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Different Graft Materials used in Middle Ear Reconstruction

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ABSTRACT

Middle ear reconstruction is a surgical intervention employed to reinstate auditory function in individuals experiencing conductive hearing loss. Several different graft materials have been used to fix holes in the tympanic membrane, such as temporalis fascia, cartilage, perichondrium, periosteum, vein, fat, and skin. This study compares the effectiveness of these graft materials in achieving successful hearing outcomes. The results show that cartilage grafts offer improved durability and resistance to reabsorption, while temporalis fascia grafts have lower-dimensional stability. Palisade cartilage and cartilage island techniques enhance graft strength but may compromise hearing restoration. The success of graft depends on factors such as patient smoking habits, perforation size and location, surgeon expertise, and middle ear mucosa status. This study provides a comprehensive analysis of graft materials in middle ear reconstruction, highlighting the advantages and limitations of each material to inform surgical decision-making.

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Introduction

The middle ear plays a important role in transmitting sound vibrations from the tympanic membrane to the stapes footplate, leveraging the harmonious functioning of the tympanic membrane, osiers, and oval window to bridge the impedance mismatch between the air-filled outer ear canal and the fluid-filled cochlea. However, in individuals with conductive hearing loss, this delicate sound conveyance process is disrupted, leading to a reduced transmission of external sound to the inner ear. To resolve this problem, ossiculoplasty is conducted to repair the middle ear structures experiencing functional impairment surgically. Autologous grafts or alloplastic passive middle ear implants (PMEIs) can also be employed for this purpose. Tympanoplasty is a surgical treatment for restore hearing and protect the ear from infections by transplanting tissue to patch a ruptured tympanic membrane (TM) [1,2].

This surgical technique was developed by Wullstein H and Sergi B et al. and later refined by Zöllner F, who built upon their foundational work to improve the procedure [3-5]. The evolution of grafting materials in tympanoplasty has been marked by significant milestones.

Temporalis fascia use as a grafting in tympanoplasty was first introduced by Heerman J. Jr. et al. [6]. Later, Tabb and Shea experimented with forearm vein grafts, while Garcia-Ibanez proposed tragus perichondrium in 1960. Later, Goodhill V (1967) pioneered the technique of using tragal cartilage with perichondrium for grafting [7]. Cartilage grafts gained popularity, particularly in advanced middle-ear cases, due to their rigidity and resistance to reabsorption. Altenau MM and Sheehy JL also explored the use of tragus grafts, double perichondrium, and cartilage with perichondrium [8]. Since then, a variety of other materials have been explored for repairing tympanic membrane perforations, including periosteum, fat, vein, dura, and skin [9].

Notable contributions include Eviatar A's extensive review in 1978, Brockman SJ's the use of cartilage in type III myringoplasty in 1995, and Eavey RD's cartilage plug technique in 1998 [10,11]. Further refinements and excellent auditory results have been reported by Luibianca-Neto JF, Sperling NF and Kay D, Gerger MJ et al, Danner CJ and Dornhoffer JL et al, solidifying the importance of cartilage grafts in primary tympanoplasty. Tympanoplasty procedures typically employ one of three surgical approaches: endomeatal, endaural, or postauricular [12-17]. The tympanoplasty surgery and extent hearing restoration to be influenced by numerous factors, like size, location, & characteristics of the perforation, also the type of graft material selected for the repair. These variables can impact the outcome of the procedure, highlighting the importance of careful consideration and individualized approach in each case [18].

Temporalis Fascia

Surgeons generally opt for the authentic temporalis fascia as a graft due nearly operative location & ease of acquisition. Hence, the effectiveness of temporalis fascia as a graft, some surgeons prefer to reserve the thicker, more durable fascia for revision cases and instead use the loose areolar fascia of the temporalis muscle for primary tympanoplasty procedures, likely due to its ease of harvest and sufficient graft quality. In a study by Deshmukh PT et al. 71.19% of patients who had temporalis fascia graft reconstruction exhibited effective graft uptake, indicating that both cartilage & temporalis fascia are feasible choices for repairing the TM due to their easily accessible availability [19,20]. The results suggest that these materials can be efficiently utilized for tympanic membrane repair, providing encouraging results for patients undergoing tympanoplasty.

Temporalis Fascia and Canal Skin Grafts

Sheehy JL et al. performed to asses the impact of two graft materials, canal skin and temporalis fascia, in closing tympanic membrane (TM) perforations [21]. The results showed that temporalis fascia outperformed canal skin for graft & hearing outcomes, indicating that temporalis fascia may be a more suitable choice for TM perforation repair.

Cartilage Grafts

Cartilage is a dependable graft for reconstructing the tympanic membrane because it receives nourishment by diffusion and integrates well into the membrane. The thickness of cartilage provides greater resistance to anatomic distortions produced by negative middle ear pressure compared to fascia. This improves the long-term integrity of the graft. Most surgeons often choose cartilage grafts in revision situations because of their strong and durable nature [22]. However, there is a continuous debate about their functional capacities.

Zahnert T et al. observed the acoustic properties and mechanical stability of cartilage from the cavum conchae and tragus, exploring its potential for use in tympanic membrane reconstruction [23]. Cartilage specimens from human cadavers were tested for Young's modulus, acoustic transfer characteristics, and mechanical stability. The results showed that both types of cartilage had similar mechanical properties, but conchal cartilage exhibited slightly better acoustic transfer qualities, particularly in the mid-frequency range. Thinner cartilage (≤500 μm) demonstrated improved acoustic transfer properties, striking a balance between mechanical stability and minimal acoustic transfer loss. The study concludes that both conchal and tragal cartilage are suitable for tympanic membrane reconstruction, with a recommended thickness of 500 μm for optimal performance. Heo KW et al. examined the effectiveness of cartilage shield grafts (CSG) in type I tympanoplasty (TP) for patients with poor prognostic factors, such as large perforations, previous surgeries, or adhesive otitis media [24]. The results showed significant enhancement in hearing, with a reduced mean postoperative air-bone gap, and a high safety profile, with a low incidence of complications, including perforation (2.1%), otorrhea (6.4%) and one patient reported autophonia and ear fullness. The study concluded that type I TP using CSG is a highly impactful procedure, even for subjects with inefficient prognostic factors, and considered as a treatment option. Bhojani D. et al. examined the anatomical outcomes and hearing improvement associated with different types of tympanoplasty procedures utilizing conchal cartilage [25]. Out of the 100 patients, there was an mean perfection of 13.33 dB in both PTA and ABG (air-bone gap). However, there was mean loss of 32.15 dB in PTA and 16.43 dB in ABG.

Pandey AK et al. retrospective analysis was undertaken on 25 patients of combined approach tympanoplasty (CAT) with attic wall repair using free auricular cartilage and fibro-periosteal tissue [26]. The study sought to assess the anatomical and functional in innovative approach. The observation revealed a morphological improvement rate of 88%, with successful graft uptake in 22 cases. Audiological outcomes improved significantly, with a reduction in air conduction threshold (ACT) and air-bone gap (ABG) post-operatively. Complications included otorrhea, recurrence, and no hearing improvement in a few cases. The study concludes that this reconstruction method is effective in preventing postoperative retractions and yields satisfactory morphological and audiological results, making it a viable option for attic and posterosuperior canal wall reconstruction in CAT. In another study by ElTaher M et al., the patients underwent myringoplasty, a surgical procedure in which the mastoid cortex periosteum was used via the postauricular route, employing the underlay technique [27]. Prior to and after surgery, a pure tone audiometry test was conducted, and patients were monitored for a minimum of 12 months. The results showed a 93% anatomical success rate, comparable to other grafting materials, and a significant improvement in hearing with a mean gain of 11 dB ($p < 0.001$). The study concludes that the periosteal graft is a suitable option for myringoplasty, offering easy harvesting and application, excellent anatomical and functional success, and significant hearing improvement.

Yurttas V et al. assessed the impact of cartilage island material in tympanoplasty, yielding impressive results. The cartilage grafts achieved a remarkable 93% success rate in closing perforations, with no instances of graft lateralization or displacement. Furthermore, the procedure significantly improved hearing outcomes, as evidenced by a mean reduction in air-bone gap from 37.27 dB preop to 27.58 dB postop. The findings suggest that when cartilage grafts are meticulously prepared and implanted, they lead to enhanced success rates and improved auditory outcomes in cartilage graft tympanoplasty, with sustained benefits observed over a average follow-up period of 15.3 months [2]. Jeffery CC et al. assessed the effectiveness of palisade cartilage and found palisade cartilage tympanoplasty demonstrates high graft success rates and favorable hearing observations in the postoperative period for perforations of different diameters, including both initial and revision cases. This procedure yields consistent and enduring outcomes with minimal occurrence of complications; comparable to temporalis is fascia tympanoplasty [28].

Temporalis Fascia Versus Cartilage

Mucha S et al. investigated the effectiveness of two graft materials, temporalis fascia and tragal cartilage, in type-1 tympanoplasty [19]. A total of 80 participants underwent the surgical procedure, with the cohort evenly split in 2 gr oups: 40 patients received temporalis fascia grafts, while the remaining 40 patients received tragal cartilage grafts. This comparative study aimed to evaluate the outcomes and potential benefits of using these two different graft materials in tympanoplasty. Follow-up evaluations were performed at the 3rd, 6th, and 12th months after surgery to examine the condition of the graft and any improvements in hearing. The findings indicated no disparity in outcomes into the 2 groups, as seen by similar rates of successful grafts and improvements in hearing. Nevertheless, the group that had cartilage treatment exhibited a higher percentage of success in terms of anatomical outcomes.

Kazikdas KC et al. The study revealed a notable difference in graft integration success rates in the two groups, with the palisade cartilage group achieving a high success rate of 95.7% compared to the temporalis fascia group, which had a success rate of 75% ($P = 0.059$). However, when examining the functional outcomes [29]. This suggests that while the palisade cartilage group had a higher graft integration success rate, both methods yielded comparable hearing outcomes.After the surgery, the use of the palisade cartilage technique led to successful outcomes, as indicated by improvements in the average difference between air and bone conduction and the threshold for speech reception. The palisade cartilage method is an excellent treatment for partial or complete perforations that have a high likelihood of transplant failure. This method enables a long-lasting and resilient repair of the eardrum, leading to satisfactory hearing results.

Demirpehlivan IA et al. performed a comparative analysis of the temporal muscle fascia, perichondrium/cartilage island flap, and cartilage palisades. A study including 120 subjects investigated the utilization of various grafting materials for tympanoplasty [30].

These materials included temporal muscle fascia (55.8%), perichondrium/cartilage island flap (28.3%), and cartilage palisades (15.8%). The pre and postoperative exams revealed a graft uptake 85%. The group with perichondrium/cartilage island flaps had the high successful graft integration rate 97.7%. In comparison, the fascia group had a rate of 80.6% and the cartilage palisades

group had a rate of 79.0%. In addition, the group of patients who received the perichondrium/cartilage island flap procedure experienced better hearing results. Their average hearing level before the surgery was 36.36 dB, and after the surgery, it improved to an average of 24.54 dB. This study presents evidence of the efficacy of various grafting materials in tympanoplasty, with the perichondrium/cartilage island flap exhibiting the best rate of successful graft integration and resulting in improved hearing outcomes. Based on the findings, cartilage grafting emerges as a more advantageous choice for initial tympanoplasties, owing to its notable efficacy, long-lasting nature, and minimal re-perforation rates. Consequently, it becomes the favored option for surgeons.

An analysis by Mohamad SH et al. compared cartilage and temporalis fascia tympanoplasty outcomes, finding no significant difference in hearing outcomes between the two [31]. However, cartilage tympanoplasty had a lower revision rate (10%) compared to fascia tympanoplasty (19%). Additionally, cartilage tympanoplasty showed better morphological outcomes, such as graft stability and appearance, than fascia tympanoplasty. Overall, while both grafts had similar hearing outcomes, cartilage may be a preferred choice due to its lower revision rate and better morphological results. A study by Lee JC et al. examined the efficacy of various grafting materials for the treatment of substantial middle ear granulation [32]. In a study involving 40 patients, the researchers examined and compared the effectiveness of temporalis fascia, cartilage island flaps, and cartilage palisades. Although all three materials exhibited high rates of graft take, both cartilage island flaps and palisades achieved a flawless success rate.

While cartilage palisades demonstrated some benefits, they were associated with relatively inferior hearing outcomes, characterized by modest improvements in air-bone gaps. In contrast, both temporalis fascia and cartilage island flaps yielded more impressive hearing results, with a notable 50% of patients in each group experiencing substantial reductions in air-bone gaps. These findings suggest that temporalis fascia or cartilage island grafting may be a superior strategy for tympanoplasty in cases complicated by severe middle ear granulation, potentially offering better auditory outcomes for patients with this challenging condition.

Rasool S. et al. sought to compare the effectiveness of two surgical techniques, palisade cartilage tympanoplasty and temporalis fascia tympanoplasty, in treating patients with chronic suppurative otitis media (CSOM) complicated by sclerotic mastoids [33]. The primary objective was to assess the efficacy of these two approaches in managing this challenging condition, with a focus on determining which method yields better outcomes in terms of hearing restoration, disease resolution, and overall patient benefit. A total of 125 patients were randomly assigned to two groups. One group received palisade cartilage tympanoplasty, while the other group received temporalis fascia tympanoplasty. Both groups also underwent a cortical mastoidectomy. The findings demonstrated substantial improvement in hearing for both groups, with comparable hearing outcomes after the surgical procedure. The rate of successful graft integration was 86% in the palisade cartilage group and 92% in the temporalis fascia group, with no statistically significant disparity between the two. The study shows that palisade cartilage tympanoplasty is a feasible substitute for conventional tympanoplasty in patients with chronic suppurative otitis media (CSOM) and sclerotic mastoids, providing similar hearing results and success rates in grafting.

Shishegar M et al. revealed a notable difference in graft acceptance rates between the two groups [34]. In the palisade cartilage tympanoplasty group, the researchers observed a remarkable 100% acceptance rate of the graft, indicating a highly successful outcome. In contrast, the temporalis fascia group showed a slightly lower acceptance rate of 92.5%. Although this discrepancy might suggest a potential advantage of the palisade cartilage technique, the researchers cautiously noted that their data did not reach statistical significance, emphasizing the need for further investigation to confirm these findings and establish clinical significance.

Fascia Lata Graft

Although fascia lata is not a commonly preferred graft material, Indorewala S et al. selected it for their study due to promising results from a previous comparative analysis [35]. This earlier study had investigated the dimensional stability of fascia lata grafts versus temporalis fascia grafts in both animal and human subjects, yielding encouraging outcomes. Building on these findings, the researchers designed a prospective study to further evaluate the dimensional stability of both temporal fascia and fascia lata grafts in mastoid cavity surgery, enrolling 11 patients in the investigation. This deliberate choice of graft material and rigorous study design aimed to provide valuable insights into the effectiveness of fascia lata as a viable alternative for grafting procedures.Following the process of harvesting and implanting the grafts, they were subsequently extracted five days later and assessed for any alterations in size. The findings indicated that temporal fascia grafts had worse dimensional stability in comparison to fascia lata grafts, thereby corroborating earlier observations in animal investigations. The absence of stability could potentially lead to the ineffectiveness of tympanic membrane perforation closures and non-tympanoplasty, indicating that fascia lata grafts may offer a more dependable alternative for this surgical procedure. Both animal and human studies have shown that the fascia lata graft exhibits superior dimensional stability when compared to the temporalis fascia. The findings of this study indicate that the lack of consistent size and shape of temporalis fascia grafts can significantly hinder the successful closure of tympanic membrane perforations during tympanoplasty procedures, especially when dealing with larger perforations [7].

Vein Graft Tympanoplasty

A significant milestone in otology was achieved with the introduction of medial grafting, a pioneering technique for repairing the tympanic membrane. In 1960, John Shea revolutionized the field by developing the medial graft technique and exploring the use of venous grafts for tympanoplasty. His innovative approach built upon his earlier success using vein grafts to repair the oval window after stapedectomy, which he cleverly adapted to also mend perforations in the tympanic membrane. This breakthrough discovery expanded the possibilities for effective tympanic membrane repair, marking a notable advancement in the field of otology.

During that period, tympanoplasty commonly used the use of skin grafts, which were positioned laterally to the annulus of the tympanic membrane. Positioning the graft on the inner side of the tympanic membrane annulus resulted in a more effective surgical procedure and prevented the potential problems linked to placing the graft on the outer side, such as blunting and lateralization. The implementation of vein grafts in tympanoplasty led to a significant change in methodology, transitioning from lateral to medial grafting. This change opened the door for numerous advancements in tympanoplasty over several decades. The annular ligament surrounding the stapes footplate measures 0.2 mm2

and contains elastic fibers that tightly regulate the movement of perilymphatic fluids, protecting the delicate structures of the inner ear from potential damage [36]. However, if this ligament's resistance is exceeded, inner ear harm can occur. In otosclerosis surgery, a vein graft is used to occupy the 0.2 mm2 space between the stapedotomy hole and the piston, mimicking the compliance and resistance of the annular ligament. Over time, the vein graft integrates with the middle-ear mucosa, develops a rich blood supply, and retains its smooth muscle cells and elastic fibers, which may undergo some ultrastructural changes. The graft becomes covered by middle-ear epithelium, and even after many years, it still contains surviving elastic fibers, with an increase in their number due to fibroblast activity, which produces a lightly colored collagen [37].

Fat Myringoplasty

Adipose tissue from various sources, including the ear lobule, abdominal wall, and buttocks, has been used for fat grafting in tympanic membrane repair. Introduced by Ringenberg in 1962, this method involves using fat cells to close perforations in the tympanic membrane. Research has shown that ear lobule fat is more compact and contains more fibrous tissue, making it a stronger scaffold for graft retention [38,39]. Postoperatively, the fat graft bulges for three months before being replaced by a smooth sclerotic area. Two theories explain the histological changes: the host cell replacement theory, where all original cells die and are replaced, and the cell survival theory, where some original cells survive with an adequate blood supply [40]. Fat myringoplasty is a simple, cost-effective, and outpatient procedure that avoids complications associated with traditional techniques, making it a promising alternative for anterior perforations. Further fat myringoplasty (FM) offers the advantage of being performed in an office setting under local anesthesia, making it a relatively safe and minimally invasive procedure [41]. This approach reduces the risk of otologic trauma associated with tympanic cavity manipulation. Additionally, FM allows for bilateral surgery and requires minimal postoperative care. The procedure's success rates vary depending on the size and location of the perforation, with higher closure rates achieved for small (93.7%) and posterior (90.5%) perforations, compared to large (70.7%) and anterior (67.7%). However, revision cases have shown poorer outcomes (52.9%) [42].

In a clinical trial conducted by Hegazy HM, the effectiveness of fat grafting was assessed for treating tiny tympanic membrane perforations resulting from trauma, infection, post-tympanostomy tube extraction, and post-myringoplasty residual perforations [43]. The study revealed an 88.2% success rate, accompanied by an average improvement of 15 dB in the air-bone gap. The success rate shows variability depending on the reason for perforation, with a range of 86.6% to 90%. The procedure had an average operative duration of 20 minutes, without any adverse effects or complications. It was determined that fat graft myringoplasty is a straightforward, rapid, and minimally invasive procedure that yields positive hearing outcomes. Therefore, it is considered an effective choice for repairing small perforations in the tympanic membrane. Chandra PR et al. did another trial to evaluate the efficacy of fat myringoplasty in the treatment of chronic suppurative otitis media [44]. A total of twenty patients who had minor central perforations in their tympanic membrane underwent treatment with fat grafting sourced from the ear. lobule. The findings revealed a mean increase in auditory sensitivity of 10.58 decibels after a period of 6 months, with effective healing of the hole observed in 90% of instances. Significantly, the rear quadrant exhibited a 100% graft absorption rate for perforations, while the anterior quadrant had a rate of 75%. The study found no significant problems and concluded that fat myringoplasty is a secure and efficient operation for tiny central perforations, particularly in the posterior quadrant. It can be performed as daycare surgery with appropriate case selection.

The success rate of middle ear reconstruction was influenced by several factors, including the presence of a wet ear that was occasionally or persistently wet, the condition of the ossicles, the mobility or fixity of the ossicular chain, the presence of pathologies such as cholesteatoma or granulations, the type of surgery performed, and the nutritional status. Furthermore, it was shown that smoking had a distinct influence on the healing process. Verma JK et al. found many factors which significantly helpful to acheve a graft procedure [45].

Most otologists prefer to use autologous grafts when conducting a tympanoplasty due to the risk of infectious disease transfer and the expense of synthetic materials. The cost element becomes further significant when considering the higher occurrence of chronic suppurative otitis among populations with lower demographic status, who get assistance from the public health system. Ultimately, the surgeon's level of expertise is another crucial determinant. Optimal outcomes cannot be anticipated if the physician lacks familiarity with the surgical approach to be utilized. [46].

Conclusion

The repair of tympanic membrane (TM) perforations is a complex process that involves utilizing various graft materials to restore the damaged area. These materials include temporalis fascia, cartilage, perichondrium, periosteum, vein, fat, and skin, each with its own unique characteristics and advantages. However, despite the effectiveness of temporalis fascia grafts in achieving good hearing outcomes, concerns have been raised regarding their dimensional stability. This instability can potentially lead to residual perforations, particularly in larger TM perforations, which can compromise the overall success of the repair.

To address these concerns, alternative techniques such as "palisade cartilage" and "cartilage island" have been developed to enhance graft strength and stability. These methods involve using cartilage to reinforce the graft, thereby improving its durability and resistance to perforation. However, it is essential to note that these alternative techniques may have a trade-off in terms of hearing restoration, highlighting the need for careful consideration and individualized approaches.

The outcome of TM perforation repair is influenced by a multitude of factors, including patient-related variables such as smoking habits, age, and gender. Furthermore, the presence of myringosclerosis or tympanosclerosis can also affect the outcome, emphasizing the importance of thorough evaluation and personalized treatment strategies.

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