is an improvement as graft harvesting can be completed in a single incision at the tragus, thus less risk for complications and less invasive than the two incisions required to harvest fascia and cartilage, with comparable graft uptake outcomes.

In our study, postoperative air conduction threshold (ACT) was $30.20 \pm 15.35$ dB HL for CP and $28.95 \pm 14.41$ dB HL for TF, respectively, compared to the $44.07 \pm 11.82$ dB HL and $43.99 \pm 10.75$ dB HL preoperatively. Because ossicular chain mobility was intact in all cases, the slightly higher preoperative ACT can be solely attributed to the large perforation as no other issues were found. In all above mentioned studies that compared cartilage with fascia grafts, hearing improved postoperatively with no significant difference noted between the grafts, similar to our results, which also showed postoperative hearing improvement regardless of grafts used.

There are a few limitations to this study. First, this is a retrospective comparative study, which decreases its level of evidence. It would be better to have a randomized comparative study with a similar or longer follow-up period. Secondly, this study has a small sample size resulting in a lack of generalizability of the findings. Thirdly, the decision to use palisade or temporals fascia grafts was solely a surgeon’s preference.

5. Conclusion

The use of perichondrium reinforced cartilage palisades in tympanoplasty was overall successful and superior to temporalis fascia for cases of large perforations, with improvement in therapeutic outcomes regarding graft uptake and comparable audimetric results. We therefore recommend perichondrium reinforced palisades as a meaningful tympanoplasty technique for closure of large perforations.

References

Aidonis, I., Robertson, T.C., Sismanis, A., 2005. Cartilage shield tympanoplasty: a reliable technique. Otol. Neurotol. 26 (5), 838–841. https://doi.org/10.1097/01.mao.0000185046.38900.1f.

Amedee, R.G., Mano, W.J., Riechelmann, H., 1989. Cartilage palisade tympanoplasty. Am. J. Otol. 10 (6), 447–450. https://doi.org/10.3317/0196-0709-19891006-00006.

Arora, N., Passey, J.C., Agarwal, A.K., Bansal, R., 2017. Type I tympanoplasty by cartilage palisade and temporalis fascia technique: a comparison. Indian J. Otolaryngol. Head Neck Surg. 63 (3), 380–384. https://doi.org/10.1007/s12070-017-1137-y.

Beutner, D., Hutterbrink, K.B., Stumpf, R., 2010. Cartilage plate tympanoplasty. Otol. Neurotol. 31 (1), 105–110. https://doi.org/10.1097/MAO.0b013e3181db35e.

Cabra, J., Moisux, A., 2010. Efficacy of cartilage plate tympanoplasty: randomized controlled trial. Otol. Neurotol. 31 (4), 589–595. https://doi.org/10.1097/MAO.0b013e3181d95e48.

Cay-Thomassen, P., Andersen, J., Uzun, C., Hansen, S., Tos, M., 2009. Ten-year results of cartilage palisades versus fascia in eardrum reconstruction after surgery for sinus or tesa retraction cholesteatoma in children. Laryngoscope 119 (5), 944–952. https://doi.org/10.1002/lary.21915.

Chenmangath, N., Aroor, R., Pratap, D., Bhat, V., 2019. A comparative study between haemococagulase and adrenaline in type 1 tympanoplasty. J. Otolaryngol. 14 (3), 117–120. https://doi.org/10.1016/j.jote.2019.02.002.

Dornhoff, J.L., 1997. Hearing results with cartilage tympanoplasty. Laryngoscope 107 (8), 1094–1099. https://doi.org/10.1097/0005537-199708000-00016.

Dornhoff, J.L., 2000. Surgical management of the atelectatic ear. Am. J. Otol. 21 (3), 315–321. https://doi.org/10.3164/oto.2000.21.3.315.

Dornhoff, J.L., 2006. Cartilage tympanoplasty. Otolaryngol. Clin. 39 (6), 1161–1176. https://doi.org/10.1016/j.otorc.2006.08.006.

Dursun, E., Terzi, S., Demir, E., et al., 2020. The evaluation of prognostic factors in endoscopic cartilage tympanoplasty [published online ahead of print, 2020 Apr 27]. Eur. Arch. Oto-Rhino-Laryngol. https://doi.org/10.1007/s00405-020-05952-y. Gama, O.B., Mbarak, C., Khamaasii, K., et al., 2008. Cartilage graft in type I tympanoplasty: audiological and otological outcome. Eur. Arch. Oto-Rhino-Laryngol. 265 (7), 739–742. https://doi.org/10.1007/s00405-008-0645-5.

Gérard, J.M., Decat, M., Gersdorff, M., 2003. Tragal cartilage in tympanic membrane reconstruction. Acta Oto-Rhino-Laryngol. Belg. 57 (2), 147–150.

Heermann Jr., J., Heermann, H., Kopstein, E., 1970. Fascia and cartilage palisade
tympanoplasty. Nine years’ experience. Arch. Otolaryngol. 91 (3), 228–241. https://doi.org/10.1001/archotol.1970.00770043034004.

Jalali, M.M., Motasaddi, M., Kouhi, A., Dabiri, S., Soleimani, R., 2017. Comparison of cartilage with temporalis fascia tympanoplasty; a meta-analysis of comparative studies. Laryngoscope 127 (9), 2139–2148. https://doi.org/10.1002/lary.26451.

Jeffery, C.C., Shillington, C., Andrews, C., Ho, A., 2017. The palisade cartilage tympanoplasty technique; a systematic review and meta-analysis. J Otolaryngol Head Neck Surg 46 (1), 48. https://doi.org/10.1186/s40463-017-0225-z. Published 2017 Jun 17.

Kazikdas, K.C., Onal, K., Boyraz, I., Karabulut, E., 2007. Palisade cartilage tympanoplasty for management of subtotal perforations: a comparison with the temporalis fascia technique. Eur. Arch. Oto-Rhino-Laryngol. 264 (9), 985–989. https://doi.org/10.1007/s00405-007-0291-3.

Kouhi, A., Khorsandi Ashthiani, M.T., Jalali, M.M., 2018. Results of type I tympanoplasty using fascia with or without cartilage reinforcement: 10 Years’ experience. Iran J Otorhinolaryngol 30 (97), 103–106.

Mürbe, D., Zahnert, T., Bornitz, M., Hüttenbrink, K.B., 2002. Acoustic properties of different cartilage reconstruction techniques of the tympanic membrane. Laryngoscope 112 (10), 1769–1776. https://doi.org/10.1097/00005537-200210000-00012.

Neumann, A., Kevenhoerster, K., Gostian, A.O., 2010. Long-term results of palisade cartilage tympanoplasty. Otol. Neurotol. 31 (6), 936–939. https://doi.org/10.1097/MAO.0b013e3181e7497.

Ocak, E., Beton, S., Taş, V., Meço, C., 2017. Cartilage reinforcement graft versus fascia graft in tympanoplasty. Turk. J. Med. Sci. 47 (4), 1124–1127. https://doi.org/10.3906/sag-1602-151. Published 2017 Aug 23.

Ozdamar, K., Sen, A., 2019. Comparison of temporal muscle fascia and tragal cartilage perichondrium in endoscopic type 1 tympanoplasty with limited elevation of tympanomeatal flap [published online ahead of print, 2019 Jul 27]. Braz J Otorhinolaryngol 51808—8094 (19), S0003-3087. https://doi.org/10.1016/j.bjorl.2019.06.014.

Pradhan, P., Anant, A., Venkatachalam, V.P., 2017. Comparison of temporalis fascia and full-thickness cartilage palisades in type-I underlay tympanoplasty for large/subtotal perforations. Iran J Otorhinolaryngol 29 (91), 63–68.

Puls, T., 2003. Tympanoplasty using conchal cartilage graft. Acta Oto-Rhino-Laryngol. Belg. 57 (3), 187–191.

Singh, S.P., Nagi, R.S., Singh, J., 2019. To compare short and long-term graft uptake and hearing outcome of type I cartilage tympanoplasty between small, medium and large perforations using reinforced sliced conchal cartilage. Indian J. Otolaryngol. Head Neck Surg. 71 (4), 550–556. https://doi.org/10.1007/s12070-019-01727-4.

Spiehmann, P., Mills, R., 2006. Surgical management of retraction pockets of the pars tensa with cartilage and perichondrial grafts. J. Laryngol. Otol. 120 (9), 725–729. https://doi.org/10.1017/s0022215106007108.

Tek, A., Karaman, M., Uslu, E., et al., 2012. Audiological and graft take results of cartilage reinforcement tympanoplasty (a new technique) versus fascia. Eur. Arch. Oto-Rhino-Laryngol. 269 (4), 1117–1126. https://doi.org/10.1007/s00405-011-1779-4.

Ton, M., 2008. Cartilage tympanoplasty methods: proposal of a classification. Otolaryngol. Head Neck Surg. 139 (6), 747–758. https://doi.org/10.1016/j.otohns.2008.09.021.

Vashishth, A., Mathur, N.N., Verma, D., 2014a. Cartilage palisades in type 3 tympanoplasty: functional and hearing results. Indian J. Otolaryngol. Head Neck Surg. 66 (3), 309–313. https://doi.org/10.1007/s12070-014-0717-3.

Vashishth, A., Mathur, N.N., Choudhary, S.R., Bhardwaj, A., 2014b. Clinical advantages of cartilage palisades over temporalis fascia in type I tympanoplasty. Auris Nasus Larynx 41 (5), 422–427. https://doi.org/10.1016/j.anl.2014.05.015.

Velepic, M., Starcevic, R., Ticac, R., Kujundzic, M., Velepic, M., 2012. Cartilage palisade tympanoplasty in children and adults: long term results. Int. J. Pediatr. Otorhinolaryngol. 76 (5), 663–666. https://doi.org/10.1016/j.ijporl.2012.01.036.

Yegin, Y., Yiyici, Z.M., Celiik, M., Guven, S., Sayin, I., Kayhan, F.T., 2016. Comparison of temporalis fascia muscle and full-thickness cartilage grafts in type 1 tympanoplasties. Int. J. Clin. Exp. Med. 9, 8731–8736.

Yung, M., 2008. Cartilage tympanoplasty: literature review. J. Laryngol. Otol. 122 (7), 663–672. https://doi.org/10.1016/j.jlary.2008.01.018.

Zahnert, T., Hüttenbrink, K.B., Mürbe, D., Bornitz, M., 2000. Experimental investigations of the use of cartilage in tympanic membrane reconstruction. Am. J. Otol. 21 (3), 322–328. https://doi.org/10.1016/s0196-0709(00)80039-3.