

# **Review Article**

## **Tympanoplasty: An overview**

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## INTRODUCTION

The tympanic membrane has a trilaminar structure with an outer layer of stratified squamous epithelium composed of keratinocytes, a middle fibrous layer of lamina propia which is constituted by fibroblasts along with Type II and III collagen, and inner non-keratinized mucosal epithelium.

The middle layer of tympanic membrane provides mechanical strength, consistency, and elasticity to it and is mainly composed of Type III collagen in the inner layer and Type II collagen in the outer layer in pars tensa whereas the lamina propria of pars flaccida is constituted by loose connective tissue and a few elastic fibrils. Collagen fibrils are arranged in a radial and circular direction in the outer and inner layers, respectively.<sup>[1]</sup> The thickness of tympanic membrane is not homogenous and varies from 30 to 150 µm with a mean value of 74 µm.<sup>[2]</sup>

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The tympanic membrane is a trilaminar structure with an outer layer of stratified squamous epithelium, middle fibrous layer, and inner mucosal layer. The thickness of tympanic membrane is not homogenous and varies from 30 to 150  $\mu$ m with a mean value of 74  $\mu$ m. The aims of tympanoplasty are two-fold: One is the elimination of disease from the middle ear and, the second is the restoration of function, that is, restoring a good hearing function. There are many classifications for the tympanoplasty and only few are in practical use. Various types of graft materials, with different placing techniques, are there in the history of tympanoplasty. The present review emphasizes some of the important aspects which have given path to the improvement of the outcome of tympanoplasty.

KEYWORDS: Graft material, interlay, onlay, tympanoplasty, underlay

Tympanoplasty is defined as a procedure to remove the disease from the middle ear and reconstruct the tympanic membrane with a graft and ossicular chain with autologous or biocompatible material.

## Aim of Tympanoplasty

The aims of tympanoplasty are two-fold: One is the elimination of disease from the middle ear and, the second is the restoration of function, that is, restoring a good hearing function.

A good hearing is achieved by grafting of the tympanic membrane (i.e., neo-tympanum), along with a mucosal lined air containing middle ear resulting in effective vibration of the neotympanum. The backbone of the tympanoplasty is achieved by establishing a connection between the neotympanum and inner ear fluid and also confirming the ossicular chain connectivity or reconstructing it in case of missing or damaged ossicles. It involves inspection of the middle ear for ensuring the presence and functional integrity of the ossicular chain apart from just repairing of the defect in the tympanic membrane.

Cortical mastoidectomy can be done, along with tympanoplasty depending on the middle ear status and also surgeon's choice.

Many classifications are in use for tympanoplasty. Some are

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#### Wullstein's classification<sup>[3]</sup>

- Type I Defect is perforation of tympanic membrane which is repaired with a graft also known as myringoplasty.
- Type II Defect is perforation of tympanic membrane with erosion of malleus. The Graft is placed on the incus or remnant of malleus.
- Type III Malleus and incus are absent. The graft is placed directly on the stapes head. It is also called myringostapediopexy or columella tympanoplasty.
- Type IV Only the footplate of stapes is present. It is exposed to the external ear and the graft is placed between the oval and round window.
- Type V Stapes footplate is fixed but round window is functioning. Another window is created on horizontal semicircular canal and covered with a graft also called fenestration operation.

## Toss classification<sup>[4]</sup>

- Type 1 Defect is perforation of tympanic membrane which is repaired with a graft with intact ossicular chain
- Type 2 Defective long process of the incus is present. An interposition of an ossicle or any other prosthesis, between the stapedial arch and the malleus handle or eardrum, is done
- Type 3 Absent or severely defective stapedial arch. The placement of a columella between the footplate and the malleus handle or eardrum
- Type 4 Sound protection of the round window with a graft and formation of an air space in the hypotympanum
- Type 5a Fenestration of the lateral semicircular canal in cases with no ossicles and a fixed footplate
- Type 5b Platinectomy.

## HISTORY

The modern era of reconstructive ear surgery has its beginning with reports published by Wullstein<sup>[3]</sup> and Zollner<sup>[5]</sup> in the fifth decade of the  $20^{th}$  century.

Initially, split or full-thickness skin was used as a graft material over the de-epithelized tympanic membrane remnant in an overlay fashion. It faced the challenge of graft eczema and inflammation with eventual reperforation which was later solved by either changing the graft materials including canal skin, vein, perichondrium, and temporalis fascia, or switching to undersurface (underlay) with connective tissue graft material in the late 1950s.

However, House clinics continued with overlay/onlay technique using canal skin. In 1958, they started using periosteal graft which was covered by canal skin. This resulted in relatively better success rate though failure rate was still 40%.<sup>[6,7]</sup>

Shea was the first to use vein as a graft material in 1957 and used the same as underlay grafting technique.<sup>[8]</sup> Storrs in 1961 began using temporalis fascia as a graft material with overlay

technique and found a successful graft uptake of 90%.<sup>[9]</sup> Tragal perichondrium was first used as onlay graft material in tympanoplasty by Goodhill *et al.*<sup>[10]</sup> However, Berthold was the first to perform myringoplasty in 1878 and achieved the closure of TM using a skin graft.

## **BLOOD SUPPLY OF THE TYMPANIC MEMBRANE**

An external plexus formed from the tympanic branch of the deep auricular artery which sends large manubrial branches along shrapnell's membrane and the manubrium with numerous radial branches in the tympanic membrane along its circumference. The malleal artery is the major blood supply of the posterior half of the tympanic membrane and is better perfused than the anterior half. The anterior half is supplied from the smaller radial branches from the internal plexus from the stylomastoid branch of posterior auricular artery<sup>[11]</sup> [Figure 1].

## NERVE SUPPLY OF TYMPANIC MEMBRANE

The anterior half of the lateral surface of the tympanic membrane is supplied by auriculotemporal nerve and posterior half is supplied by the auricular branch of the vagus. The medial surface is supplied by the tympanic branch of the glossopharyngeal nerve (Cranial Nerve  $9^{th}$ )<sup>[12]</sup> [Figure 2].

## What is Tympanic Membrane Perforation?

A normal tympanic membrane has a complex layered structure consisting of outer thin stratified squamous epithelium, medially lined by flat respiratory epithelium, and a middle fibrous layer which also contains vascular elements.

Tympanic membrane perforations are fistulas between the ear canal and the middle ear spaces. The reason for not healing spontaneously and persisting as a stable perforation is due to contact inhibition between the squamous epithelium of the lateral surface of the tympanic membrane and the mucus membrane present on the medial surface thereby preventing active growth of either epithelium. This being the reason to disrupt the junction between the squamous and respiratory epithelium while doing tympanoplasty known as freshening of margins.

## Tympanosclerosis

Plaques of tympanosclerosis are patches of hyalinized (calcified) scar that replaces a portion of the fibrous layer of the tympanic membrane following inflammation from chronic otitis media. The clinical significance is that it interferes with the healing of the perforation by blocking vascularization of the graft and this is why it should be meticulously removed from the mucosal side by fine dissection sparing the squamous side intact. Tympanosclerosis is also a telltale sign of healed perforation and may also present with hearing loss. Mostly, it is an incidental finding on routine ear examination.



Figure 1: Tymphnic branch of deep auricular artery



Figure 2: Nerve supply of Tympanic Membrane

## DIMERIC TYMPANIC MEMBRANE

Following acute suppurative otitis media, if tympanic membrane perforates then most of the time, it heals spontaneously with preservation and continuity of all the three layers of tympanic membrane, but sometimes the perforation closes by rapid healing of outer squamous epithelium before fibrous layer element catches the pace and this results in lacking or attenuated middle fibrous layer. The resulting healed perforation has only two layers – outer squamous inner mucosal with absent middle fibrous layer. This results in a dimeric patch of varying size which lacks tensile strength, elasticity, blood supply, and a lower resistance to future perforation. Depending on the size and site of dimeric patch, subject may have hearing loss of varying degree.

## **GRAFT MATERIAL**

A number of graft materials can be used and autologous graft material is preferred due to biocompatibility and ethical issues. In addition, an ideal graft material should provide a stable scaffold with active fibroblasts and regenerative tissue and preferably be obtained from the same incision site.

The various graft materials which can be derived are superficial temporalis fascia, tragal cartilage, or perichondrium, or a combination of the two, vein graft, and tensor fascia lata. For very small perforation, fat can be used to plug the perforation. Loose areolar tissue over the superficial temporalis fascia, if handled properly, is an ideal graft material as it contains actively dividing fibroblasts which helps in early healing but, if not spread uniformly, there is a high chance of minute perforations left after drying and this may lead to residual perforation. Since there are many options for graft material vein graft, it should not be preferred as it leads to loss of that vein system which can be later used for parenteral medications.

## WHAT HAPPENS FOLLOWING GRAFTING?

The incorporation of the graft requires three successful elements. First, a scaffold is provided by the fascia or any graft material which is composed of fibroblasts in a collagen matrix. Scaffolds act as a guide for the cell migration from the edges of the perforation. It should have a low metabolic rate and its extracellular matrix permits it to persist until it becomes vascularized. Second, replicating and migrating keratinocytes which are present in the drum remnants and the margins of the freshened edges of the perforation are the source for the migrating epithelium. Third, bioactive molecules activate the process of healing which is achieved by tissue injury while freshening the margins of the perforation.

## APPROACHES TO TYMPANOPLASTY

Approach to tympanic membrane or tympanomastoid region can be done by three ways:

- a. Transcanal/permeatal approach
- b. Endaural approach
- c. Postaural approach.

Each of the approaches has its advantages, disadvantages, and some limitations. Furthermore, there are certain factors that need to be considered before deciding on the approach to be followed which include, the size and site of the perforation, size of the ear canal, surgeon preference, and patients concern for cosmesis and occupation.

## **Transcanal/Permeatal Approach**

Transcanal/permeatal approach has been in practice since many decades, it offers minimal to no operative scar (Minimal incision

Tympanoplasty

is required for graft harvesting). In recent years with increasing use of endoscopes for ear surgery, the transcanal approach is being increasingly used. Variations in the size and contour of external auditory canal along with experience and preference of the operating surgeon play an important role. The only limitation arises when the canal size is smaller for the adequate exposure of the whole tympanic membrane. In such cases, widening can be achieved by incisions at incisura terminalis which cause widening of the canal. Ideally, panoramic view of the circumference of the tympanic membrane should be obtained using the largest possible size speculum. Mastoidectomy is not possible if change of plan is required.

Perforations involving the annulus and/or with ossicular chain pathology should not be approached by this route due to a high risk for ingrowth of squamous epithelium into the middle ear as well as it may be associated with ossicular discontinuity.

#### **Endaural Approaches**

A detailed description of the approach was made by Heerman in 1930, later it was popularized by Lempert who used it for fenestration surgery. Further modifications suggested by Shambaugh and by Farrier are still widely used.

The basic principles that determine the type of endaural incisions to be used are based on: <sup>[13]</sup>

- 1. The anticipated location and extent of pathological conditions that are to be dealt with
- 2. The flexibility of the procedure during surgery.

#### Incisions

- Heerman incision
- Lempert incision
- Farrier incision
- Shambaugh incision.

Incision suggested by Farrier and Shambaugh are the modifications of the Lempert. If a small meatus is present, an endaural incision with its incorporated meatoplasty is the preferred incision.

It has a limited access to the anterior eardrum margin.

#### **Postaural Approach**

- The approach starts from behind the ear; the pinna is retracted anteriorly and secured with appropriate-size retractors.
- Wilde's incision is used followed by dissection of soft tissue and entry into the ear canal. Superficial temporalis fascia as a graft can be harvested through the same incision. It requires a fair amount of soft-tissue dissection with associated morbidity as well as it also provides favorable access to the anterior margins of the eardrum. The approach also offers possible shifting to mastoidectomy, if required, bulge in the anterior wall of the external auditory canal can be easily managed and the approach requires no aural

speculum. Overall, exposure is excellent allowing enhanced middle ear exposure and precise graft placement.

## TYPES BASED ON THE PLACEMENT OF THE GRAFT (TECHNIQUE)

#### **Overlay or Outersurface Tympanoplasty**

The canal skin along with periosteum (tympanomeatal flap) is elevated as far as the annular ligament. The dissection remains superficial to the fibrous layer of the tympanic membrane remnant such that the remnant is de-epithelized in continuity with the canal skin. Canalplasty, if required is performed and is followed by placing the graft by first cutting a slit in it and then sliding and securing under the handle of malleus, the rest of the graft is placed lateral to the fibrous layer of the tympanic membrane [Figure 3].

Advantage of the technique includes higher graft take up rate but at the same time it also suffers from certain disadvantages of significant value, such as blunting of anterior tympanomeatal angle and lateralization of the graft. Both of this condition results in a healed ear but with worse hearing. Hence, the technique requires a high level of precision. To correct the condition the only option is re-exploration.

Furthermore, it has been noticed that healing time is longer as compared to the underlay technique. Other problems encountered are epithelial cysts which are epithelial tissue remnants between fascia (graft) and fibrous layer of tympanic membrane. Treatment is incision and evacuation of cyst. Some of the long-term sequelae can be formation of small pearls on the tympanic membrane or ear canal which is due to turning under of the skin edges when replacing the canal skin. Even cholesteatoma can develop after years because of entrapment of epithelium. To prevent anterior blunting, one needs to remove the anterior canal bulge so that the anterior angle is open.

#### Blunting in the anterior sulcus

It may be due to excess fibrous tissue anteriorly or due to placement of graft over the anterior canal bone. Minor degree is



Figure 3: Graft placement in overlay technique

of no consequence and results from formation of excess fibrous tissue. As severity increases, it involves the handle of malleus thereby interfering with hearing. In severe blunting, manubrium becomes indistinguishable and the anterior half of tympanic membrane becomes immobile and takes a concave appearance with no clearcut distinction between edge of tympanic membrane and bony wall though the posterior half of tympanic membrane may show fair mobility.

## Underlay technique

It involves placing the graft material medial to the tympanic membrane remnant, that is, medial to mucosal layer. It was developed to overcome the disadvantages of overlay technique discussed earlier. Initially, it was a challenge to place the graft successfully because of limited exposure through transcanal approach and lesser-developed optics. It was overcome by the postaural approach [Figure 4].

## Interlay technique

In this, the tympanomeatal flap is elevated up to fibrous layer of the tympanic membrane leaving behind mucosal layer undisturbed and then placing the graft between the fibrous and mucosal layer of Tympanic membrane [Figure 5].



Figure 4: Graft placement in underlay technique





## **Overlay-underlay technique**

In this technique anteriorly, the graft is placed between the medial mucosal layer and middle fibrous layer, that is, in an interlay fashion thereby providing support to the graft and also preventing anterior recession of the graft.

Posteriorly, graft is placed over the malleus handle medial to mucosal layer of tympanic membrane.

The technique is useful for large central perforation as it provides extra support anteriorly.

## CARTILAGE TYMPANOPLASTY

## Source of Cartilage

Tragal cartilage – it is ideal because it is thin, flat, and of sufficient size even permitting reconstruction of the entire tympanic membrane. It is usually perichondrium/cartilage island flap thereby incorporating one side perichondrium with the cartilage and leaving perichondrium of other side preferably medial side *in situ* for maintaining shape of tragus. It is preferred in transcanal approach or endaural.

The cartilage can be used for both full thickness and thinned out also but the later suffers from curling effect of the graft though it provides better acoustic gain as compared to full thickness.

## Cartilage from Cymba Area of the Conchal Bowl

It is generally used if the surgical approach is post-auricular. The cartilage of the cymba is having acceptable thickness of 1 mm as that of tragus and is regular. Other areas of conchal cartilage are thicker and irregular.

It is generally preferred in palisade technique where cartilage is cut into several slices that are subsequently pieced together in a jigsaw puzzle manner to reconstruct the tympanic membrane.

Cartilage grafts seem to be nourished largely by diffusion and become well incorporated in the tympanic membrane.

Cartilage as graft material particularly as perichondrium/ cartilage Island flap is used to reconstruct large pars tensa perforation with recurrent perforation or atelectasis apart from a first choice graft material by surgeries.

Use of cartilage in a palisade manner can be done using both cymba concha or tragus cartilage in cases with cholesteatoma requiring reconstruction and reinforcement of the scutum and posterior half of tympanic membrane has helped in reducing the incidence of recurrent atrophy and retraction pockets.

Points to remember: In a perichondrial graft, the surface that was in contact with the cartilage should be positioned toward the middle ear. With a vein graft, the intimal surface should be medially placed.

## CONCLUSION

There are several methods, approaches, and technique of doing tympanoplasty with various graft materials with each having its own benefits and certain limitations along with surgeons choice. As per the convenience and patients anatomy, appropriate selection need to be made.

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